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REVIEW

Comparison of drug-related problem risk assessment tools for older adults: a systematic review

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Abstract

Purpose This study aims to systematically review studies describing screening tools that assess the risk for drug-related problems (DRPs) in older adults (≥ 60 years). The focus of the review is to compare DRP risks listed in different tools and describe their development methods and validation.

Methods The systematic search was conducted using evidence-based medicine, Medline Ovid, Scopus, and Web of Science databases from January 1, 1985, to April 7, 2016. Publications describing general DRP risk assessment tools for older adults written in English were included. Disease, therapy, and drug-specific tools were excluded. Outcome measures included an assessment tool's content, development methods, and validation assessment.

Results The search produced 15 publications describing 11 DRP risk assessment tools. Three major categories of risks for DRPs included (1) patient or caregiver related risks; (2) pharmacotherapy-related risks; and (3) medication use process-related risks. Of all the risks included in the tools only 8 criteria appeared in at least 4 of the tools, problems remembering to take the medication being the most common (n=7). Validation assessments varied and content validation was the most commonly conducted ($n = 9$). Reliability assessment was conducted for 6 tools, most commonly by calculating internal consistency ($n = 3$) and inter-rater reliability ($n = 2$).

Conclusions The considerable variety between the contents of the tools indicates that there is no consensus on the risk factors for DRPs that should be screened in older adults taking multiple medicines. Further research is needed to improve the accuracy and timeliness of the DRP risk assessment tools.

Keywords Drug-related problem · Risk management · Geriatrics · Mass screening · Risk assessment · PRISMA statement

Introduction

Drug-related risk management has become an important area of research in patient safety. It is estimated that approximately half of the drug-related incidents contributing to severe harm could be prevented by managing risks through interventions at different points of the medication use process [1]. The World Health Organization's (WHO) program, Medication Without Harm, aims to globally reduce severe avoidable drug-related harm by 50% in 5 years [2]. Drug-related risk management aims at reducing medication errors that might potentially or actually cause drug-related problems (DRPs) or risk of DRPs [3]. A DRP is an event or circumstance involving drug therapy that actually or potentially interferes with desired health outcomes (PCNE) [4]. Another definition for a DRP emphasizes that a DRP can either cause harm or result in medication treatment not reaching its goal [5].

Identification of actual or potential risk factors for DRPs should be considered an essential part of safe medication use particularly in older adults. Although there is considerable research on explicit criteria assessing inappropriate prescribing, these criteria mainly target a small part of the whole problem [6]. DRP's can occur in any phase of the medication use process. Through DRP risk identification in patient selection for different interventions, DRPs can be identified and resolved with a more targeted approach. DRP risk assessment tools have been developed taking into consideration special features of geriatric patients. However, the content of these

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tools have not been systematically reviewed. The objective of this study was to systematically review the content of screening tools intended for assessing risks for DRPs in older adults (≥ 60 years). The focus of the review was to compare DRP risk factors in different tools and describe the methods applied in their development and validation.

Methods

Search strategy and literature search

This systematic review conformed to the PRISMA checklist [7, 8]. The evidence-based medicine (EBM), Scopus, and Web of Science (WOS) databases were searched from January 1, 1985, till April 6, 2016 and Medline Ovid database from January 1, 1985, till April 7, 2016 for eligible publications. The search terms used in the systematic search were ((elderly OR aged OR ageing) AND ("medication-related problem*" OR "drug-related problem*" OR "drug therapy problem*" OR "medicine-related problem*" OR "medication management problem*" OR "therapy-related problem* OR "DRP*") AND (risk OR risk assessment) AND (screen OR "screening tool" OR form OR assessment* OR evaluation* OR indicator* OR criteria OR survey* OR questionnaire* OR factor* OR "risk factor*)). CINAHL database was included in the pilot search but was excluded from further searches because of a very low number of potentially relevant publications. Thus, the results for the CINAHL database are reported according to the pilot search on October 29, 2013.

The publications found in the searches ($n = 4279$) were first evaluated according to the predetermined inclusion and exclusion criteria (Table 1) by one of the authors (EP) by reading the title (Fig. 1). Then two authors (EP and SJ) assessed the publications independently by reading the abstract ($n = 196$) and finally by reading the whole text ($n = 54$). Duplicates ($n = 34$) were excluded before reading the full-texts. Any disagreements were resolved through discussion. Reasons for exclusion of the full-text publications ($n = 44$) are reported in Fig. 1. A manual search of the references and author's own collection of publications was conducted (EP), and 5 publications meeting inclusion criteria were discovered, one of which was not explicitly meant for older adults [9]. This publication was included in the review due to its importance for development of other DRP risk assessment tools. Of these five publications, two were received from the authors of included publications as additional information [10, 11]. Manually researched publications were also assessed by a second assessor (SJ).

To get insight into the clinical use and clinical validation of these screening tools, we contacted the authors of the publications. For those screening tools, we were unable to contact the author we made an additional search from the Medline database to find the publications that cited the original screening tool. From these sources, we were able to find publications describing clinical use or validation in patient surroundings.

Data extraction and analysis

Country of origin, criteria contents, setting in which the tool is meant to be used, development methods, and the evidence used to determine the criteria, nature of the criteria (explicit/implicit), the primary user of the tool, and information on the primary validity or reliability of the tool were analyzed. Also information on clinical use and validation was extracted.

Results

This systematic review identified 15 publications describing 11 DRP risk assessment tools, 10 of which were specially designed for older adults aged 60 years and above (Fig. 1, Tables 2 and 3 and Online Resource 1). The general tool,

Table 1 Inclusion and exclusion criteria used in the literature search

Inclusion criteria	Exclusion criteria
Patients ≥ 60 years old (evidence-based medicine, Scopus, Web Of Science, Medline). Patients ≥ 65 years old (CINAHL)	Patients < 60 years old. (CINAHL <65 years old)
English	Language other than English
Describes a general drug-related problem risk assessment tool	Describes a disease, therapy, and drug-specific tool or a tool focusing solely on inappropriate prescribing or adherence
Describes the end user of the tool and in what setting it is meant to be used	Does not describe by whom and in what setting the tool is meant to be used
Published between January 1, 1985–April 7, 2016 (CINAHL January 1, 1985–October 29, 2013)	Published before January 1,1985, or after April 7, 2016
The tool focuses on older population in general	The tool focuses on other than older population or only on a certain part of the older population, e.g., having the same disease or drug therapy
Published in a peer-reviewed journal	Published in other than peer-reviewed journal

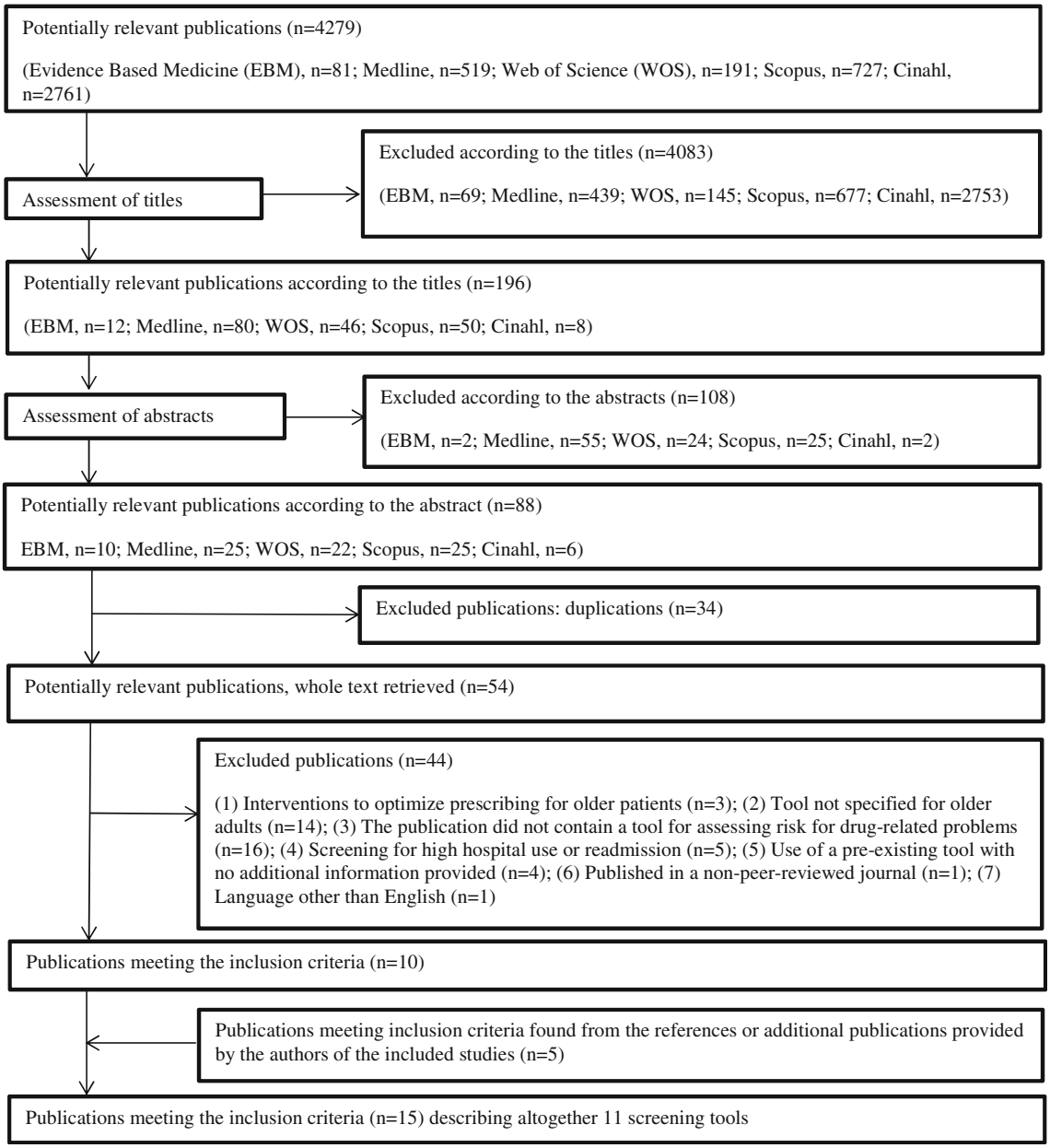

Fig. 1 Flowchart of the study

without age specifications, was the earliest tool, published in 1989 [9] and used as a foundation for four other tools developed later [15, 27, 35, 38].

Seven of the tools (64%) were intended to be used in primary care, mostly in home care or community nursing ($n = 4$) [20, 33, 34, 38] (Table 2). Three of the tools targeted ambulatory care [9, 14, 15], one focused on intermediate care [27], and one targeted computer screening of risks for DRPs [34]. Nearly all ($n = 10/11$) of the tools were developed to be used explicitly [9, 15, 17, 20, 27, 30, 33–35, 38]. Two of the tools had an established scoring system making the interpretation of the results explicit [14, 17]. Four of the tools were designed to be completed by the patient [15, 27, 30, 35]. Four tools were designed to be used by pharmacists [9, 14, 17, 34] or nurses [17, 20, 33, 38], while two of the tools had several possible end users [17, 38].

Contents of the tools

The risk assessment tools encompassed 4–71 criteria, seven of the tools containing less than 20 criteria (Tables 3 and Online Resource 1). These criteria were divided into three main risk categories: patient or caregiver-related risks, pharmacotherapy-related risks, and medication use process-related risks (Online Resource 1). The patient or caregiver-related risks included older age, multiple comorbidities, and

Table 2 Summary of the risk assessment tools, their development methods, and validity and reliability assessments

Name of the tool	Authors and country where research was conducted	Purpose and end user of the tool	Setting	Development process	Implicit/ explicit	Primary validation	Reliability
Prognostic indicators for ambulatory patients who would need pharmacist monitoring	Koehler et al. 1989 USA [9]	To determine which patients would potentially benefit the most from a pharmacist intervention. End user: Pharmacist	Ambulatory care	Draft made based on existing literature ([12, 13] and other literature not specified). Expert panel of ambulatory care pharmacist ($n = 8$) were asked to rank the potential criteria on two rounds. Top six were included in the criteria	Use of the tool explicit, interpretation of the results requires clinical judgment	Content validation demonstrated by medical chart review ($n = 239$). Compared the numbers of patients presenting each indicator with those who didn't and if they were more likely to present adverse outcomes specified the same way as the indicators. (Chi-square and logistic regression analysis)	No measure for reliability reported
Risk assessment profile (RAP)	Sidel et al. 1990 USA [14]	To detect older patients at high risk for medication-related problems who might potentially benefit from a community-based intervention by a pharmacist. End user: Pharmacist	Ambulatory care	71 questions in 9 categories were developed using the research team s expertise and existing literature (not specified). A few questions were additionally included from a wider survey (no reference information presented). A weighted scale was developed for scoring the risk	Use of the tool implicit. However the scoring does make the interpretation of the results explicit	No measure for validity reported	No measure for reliability reported
10-item self–-administered medication-risk questionnaire	Barenholtz Levy 2003 USA [15]	To detect those older patients (≥ 60 years) that has the most risk for medication-related problems. End user: Patient	Ambulatory care	Ten items selected for inclusion from existing literature ([9, 16] and unpublished screening tools from colleagues). Clarity of the questionnaire pilot-tested	Use of the tool explicit, interpretation of the results/-answers of the questions requires clinical judgment	Content validation: number of yes answers on the questionnaire correlation with higher drug regimen review severity scores ($r = 0.556$; $p = 0.01$) Drug regimen review scores were based on an earlier drug-related problem categorization (Strand et al. 1990)	Inter-rater reliability ($r = 0.847$; $p < 0.001$), Test-retest reliability ($r = 0.889$; $p < 0.001$), Internal consistency ($\alpha = 0.69$)
Self-medication risk assessment instrument	Fuller and Watson 2005 UK [17]	To identify people who may have difficulty managing their medication safely. End user: Nurse, Pharmacist, Physician, Community therapist or Social service career	Primary care, both in-patient and out-patient, and social care	List was based on findings in earlier studies by the author [18, 19]	Use of the tool and the interpretation of the results are explicit	Content validation: correlation between the different questions on the tool and a subjective assessment of risk by the assessor	Inter-rater reliability ($r = 0.82$ $p < 0.01$), Intra-rater reliability ($r = 0.97$ $p < 0.01$), Internal consistency ($\alpha = 0.33$)

Table 2 (continued)

Name of the tool	Authors and country where research was conducted	Purpose and end user of the tool	Setting	Development process	Implicit/ explicit	Primary validation	Reliability
Risk Factors for an Untoward Medication Event	Johnson et al. 2005 Australia [20]	To distinguish elders at high risk of an untoward medication event. End user: Nurse	Primary care/-community nursing	The survey tool included a broad list of previously validated items, tools, and scales, for example, related to medication complexity, adherence, cognitive function, patient's ability to self-medicate, and person administering the medication [9, 21–26]	Use of the tool explicit, interpretation of the results of the questions requires clinical judgment	Content validation: compared the results from a structured interview to adherence and drug-regimen complexity scores mentioned earlier by using regression analysis and cluster analysis	No measure for reliability reported
Risk factors for medication misadventure (MRQ)	George et al. 2006 UK [27]	To identify risk factors for unplanned hospitalizations among residents of sheltered housing complexes (SHCs). End user: Patient	Intermediate care/sheltered housing	Tool is an extended version of the 10-item self-administered medication-risk questionnaire. The additional contents include Townsend scale for disability and patient self-reported adherence tool, Morisky scale [15, 24, 28, 29]	Use of the tool explicit, interpretation of the results requires clinical judgment	The individual scales used were validated in previous studies. [24, 28, 29]. Content validation: analysis of whether or not the individual questions in the tool predict hospitalization and further analysis by logistic regression model (forward selection method validated by backward selection method)	Internal consistency of the disability score (Crohnbach's $\alpha = 0.91$)
Name of the tool	Authors and country	Purpose of the tool/end user	Setting	Development process	Implicit/explicit	Primary validation	Reliability
Medication risk assessment form	Pit et al. 2007 and 2008 Australia [30, 31]	To identify patient risk factors for medication misadventures. End user: Patient	Primary care/general practitioner's surgery	Existing studies including a list of triggers published by the Australian National Prescribing Service and expert opinion through comments and a workshop. Pretested for comprehensibility and pilot-tested [31, 32]	Use of the tool explicit, interpretation of the results of the questions requires clinical judgment	The acceptability, feasibility, and quality of the form were determined through direct observation, cognitive laboratory techniques, or unstructured interviews. No data presented. Content validation: comparing the results of the risk assessment to the GP's choices on who to make the medication review	As part of direct observation, a member of the research group was located in the waiting room to observe whether the patients were able to complete the form. No data presented
Safe Medication Assessment (SMA) Tool	Gusdal et al. 2011 Sweden [33]	To identify factors highly related to unsafe medication management among older patients. End user: Home care district nurse	Primary care/-homecare	Used findings of the Swedish working group for better use of medicines as a basis and expert opinion through ranking the items. Pilot tested	Use of the tool explicit and interpretation of the results of the questions	Applicability of the tool: a subjective opinion of the nurses, for example, on whether they received any new information (64%), did it lead to any interventions	Inter-item correlation (Crohnbach's $\alpha = 64\%$)

Table 2 (continued)

Name of the tool	Authors and country where research was conducted	Purpose and end user of the tool	Setting	Development process	Implicit/ explicit	Primary validation	Reliability
					require clinical judgment	(23%), and whether the possible extra time used (81%) was worth it (79%)	
Monitor-Rx	Lukazewski et al. 2012 Addtional information from the author: Feinberg et al. 2004 USA [11, 34]	To detect older patients at risk for medication-related geriatric syndromes. End user: Pharmacist	Primary care/-homecare	No specific information, part of a large investment project run by Agency for Healthcare Research and Quality, based on an earlier GRAM® software [11]. Process seemed to focus especially on the risk for falls and delirium and the medicines related to them	Use of the tool completely explicit	Content validation: the percentages of detected patients having a specific geriatric syndrome by using Monitor-Rx and by geriatric pharmacists. Results varied depending on the geriatric syndrome in question	No measure for reliability reported
Medication user self-evaluation (MUSE) tool	Doucette et al. 2013 USA [35]	To identify Medicare Part D beneficiaries who would benefit from a comprehensive medication review (a part of MTM services). End user: Patient	Primary care/Medicare beneficiaries	The draft tool based on literature, previous tools, and expert opinion. The final tool was formed using ordinal logistic model with clinical pharmacist opinion as the golden standard. Akaike information criterion (AIC) model selection measure was used in finalizing the tool. [9, 15, 36, 37]	Use of the tool explicit, interpretation of the results of the questions requires clinical judgment	Content validation: validation of the model with more cases with clinical pharmacist opinion as the golden standard (prediction accuracy 68%)	No measure for reliability reported
Drug-related problem risk assessment tool (DRP-RAT)	Dimitrow et al. 2011, 2014 and 2015 Finland [38–40]	To identify those home care patients aged ≥ 65 years at high risk for adverse drug reactions or other drug-related problems. To assist in recommending the potential risk clients intervening actions for optimizing their pharmacotherapy. End user: Practical nurse or Nurse	Primary care/-homecare	Used two systematic reviews ([40] and an unpublished one) and expert opinion to form a draft tool. Earlier tools that were used as foundation for the draft [9, 15, 17, 20, 31, 33]	Use of the tool explicit, interpretation of the results of the questions requires clinical judgment	Content validation through Delphi-technique. Feasibility: qualitative analysis of the discussions during training (what assisted and what hindered the use of the tool)	Tested practical nurses (PN) ability to recognize risk medication compared with the actual medication list (88% accuracy)

medication adherence or self-management problems as risk factors for clinically significant DRPs. The items concerning medication adherence and self-management demonstrated more variety between the tools compared to any other risk categories. Pharmacotherapy-related risks most commonly indicated risks caused by polypharmacy, potentially inappropriate medications for older adults (PIMs), potential ADRs, and recent changes in medication regimen. Most common PIMs listed in the tools included carbamazepine ($n = 3$) [15, 27, 38], digoxin ($n = 3$) [15, 27, 38], lithium ($n = 3$) [15, 27, 38], theophylline ($n = 3$) [15, 27, 38], and warfarin ($n = 3$) [15, 27, 38]warfarin (n = 3) (ref). The most common potential ADRs were classified as drowsiness ($n = 2$) [30, 38], visual problems ($n = 2$) [14, 38], nausea ($n = 2$) [30, 38], constipation ($n = 2$) [30, 38], skin rash ($n = 2$) [30, 38], and dizziness ($n = 2$) [30, 38]. The tools included a few risks related to the medication use process such as health service visits, number of physicians involved in patient's care, and living arrangements.

The most common risks that appeared in at least four of the tools were established (Tables 3 and Online Resource 1). "Problems remembering to take the medication" was the most frequent item and was included in seven of the tools [14, 20, 27, 30, 33, 35, 38]. Only one of the tools gave options for resolving the risks identified [38].

Validity and reliability

The primary validity of the tool was assessed more commonly ($n = 9$) than reliability ($n = 6$) (Tables 2 and 3). For one of the tools, validation was not reported [14], and reliability was not assessed for five of the tools [9, 14, 20, 34, 35]. There seemed to be no consistent type of validity or reliability assessment. Content validation ($n = 9$) [9, 15, 17, 27, 30, 34, 35, 38] and assessing the applicability of the tool ($n = 3$) [30, 33, 38] were the most common types of validation. Internal consistency ($n = 3$) [15, 17, 27] and inter-rater reliability ($n = 2$) [15, 17] were the most common types of reliability assessment.

The outcome variables used for primary validation varied from study to study. For example, number of recognized risk factors (intervention group vs. control group) and measures used to assess adherence and medication regimen complexity were used as outcomes in different studies. Also it is worth noting that validation of the scoring was not reported for both tools that had a scoring system [14, 17]. The most comprehensive evaluation of primary validity and reliability were done in Barenholz-Levy's, Fuller and Watson's, Gusdal's, and Dimitrow's research [15, 17, 33, 38].

Additional clinical validation [10, 41] was done only for two of the screening tools (Table 4) [15, 38]. Three of the tools [9, 15, 38] were reported in clinical use in scientific publications [42–50].

Discussion

This is the first systematic review evaluating and comparing the content and development processes of published criteria for DRP risk assessment for older adults. It provides insights into the evidence and content of DRP risk assessment tools. This information is important because these tools maybe used for clinical decision making, by screening older adults at risk for DRPs.

Our systematic review found considerable variety in the number and contents of the criteria included in the risk assessment tools; only eight of the risks were similar between the tools (Problems with remembering to take the medication ($n = 7$) [14, 20, 27, 30, 33, 35, 38], Not knowing indications for the medicines ($n = 5$) [15, 27, 30, 33, 38], More than one physician involved in patient's care ($n = 5$) [15, 20, 27, 30, 38], ≥ 12 doses per day ($n = 5$) [9, 15, 20, 27, 38], ≥ 5 medicines in use ($n = 4$) [9, 15, 27, 30], ≥ 3 illnesses ($n = 4$) [15, 27, 30, 38], ≥ 4 changes in the medication regimen within the last year ($n = 4$) [9, 15, 27, 30], and Problems taking medicine out of the bottle or using a dose dispenser or therapeutic devises ($n = 4$) [14, 30, 33, 38]). The different settings and end users they were designed for may partly explain the variety in the content of the tools. Four of the tools were designed for patients [15, 27, 30, 35], and the rest for healthcare professionals [17, 20, 33, 38]. The earliest tool was published two decades ago [9], and the most recent was published in 2014 [38]. This time period corresponds to the publication of criteria used in the assessments of PIMs, which may partially explain the different content of the tools. Five of the tools used previously published tools as a basis for the development [15, 20, 27, 35, 38]. This may be considered a strength if the tool used as a foundation was developed through a rigorous method and is well validated. The data that is used should not be outdated but represent the knowledge of risks for DRPs in the elderly population at the time of publication. The critical evaluation of the previous criteria is needed if the specific criteria are to be used as a foundation for a new risk assessment tool. The use of previous tools might bring more evidence and validity for the new tool but might also limit the ingenuity and timeliness of the contents of the new tools.

The primary validity and reliability assessments of the tools varied substantially. Content validation was done for most of the tools ($n = 9/11$) [9, 15, 17, 20, 27, 30, 34, 35, 38], while two of the tools [14, 33] were not assessed for content validity which is a significant limitation [51]. Five of the tools [9, 30, 33, 35, 38] used expert opinion in their development process, but only one of them was further validated using the Delphi method [38]. Two other tools used expert opinion consensus to rank the items that would be included in the final tool in one or more rounds [9, 33]. A recent review on methodology to assess content validity highlights the importance of determining content validity for new instruments [51]. The

Table 3 Summary of the characteristics of the drug-related problem risk assessment tools ($n = 11$)

Country of origin	USA ($n = 5$) [9, 14, 15, 34, 35]	
	UK ($n = 2$) [17, 27]	
	Australia ($n = 2$) [20, 30]	
	Sweden ($n = 1$) [33]	
	Finland ($n = 1$) [38]	
Setting	Primary care	Homecare or community nursing ($n = 4$) [20, 33, 34, 38]
		General practitioner's surgery ($n = 1$) [30]
		Medicare beneficiaries ($n = 1$) [35]
		Primary care and social care ($n = 1$) [17]
	Ambulatory care ($n = 3$) [9, 14, 15]	
	Intermediate care/sheltered housing ($n = 1$) [27]	
Use of the tool implicit / explicit	Explicit ($n = 10$) [9, 15, 17, 20, 27, 30, 33–35, 38]	
	Implicit ($n = 1$) [14]	
Number of criteria	1–4 criteria ($n = 1$) [20]	
	5–9 criteria ($n = 3$) [9, 17, 35]	
	10–14 criteria ($n = 1$) [15]	
	15–19 criteria ($n = 2$) [27, 33]	
	20–29 criteria ($n = 1$) [38]	
	30–34 criteria ($n = 1$) [30]	
	≥ 35 criteria ($n = 1$) [14]	
	Unknown ($n = 1$) [34]	
The most common risks that appeared in at least four of the tools	Problems with remembering to take the medication ($n = 7$) [14, 20, 27, 30, 33, 35, 38]	
	Not knowing indications for the medication ($n = 5$) [15, 27, 30, 33, 38]	
	More than one physician involved in patient's care ($n = 5$) [15, 20, 27, 30, 38]	
	≥ 12 doses per day ($n = 5$) [9, 15, 20, 27, 38]	
	≥ 5 medicines in use ($n = 4$) [9, 15, 27, 30]	
	≥ 3 illnesses ($n = 4$) [15, 27, 30, 38]	
	≥ 4 changes in the medication regimen within the last year ($n = 4$) [9, 15, 27, 30]	
	Problems taking medicine out of the bottle or using a dose dispenser or therapeutic devises ($n = 4$) [14, 30, 33, 38]	
End user of the tool*	Patient ($n = 4$) [15, 27, 30, 35]	
	Pharmacist ($n = 4$) [9, 14, 17, 34]	
	Nurse ($n = 4$) [17, 20, 33, 38]	
	Practical nurse ($n = 1$) [38]	
	Physician ($n = 1$) [17]	
	Social service carer ($n = 1$) [17]	
	Community therapist ($n = 1$) [17]	
Validity assessment**	Content validation ($n = 9$) [9, 15, 17, 20, 27, 30, 34, 35, 38]	
	Applicability of the tool ($n = 3$) [30, 33, 38]	
	No reported validity assessment ($n = 1$) [14]	
Reliability assessment**	Internal consistency ($n = 3$) [15, 17, 27]	
	Inter-rater reliability ($n = 2$) [15, 17]	
	Intra-rater reliability ($n = 1$) [17]	
	Test-retest reliability ($n = 1$) [15]	
	Inter-item correlation ($n = 1$) [33]	
	Other assessments ($n = 2$) [30, 38]	
	No reported reliability assessment ($n = 5$) [9, 14, 20, 34, 35]	

*Results do not add up to 11 since there could have been several possible end users

**Results do not add up to 11 since several assessments of validity and reliability could have been undertaken

Table 4 Clinical validation and use of the DRP risk assessment tools

Author of the tool	Information source: author or Medline	Clinical validation	Clinical use
Koecheler et al. 1989 [9]	Medline (30 search results)	None	Malone et al. [42] IMPROVE study of which there is considerable amount published [43–47]
Sidel et al. 1990 [14]	Medline (13 search results)	None	None
Barenholz Levy 2003 [15]	Author	Barenholz Levy and Steffen: significant correlation with perceived medication management hassles and reports of care recipients' falls, injuries, emergency department visits, unplanned healthcare visits, CDC Healthy Days, and amount of unused medications that interfere with current medication management. [41]	Moore et al. [48]. Tan et al. [49]
Fuller and Watson 2005 [17]	Author	None	None
Johnson et al. 2005 [20]	Medline (10 search results)	None	None
George et al. 2006 [27]	Medline (6 search results)	None	None
Pit et al. 2007 [30]	Medline (5 search results)	None	None
Gusdal et al. 2011 [33]	Medline (5 results)	None	None
Lukazewski et al. 2012 [34]	Author	None	None
Doucette et al. 2013 [35]	Author	None	None
Dimitrow et. al. 2014 [38]	Author	Dimitrow et al.: additional content validation by geriatrician's appraisal of relevance of the questions. Feasibility according to a geriatrician's assessment of the clinically important information the tool presented. Validity in patient surroundings and comparison to a geriatricians risk appraisal with or without the DRP-RAT. [10]	Toivo et al. [50]

recommendation of the authors was that content validity processes and indices are critical factors in the instrument development process and should be treated and reported as other types of construct validation. It is also important to keep in mind that every technique used in developing a risk assessment tool has its own limitations [52]. For example, the criteria developed through literature review may not evaluate the quality of evidence. Furthermore, consensus panels, such as Delphi method, only provide knowledge on the opinion of those experts included in the process at that moment in time. These aspects of instrument validation should be considered when deciding which tools will be used in clinical practice. Very few tools were additionally validated or used in clinical settings (Table 4). This presents a further limitation for the evidence-based use of these risk assessment tools.

Most tools ($n = 7/11$) [17, 20, 30, 33–35, 38] were designed to be used in different primary care settings (homecare or community nursing ($n = 4$) [20, 33, 34, 38], general practitioner's surgery ($n = 1$) [30], Medicare beneficiaries ($n = 1$) [35], and primary care and social care ($n = 1$) [17]) which may partly explain the variety in the risks for DRPs found in the tools. This is in line with findings from Devik et al. [53] from Norway and Leikola et al. from Finland [54]. Both found that DRPs identified in older adults varied in number and in nature depending on whether the patients resided at home or nursing home. These findings demonstrate that the transfer of a tool to a new setting must be accompanied by a new validation of the applicability [51]. That is why tools validated in different settings and for different end users need to be available, which was demonstrated in our systematic review. Also the content and feasibility of the risk assessment tools require regular updating with new research data, pharmacotherapies, and current care guidelines.

No consensus existed in potential ADRs and potentially harmful medication categories listed in the tools. No single risk medication appeared in more than three of the tools, and no single ADR appeared in more than two tools (Online Resource 1). The most common risks for DRPs in the tools were focused on the number of regularly used medicines ($n = 4$) [9, 15, 27, 30], number of doses ($n = 5$) [9, 15, 20, 27, 38],

and problems remembering to take the medicines ($n = 7$) [14, 20, 27, 30, 33, 35, 38]. However, the number of medicines a patient is taking has a limited ability to represent the risk for DRPs [55]. When the patient's medication regimen is planned appropriately, polypharmacy should not be harmful. On the other hand, if the criterion for the risk for DRPs is set, e.g., to 10 medicines, it will exclude many patients at potential risk who have fewer medicines [10]. Two recently established sets of core outcomes measures for trials aimed at improving the appropriateness of polypharmacy in older adults [56] could be useful in guiding further criteria development and standardization of criteria.

Strengths and limitations

The thorough pilot testing of the search terms, systematic data abstraction, and analysis according to PRISMA Guidelines [7, 8] resulted in a robust search strategy and systematic review process. Notwithstanding this, a variety of terms used to describe DRPs or different kinds of risk assessments for DRPs [5] means that some publications may not have been identified. However, to improve the coverage, we also searched the references of the included articles and contacted the authors in unclear situations. The language was restricted to English, so possible studies published in other languages were excluded. Because of the lack of potentially relevant publications in the CINAHL database in the first phase of the literature search in 2013, it was excluded from the newer search covering the years 2013–2016. The publications were assessed for inclusion by two authors (EP and SJ) by using predetermined inclusion and exclusion criteria. However, data were extracted from the included publications and analyzed by only one of the authors (EP). This might have created bias in this study.

Future studies

Establishment of new criteria should be continued since only 11 risk assessment tools were located, of which seven tools were developed over 10 years ago and two over 5 years ago. There was considerable variety in essential factors that could cause risk for DRPs. This systematic review provides a good foundation on which to create a better consensus. Current research and recommendations concerning PIM criteria and DRP classifications needs to be taken into account in future research projects.

Conclusions

The considerable variety between the content of the assessment tools indicates that there was no consensus on the risk factors for DRPs that should be screened in older adults. Further research is needed to improve the appropriateness and timeliness of the DRP risk assessment tools.

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