REVIEW

VALIDITY OF TOOLS FOR ASSESSING THE RISK OF FALLS IN PATIENTS

Kamila Majkusová¹, Darja Jarošová²¹Department of Nursing and Midwifery, Faculty of Medicine, University of Ostrava, Czech Republic (student)²Department of Nursing and Midwifery, Faculty of Medicine, University of Ostrava, Czech Republic

Received April 24, 2017; Accepted June 12, 2017. Copyright: This is an open access article distributed under the terms of the Creative Commons Attribution International License (CC BY). <http://creativecommons.org/licenses/by/4.0/>

Abstract

Aim: The aims were to analyze studies determining the validity of tools assessing the risk of falls in adult inpatients and to define a suitable tool to be used in acute and long-term care for preventing patient falls. **Design:** A review study. **Methods:** The studies were searched using predefined criteria in the electronic databases EBSCO, CINAHL, Medline, ScienceDirect, Wiley Library Online, ProQuest and ScienceDirect over a period of 2005–2015. After sorting the retrieved materials according to the PRISMA recommendations, a total of 12 articles were analyzed. **Results:** The validity of 11 tools for assessing the risk of falls in inpatients was determined. The studies varied in validity results, with one of the reasons being differences in design of the studies. The most frequently validated tools the Morse Fall Scale and Hendrich II for acute and long-term care and STRATIFY for acute care showed rather varied parameters defining their validity, with sensitivity ranging from 34% to 95% and specificity from 2% to 91%. Validity also depended on cut-off scores of the validated tools. **Conclusion:** Although one of the most frequently used tools for assessing the risk of falls in inpatients is the Morse Fall Scale, none of the tested tools is clearly recommended as the most suitable one for preventing falls in acute and long-term care settings explicitly showing high validity results.

Keywords: assessment, fall, risk, tool, validity.

Introduction

Patient falls are currently the most frequently reported adverse event in healthcare facilities. They constitute a serious problem for patients as well as healthcare staff and management. Preventing falls should be a priority in provision of safe care. Although the risk of falls cannot be eliminated, it may be reduced considerably by introducing effective fall prevention programs, of which a key component is identification of persons at risk for falls (Oliver et al., 1997; Close et al., 1999). In most healthcare providers, fall risk assessment is an integral part of initial nursing evaluation (Marx, 2005). Fall risk assessment tools are scales evaluating various fall risk factors, with individual items being assigned points that are summed up to achieve the final score which measures the likelihood that the patient will sustain a fall (Morse, 2009). The causes of falls are multifactorial and fall risks rise with an increasing number of fall risk factors present (Tinetti, Williams, Mayewski, 1986). The tool to be used must

correspond with the setting and specific client population (Morse, 2009). Tests of the predictive validity of fall risk assessment tools determine whether a particular tool fulfils its purpose and is able to clearly distinguish individuals at risk for falls from those not at risk (Oliver, Healey, Haines, 2010). Validity is a key parameter of a psychometric instrument, expressing the extent to which the tool measures what is intended (Gurková, 2011). In case of a fall risk assessment tool, validity measures whether or not it is able to identify the risk of falls in adult inpatients and classify patients as having a fall risk if they actually are at risk of falling (Jedlinská, Holmerová, 2012). To evaluate the validity of tools included in this review, the terms sensitivity, specificity, positive and negative predictive values of fall risk assessment tools were used as defined in a pilot study evaluating the validity of screening scales for fall risk assessment (Jedlinská, Holmerová, 2012). Sensitivity of a fall risk assessment tool is defined as the ratio of fallen individuals to those identified as being at risk by the scale; specificity is the proportion of persons without a history of falls having negative test results. Positive predictive value (PPV) is defined as the likelihood that an individual with a positive result would sustain a fall; negative predictive value (NPV) as the likelihood that

Corresponding author: Kamila Majkusová, Department of Nursing and Midwifery Faculty of Medicine, University of Ostrava, Syllabova 19, Ostrava-Zábřeh, Czech Republic; e-mail: kamila.majkusovamno@seznam.cz

a negative result rules out a fall. The higher the sensitivity and specificity, the more effective the test is (Zvárová, 1998). According to Oliver et al. (2004), a tool should ideally have 70% sensitivity and 70% specificity to be of high predictive value; too high sensitivity is achieved at the expense of low specificity and vice versa. Another parameter of validity of a tool is the area under the ROC (receiver operating characteristic) curve that measures the accuracy of the test. The values range from 0.5 to 1, with those lower than 0.5 being insufficient, suggesting that the results are close to random. The higher the area under the ROC curve, the more effective the test is (Balla et al., 2004). Also used for objective evaluation of a tool's effectiveness is the Youden Index calculated by subtracting 1 from the sum of sensitivity and specificity (Youden, 1950). The values range from 0 to 1, with those close to 1 suggesting higher validity of the tool. Results close or equal to 0 indicate that its accuracy is equal to a random guess. The index is a criterion for selecting the optimum cut-off point (Schisterman et al., 2005) which is also crucial for evaluating the effectiveness of a particular assessment tool.

Aim

The literature review aimed at determining the validity of selected risk assessment tools for falls in hospitalized patients using sensitivity, specificity, PPV, NPV and area under the ROC curve in research studies carried out both in the Czech Republic and abroad.

Methods

Design

A literature review.

Eligibility criteria

For the analysis, research studies evaluating the validity of risk assessment tools for falls in hospitalized adults receiving acute or long-term care and published in 2005–2015 were searched. The inclusion criteria were as follows: English or Czech language, full-text article, available results of evaluation of the validity of a fall risk assessment tool with at least four of the test characteristics (sensitivity, specificity, PPV and NPV) and a research study of adult patients staying in a healthcare facility. The levels of evidence were assessed according to Haynes' pyramid of information resources (Běhounek, Hora, Klečka, 2011). Included in the review were studies of Haynes' pyramid levels of evidence of 2, 3, 4 and 5 (2 – evidence from a randomized controlled trial; 3

– evidence from a prospective, or cohort, study; 4 – evidence from a retrospective / case-control study; and 5 – evidence from a cross-sectional study). Excluded from the review was the highest level of evidence from secondary research studies (systematic reviews and meta-analyses) as these do not contain details of the analyzed studies.

Sources

The data resources were articles found by searching the electronic bibliographic databases EBSCO, CINAHL, Medline, ScienceDirect, Wiley Library Online, ProQuest and ScienceDirect.

Search

The relevant articles were searched using the key words *assessment*, *risk*, *fall* and *validity* and the Boolean operators OR and AND in February and March 2016. Excluded were articles that did not evaluate the validity of fall risk assessment tools or studies testing fall risk assessment tools in specific patient groups only (e.g. persons with Parkinson's disease or those after stroke) or children. Also excluded were all studies that did not evaluate the validity of fall risk assessment tools in persons staying in healthcare facilities. Yet other exclusion criteria were studies with lower quality of evidence than Haynes' pyramid of information resources level 5, systematic reviews and meta-analyses (Běhounek, Hora, Klečka, 2011).

Study selection

In the international electronic databases, a total of 49 relevant documents were identified based on the above search strategy and pre-defined criteria. Those were sorted according to the inclusion and exclusion criteria.

Data analysis

For the retrieved studies, the sensitivity, specificity, PPV, NPV, area under the ROC curve and cut-off of assessment tools and fall incidence rates were analyzed. Of the 49 relevant records, twelve studies met all the criteria and were included in the review (Figure 1).

Results

Recently, numerous research studies on fall risk assessment tools have been published worldwide. Based on the inclusion criteria, twelve studies measuring their validity were found. These retrieved studies (Table 2) were analyzed and data on their validity were identified (Table 1). The most common fall risk assessment tool was the Morse Fall Scale (MFS) tested in 8 studies, including one in which the scale was adapted for use in the South Korean

Figure 1 Selection of studies (PRISMA flow chart)

healthcare system (Sung et al., 2014), followed by the Hendrich II Fall Risk Model (5 studies). Four studies validated the St Thomas's Risk Assessment Tool in Falling Elderly Inpatients (STRATIFY); in one, the scale was modified as The Northern Hospital Modified St Thomas's Risk Assessment Tool (TNH-STRATIFY). The other scales were tested in only one study each: Maine Medical Center Fall Risk Assessment/Interventions (MMC), Fall and Injury Risk Assessment Tool/New York-Presbyterian (NY), Conley Scale, Jurásková's modified scale for fall risk assessment in a patient/client, fall risk assessment screening test for identification of patients at high risk for falls (STRP), Downton Fall Risk Index, Tullamore Tool and Tinetti Fall Risk Index. Overall, eleven tools for assessing fall risk in patients were validated in those twelve studies. The tools were most frequently validated in internal medicine departments (11 studies), followed by surgery departments (8 studies), oncology departments (3 studies), rehabilitation departments (2 studies), long-term, palliative and intensive care department and neurology department (1 study each). A Portuguese study (Caldevilla et al., 2013) did not specify the

department at which the study was performed and only mentioned inpatients in acute care hospitals. The numbers of respondents varied among the studies. In two studies, the numbers of patients included were not reported as the authors only stated the numbers of falls recorded (Schwendimann, De Geest, Milisen, 2006; da Costa-Dias, Martins, Araújo, 2014). The samples ranged in size from 122 patients (Jedlinská, Holmerová, 2012) to 5,489 patients (Kim et al., 2007). Similarly, the studies varied in their duration, with the shortest study taking 5 weeks to complete (Barker et al., 2011) and the longest study validating tools for two and a half years (Caldevilla et al., 2013); the duration was not specified for one study (Vassallo et al., 2005). The respondents' mean age ranged from 45 years (Baek et al., 2013) to 84 years (Vassallo et al., 2005); in only one study (Chapman, Bachand, Hyrkäs, 2011), no respondents' mean age was stated. The incidence of falls reported in the studies ranged from 21 falls (Jedlinská, Holmerová, 2012) to 386 falls (Schwendimann, De Geest, Milisen, 2006). The incidence of falls depended on the number

Table 1 Validity of fall risk assessment tools

Scale/author(s) (year)	cut-off score	sensitivity (%)	specificity (%)	PPV (%)	NPV (%)	ROC	note
Morse Fall Scale							
da Costa-Dias, Martins, Araújo (2014)	25	95	20	37	89	NA	YI 0.15
	45	78	52	45	80	0.648	YI 0.300
Schwendimann, De Geest, Milisen (2006)	25	91.5	13.9	12.8	92.2	0.527	
	55	74.5	65.8	23.2	94.9	0.701	
Kim et al. (2007)	25	88.3	48.3	1.9	99.7	NA	
	50	55	91.2	6.4	99.5	NA	
	40	68	76	NA	NA	0.8	
Baek et al. (2013)	25	74	77	41	93	NA	YI 0.51
	51	72	91	63	94	NA	YI 0.63
Chapman, Bachand, Hyrkäs (2011)	25	77.2	72.8	98.8	9.9	NA	
Nassar, Helou, Madi (2013)	51	36.9	53.9	12.4	98.2	NA	
Jedlinská, Holmerová (2012)	25	91	2	17	50	NA	
Morse Fall Scale – Korea (MFS-K)							
Sung et al. (2014)	25	91	38	49.2	86.4	0.646	
	45	62	79	66	76	0.71	
Hendrich II							
Chapman, Bachand, Hyrkäs (2011)	5	64.9	69	98.1	7.5	NA	
Lovallo et al. (2010)	5	50	68	9	95	0.331	internal medicine department
		33.33	73.81	2	98	0.585	surgery department
Kim et al. (2007)	5	70	61.5	2	99.5	0.73	
Nassar, Helou, Madi (2013)	5	55.3	89.3	16.5	98.3	NA	
Caldevilla et al. (2013)	5	93	35	17	97	0.65	at admission
		75	46	17	93	0.64	at discharge
STRATIFY							
Kim et al. (2007)	2	55	75.3	2.4	99.3	0.71	
	3	25	91.1	3	99.1	NA	
Barker et al. (2011)	5	35	93	32	94	NA	
Vassallo et al. (2005)	2	68.2	66.4	28.3	91.5	NA	
TNH-STRATIFY (The Northern Hospital Modified St Thomas's Risk Assessment Tool)							
Barker et al. (2011)	11	65	79	23	96	NA	
Other scales							
MMC (Maine Medical Center)							
NY	9	64.9	65.8	98	6.8	NA	
	3	78.9	58.4	98.6	6.9	NA	
Chapman, Bachand, Hyrkäs (2011)							
Conley Scale							
	2	77.27	49	9	97	0.577	internal medicine department
Lovallo et al. (2010)		46.67	72.52	3	98	0.812	surgery department
Jurásková's scale							
	5	100	7	18	100	NA	
STRP							
	3	100	2	17	100	NA	
Jedlinská, Holmerová (2012)							
Downton							
	3	81.8	24.7	17.5	87.5	NA	
Tinetti							
	3	77.3	30.9	17.9	87.5	NA	
Tullamore							
	3	90.9	40.7	22.9	95.8	NA	
Vassallo et al. (2005)							

NA – data not available; PPV – positive predictive value; NPV – negative predictive value; ROC – area under the ROC (Receiver Operating Characteristic) curve; YI – Youden Index; MMC – Maine Medical Center Fall Risk Assessment/Intervention; NY – Fall and Injury Risk Assessment Tool/New York-Presbyterian; STRP – fall risk assessment screening test for identification of patients at high risk for falls

of respondents, study duration and type of department at which the study was carried out. Validity assessment was mainly influenced by when a patient was identified as being at risk for falls by the tool, that is, when a patient achieved the lowest

number of points needed for inclusion in a fall risk category, irrespective of the defined level of that risk (low, medium or high) (Jedlinská, Holmerová, 2012). Therefore, another parameters analyzed in this review was the cut-off score, or the number of points

Table 2 Characteristics of studies included in the literature review

Author(s) (year)	Scale	Clinical setting	Number of patients	Incidence of falls	Mean age	Study duration	Level of evidence
da Costa-Dias, Martins, Araújo (2014)	MFS	internal medicine surgery long-term and palliative care	NA	100	69	1 year	4
Kim et al. (2007)	MFS	internal medicine	5,489	60	56	4 months	3
Barker et al. (2011)	Hendrich II	oncology	M: 2,842	44	61	3 weeks	3
	STRATIFY	surgery	F: 2,647		60	2 weeks	
Schwendimann, De Geest, Milisen (2006)	TNH-STRATIFY	internal medicine surgery	phase 1: 263	0	70	4 months	3
	STRATIFY		phase 2: 52				
Sung et al. (2014)	MFS-K	internal medicine, surgery, neurology, rehabilitation	166	66	falling 65 non-falling 55	11 months	5
Baek et al. (2013)	MFS	internal medicine, surgery, oncology, intensive care units	845	151	falling 48 non-falling 35	9 months	4
Chapman, Bachand, Hyrkäs (2011)	MFS	internal medicine	1,546	73	NA	2 months	5
Lovallo et al. (2010)	Hendrich II	surgery	1,148	59	69	2 years	3
	Conley Scale	rehabilitation					
Nassar, Helou, Madi (2013)	MFS	internal medicine	1,815	60	56	2 years	3
	Hendrich II	surgery					
Jedlinská, Holmerová (2012)	MFS	oncology	122	21	78	8 months	3
	Jurásková STRP	intensive care					
Vassallo et al. (2005)	MFS	acute internal medicine	135	29 falls in 22 patients	84	NA	3
	Downnton STRATIFY	medicine					
Caldevilla et al. (2013)	Tullamore	departments	586	104	78	2.5 years	3
	Tinetti						
	Hendrich II	acute care department					

Level of evidence: 2 – evidence from a randomized controlled trial, 3 – evidence from a prospective, or cohort, study, 4 – evidence from a retrospective study (case-control study), 5 – evidence from a cross-sectional study; MFS – Morse Fall Scale; MFS-K – Morse Fall Scale-Korea; NY – Fall and Injury Risk Assessment Tool/New York-Presbyterian; STRP – fall risk assessment screening test for identification of patients at high risk for falls; NA – data not available; M – males; F – females

predicting the risk of falls. Most of the assessment tools analyzed in the studies agreed on cut-off scores. For the MFS, the study authors agreed on the lowest cut-off score for the defined risk of falls (25 points) but failed to agree in the optimal cut-off score. The optimal cut-off scores for the MFS with the highest validity ranged from 40 points (Kim et al., 2007), with a sensitivity of 68% and specificity of 76%, to 55 points (Schwendimann, De Geest, Milisen, 2006), with a sensitivity and specificity of 74.5% and 65.8%, respectively. DaCosta-Dias et al. (2014) reported the optimal cut-off score of 45

points, with a specificity of 78% and sensitivity of 52%. The largest differences in cut-off scores were noted for the STRATIFY, with the cut-off scores ranging from 2 points (Vassallo et al., 2005; Kim et al., 2007) to 5 points (Barker et al., 2011). In the modified TNH-STRATIFY, the cut-off for fall risk was as high as 11 points (Barker et al., 2011). Four of the studies also analyzed the area under the ROC curve showing the relationship between test specificity and sensitivity. In case of the MFS, the area under the ROC curve ranged from 0.527 for 25 points (Schwendimann, De Geest, Milisen, 2006)

to 0.800 (Kim et al., 2007) for the optimal cut-off of 40 points. For the Hendrich II model, the area under the ROC curve ranged from 0.333 (Lovallo et al., 2010) to 0.730 (Kim et al., 2007). Moreover, two studies (Baek et al., 2013; da Costa-Dias, Martins, Araújo, 2014) reported the Youden Index (YI) that ranged from 0.16 to 0.51 for the MFS cut-off score of 25 points. Higher (and thus better) YI values were observed for higher MFS cut-off scores. For instance, the YI values were 0.300 for a MFS cut-off score of 45 points (da Costa-Dias, Martins, Araújo, 2014) and 0.630 for 51 points (Baek et al., 2013).

Of all the analyzed research studies, eight were concerned with validity of the fall risk assessment tool Morse Fall Scale; those were mostly carried out in clinical departments providing acute internal medicine and surgical care. The studies focused on various parameters of validity of the tool. Its sensitivity ranged from 36.9% (Nassar, Helou, Madi, 2013) to 95% (da Costa-Dias, Martins, Araújo, 2014), specificity from 2% (Jedlinská, Holmerová, 2012) to 91% (Baek et al., 2013), PPV from 98.8% (Chapman, Bachand, Hyrkäs, 2011) to 1.9% (Kim et al., 2007) and NPV from 99.7% (Kim et al., 2007) to 9.9% (Chapman, Bachand, Hyrkäs, 2011). The area under the ROC curve was reported by only three studies, ranging from 0.527% (Schwendimann, De Geest, Milisen, 2006) to 0.800% (Kim et al., 2007).

Table 1 summarizes data from five studies on validity of the fall risk assessment tool Hendrich II. All the studies validating the Hendrich II agreed on a cut-off score of 5 points. Sensitivity ranged from 33.33% (Lovallo et al., 2010) to 64.9% (Chapman, Bachand, Hyrkäs, 2011) and specificity from 35% (Caldevilla et al., 2013) to 89.3% (Nassar, Helou, Madi, 2013). Both PPV and NPV varied considerably across the studies, ranging from 2% (Kim et al., 2007; Lovallo et al., 2010) to 98.1% (Chapman, Bachand, Hyrkäs, 2011) and from 7.5% (Chapman, Bachand, Hyrkäs, 2011) to 99.5% (Kim et al., 2007), respectively.

The STRATIFY tool was validated by three studies included in this review. The cut-off score ranged from 2 to 5 points. Sensitivity and specificity values ranged from 25% (Kim et al., 2007) to 68.2% (Vassallo et al., 2005) and from 66.4% (Vassallo et al., 2005) to 93% (Barker et al., 2011), respectively. Neither PPV nor NPV varied considerably across the studies, ranging from 2.4% (Kim et al., 2007) to 32% (Barker et al., 2011) and from 91.5% (Vassallo et al., 2005) to 99.3% (Kim et al., 2007), respectively. The area under the ROC curve, reported in only one study, was 0.71 for a cut-off score of 2 points (Kim et al., 2007).

Moreover, data on eight other fall risk assessment tools were obtained from the analyzed studies (MMC, NY, Conley Scale, Jurásková's scale, STRP, Downton Fall Risk Tool, Tullamore Tool and Tinetti Fall Risk Index). Their sensitivity ranged from 46.67% for the Conley Scale (Lovallo et al., 2010) to 100% for Jurásková's scale and STRP (Jedlinská, Holmerová, 2012). The two latter scales also had the lowest specificity values, namely 2% (STRP) and 7% (Jurásková's scale) (Jedlinská, Holmerová, 2012). The area under the ROC curve was only reported for the Conley Scale, with much better value being found when the scale was validated in surgery departments (0.812) as compared to internal medicine departments (0.577) (Lovallo et al., 2010).

Discussion

Despite the fact that there are numerous assessment tools have been developed to identify patients at risk for falls (Perell et al., 2001), their use in general practice is rather limited as only few of them have been tested in settings other than those for which they were created (Myers, 2003; Oliver et al., 2004). In the research studies that met the criteria for inclusion in this review, a total of 11 fall risk assessment tools were tested in the setting of acute and subsequent healthcare. Most attention was focused on the most frequently used assessment tools, the Morse Fall Scale (MFS), Hendrich II and STRATIFY. The MFS and STRATIFY were scientifically developed as part of nursing research and prospectively tested in various healthcare settings (Morse et al., 1989; Oliver et al., 1997; Myers, 2003; Oliver, 2004; Bóriková, Tomagová, Žiaková, 2017). The Hendrich tool was developed in acute care departments with a varied patient population (Hendrich, Bender, Nyhuis, 2003). The studies analyzed in this review validated version II of the Hendrich tool.

Of the three tools, the MFS was most frequently validated by the analyzed studies; the scale was tested in various healthcare facilities and patient samples. The MFS was developed by Janice M. Morse after 10-year detailed research of risk factors associated with falls. Given numerous studies investigating the MFS and its validity that have been published, it seems to be one of the tools most commonly used to assess the risk of falls in both acute (Schwendimann, De Geest, Milisen, 2006) and long-term inpatients. According to the author, it may also be used to assess the risk of falls in persons staying in nursing and social care residential facilities (Morse et al., 1989). The analysis of selected research

studies shows that the MFS was mainly tested in internal medicine, surgery and oncology departments. The tool assesses the following six risk factors: history of falling, secondary diagnosis, ambulatory aids, intravenous therapy, gait and mental status of the patient. A large majority of users claim it is a quick and easy-to-use method estimated to take less three minutes to rate a patient (Morse, 2009). According to J. Morse, patients are at a low risk of falls when they reach only 25 points (Morse, 2009). Most of the authors, however, agree that an optimal range of 40–55 points is associated with a higher validity of the tool (Schwendimann, De Geest, Milisen, 2006; Baek et al., 2013; Nassar, Helou, Madi, 2013; da Costa-Dias, Martins, Araújo, 2014; Bóriková et al., 2017). The MFS showed higher sensitivity but, frequently, also lower specificity. It means that only a small proportion of patients identified as being at risk of falling did sustain falls. The MFS mostly showed low positive predictive value and higher negative predictive value, that is, a higher probability that many patients were identified as false-positive for falls. The sensitivity of the MFS varied considerably in the studies analyzed (Jedlinská, Holmerová, 2012; Baek et al., 2013). Moreover, Chapman, Bachand and Hyrkäs (2011) reported PPV and NPV rather different from the values found by the other authors.

Another frequently validated fall risk assessment tool was the Hendrich II Fall Risk Model. According to its authors the tool may be used in both acute and long-term care settings. A high risk of falls is identified if 5 or more points are achieved. The risk factors also include the use of antiepileptic drugs and benzodiazepines. It takes approximately 10 minutes to complete. All authors validating the Hendrich II tool agreed on a cut-off score of 5 points (Kim et al., 2007; Lovallo et al., 2010; Chapman, Bachand, Hyrkäs, 2011; Caldevilla et al., 2013; Nassar, Helou, Madi, 2013). The tool showed lower sensitivity and higher specificity values, as well as very low PPV and very high NPV. Chapman, Bachand and Hyrkäs (2011) reported completely different results, possibly due to the study design.

The third most frequently validated tool was the STRATIFY, assessing the risk of falls in five domains (recent history of fall, agitation or confusion, visual impairment, especially frequent toileting, limited transfer and mobility). In case of a positive answer, that is, the presence of a risk, each item is scored one point; thus, the highest score of 5 points may be achieved (Oliver et al., 1997). The tool was developed and validated in the United Kingdom in the 1990s. It is intended for use in hospitals and requires approximately one minute

for completion (Oliver et al., 1997; Coker, Oliver, 2003; Papaioannou et al., 2004). The cut-off score determining the risk of falls ranges from 2 to 5 points, or 11 points in case of the modified TNH-STRATIFY. A systematic review by Scott et al. (2007) reported higher sensitivity and specificity values in STRATIFY for a cut-off score of 9 points, suggesting that the tool was considerably modified. Systematic reviews also reported various cut-off scores exceeding 5 points, as was the case of the original version from the 1990s (Oliver et al., 1997). Systematic reviews showed clear associations with YI values and sample sizes – the smaller the sample, the worse and the lower the YI value. Similarly, the YI values were affected by the study design, with retrospective studies showing better YI values than prospective studies. Interestingly, Haines et al. (2007) found that the validity of the STRATIFY and MFS was identical to that of healthcare workers' clinical judgment.

In their systematic review, Aranda-Gallardo et al. (2013) defined validity of the three fall risk assessment tools using the so-called odds ratio (OR), that is, the ratio of the odds of sustaining a fall in test positives relative to the odds of sustaining a fall in test negatives (Glas et al., 2003). The highest OR was observed for the STRATIFY (OR = 7.640), as compared with the MFS (OR = 5.068) and Hendrich II (OR = 3.362). For statistical analysis of validations in the above systematic review, studies with a low mean age of patients had to be excluded (Kim et al., 2007; Barker et al., 2011); after the exclusion, the validity of the tools improved. The inconsistent results reported by the systematic review authors may be explained by the fact that the validation was carried out in a population different from that for which the tool was developed (Aranda-Gallardo et al., 2013).

The predictive validity of a test may also be effectively expressed using the area under the ROC curve. This important parameter of accuracy of assessment tools was used by authors of only six studies included in this literature review. Moreover, the values reported were rather low, with most of them being close to the lower limit of 0.5 meaning that the test may still be considered valid. The best value was found for the MFS in only one study (Kim et al., 2007), with the area under the ROC curve approaching 1, being 0.8 with an optimal cut-off score of 40 points. A similar value of 0.812 was observed for the Conley Scale (Lovallo et al., 2010) in surgery departments. According to Perell et al. (2001), a test has a high predictive validity if its sensitivity and specificity exceed 80% and 75%, respectively. As already mentioned, Oliver et al.

(2004) reported a high predictive validity of approximately 70%.

The difficulty of testing the validity of fall risk assessment tools also stems from the fact that falls are not a disease but a consequence of many factors. Falls cannot be compared to diseases that can be detected, for example, by laboratory tests whose validity can be assessed more accurately. The same is true for fall risk assessment tools. The causes of falls are multifactorial; patients at a high risk for falls may not fall if adequate preventive measures are taken. On the other hand, patients with no clear risk factors for falling may sustain falls. Or they may fall even though maximum preventive measures are adopted. Pavlík (2015) asked what sensitivity and specificity values are generally sufficient to ensure a good quality of a test. He concluded that there is no clear answer as this is greatly dependent on the state of knowledge of a particular field and the accuracy of available tests that can be achieved. In certain areas, values exceeding 60% may be considered successful; in others, both diagnostic parameters are close to 100%, that is, there are virtually no false-positive or false-negative results. The relevance of specificity and sensitivity estimates also depends on the quality of the primary study, in particular an adequate size and representativeness of the sample. According to Papaioannou et al. (2004), the features of a good fall risk assessment tool include good predictive validity, feasibility and reproducibility. An optimal fall risk assessment tool should be easy and rapid to use and simple to interpret to eliminate the risk of misunderstanding and misinterpretation of individual items and to achieve as few false-positive results as possible. High levels of false positivity lead to unnecessary interventions performed by healthcare workers; preventive measures become routine, making no difference to the final effect. As a result, attention is not paid to patients that actually are at risk. An adequate tool should be selected based on previous validation in a similar group of patients for which it will be used at an optimal time and with a threshold defining the risk of falls and thus the need for fall prevention interventions (Kim et al., 2007).

Conclusion

There is no single universal fall risk assessment tool for all care providers or all patient populations. According to Perell et al. (2001), the criteria for selecting a fall risk assessment tool include similarity of patient population to ones in which the tool was tested, procedures explicitly outlining its appropriate use, reasonable time needed to administer it and

established thresholds identifying when to initiate interventions. Fall risk assessment tools with unknown validity and reliability should not be used in practice (Barker et al., 2011). One of the most frequently used tools for assessing the risk of falls in hospital patients receiving acute and long-term is the Morse Fall Scale. Yet there is no currently available tool that is clearly intended for preventing falls in acute and long-term care settings and that explicitly shows high validity results. Generally, authors (Papaioannou et al., 2004; Kim et al., 2007) agree that an optimal fall risk assessment tool has to be simple, rapid, unambiguous to interpret and always validated for a particular socio-cultural setting and patient population before it is used in practice. The design of a research study validating a tool should be similar, with a sufficiently large population tested and sufficient duration. The present review of selected fall risk assessment tools showed rather varied results possibly due to the above differences. Diagnosing individuals at risk for falls is a key intervention among those multifactorial ones that need to be performed to prevent falls.

Limitations of study

Included in the study were only articles documenting results in Czech and English languages and full texts of articles published in available electronic bibliographic databases.

Ethical aspects and conflict of interest

All bibliographic resources used were cited. The authors declare that the study has no conflict of interest.

Author contribution

Concept, design, analysis and interpretation of data, the drafting of the manuscript and the final completion of the article (KM). Supervision, revision of the manuscript and the final approval of the article (DJ).

References

- Aranda-Gallardo M, Morales-Asencio JM, Canca-Sanchez JC, Barrero-Sojo S, Perez-Jimenez C, Morales-Fernandez A, de Luna-Rodriguez ME, Moya-Suarez AB, Mora-Banderas AM. Instruments for assessing the risk of falls in acute hospitalized patients: a systematic review and meta-analysis. *BMC Health Services Research*. 2013;13:122.
- Baek S, Piao J, Jin Y, Lee SM. Validity of the Morse Fall Scale implemented in an electronic medical record system. *Journal of Clinical Nursing*. 2013;23(17–18):2434–2440.
- Balla B, Mocák J, Varmusová E, Kavková D, Tudík I. Hodnotenie úspešnosti laboratórnych metód. *Chemické listy*. 2004;98:86–91. (in Slovak)

- Barker A, Kamar J, Graco M, Lawlor V, Hill K. Adding value to the STRATIFY falls risk assessment in acute hospitals. *Journal of Advanced Nursing*. 2011;67(2):450–457.
- Běhounek P, Hora M, Klečka J. Medicína založená na důkazech. *Česká urologie*. 2011;15(1):10–14. (in Czech)
- Bóriková I, Tomagová M, Miertová M, Žiaková K. Predictive value of the Morse Fall Scale. *Central European Journal of Nursing and Midwifery*. 2017;8(1):588–595.
- Bóriková I, Tomagová M., Žiaková K. Rizikové faktory pádu u hospitalizovaných pacientů. *Praktický Lékař*. 2017;97(1):26–30. (in Slovak)
- Caldevilla MN, Costa MA, Teles P, Ferreira PM. Evaluation and cross-cultural adaptation of the Hendrich II Fall Risk Model to Portuguese. *Scandinavian Journal of Caring Sciences*. 2013;27(2):468–474.
- Close J, Ellis M, Hooper R, Glucksman E, Jackson S, Swift C. Prevention of falls in the elderly trial (PROFET): a randomised controlled trial. *Lancet*. 1999;353(9147):93–97.
- Coker E, Oliver D. Evaluation of the STRATIFY falls prediction tool on a geriatric unit. *Outcomes Management*. 2003;7(1):8–14.
- da Costa-Dias MJM, Martins T, Araújo F. Study of the cut-off point of the Morse Fall Scale (MFS). *Revista de Enfermagem Referência*. 2014;4(1):63–72.
- Glas AS, Lijmer JG, Prins MH, Bossel GJ, Bossuyt PM. The diagnostic odds ratio: a single indicator of test performance. *Journal of Clinical Epidemiology*. 2003;56(11):1129–1135.
- Gurková E. *Hodnocení kvality života. Pro klinickou praxi a ošetrovatelský výzkum*. 1. vyd. Praha: Grada Publishing; 2011. (in Czech)
- Haines TP, Hill K, Walsh W, Osborne R. Design-related bias in hospital fall risk screening tool predictive accuracy evaluations: systematic review and meta-analysis. *Journal of Gerontology: Biological Sciences and Medical Sciences*. 2007;62(6):664–672.
- Hendrich AL, Bender PS, Nyhuis A. Validation of the Hendrich II Fall Risk Model: a large concurrent case/control study of hospitalized patients. *Applied Nursing Research*. 2003;16(1):9–21.
- Chapman J, Bachand D, Hyrkäs K. Testing the sensitivity, specificity and feasibility of four falls risk assessment tools in a clinical setting. *Journal of Nursing Management*. 2011;19(1):133–142.
- Jedlinská M, Holmerová I. Hodnocení validity vybraných screeningových škál posuzujících riziko pádu u hospitalizovaných seniorů. *Praktický Lékař*. 2012;92(7):392–395. (in Czech)
- Kim EA, Mordiffi SZ, Bee WH, Devi K, Evans D. Evaluation of three fall-risk assessment tools in an acute care setting. *Journal of Advanced Nursing*. 2007;60(4):427–435.
- Lovullo C, Rolandi S, Rossetti AM, Lusignani M. Accidental falls in hospital inpatients: evaluation of sensitivity and specificity of two risk assessment tools. *Journal of Advanced Nursing*. 2010;66(3):690–696.
- Marx D. Riziko pádů ve zdravotnických zařízeních. *Diagnóza v ošetrovatelství*. 2005;1(3):139–140. (in Czech)
- Morse JM, Black C, Oberle K, Donahue P. A prospective study to identify the fall-prone patient. *Social Science & Medicine*. 1989;28(1):81–86.
- Morse JM. *Preventing patients falls. Establishing a fall intervention program*. 2nd ed. New York: Springer Publishing Company; 2009.
- Myers H. Hospital fall risk assessment tools: a critique of the literature. *International Journal of Nursing Practice*. 2003;9(4):223–235.
- Nassar N, Helou N, Madi C. Predicting falls using two instruments (the Hendrich Fall Risk Model and the Morse Fall Scale) in an acute care setting in Lebanon. *Journal of Clinical Nursing*. 2014;23(11–12):1620–1629.
- Oliver D, Britton M, Seed P, Martin FC, Hopper AH. Development and evaluation of evidence based risk assessment tool (STRATIFY) to predict which elderly inpatients will fall: case-control and cohort studies. *BMJ*. 1997;315(7115):1049–1053.
- Oliver D. Prevention of falls in hospital inpatients: agendas for research and practice. *Age Ageing*. 2004;33(4):328–330.
- Oliver D, Daly F, Martin FC, McMurdo ME. Risk factors and risk assessment tools for falls in hospital in-patients: a systematic review. *Age Ageing*. 2004;33(2):122–130.
- Oliver D, Healey F, Haines TP. Preventing falls and fall-related injuries in hospitals. *Clinics in Geriatric Medicine*. 2010;26(4):645–692.
- Papaioannou A, Parkinson W, Cook R, Ferko N, Coker E, Adachi JD. Prediction of falls using a risk assessment tool in the acute care setting. *BMC Medicine*. 2004;2:1.
- Pavlik T. *Biostatika pro matematickou biologii*. In: Holčík J, Komenda M et al. *Matematická biologie: e-learningová učebnice*. 1. vyd. Brno: Masarykova univerzita; 2015 [cited 2016 Oct 10]. Available from: <http://portal.matematickabiologie.cz/index.php?pg=aplikovan-a-analyza-klinickyh-a-biologickyh-dat--biostatistika-pro-matematickou-biologii> (in Czech)
- Perell KL, Nelson A, Goldman RL, Luther SL, Prieto-Lewis N, Rubenstein LZ. Fall risk assessment measures: an analytic review. *Journals of Gerontology, Series A, Biological Sciences and Medical Sciences*. 2001;56(12):M761–766.
- Scott V, Votova K, Scanlan A, Close J. Multifactorial and functional mobility assessment for fall risk among older adults in community, home-support, long-term and acute care settings. *Age and Ageing*. 2007;36(2):130–139.
- Schisterman EF, Perkins NJ, Liu A, Bondell H. Optimal cut-point and its corresponding Youden Index to discriminate individuals using pooled blood samples. *Epidemiology*. 2005;16(1):73–81.
- Schwendimann R, De Geest S, Milisen K. Evaluation of the Morse Fall Scale in hospitalised patients. *Age and Ageing*. 2006;35(3):311–313.
- Sung YH, Cho MS, Kwon IG, Jung YY, Song MR, Kim K, Won S. Evaluation of falls by inpatients in an acute care hospital in Korea using the Morse Fall Scale. *International Journal of Nursing Practice*. 2014;20(5):510–517.
- Tinetti ME, Williams TF, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. *American Journal of Medicine*. 1986;80(3):429–434.
- Vassallo M, Stockdale R, Sharma JC, Briggs R, Allen S. A comparative study of the use of four fall risk assessment tools on acute medical wards. *Journal of the American Geriatrics Society*. 2005;53(6):1034–1038.
- Youden WJ. Index for rating diagnostic tests. *Cancer*. 1950;3(1):32–35.
- Zvárová J. *Základy statistiky pro biomedicínské obory*. 1. vyd. Praha: Karolinum; 1998. (in Czech)