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Which criteria are important in usability evaluation of mHealth applications: an umbrella review

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Abstract

Introduction Usability plays a critical role in the design of mHealth applications. A well-designed app enhances user experience and contributes to better healthcare outcomes. However, it remains unclear which usability criteria are often neglected, leading to issues in the actual use of these applications. This study aimed to identify and categorize the usability issues of mHealth applications, mapping them to Nielsen's usability principles to determine the most critical criteria.

Methods The PRISMA guidelines were followed to report the results. Different databases (PubMed, Scopus, WoS) were searched for systematic reviews and/or meta-analyses about usability evaluation in mHealth applications. Two reviewers independently applied predefined selection criteria, extracted data, and assessed methodological quality using the AMSTAR tool.

Results Eight studies met the inclusion criteria. The most common method used in studies to evaluate the usability of mHealth applications was the questionnaire. Researchers identified 79 usability issues from the studies. Eleven of the issues were related to the Aesthetic and minimalist design category. The category of Flexibility and efficiency of use was next ($n=10$).

Conclusion This study identified the usability issues that individuals face when using mHealth applications. By mapping these issues to evaluation criteria, developers can systematically address and prevent them. Attention to these issues will lead to better design and more effective use of mHealth applications.

Keywords Usability evaluation, Mobile application, mHealth, Systematic review

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Introduction

Population aging, the prevalence of chronic diseases, and the severe shortage of health services and resources have led healthcare systems to use mobile health (m-Health) applications. The use of these applications has led to greater access to healthcare and its delivery, quick communication with healthcare providers, and better self-management and self-monitoring [1–4]. Mhealth applications refer to the use of mobile devices, such as smartphones, tablets, and personal digital assistants (PDAs), to deliver healthcare services and manage health. These applications leverage mobile wireless technologies to support public health and clinical practices, including remote patient monitoring, health data collection, and health education [5, 6].

Mobile health apps have the potential to effectively improve the quality of care and can be rapidly adapted on a large scale [7]. Despite all the advantages of mHealth applications such as self-management, quick communication, etc., a significant challenge for users, doctors, and healthcare organizations is to choose which applications are effective and should be recommended to patients or used in the care system. Applications are often developed hastily; as a result, most mHealth programs have not been tested for safety or effectiveness [8–10]. One of the important aspects that may affect the effectiveness of mHealth applications is their usability [11]. If an application lacks adequate usability, it will be used less frequently and will not have a significant impact on health care [12, 13].

There are various definitions for usability. For example, the definition is stated by Nielsen [14] and includes five attributes, i.e., efficiency, learnability, memorability, errors/safety, and satisfaction. International standards such as ISO (International Organization for Standardization) have also defined usability as: "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [15]. There are various techniques to evaluate usability [16–19], each considering different criteria to measure usability attributes. A body of research [6, 20, 21] has also proposed criteria to measure usability in mHealth applications. However, it is not clear which criteria are important and have been neglected in the design of these applications. To find out what criteria have been neglected, the existing related literature needs to be reviewed.

The number of studies evaluating mobile applications is steadily increasing, with many systematic reviews being conducted across various settings and systems. This growing diversity highlights the need for a general study to determine the necessary criteria for evaluation in such a varied landscape. Various systematic review studies [22–24] have focused on the usability evaluation of mHealth applications. The goal of the present systematic review is to identify the issues users face when using these applications. By mapping these issues to evaluation criteria, we can determine which criteria are most important. Nielsen's criteria [25], which categorize usability principles, is one of the most widely used frameworks for assessing usability. In this study, we mapped identified usability issues to these criteria for better understanding, and any remaining issues were mapped to new criteria. This approach aims to consolidate and refine existing knowledge, providing a comprehensive guide for future research and practice in the mHealth landscape.

Methodology

We adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines while presenting the results [26].

Data sources and search strategy

We conducted a comprehensive search for related systematic reviews across the following databases (with no restriction on the year of publication and language): PubMed, Web of Science, and Scopus. Keywords were identified by reviewing thesaurus systems such as MeSH (Medical Subject Headings), the free text method, expert opinions, and the review of relevant primary studies and reviews. We used a combination of multiple search terms and Boolean operators that relevant to 'mHealth application', 'Usability evaluation', and 'systematic review' (Please refer to Supplementary Material 1 for the complete list of search terms and strategies).

Eligibility criteria

We included only systematic reviews, literature reviews, narrative reviews, and meta-analytical reviews that were written in English. We considered studies on the usability evaluation of mHealth applications that reported usability issues, barriers, or usability attributes. The exclusion criteria were: (1) studies that systematically evaluated applications in app stores, (2) systematic reviews that did not report usability issues, (3) systematic reviews that evaluated non-health mobile apps (4) systematic reviews that identified criteria, dimensions, and evaluation tools for health apps, (5) letters to the editor and protocol studies, (6) no full-text available.

Study selection

Mendeley version 2.92.0 was used to eliminate duplicates. The remaining studies were imported to an internet-based platform (Rayyan QCRI systematic review software) for review [27]. Rayyan QCRI is a free web and mobile application that helps expedite the initial screening of both abstracts and titles through a semi-automated process. During the screening stage, two authors (ZG and

MM) independently reviewed all titles and abstracts of the studies. Studies were chosen based on the eligibility criteria. In the subsequent stage, the same two authors independently examined the full text of the studies to identify the relevant studies. Any disagreement on the inclusion of a study was discussed by the two authors; when there was no agreement, a third author (R Kh) was consulted.

Methodological quality assessment

The methodological quality of the included reviews was evaluated using the Assessment of Multiple Systematic Reviews (AMSTAR) scale [28]. AMSTAR is a scale consisting of 11 items that assess the quality of studies based on factors such as an a priori design, assessment quality, and publication bias. Each item has three options: yes, no, or not applicable. If the specific criterion was met (yes), a score of one was assigned; and for the other two alternatives, a score of zero was assigned. The range of the overall quality score for each review ranged between 0 and 11. AMSTAR characterizes quality at three levels: high (total score 9 to 11), moderate (score 5 to 8), or low (score 0 to 4). All included studies were evaluated independently by two authors (ZG, MM). Any disagreement at this stage was resolved by consensus between the two authors and consultation with the third expert (R Kh).

Data extraction

A data extraction form was created in Microsoft Word 2019. Author's name, objective(s), year of publication, type of review, number of studies included in the systematic review, kind of disease, outcome measures in included studies, usability evaluation methods, usability issues/barriers, and target usability attributes were extracted from each study. Two authors (ZG, MM) independently performed data extraction. Disagreements were resolved through discussions between the authors. Usability issues extracted from the studies were mapped to Nielsen's ten heuristic principles. Usability issues that could not be mapped to these principles were categorized according to the related studies, based on their similarity [29–33].

Results

A total of 648 studies were identified. After removing duplicates, 413 remained and were screened for title and abstract. Of these, 43 studies were reviewed in full text. Eight studies met the inclusion criteria (Fig. 1).

Study characteristics

Table 1 shows the summary of the characteristics of the included studies. Based on the type of review addressed, four studies were found to be systematic reviews [13, 34–36], three systematic literature reviews [11, 37, 38] and one scoping review [39]. Six of the included studies were done on pain management [37], visually impaired [38], substance use disorder [34], bipolar disorder [39], type 2 diabetes [35], and deaf people [36]. One study was on postoperative care [13], and one review was on usability in the mHealth apps (general) [11].

The number of studies included in the systematic reviews varied widely. The study by Al-Razgan et al. had the highest number of studies included [34], with 60 studies. The lowest number of included studies was in the research by Tatham et al., which used 12 studies [35]. Almost all the included systematic reviews aimed to assess the current usability status of mHealth applications in specific diseases and to provide an overview of the features and problems. These systematic reviews also focused on providing insights for the development of a usability evaluation model for mobile applications in specific health domain. Two studies (25%) were published in 2020 [13, 36].

Usability issues or barriers

From the studies, 79 issues were obtained altogether. Having mapped the issues, the reviewers placed 47 issues (65%) into usability categories. Based on the discussion between the team members, 34% of these issues such as low technological literacy among elderly clients [36], and difficulty in diary entry because of few irrelevant symptoms for constant pain [37] were not considered for usability evaluation.

As shown in Table 2, out of Nielsen's ten principles, the reported issues were mapped to only five of these principles. Among these criteria, most issues were related to the Aesthetic and minimalist design category ($n = 11$). After that, the category of Flexibility and efficiency of use ($n = 10$) included the most items. No items were mapped to the Consistency and standards, Error prevention, Recognition rather than recall, Help users recognize, diagnose, and recover from error, Help and documentation categories. The rest of the issues were mapped to the categories of Technical features and support ($n = 8$), Pleasant and respectful interaction with the user ($n = 3$), Privacy and Security ($n = 2$), Compatibility between different platforms ($n = 2$), Functionality ($n = 1$), Navigation ($n = 1$), Learnability ($n = 1$), Avoid misleading relations ($n = 1$), User engagement ($n = 1$).

The most frequent usability attributes in included reviews

The most frequent usability attribute in the included reviews was satisfaction, followed by effectiveness (Table 3). Other attributes of usability that are usually evaluated in studies and mentioned in the included reviews are efficiency, operability, and accessibility. Other characteristics were mentioned in one or two studies. The included review studies usually categorized these

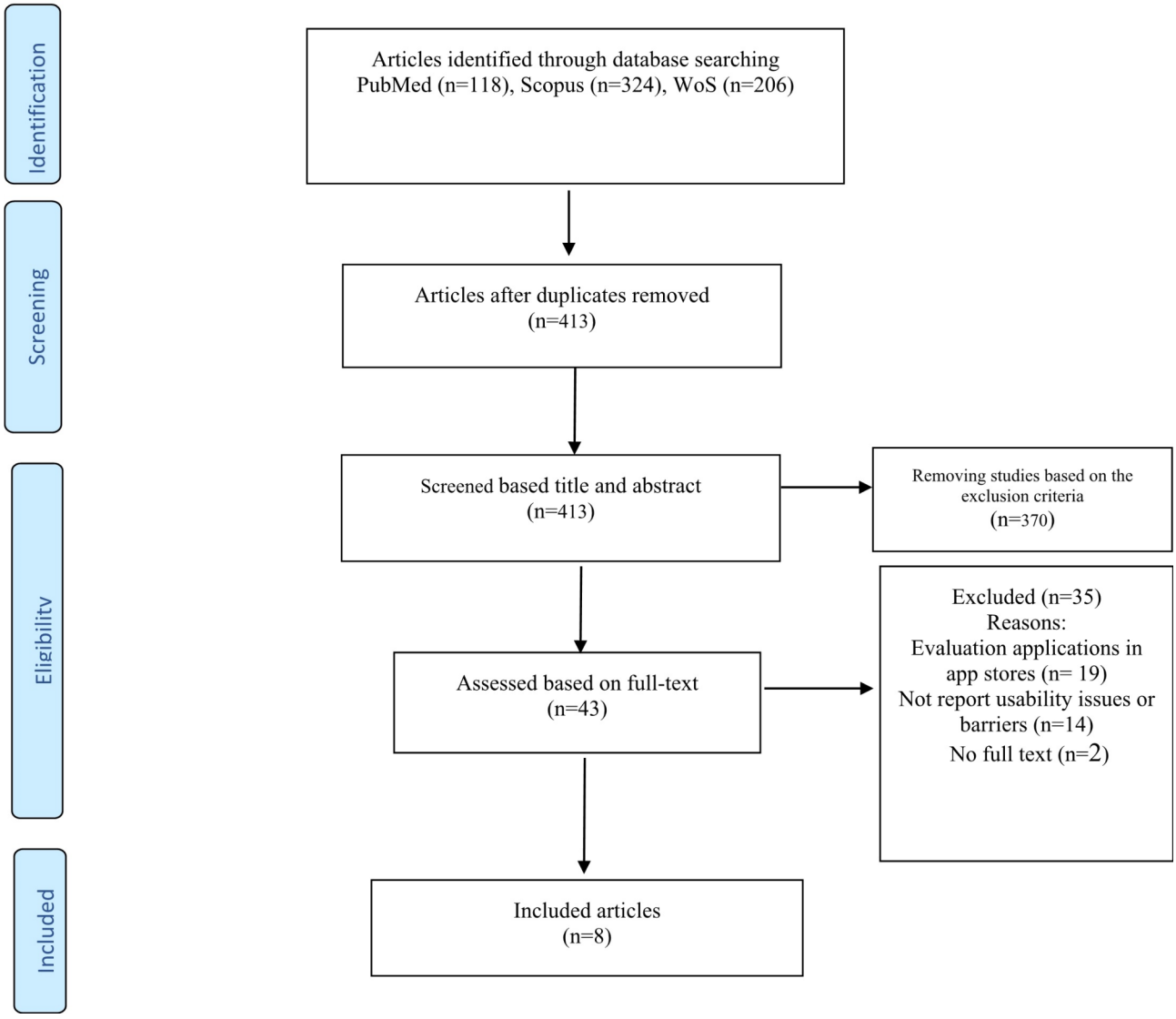

Fig. 1 PRISMA flow diagram

characteristics according to the existing standards and tools such as the MAUQ (mHealth App Usability Questionnaire), SUS (System Usability Scale), ISO 9241–11, and ISO/IEC 9126–1.

Usability evaluation methods

The questionnaire was the most common method used in studies for evaluating the usability of mHealth applications, as shown in Fig. 2 [11, 13, 34, 35, 37, 38], The researchers had either used self-created or standard questionnaires such as SUS, uMARS (User Version of the Mobile Application Rating Scale), or CSUQ (Computer System Usability Questionnaire). After the questionnaire, the most common method was the interviews [11, 13, 34, 37]. Almost half of the studies (46%) used these two methods. Some studies reported that these two methods were used together [11, 37]. Methods such as observation [37], usage (monitoring of user engagement with the app) [13], and implementing a log [11] were the least used for evaluating the usability of health-related applications.

Methodological quality assessment

Quality assessment in eight reviews based on the AMSTAR checklist is presented in Fig. 3 (Supplementary Material 2). One study was considered high quality based on the categorization of the AMSTAR total score [36], six were moderate [11, 13, 34, 35, 37, 38], and one was low quality [39]. As indicated in this table, no study evaluated the likelihood of publication bias. Only one [39] used publication status as an inclusion criterion. Only one study [36] adhered to the priori principle and followed it. All studies conducted a comprehensive literature review and used appropriate methods to combine the findings of these studies. Seven of the eight reviews described the

Table 1 Characteristics of the included studies

Authors	Year	Objectives	Type of study	Number of studies included in systematic	The domain of applications	Quality assessment
Shah and Chiew [37]	2019	Identifying, analyzing, and synthesizing the current of the design approaches and the usability features and assessment approaches of pain management mobile applications.	Systematic Literature Review	27	Pain Management	Medium
Al-Razgan et al. [38]	2021	To find discussions of usability issues related to people with visual impairments in recent studies and how they were solved using mobile applications	Systematic Literature Review	60	Visually impaired users	Medium
Carreiro et al. [34]	2020	To describe the current landscape, effectiveness and usability of connected interventions for substance use disorder.	Systematic review	32	Substance use disorder	High
Zapata et al. [11]	2015	To investigate the empirical usability evaluation processes described in a total of 22 selected studies related to mHealth applications by means of a systematic literature review	Systematic Literature Review	22	mHealth app (general)	Medium
Tatham et al. [39]	2022	To explore current process and outcome measures of mental health apps for bipolar disorder with the aim to provide a comprehensive overview of current research. This will identify the best practice for evaluating mental health apps for bipolar disorder and inform future studies.	Scoping Review	12	Bipolar Disorder	Medium
Fu et al. [35]	2017	To assess the usability and clinical effectiveness of diabetes mobile applications (diabetes apps) developed for adults with type 2 diabetes	Systematic review	20	Type 2 diabetes	Medium
Nathan et al. [36]	2018	To investigate few important dimensions to be applied in developing a usability evaluation model for mobile applications for deaf specifically.	Systematic review	43	Deaf people	Low
Patel et al. [13]	2020	To evaluate the (1) methodology of usability analyses, (2) domains of usability being assessed, and (3) results of usability analyses.	Systematic review	33	Postoperative Care	Medium

characteristics of the included studies and also provided a list of studies.

Discussion

The present systematic review of reviews identified design issues that mHealth application users face. Having reviewed the studies, the extracted issues were mapped to Nielsen's ten principles. Most issues among the criteria were related to Aesthetic and minimalist design followed by Flexibility and efficiency of use, according to this study.

In line with this study, Farzandipour et al. [40] showed that Flexibility and efficiency of use was a major usability issue in three admission and medical record subsystems integrated into hospital information systems. Agnisarman et al. [41] showed that Esthetic and minimalist design was the second usability issue in the home-based video telemedicine system. Dias et al. [42] in their systematic review also demonstrated that flexibility and efficiency of use were the most frequent instances of usability issues in health information systems.

Although this study identified some usability issues such as Aesthetic and minimalist design and Flexibility and efficiency of use, some studies others contended that based on the use and features of each application, it is necessary to have a dynamic evaluation for each mHealth application. In this methodology, the relevant criteria for each application are selected according to its use cases. For example, the evaluation criteria for an app that manages chronic disease are completely different from the evaluation criteria for the app that locates the nearest pharmacy. Furthermore, the 'calculation accuracy' metric is exclusively used for apps that provide at least one calculation. This type of evaluation can result in a more precise and efficient evaluation of the application [43, 44].

In this study, the most frequent usability attributes were satisfaction and effectiveness, which is consistent with the results of previous studies. Weichbroth et al. [45] demonstrated in their review study that roughly 88% of the studies that assessed the usability of mobile applications used satisfaction and effectiveness attributes. The operability attribute was the most frequent usability attribute in the studies of Shah and Chiew [37] and Zapata et al. [11], while this attribute was not mentioned at all in other reviews. The reason for this finding can be the different naming of usability attributes in different studies.

The findings of this study indicate that the predominant methods for evaluating mHealth applications were questionnaires and interviews. Researchers utilized a range of both general and specialized questionnaires to evaluate various aspects of mHealth applications. Typically, existing questionnaires are employed [46, 47], although there are instances where new instruments are developed to address specific research needs [48, 49].

Table 2 Categorization of usability issues

Category name	Usability issues
Visibility of system status	The application's sluggish reaction time [37] Extended duration of loading [34]
Match between system and the real world	Bewilderment in comprehending the jargon [37] This indicated a discrepancy between the design of technology and the practical experience of patients [35]
User control and freedom	The pressure to respond to all queries due to the unavailability of the slider [37]. There was no option to navigate back to the previous screens [37].
Flexibility and efficiency of use	Hard to use [37] Patients could not enter data manually [35] There were more errors due to spending too much time correcting the values [35] Ineffectiveness due to lack of interaction with health care professionals [37] Boring because of not enough content [34] There is an excessive number of reports [34] The intricate hierarchical arrangement and superfluous alternatives made it arduous to locate [37] The device was unwieldy and cumbersome [34] People with visual impairment face challenges in finding the bar code [38] Accessibility and usability problems for people with visual impairments [38]
Aesthetic and minimalist design	Buttons malfunctioning [37] The uselessness of some applications due to their lack of proper display [37] The difficulty of using the slider [37] Difficulty of users with stylus-based input [37] User problem with number selection boxes [37] Lack of sufficient area to identify the problem area on the body diagram [37] Users encountered difficulty in controlling the slider while scrolling down the screen [37] The font size was too diminutive for some users [37] The color scheme was not compatible with color blindness [37] The content was challenging to navigate on small screens of study phones [34] Usability issues identified were primarily due to product design flaws [35]
Privacy and Security	Users expressed apprehension about privacy and the possibility of legal consequences [34] There were concerns regarding privacy [39]
Compatibility between different platforms	The app was exclusively available on study smartphones and not participants' personal phones [34] The application was restricted to Android users [34]
Functionality	Some users felt uneasy about the GPS function of the app [34]
Navigation	Difficulty in system navigation whenever tasks required multiple steps [35]
Learnability	Users encountered difficulty in learning the application [37]
Avoid misleading relations	There were concepts that overlapped with one another [37]
User engagement	Communication about the app was inadequate between staff and clients, as well as among staff members themselves [34]
Pleasant and respectful interaction with the user	Over-alerting or repeated notification [37] Confusing pop-up screen messages [37] Alerts at inopportune times [34]
Technical features and support	The software frequently crashed or malfunctioned [37] Connectivity problems [34] Some clients had concerns about being monitored with the GPS feature [34] Additional technical support was necessary beyond the initial tutorial [34] Lower-income, middle-aged, and minority participants had limited experience with smartphone technology [34] Poor comprehension and perception of the GPS features [34] The location tool was susceptible to high-risk malfunctions, such as providing incorrect location data [34] Bluetooth malfunction [34]

In line with the present study, Hajesmaeel-Gohari et al. [50] showed that SUS, PSSUQ (Post-Study System Usability Questionnaire), and CSUQ were three widely used questionnaires to evaluate the usability of mHealth applications. Other studies showed that the use of standard checklists and questionnaires can determine system usability problems to an acceptable extent [51]. Zhou showed in his study [48] that although the MAUQ questionnaire was specifically designed to evaluate the usability of mHealth applications, it has rarely been used in usability evaluation studies. This lack of use may be due to the fact that this questionnaire was introduced in 2019, and researchers are not as acquainted with it. It is probable that researchers employ the MAUQ questionnaire in their evaluations, which is specifically designed to assess the usability of mHealth applications. Considering that many users used questionnaires to evaluate different aspects of mHealth applications, it is necessary to

Table 3 Usability attributes in the included reviews

Studies	Shah and Chiew, 2019 [37]	Al-Razgan et al., 2021 [38]	Carreiro et al., 2020 [34]	Zapata et al., 2015 [11]	Tatham et al., 2022 [39]	Fu et al., 2017 [35]	Nathan et al., 2018 [36]	Patel et al., 2020 [13]
Usability attributes								
Satisfaction	√			√		√	√	√
Operability	√			√				
Effectiveness	√		√	√			√	
Efficiency	√			√			√	
Appropriateness	√							√
Ease of use								√
Usefulness								
Accessibility	√	√					√	
Attractiveness	√			√				
Understandability	√			√				
System information arrangement								√
Recognizability	√							
Screen division layout		√						
Gestures		√						
Audio guidance		√						

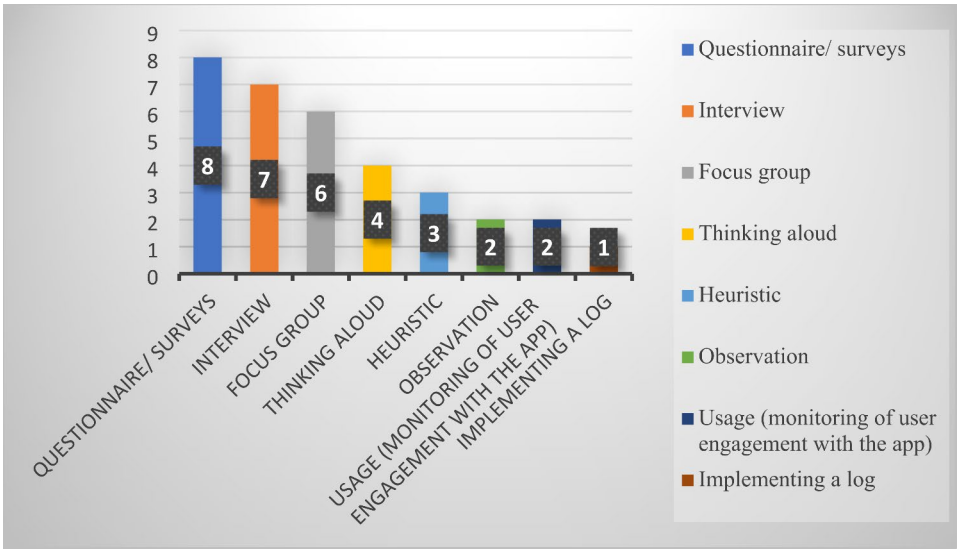

Fig. 2 Frequency of usability evaluation methods

focus on the development and use of specific questionnaires for the evaluation of applications.

About three quarters of the articles included in this review were published in the last five years, which shows that the development and evaluation of mHealth applications is an area of interest for researchers. Therefore, identifying the commonly used criteria in usability evaluation can greatly help to researchers.

This study had two limitations. First, the scope of the research was limited to three databases, PubMed, Scopus, and Web of Science. But considering that the usability evaluation was on health applications, these databases are the most frequently use and we hope we haven't missed too many articles. Second, there is no specific standard for categorizing criteria and different studies used different methods. We used Nielsen's well-known criteria in this study.

To our knowledge, this is the first time that the important criteria in usability evaluation of mHealth applications are gathered from systematic reviews. Furthermore, this study provides a comprehensive framework of important and commonly used criteria in the evaluation of mHealth application usability. Based on the categorization organized in this study, creating a new evaluation

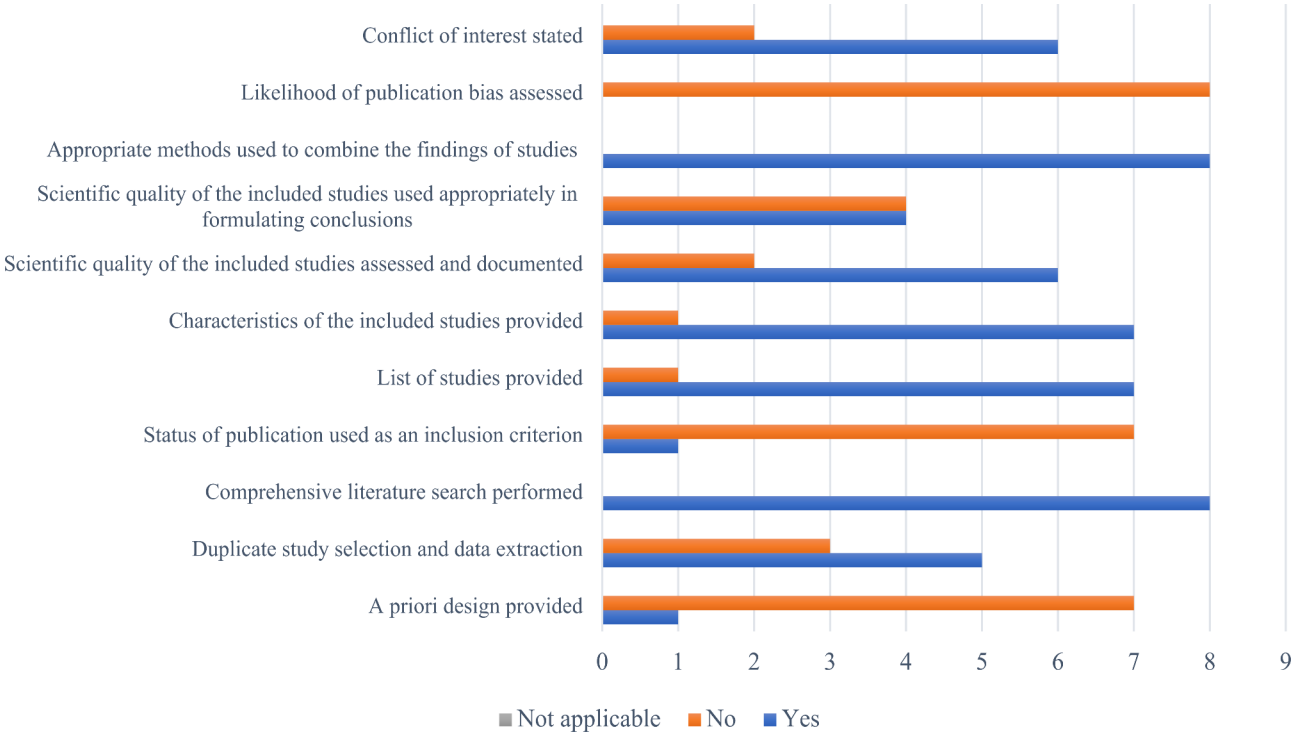

Fig. 3 Quality assessment result for included studies

tool for mHealth applications can be a useful perspective for future research. Such a tool can assist mobile health application designers in evaluating their system before implementation, thereby improving the overall user experience.

Conclusion

The results of this study indicate that, in addition to various usability issues in mHealth applications, significant challenges exist in the areas of aesthetic and minimalist design, as well as flexibility and efficiency of use. Challenges such as difficult data entry for patients can diminish efficiency, while issues like improper data display and slider difficulties can compromise minimalist design, potentially leading to abandonment of the application. These two criteria require greater attention in mHealth application design because they are interconnected; a flexible design enhances efficiency of use, while a minimalist design promotes more effective and frequent use of these applications. Given that one of the primary goals of system development is to increase task efficiency for users, it is recommended to prioritize usability attributes that enhance both efficiency and minimalist design. Mapping these issues to evaluation criteria can help evaluators focus on these aspects during the design of mHealth applications. Addressing these concerns will lead to better-designed and more user-friendly mHealth applications. As mHealth continues to gain popularity, this study can contribute to improved healthcare outcomes and patient engagement.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12911-024-02738-2.

Supplementary Material 1

Supplementary Material 2

Author contributions

All authors contributed to the conception and design of this research. ZG and MM carried out the search procedure (screening the studies, assessing the full-texts, and extracting data) with confirmation and arbitration by R Kh. All authors contributed to the analytic strategy to achieve the final classification of issues. R Kh critically revised the manuscript. All authors provided the final approval and agreed to be accountable for all aspects of this work.

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Data availability

The corresponding author can provide the data generated and analyzed during this study upon request.

Declarations

Ethics approval and consent to participate

This manuscript does not include any experimental animals or human patients. The ethics committee of Kerman University of Medical Sciences approved this study (ethics code: IR.KMU.REC.1402.075).

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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