SINERGI Vol. 28, No. 2, June 2024: 287-304
http://publikasi.mercubuana.ac.id/index.php/sinergi
http://doi.org/10.22441/sinergi.2024.2.009

Usability evaluation for mobile health application: Systematic Literature Review

Winnie Septiani*[1], Novia Rahmawati[1], Dian Mardi Safitri[1], Martino Luis[2]
[1]Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Trisakti, Indonesia
[2]College of Engineering, Mathematics and Physical Sciences, University of Exeter, United Kingdom

Abstract
Health applications have unique characteristics compared to other applications. This application is needed to support the health of users/families with various facilities provided according to their functions and objectives. Usability measurement is carried out to evaluate the successful use of the application using various usability criteria. This study aimed to identify, analyze, and synthesize the usability evaluation of a mobile health application. The review was carried out on 65 selected papers from 799 usability papers from the Web of Science and Scopus in the 2013 to 2023 time period. The Systematic Literature Review approach used is the Preferred Reporting Item for Systematic Reviews and Meta-Analysis (PRISMA). Based on the review results, it was identified that usability measurement on mobile health applications aims to validate system design, compare usability methods, improve application performance, and evaluate usability. Meanwhile, mHealth apps mostly function for treatment and self-care/self-management. Most of the reviewed papers used the general public as respondents. The respondents or participants in these studies are diverse and can be categorized into five groups: patients, healthcare professionals, older adults, experts, and the general public. Most of the research aims to evaluate usability with the most widely used method, the System Usability Scale, which is equipped with other supporting methods.

Keywords:
Health Application;
Mobile application;
Systematic Literature Review;
Usability;

Article History:
Received: August 9, 2023
Revised: January 24, 2024
Accepted: February 4, 2024
Published: June 2, 2024

Corresponding Author:
Winnie Septiani
Department of Industrial Engineering, Faculty of Industrial Technology, Universitas Trisakti, Indonesia
Email: winnie.septiani@trisakti.ac.id

INTRODUCTION

Health services remain new to online services accessed through mobile phone applications or web pages. With online health services, the reach of health center assistance is more inclusive, so patient access to referral hospitals is becoming closer and faster. The patient lines can be reduced in hospitals or health clinics [1]. People have significantly benefited from technological developments in healthcare because their access to healthcare providers has become more accessible and better. The comfort of access to health services and guaranteed health logistics support can increase human life expectancy [2]. The extensive use of mobile applications for health services (m-Health) is increasingly rising during the Covid-19 pandemic [3][4]. This increase is a developed opportunity and a challenge to meet user needs according to the function of the application. This application is needed to support the health of the user/user's family, prepare, provide treatment or monitor the process [5].

People's need for health service applications that are easy to use and reliable is increasing, considering that users of these applications also have limitations. Health applications must have a design that makes them easy to use because often, the users are elderly patients or those who have physical limitations because they are unwell [6]. This application often comprises carers, guardians, or closest relatives of patients who help patients access telehealth or telemedicine services.

Usability issues occur when users of all mobile and web-based applications cannot continue using the application because they are distracted by some of the design or content of the online application [7]. This issue is faced by telehealth or telemedicine service providers due to the limitations or disabilities of users of mobile health applications. Usability measurement for an application aims to evaluate the use of the application specifically to complete it effectively, efficiently, and comfortably [8]. Usability measurement is critical to testing the reliability of an application [9]. Four categories are related to this issue: information delivery, navigation control, layout (position of text, diagrams, video, and navigation buttons), and aesthetics.

Usability is a measure of the success of a technology product [10]. Usability is also part of an acceptability system. System acceptability is divided into two aspects, specifically, social and practical acceptability. Usability is precisely part of this practical acceptability, where there are five general usability criteria: learnability, efficiency, memorability, errors, and satisfaction [11]. M-Health is defined as using smartphones for more specific needs to gain health information for someone and their families [12]. In this literature review, health application is limited to mobile health (m-Health), and it is limited to mobile health. [4] defines mobile health as mobile and wireless technologies that support health goals. [5] describes usability as a critical need for e-health technology. E-health technology has unique characteristics.

Popular usability instruments used are task performance logging [5], think-aloud [13][14], and the System Usability Scale (SUS) [15]. With outcome variables of task completion, SIS Usability Score, and critical usability issues, think-aloud is the most effective tool to explain the usability of e-health [5]. The system usability scale is a popular method, but its use requires combining it with other methods. The SUS is insufficient as a stand-alone usability benchmark for M-health.

Based on the results of the search for Systematic Literature Review (SLR) articles, especially on the mHealth Application, three SLR articles were obtained. [16] have compiled a literature review for mobile health using 111 studies. The results of their analysis identified two usability issues: application (user interface, task) and device (screen size, input media, network). [17] have compiled a usability review for mHealth applications, 19 articles were selected. Reviews are carried out on usability characteristics, methods that are often used, outcomes, and operating systems used. The operating systems used in m-health applications are Android operating system (OS), IOS, and Windows. Evaluation methods that are widely used are questionnaires and interviews. The indicators used are efficiency, effectiveness and satisfaction. [18] have compiled a usability evaluation review for mHealth applications specifically for elderly individuals. The review is based on research activity, methods, and functions. Functions are divided into four major groups: wellness management (n=39), Disease management (n=36), Healthcare services (n=17) and social contact (n=4). Based on the results of the three SLR articles, the review of the use of methods is still general, not specifically tracing the problems and supporting methods used to evaluate usability in mHealth applications. This is an opportunity to continue the SLR that has been produced previously.

The review was carried out using a systematic literature review method on 61 selected papers from 799 usability papers in 2013-2021 from the Web of Science and Scopus. The study aims to provide an overview of the usability measurement research map for m-Health applications and complement the literature that took the same topic before. This study shows the publication range for research on usability measurement and arranges for grouping the types of journals based on the scientific discipline category. This research timeline can show how the COVID-19 pandemic may affect research color Usability measurement for the m-Health application. The type of m-Health application turns out to be highly diverse, so in this study, the functions of the existing m-Health application were also identified. The health services provided by these groups are also compiled from these acknowledged functions. Classification is based on the research objectives, starting from validation, method comparison, application improvement, and usability evaluation to complete the contribution to the usability evaluation study. Mapping of research methods was also carried out in this study, considering that there are many different methods in usability evaluation—the findings in this literature study.

Literature research on usability has focused on the software development process [10]. The research examines the literature on mobile health application substances, some of which were published during the COVID-19 pandemic. This study contributes by filling the research gap in the literature review regarding the specific usability evaluation of the mobile health application. The development of usability research on m-Health services will be explored

because the pandemic has changed the healthcare service industry, and the m-Health application has become one of the spearheads of health services worldwide.

The development of research directions on the usability measurement of M-Health applications becomes very interesting to analyze. Considering the publication period, it is challenging for this research to focus on assessing the usability of the M-Health application, specifically in the conditions of the COVID-19 pandemic. There are changes in the situation between the period before the pandemic and the pandemic. However, this literature review shows that the pandemic is momentum for increasing the use and development of M-Health.

This SLR is expected to contribute information and knowledge about the use of usability methods to evaluate mHealth applications. In addition, SLR is expected to be a reference for obtaining a description of the respondents and the number of respondents in the usability evaluation of m health applications.

The fuzzy logic controller is a popular and promising method for Functional Electrical Stimulation applications. It has the benefit of efficiently managing intricate, nonlinear systems. The simplicity and flexibility of the fuzzy logic controller make it especially helpful in real-world situations. However, it might not be as accurate as more complex control techniques and might need to be adjusted to get the best outcomes [19].

It is easier to identify early signs of diabetes by looking at the eyes. Cataracts can identify early signs of diabetes earlier and with greater speed thanks to a smartphone camera. The quality measurement was examined using an f1 score, precision, and recall. Consequently, the goal is for artificial intelligence (AI) technology to enable patients to receive better medical care for their ailments [20].

METHOD

The preparation of this systematic literature review uses the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach. A literature review is carried out in systematic stages, starting from planning, determining research questions, searching for papers, identifying, analyzing, and compiling a synthesis of review results.

Research Question

There are five research questions formulated in this SLR, which are as follows:

RQ1: What group of journals are the most published on usability evaluation research for Mobile Health Applications?
RQ2: What is the trend toward usability evaluation research for Mobile Health Applications?
RQ3: What types of Mobile Health Applications have been evaluated for usability?
RQ4: What usability methods are widely used to evaluate the usability of Mobile Health Applications?
RQ5: What are the characteristics of the respondents/resources and the number of samples used to evaluate the usability of the Mobile Health Application?

Search Strategy and Information Sources

The electronic database selected for the Usability Evaluation for mobile health application paper is Scopus electronic databases.

The search begins by specifying a common keyword, namely System Usability. Then the following paper selection is carried out with more specific keywords, namely: “usability scale," “usability evaluation," “usability testing," “health application,” mobile health application, and “M-Health Application.” The selection is determined based on keywords, titles, abstracts, and research objectives. In this systematic review, the search strings per chosen electronic database were as follows: TITLE-ABS-KEY ((“system usability*”OR “usability scale*”) AND (“health application” OR “mobile health application*” OR “M-Health Application*”)).

Inclusion and Exclusion Criteria

The Inclusion Criteria set out in this study are:

1. Articles published in the period 2013-2021.
2. The discussion focuses on usability evaluation.
3. The research object is limited to Health applications.
4. The application form is limited to Mobile applications only.
5. The use of mobile health applications is not restricted.
6. The article provides information on the use of the usability method.
7. The article provides information on determining the sample and the number of samples.

Articles will be excluded with the following criteria:

1. Do not meet the inclusion criteria.
2. The application form used is not a mobile application, such as a web or display from a medical device.

3. The research focuses only on the application's design and does not conduct usability evaluation trials.
4. The article is in the form of a literature review, comment, or opinion.

Study Selection Procedure

This study is carried out in stages to ensure that the selected paper is under the research question that has been formulated. The initial screening starts with a general keyword, System Usability, to determine whether the Systematic Literature review can be more specific for health applications. The second screening is specific to usability evaluation for mobile health applications. The stages of SLR screening with the PRISMA approach can be seen in Figure 1.

Analysis of Selected Studies

The study was conducted using data papers from 2013 to 2021. The distribution of usability measurement papers for health applications per year can be seen in Figure 2. Based on the figure, the trend of usability evaluation research for Mobile Health Applications is increasing in 2020 and 2021. This figure indicates that mobile health applications are increasingly used during the COVID-19 pandemic.

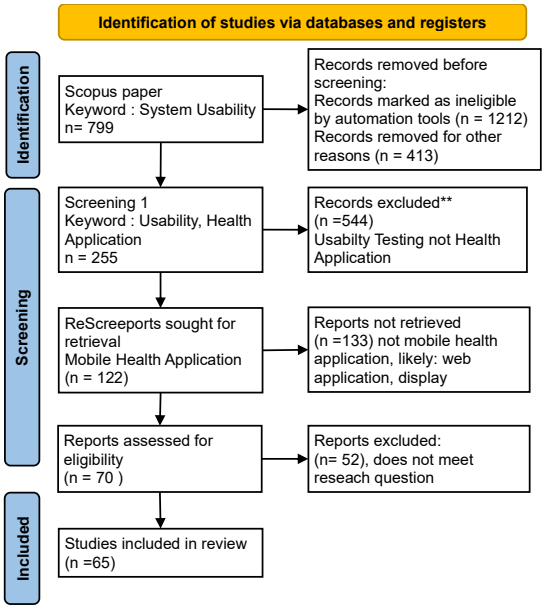

Figure 1. Study Selection Process

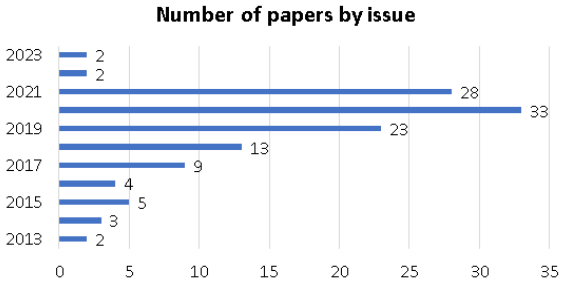

Figure 2. Total publications for each year (2013-2023)

RESULTS AND DISCUSSION

Publication source of m-Health Apps

Sources of publications are varied, and Scopus indexes all these journals. There are 27 journals used for the publication out of 71 articles. There are no articles published in the conference proceedings in this review. Table 1 presents the source titles of the m-Health Apps articles. The publication sources are then grouped based on the journal theme. A total of 13 journals focused on medical technology, while seven journals focused on health and one focused on technology. The remaining journal themes focus on ageing (2 out of 27 source titles) and human factors (4 out of 27 source titles). Table 1 shows the groups of publication sources by journal theme.

Journal sources vary widely, but only one journal specializing in m-Health, specifically JMIR m-Health and uHealth. The articles in this review are mainly based on these sources, 20 out of 61. Several other journals focus on medical technology with more comprehensive mobile, web, and device applications. One example is the Journal of Medical Internet Research, which focuses on digital health, both eHealth and m-Health. However, the review in this study will only focus on discussing m-Health Apps because current technology has led to application development instead of web-based. Apart from the medical side, the field of human factors has also begun to develop a broad discussion of m-Health Apps. It can be seen that human factors are one of the groups of journal themes in Table 2.

A total of 13 of the 27 journals included in the medical technology theme, defined as the application of scientific technology to develop solutions to health problems such as disease prevention and monitoring good health.

Table 1. Source titles of the m-Health Apps articles

No	Source Title	Number of papers
1	JMIR m-Health and uHealth	20
2	JMIR Human Factors	11
3	CIN - Computers Informatics Nursing	2
4	Journal of Medical Internet Research	2
5	International Journal of Medical Informatics	2
6	JMIR Rehabilitation and Assistive Technologies	2
7	Journal of Medical Systems	2
8	BMC Medical Informatics and Decision Making	1
9	JMIR Formative Research	1
10	Journal of the American Medical Informatics Association	1
11	Gerontechnology	1
12	JMIR Research Protocols	1
13	International Journal of Human-Computer Interaction	1
14	International Ophthalmology	1
15	Journal of Technology in Human Services	1
16	International Journal of E-Health and Medical Communications	1
17	Revista gaucha de enfermagem	1
18	Open Access Macedonian Journal of Medical Sciences	1
19	Research in Social and Administrative Pharmacy	1
20	Designs	1
21	Journal of Obesity and Metabolic Syndrome	1
22	Anesthesia and Analgesia	1
23	JMIR Aging	1
24	International Journal of Engineering and Technology (UAE)	1
25	JMIR Mental Health	1
26	JMIR Cancer	1
27	Telemedicine and e-Health	1
28	International Journal of Environmental Research and Public Health	1
29	Healthcare	1
30	BMC Medical Informatics	1
31	Multimodal Technologies and Interaction	1
	Total	66

Table 2. Group of journal theme

No	Group Title	Journal	Total Journal
1	Medical/Health Technology	JMIR m-Health and uHealth; Journal of Medical Internet Research; CIN - Computers Informatics Nursing; International Journal of Medical Informatics; JMIR Rehabilitation and Assistive Technologies; Journal of Medical Systems; BMC. Medical Informatics and Decision Making; JMIR Formative Research; Journal of the American Medical Informatics Association; JMIR Research Protocols; International Journal of E-Health and Medical Communications; JMIR Mental Health; Telemedicine and e-Health	12
2	Medical Science	Research in Social and Administrative Pharmacy; Journal of Obesity and Metabolic Syndrome; Anesthesia and Analgesia; JMIR Cancer; Healthcare	8
3	Technology	Journal of Technology in Human Services; BMC Medical Informatics and Decision making; Multimodal Technologies and Interaction	3
4	Human Factor/ Engineering	JMIR Human Factors; International Journal of Human-Computer Interaction; Designs; International Journal of Engineering and Technology (UAE.); International Journal of Environmental Research and Public Health	5
5	Aging	Gerontechnology; J.M.I.R. Aging	2

Meanwhile, seven journals that discuss the application of health sciences, in general, are included in the medical science theme, four journals that discuss multi-disciplinary interactions between humans and devices/machines are included in the human factor theme, and two journals focus on ageing. In contrast, the remaining one journal focuses on technology development only.

Types of m-Health Apps

The types of m-Health applications are divided based on the intended use. Table 3 presents the names of all articles' mobile applications and their functions. The app's functionality varies from general health to specifics such as mental health. In addition, the name of the m-Health application also varies and mostly according to its function. For instance, i-PreventDiabetes is intended to prevent diabetes as the name implies by monitoring habits and lifestyle. 5 articles discuss several applications to compare their usability, and 4 out of 5 articles discuss applications with the same function. In contrast, one article compares several applications with different functions but still in the same health scope.

The function of this mHealth application not only serves to assist in preventive actions but also functions to perform self-treatment for specific health conditions.

Table 4 shows the grouping of applications by function. Treatment and self-care/self-management were the two most widely designed application types, with 18 out of 61 each. This treatment application is intended for outpatient treatment assistance with symptoms of certain diseases ranging from chronic diseases to mental illnesses. This group of applications is intended for patient and caregiver users by providing education or simple treatment instructions without the help of a doctor.

Meanwhile, self-care/self-management is aimed at helping people who are taking self-care measures, either physically or mentally. Most of the mHealth apps for self-care services are intended for people with Type II diabetes. This is because people with Type II diabetes need to control their lifestyle and diet. VASelfCare [8] is one of the mHealth Applications designed as a virtual assistant to support older adults with Type 2 Diabetes Mellitus (T2D) in medication adherence and lifestyle changes. Treatment and self-care groups have the largest number because these applications are most needed by users who will access health information through technology. Therefore, it is important to evaluate the usability of the applications.

Similarly, the types of applications used for health services in general and intervention programs also have the same value, 7 out of 61. Health service applications are generally intended to help make it easier for patients to find hospital information, consult doctors, and others. Meanwhile, the intervention program is designed to provide the general public with knowledge or education about the health sector. Five articles discuss the comparison of the usability of several mHealth applications, which are included in the category of clustering mHealth apps. Other types of mHealth are applications used for medication (4 out of 61) and counseling programs (2 out of 61). Medication apps are used to help provide information related to access to medicines, while counseling is used to consult professionals in general areas of health.

Table 3. Identify the Functions of Health Apps

No	Mobile Application Name	The function of the application
[21]	Danish Mental Health Service	Treatment for mental disorders
[22]	e-service Journalen (Sweden)	Access health information
[23]	VASelfCare	A virtual assistant to help older people with diabetes
[24]	General Health Informative Apps, Institutional Apps, Fitness Apps, Physician Information, Mother & Child, Disease-Specific Care App, Food & Nutrition, Herbology, and Homeopathic	One-third of the total applications were developed to provide information related to health care, 12% for institutional applications (12%), 10% for applications related to doctor's information, and the other 10% were related to body fitness. Similarly, 9% of applications are related to mother & child, while another 9% are related to herbology. Finally, food & nutrition accounted for 7%, disease-specific treatment applications accounted for 5%, and homeopathy accounted for 4% of total applications.
[25]	The Self-Monitoring Activity-Restriction and Relaxation Treatment (SMART)	Treatment for young people with mild traumatic brain injury (mTBI)
[26]	PainSmart	Treatment for cancer patients
[27]	Glucose Buddy, MyNetDiary, mySugr, and OnTrack	Applications for data recording, blood glucose analysis, and data sharing are essential for diabetes competence, autonomy, and connection with healthcare providers.
[28]	Brain Buddy	Apps to help the elderly reduce the use of anticholinergic drugs
[29]	ClinicalConnect	An application that provides the exchange of health information between healthcare and care providers in South West Ontario
[30]	HeartAround	Application for assisted independent living, combining communication, health monitoring, and emergency response features
[31]	the Healing Hearts and Home© (HHH©)	An application to support caregiver self-efficacy through providing tutorials for postoperative care, feeding, and medication.
[32]	Fique Atento, pode ser câncer	Mobile application for early detection of childhood cancer.
[33]	i-PreventDiabetes	Self-care app for people with prediabetes that allows lifestyle monitoring, goal setting, and activity planning
[34]	Preparadxs app	Apps to prevent HIV
[35]	Steady-MS	Apps to prevent the risk of the elderly falling
[36]	The Be Prepared	application to support patients in optimizing their health and risk behavior before surgery
[37]	GlaucoCheck	Treatment for glaucoma patients
[38]	EarlyDetect	Application to help doctors diagnose mental disorders

No	Mobile Application Name	The function of the application
[39]	the Timed Up and Go (Self-TUG), tandem stance (Self-Tandem), and Five Times Sit-to-Stand (Self-STS)	Application to provide more detailed prognostic information about participants' physical performance for users, therapists, and other healthcare personnel.
[40]	Dr. Youth app	An application to monitor obesity indicators and subtypes.
[41]	the ASSISTwell	Apps for the elderly with diabetes
[42]	BlueWatch	Application for self-monitoring of adults experiencing depressive symptoms
[43]	BEDSide Mobility	Application to support nurses in their daily workflow and to facilitate bedside documentation
[44]	HE4EH	Apps for the elderly with diabetes
[45]	PresRx O.C.R.	A mobile medical device (m-health) that automatically fills in the drug name and dosage instructions directly from the patient's drug label by OCR
[46]	Care4Life	Apps for diabetics
[47]	My Diabetes Care	Apps for diabetics
[12]	The AmeeSehat	Application to provide information and advice about a healthy marriage
[5]	Stopstone	Application to motivate young teens to quit smoking
[8]	NeuroCare	Application for pediatric concussion management intervention
[48]	SurgCare	Application for post-drainage monitoring patients with drainage
[49]	MediBloc Panacea	Application to access medical documents for patients
[50]	Online consumer medication information systems (OCMIS)	Information systems about the pharmaceutical sector
[51]	the Pedi Crisis 2.0	Application to support physician response to pediatric perioperative critical life-threatening events
[52]	iMHere 2.0 and Fitbit	Application to manage their medication schedule, report minor skin problems and do mental health. The Fitbit app can display data collected by the wearable, such as step count, heart rate, and sleep duration.
[53]	mRehab	Application to select rehabilitation activities and receive feedback
[54]	LIFE4YOUth	An app to promote healthy eating, physical activity, smoking cessation, and low-risk drinking among high school students
[55]	Home Modifications for Aging and Disability	Occupational Therapist Mobile App Directory Providing Home Modification
[56]	The Pregnancy and Work	Application to provide advice on adjustment of work during pregnancy
[57]	Calories Counter; LifeSum; MyPlate Calorie Tracker; Argus; Lose It! Calorie Counter & Diet Tracker; MyDietCoach	Applications to help individuals lose weight
[58]	ICmed	Applications to support parental independence and family care
[59]	The Medication Error Reporting App (MERA.)	Mobile application to report medication errors anonymously
[60]	Voice-only reporting (VOR) and voice-button reporting (VBR)	Mobile voice enhancement app for reporting food intake for the elderly
[61]	NoObesity	Applications to support the prevention and management of obesity in children
[62]	The 365 Healthy Swallowing Coach	Application to improve the swallowing function of older adults
[63]	The Colorectal Cancer Awareness Application (ColorApp)	Mobile application for public education about colorectal cancer
[64]	a meal planning app, recipe app, recipe manager app, family organizer app, and barcode scanning app	An app to help parents plan, buy and prepare healthy family meals
[65]	mMbile PHR (mPHR)	Application to provide patient information
[66]	Website of HOCOS.	Application to support hand therapists in the management of psychosocial problems
[67]	VA FitHeart	Mobile app for technology-facilitated home cardiac rehabilitation
[68]	MCR-ARC's published InstantAtlas reports	Health report platform app
[69]	MyMedRec, DrugHub, Pillboxie, and PocketPharmacist	Applications for medicine
[70]	The MindClimb	Applications for treatment for cognitive behavioral therapy (CBT)
[71]	SPLENDID app	The m-Health system application is used to monitor the eating habits of teenagers in real life
[15]	DigiDiet (Digital Diet)	The application was initially designed for use by patients with metabolic syndrome to improve eating habits
[72]	The strength App	Application to support patients with rheumatic diseases

No	Mobile Application Name	The function of the application
[73]	ScreenMen	Application to improve the taking of health checks in men
[74]	Squire	Application to increase speed and efficiency in reaching the right team members during inpatient care
[75]	The app for frozen shoulder patients	An application to support patients affected by “stage two” stiff shoulder disease.
[76]	EatWellQ8	Application for diet assessment
[77]	HealthMindr app	The app includes a self-assessment tool; prevention recommendations; ordering commodities (condoms, HIV self-test)
[78]	TouchStream apps	An app to support the complex needs of elderly cancer patients and their caregivers
[79]	mHealth Applications for Type 2 Diabetes Melitus (T2DM)	Applications for Type 2 Diabetes Mellitus (T2DM) patients help control their health condition.
[80]	Three-Way Digital Healthcare System	An application designed to monitor the health status of people with disabilities.
[81]	MHealth Application for Albinism	The mobile app created and evaluated in the present research, which aims to help individuals with albinism manage their condition, could serve as a supplementary tool alongside other medical approaches like medication and psychological therapies, resulting in time and cost savings.
[83]	Usability Guideline for mHealth Application (UGmHA)	A fresh collection of usability principles for mHealth apps (UGmHA) has been formulated using Quinones et al.'s structured approach, encompassing seven phases commencing from the Exploratory phase and concluding with the Refining phase.

Table 4. Grouping of application types based on usage

No	Reference	Application function group	Mobile Application Name	Number of Papers
1	[21], [25], [31], [32], [34], [37], [38], [43], [48], [51], [55], [58], [65], [68], [72], [75], [77], [78], [83]	Treatment	Danish Mental Health; SMART application for mild traumatic brain injury (mTBI); PainSmart Apps for cancer patient; Healing Hearts and Home© (HHH©) application; Fique Atento, pode ser câncer for pediatric cancer; Preparadxs app for HIV; GlaucoCheck for glaucoma patients; EarlyDetect for mental health; BEDSide Mobility app for nurse’s tasks; SurgCare App for Postdrainage Monitoring; Pedi Crisis App for Pediatric Anesthesia; Home Modifications for Aging and Disability; ICmed for older adults and their caregiver; the Missouri Cancer Registry’s Published Interactive Mapping Reports; app to help people with chronic illness; The Unity3D game engine for frozen shoulder patients; TouchStream for Older Adults With Cancer	18
2	[22], [29], [49], [52], [62], [73], [74]	Health care service (General)	e-service Journalen (Swedia); ClinicalConnect (South West Ontario); MediBloc Panacea for Monitoring Medical Record Changes; iMHere 2.0 app for patients and a Web portal for clinicians; FirstER app for medical information, especially for emergency patients and medical staff; ScreenMen app to improve health screening uptake in men; Squire is a Web-based app to improve the speed and efficiency in reaching the appropriate team member during the care of a hospitalized patient	7
3	[5], [8], [15], [23], [30], [33], [35], [36], [39], [40], [41], [42], [44], [46], [53], [61], [67], [79], [80]	Self-Care/ self-management	VASelfCare application for Diabetes; HeartAround Mobile Apps for older adults; i-PreventDiabetes; The fall risk app Steady-MS; the Be Prepared m-Health app; Timed Up and Go (Self-TUG), tandem stance (Self-Tandem), and Five Times Sit-to-Stand (Self-STS) for elderly; Dr. Youth app for Obese Patients; ASSISTwell self-management application for Diabet; BlueWatch Mobile App for mental health; OneTouch app for diabetes; Care4Life for diabetes; application for older adults, an online telerehabilitation portal for healthcare professionals, a mobile health app for adolescents; NeuroCare app for the self-management of pediatric concussion; mRehab for individuals with stroke; voice-only reporting (VOR) and voice-button reporting (VBR) for food intake; The NoObesity Professional app; DigiDiet for use by patients with metabolic syndrome, mHealth Applications for Type 2 Diabetes Melitus (T2DM), Three-Way Digital Healthcare System, MHealth Application for Albinism	18
4	[24], [27], [57], [64], [69]	Clustering m-Health apps	9 cluster-m-Health apps in Bangladesh (General Health Informative Apps, Institutional Apps, Fitness Apps, Physician Information, Mother & Child, Disease-Specific Care App, Food & Nutrition, Herbology, and Homeopathic); Four top-rated commercially diabetes apps (Glucose Buddy, MyNetDiary, mySugr, and OnTrack); 7 Apps of Diet-Tracking Apps; 5 commercially apps for supporting the healthy food; 5 mobile medication management (MediSafe, MyMedRec, Pillboxie, DrugHub, and Pocket Pharmacist)	5

No	Reference	Application function group	Mobile Application Name	Number of Papers
5	[28], [45], [50], [59]	Medication	Brain Buddy apps for older adults' medication; PresRx OCR iPhone application; Online Consumer Medication Information Systems (OCMIS); Medication Error Reporting App (MERA);	4
6	[12], [56]	Counseling	Ameesehat app for premarital counseling; Pregnancy and Work (P and W) app	2
7	[54], [62], [63], [66], [70], [71], [77], [84]	Intervention program /education	LIFE4YOUth; The 365 Healthy Swallowing Coach app; The Colorectal Cancer Awareness Application (ColorApp); Hand Therapy Online Coping Skills (HOCOS); MindClimb app for adolescents with anxiety; App for Monitoring Daily Meal Distribution and Food Selection in Adolescents; a Web-based graphical food frequency assessment, Usability Guideline for mHealth Application (UGmHA)	8

Purpose of The Article

Although all the articles in this review use the same usability testing method, some articles have different purposes, as presented in Table 5. One article can even serve two different purposes, so the total paper count is calculated as a percentage. Most of the articles are devoted to evaluating the usability of the mHealth application, with 71.4%. These articles test the usability of the mHealth app that is already available.

Meanwhile, 21.4% of articles aim to develop and improve the function of the mHealth Application. The improvement in this term means that the existing application does not meet the usability principle, so a redesign is carried out or an application that has not existed before so that the usability principle proposes a new application design.

On the other hand, three articles aim to compare the usability of multiple mHealth Apps and not just focus on evaluating a single app. At the same time, the remaining two articles aim to validate and develop the SUS questionnaire as a usability method in regional languages so that it is included in the validation category. Figure 3 shows the different purposes of the articles.

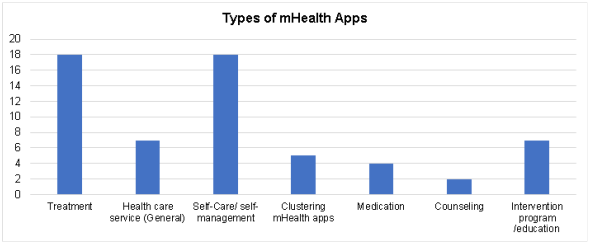

Figure 3. Type of m-Health Applications.

Table 5. Grouping objectives of usability evaluation for mobile health application research

No	Research objective group	Reference	Research Objectives	Number of Papers
1	Validation	[21]	Translating and validating the SUS questionnaire into Danish (SUS-DK)	4
		[52]	Develop and validate the new m-Health app usability questionnaire	
		[79]	Performa systematic assessment of the 11 mHealth applications to assist in the self-management of T2DM.	
		[82]	Develop a comprehensive set of usability guidelines for mHealth applications	
2	Compared method/apps	[5]	Comparing three usability benchmarking instruments	3
		[57]	Reviewing the usability of the current iPhone operating system (iOS) and Android app's diet tracking, the extent to which app features align with behavior change constructs	
		[15]	Design and evaluate two innovative mobile voice enhancement applications	
3	Apps improvement	[25]	Improve usability and acceptance of system Apps	15
		[65]	Develop a cancer pain assessment mobile application prototype	
		[37]	Develop and evaluate the usability of mobile applications	
		[40]	Develop a mobile application for behavior monitoring and test its usability	
		[44]	Presenting the development of heuristic evaluation for m-Health (HE4EH) applications	
		[8]	Describe the development and usability of mobile applications	
		[48]	Develop an image-based smartphone app, SurgCare	
		[49]	To develop a medical document monitoring system	
		[15]	Design and evaluate two innovative mobile voice enhancement applications	
		[63]	Developing mobile applications for public education	
		[66]	Describe the development and assess the usefulness of HOCOS	
		[70]	Develop, design, and test the acceptability, learning ability, heuristics, and usability of MindClimb	
		[72]	Develop a mobile application and explore the patient's perceived usefulness of the application	
		[74]	Design and develop Squire and evaluate the use	
4		[22]	Evaluation of usability aspects of Swedish PAEHR users	52

No	Research objective group	Reference	Research Objectives	Number of Papers
	Usability evaluation	[23]	Report usability evaluation	
		[24]	Investigating the use of Mobile Health applications in Bangladesh	
		[27]	Assess the usability of designed diabetes apps	
		[28]	Testing the usability and feasibility of Brain Buddy apps	
		[29]	Rate the usability of the mobile interface	
		[30]	Evaluating the usability of the “HeartAround” homecare platform	
		[31]	Tried to determine the usability and usefulness of the application	
		[32]	Evaluating the usefulness of mobile applications for the early detection of childhood cancer	
		[33]	Evaluating usability barriers and enablers	
		[34]	Knowing the usability and perception of the application	
		[35]	Test and improve the usability of the application	
		[36]	Evaluating the usability of the Be Prepared m-Health application prototype	
		[37]	Develop and evaluate the usability of mobile applications	
		[38]	Assess users’ perceptions of usability and emotions	
		[39]	Testing the usability of 3 smartphone apps	
		[40]	Develop a mobile application for behavior monitoring and test its usability	
		[41]	Testing the usability factor of ASSISTwell self-management app	
		[42]	Perform usability evaluation	
		[43]	Rate the usability of the BEDside Mobility app	
		[45]	Evaluating PresRx OCR for user interface acceptance	
		[46]	Testing the usability of the m-Health. diabetes system	
		[12]	Evaluating usability issues	
		[8]	Describe the development and usability of mobile applications	
		[50]	Measure and compare the usefulness of an online consumer drug information system (OCMIS)	
		[51]	Society for Pediatric Anesthesia Pedi Crisis. Mobile Application Development and Usability Testing	
		[53]	Assess the usability, perceived usefulness, and acceptability of the m-Rehab system	
		[54]	To investigate the usability of an m-Health intervention (LIFE4YOUth)	
		[55]	Develop and test the usability of the PL mobile app directory	
		[56]	Evaluating the usability of the m-Health P and W applications	
		[58]	Determining the use of mobile applications	
		[59]	Report usability testing of a Drug Error Reporting Application (MERA)	
		[61]	Rate the usability and acceptance of the NoObesity app	
		[62]	Assessing the usefulness of swallowing training applications quantitatively and qualitatively	
		[64]	Determining the feasibility of commercially available applications	
		[65]	Assess user experience	
		[66]	Describe the development and assess the usefulness of HOCOS	
		[68]	Conduct usability testing studies	
		[69]	Explore the usability of the app	
		[70]	Develop, design, and test the acceptability, learning ability, heuristics, and usability of MindClimb	
		[71]	Evaluating the acceptability and usability of the m-Health system	
		[15]	Field user experience testing is carried out	
		[72]	develop mobile applications and explore the patient’s perceived usefulness of the application	
		[73]	Evaluating the utility and usability of ScreenMen	
		[74]	Design and develop Squire and evaluate the use	
		[75]	Evaluating the feasibility of a mobile health (m-Health) intervention	
		[78]	Evaluating the feasibility and usability of the application	
		[80]	Evaluating the formative usability of a three-way digital healthcare system	
		[81]	Evaluating the feasibility and usability of the application for albinism self-management	

The literature review results are mapped in Figure 4, indicating the usage of mobile health applications. Most of these applications are utilized for healthcare treatment and self-care/self-management purposes. Research on the evaluation of usability for mobile health applications, exceeding 70%, aims to test the usability of applications that have been designed and implemented within the broader community. Over 90% of these studies employ the System Usability Scale (SUS) as their method.

However, the effectiveness of using SUS needs to be supplemented with other methods such as heuristic approaches, User Experience Questionnaires, Think Aloud, and other methods that align with the application's design. The respondents or participants in these studies are diverse and can be categorized into five groups: patients, healthcare professionals, older adults,

experts, and the general public. The number of responses varies, ranging from n = 2 to over 2000 respondents.

Popular methods used in usability evaluation are SUS, Heuristic, Think aloud and UEQ (User Experience Questionnaire), as shown in Table 6. The usability system is a popular method, but its use requires a combination with other methods. The SUS is insufficient as a stand-alone usability benchmark for M-health.

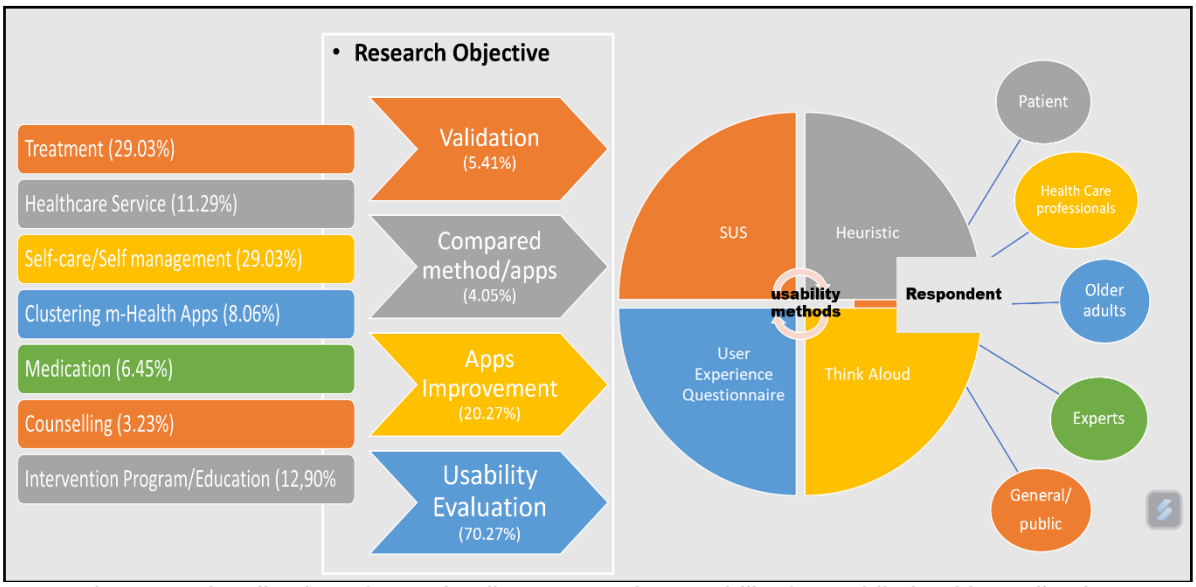

Figure 4. Visualization of mapping literature review usability for mobile health application

Methods used in the evaluation of m-Health Apps

Table 6. Mapping the use of usability methods in health applications

No	Usability Methods				
	SUS	Heuristic	Think-aloud	UEQ (User Experience Questionnaire)	Others
[19]	√	-	-	-	-
[22]	√	-	-	-	-
[23]	√	-	-	-	-
[24]	√	√	-	-	-
[25]	√	-	√	-	-
[63]	√	-	-	-	-
[27]	√	√	-	-	-
[28]	√	-	-	-	Usability testing
[29]	√	-	-	-	Productivity and quality questionnaires
[30]	√	-	-	-	Interviews and qualitative analysis
[31]	√	-	-	-	The Coping Health Inventory for Parents (CHIP) and the Perceived Stress Scale (PSS)
[32]	√	-	-	-	-
[33]	√	-	√	√	Question-asking protocol and open-ended questions
[34]	√	-	-	-	an open-ended interview question
[35]	√	-	√	-	Mobile Device Proficiency Questionnaire (MDPQ.)
[36]	√	-	-	-	-
[37]	√	-	-	-	-
[38]	√	-	-	-	Modality-directed emotion questionnaires
[39]	√	-	-	√	Semistructured interviews.
[40]	√	-	-	-	Usability testing
[41]	√	-	√	-	Semistructured interviews
[42]	√	-	-	-	Semistructured interviews
[43]	√	-	-	-	-
[44]	-	√	-	-	Interset Checklist Items
[45]	√	-	-	-	-
[46]	√	-	-	-	Usability testing, user characteristics
[12]	√	-	√	-	-

No	Usability Methods				
	SUS	Heuristic	Think-aloud	UEQ (User Experience Questionnaire)	Others
[5]	√	-	-	-	Usability testing, After-Scenario Questionnaire (ASQ), interview
[8]	√	-	√	-	Posttest questionnaire, a semistructured interview
[48]	√	-	-	-	Usability testing
[49]	√	-	-	-	questionnaire, survey
[50]	√	-	-	-	Usability testing, a post hoc questionnaire
[51]	√	-	-	-	usability testing
[52]	√	-	-	-	m-Health app usability questionnaire, Post-Study System Usability Questionnaire (PSSUQ.)
[53]	√	-	-	-	mRehab Acceptance Questionnaire, semi structured interview
[54]	√	√	-	-	-
[55]	√	-	-	-	Semi structured interviews
[56]	√	-	√	-	-
[57]	√	-	-	-	-
[58]	√	-	-	-	The Modified Mobile Application Rating Scale (M-MARS)
[59]	√	-	-	-	Focus group discussions.
[60]	√	-	-	-	-
[61]	√	-	-	-	Reach Effectiveness Adoption Implementation Maintenance framework; Bandura model of health promotion; and Nonadoption, Abandonment, and Challenges to the Scale-up, Spread, and Suitability framework.
[60]	√	-	-	-	Modified Computer Self-Efficacy Scale (mCSES) surveys, interviews
[63]	√	-	-	-	The nominal group technique (NGT.)
[64]	√	-	-	-	Capability, Opportunity, Motivation, and Behavior (COM-B) self-evaluation survey; and using the user version of the Mobile App Rating Scale (uMARS)
[60]	√	-	-	-	Interview
[67]	√	-	-	-	The Unified Theory of Acceptance and Use of Technology and the Theory of Planned Behavior informed the analysis
[68]	√	-	-	-	a pretest questionnaire, a multi-task usability test,
[69]	√	-	-	-	Focus-group discussions
[70]	√	√	√	-	Nielsen's usability heuristics
[71]	√	√	√	√	-
[60]	√	-	-	-	Key-in–based aid (KBA); Photo-based aid (PBA) extends; Gesture-based aid (GBA)
[72]	√	-	-	-	Self-efficacy and emotions, usability testing
[73]	√	-	√	-	-
[74]	√	-	-	-	Squire's Net Promoter Score (NPS), a survey
[75]	√	-	-	-	USE (Usefulness, Satisfaction, and Ease of use), Technology Acceptance Model-2 (TAM-2)
[76]	√	-	-	-	EatWellQ8 Food Frequency Questionnaire
[77]	√	-	-	-	Survey
[78]	√	-	-	-	A modified satisfaction survey; interviews.
[79]	-	-	-	-	Mobile App Rating Scale (MARS), ID3 Algoritm
[80]	√	-	-	-	Satisfaction Evaluation
[81]	√	-	-	-	mHealth App Usability Questionnaire
[82]	-	-	-	-	Usability guidelines for mHealth applications (UGmHA)

The sample used in the evaluation of m-Health Apps

Figure 5 shows a total of 64% of articles that have used real users as a sample to evaluate the usability of m-Health Apps. The actual users involved include patients, healthcare professionals, and experts. Most of the samples were older adults over 50 years old who need self-care management services. While the rest of the articles have involved samples of non-expert users, some did not explain the descriptive sample information in detail.

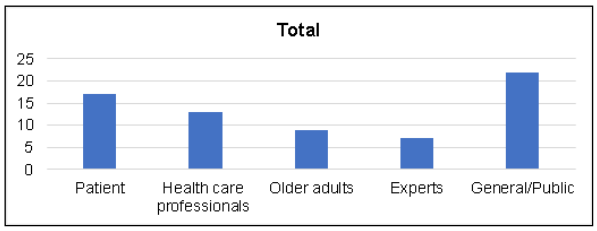

Figure 5. Group of Research Respondents from Usability Evaluation of Mobile Health Application

Usability evaluation emphasizes the comfort and convenience of users when using the application, so the respondents of this research are mostly application users. In the use of general applications, the respondents are General/public as well, such as undergraduate students, bankers, teachers, housewives, parents, children, working pregnant women and others.

This study resulted in a grouping of respondents in usability research for M-Health: patients, healthcare professionals, older adults, Experts, and General/Public respondents. Table 7 shows the articles grouping based on the study's respondents and the number of samples. The number of respondents varies widely, ranging from five to 2539 people. The group with the highest number of articles in the research group uses patients as research respondents. Determining the number of respondents in usability measurement is very important.

Table 7. Identify the respondent group and the number of samples

No	Reference	Group of Research Respondents	Number of samples	Number of papers
1	[21], [22], [23], [35], [36], [37], [40], [42], [45], [46], [48], [49], [50], [65], [72], [75], [78]	Patient	[21] n=74 patients; [22] n=2539 patients; [23] n=23 patients; [35] n=10 patients; [36] n=86 people undergoing major surgery; [37] n=36 patients and their relatives; [40] n=50 obese adults; [42] n=5 participants with clinical depression, 5 mental health professionals, and 5 researchers; [45] n=12 patients; [46] n=10 patients; [48] 80 patients; [49] 70 patients; [50] 137 patients; [65] Questionnaire, n= 1000; 1. Interviewed: 24 patients; [72] 18 patients and 7 health care providers; [75] 5 patients; [78] 18 patients	17
2	[8], [21], [29], [32], [43], [50], [51], [55], [59], [66], [70], [72], [74]	Health care professionals	[21] doctor (n = 64); [29] 77 Health care providers; [32] 19 nurse; [43] 10 nurse; [8] 7 health care professionals; [50] 81 physicians, and 68 pharmacists; [51] 35 anesthesiology clinicians; [55] Older adults (n=6) and OTs (n=6); [59] 45 different testers (pharmacists, doctors, and nurses); [66] 4 ICT experts and 12 therapists; [70] 8 adolescents and 3 therapists; [72] 18 patients and 7 health care providers; [74] 109 residents in internal medicine	13
3	[23], [30], [39], [41], [55], [60], [62], [63], [69]	Older adults	[23] 11 older adults; [30] 11 men dan 13 elderly women; [39] 189 participants; [41] 12 elderly participants; [55] Older adults (n=6) and OTs (n=6); [15] 57 adults aged 60-90 years; [65] 11 participants from two district-run senior welfare centers; [63] 10 participants aged 50 years; [69] 35 participants aged 50	9
4	[12], [23], [27], [42], [44], [54], [66], [79], [80], [81]	Experts	[23] 9 experts; [27] 2 single domain experts and 2 dual domain experts; [44] 10 participants; [42] 5 participants with clinical depression, 5 mental health professionals, 5 researchers; [12] 10 final users and three experts; [54] Heuristic Evaluation : 15 Expert, Usability test : 5; [66] 4 ICT experts ; [79] 2 Expert; [80] 3 expert; [81] 8 expert	7
5	[5], [8], [12], [24], [25], [26], [31], [33], [34], [38], [52], [53], [56], [57], [58], [60], [61], [64], [68], [71], [73], [76]	General/Public	[24] 30 participants: undergraduate students, banker, teacher, intern doctor and housewife; [25] 4 parents or child[12] 60 participants; [5] 36 Dutch participants; [8] 7 youths ren k; [26] 16 participants; [31] 5 participants; [33] 20 participants; [34] 69 respondents users; [38] 191 participants in Canadian territory; [52] 128 study participants; [53] 11 individuals with stroke; [56] 12 working pregnant women; [57] 3 undergraduate students; [58] Participants (n=24, 12 dyads); [61] 20 to 40 families; [64] Survey participants (N=133); [68] 7 potential respondents, increased the number to 7 subjects; [71] 26 students; [60] 124 young adults; [73] 24 men participated; [76] 235 participants	22

Usability measurements that use a small number of respondents are usually very application-specific. Applications like this are usually designed specifically for particular needs and are used for a limited number of people. Meanwhile, a more significant number of respondents are required to measure usability for widely used applications.

Usability evaluation and measurement with professional healthcare respondents are carried out on applications by health service workers. The number of respondents required is not as high as that required in research that measures the usability of patient applications.

Healthcare professionals involved in the usability measurement study were doctors (including specialist doctors), pharmacists, therapists, nurses, and other paramedical professionals. The characteristics of the number of health professionals' respondents are the same as those of the article group that used experts as research respondents. Usability measurement using expert respondents does not require numerous samples, which follows research characteristics with a general expert judgment approach.

Research that uses the elderly as respondents has its challenges, especially in communication problems. This problem causes some studies to have a limited number of respondents. Researchers can measure usability by collaborating with various elderly activity centers. Research that uses respondents from the general public shows efforts to increase the delivery of health services to individuals and communities. The scope of this research is wide-ranging and requires the involvement of a broader range of respondents. The public uses the M-Health application, and has universal service affordability. The community needs M-health services like this during a pandemic, especially during the implementation of social activity restrictions. So, usability measurement requires a more diverse respondent. In usability assessment, the chosen respondent categories (patients, healthcare professionals, older adults, experts, general/public) are determined based on the application's functionalities and testing requirements. The number of respondents also varies, depending on the application's user reach.

CONCLUSIONS

The main findings from the results of this Systematic Literature Review (SLR) are as follows:

Mobile Health applications developed in the last ten years are highly diverse. This review resulted in five categorizations of application functions, namely treatment (n=18), health care service (n=7), self-care/self-management (n=18), clustering mHealth applications (n=5), medication (n=4), counseling (n=2), and intervention programs/education (n=8). The dominant functions of the applications are in the treatment and self-care categories.

The goal of usability measurement is that 70.27% aims to evaluate usability on three indicators: effectiveness, efficiency, and comfort. Measurement results will be used to validate and improve applications before and after being applied in the community.

More than 90% of articles use the SUS method. SUS is widely used because it is easy to implement, but to enhance evaluation results, the integration of usability with other methods such as heuristic methods, think-aloud, UEQ (User Experience Questionnaire), usability testing, and others is recommended. The review has identified several other methods supporting SUS, primarily for measuring usefulness, satisfaction, and ease of use.

Respondents in usability evaluations are application users. Respondents in this study are grouped into five main respondent categories: patients (n=17), healthcare professionals (n=13), older adults (n=9), experts (n=7), and the general public (n=22). Healthcare professionals include doctors, nurses, healthcare providers, physicians, therapists, and others. The reach of application users influences the number of respondents.

The review results provide information, knowledge, and inspiration for developing Health applications that meet usability standards. In addition, various usable methods have been identified. Limitations have not been specifically identified in terms of the usability dimensions that are most evaluated, and the reliability of the identified methods has not been measured.

ACKNOWLEDGMENT

This research was supported by Trisakti University financial funding who provided greatly assisted this Systematic Literature Review paper.

REFERENCES

[1] U. e M. Shah and T. K. Chiew, "A systematic literature review of the design approach and usability evaluation of the pain management mobile applications," *Symmetry*, vol. 11, no. 3, pp. 1–24, 2019, doi: 10.3390/sym11030400.

[2] A. M. Fathollahi-Fard, A. Ahmadi, and B. Karimi, "Sustainable and Robust Home Healthcare Logistics: A Response to the COVID-19 Pandemic," *Symmetry*, vol. 14, no. 2, pp. 1–33, 2022, doi: 10.3390/sym14020193.

[3] P. Ramírez-Correa et al., "Telemedicine Acceptance during the COVID-19 Pandemic: An Empirical Example of Robust Consistent Partial Least Squares Path Modeling," *Symmetry*, vol. 12, no. 10, p. 1593, Sep. 2020, doi: 10.3390/sym12101593.
[4] X. Wang, C. Markert, and F. Sasangohar, "Investigating Popular Mental Health Mobile Application Downloads and Activity During the COVID-19 Pandemic," *Hum. Factors*, pp. 1–12, 2021, doi: 10.1177 /0018720821998110.
[5] M. Broekhuis, L. van Velsen, and H. Hermens, "Assessing usability of eHealth technology: A comparison of usability benchmarking instruments," *Int. J. Med. Inf.*, vol. 128, pp. 24–31, 2019, doi: 10.1016/j.ijmedinf.2019.05.001.
[6] G. M. Aliberti et al., "Perspectives of primary care clinicians in Massachusetts on use of telemedicine with adults aged 65 and older during the COVID-19 pandemic," *Prev. Med. Rep.*, vol. 26, p. 101729, 2022, doi: 10.1016/j.pmedr.2022.101729.
[7] L. C. Li *et al.*, "Usability testing of ANSWER: A web-based methotrexate decision aid for patients with rheumatoid arthritis," *BMC Med. Inform. Decis. Mak.*, vol. 13, no. 131, pp. 1–12, 2013, doi: 10.1186/1472-6947-13-131.
[8] H. Sandhu, K. Wilson, N. Reed, and A. Mihailidis, "A mobile phone app for the self-management of pediatric concussion: Development and usability testing," *JMIR Hum. Factors*, vol. 6, no. 2, 2019, doi: 10.2196/12135.
[9] H. R. Hartson, T. S. Andre, and R. C. Williges, "Criteria for evaluating usability evaluation methods," *Int. J. Hum.-Comput. Interact.*, vol. 15, no. 1, pp. 145–181, 2003, doi: 10.1207/S15327590IJHC1501_13.
[10] F. Paz and J. A. Pow-sang, "A systematic mapping review of usability evaluation methods for software development process," *Int. J. Softw. Eng. Its Appl.*, vol. 10, no. 1, pp. 165–178, 2016, doi: 10.14257/ijseia.2016.10.1.16.
[11] J. Nielsen, *Usability Engineering*, 1st ed. Academic Press, 1993.
[12] Z. Wiyanti, F. Oenzil, M. Masrul, and D. Djafri, "A mobile health app for premarital related word advice (Ameesehat): Usability and usefulness evaluation study," *Open Access Maced. J. Med. Sci.*, vol. 9, no. E, pp. 474–480, 2021, doi: 10.3889/oamjms.2021.5914.
[13] O. Alhadreti and P. Mayhew, "Rethinking thinking aloud: A comparison of three think-aloud protocols," in *Conference on Human Factors in Computing Systems - Proceedings*, 2018, pp. 1–12. doi: 10.1145/3173574. 3173618.
[14] M. Hertzum et al., "What do thinking-aloud participants say? A comparison of moderated and unmoderated usability sessions," *Int. J. Hum.-Comput. Interact.*, vol. 31, no. 9, pp. 557–570, 2015, doi: 10.1080/10447318.2015.1065691.
[15] Y. C. Liu *et al.*, "Design and usability evaluation of mobile voice-added food reporting for elderly people: Randomized controlled trial," *JMIR MHealth UHealth*, vol. 8, no. 9, pp. 1–21, 2020, doi: 10.2196/20317.
[16] T. A. Al-Saadi et al., "A Systematic Review of Usability Challenges and Testing in Mobile Health," *Int. J. Account. Financ. Report.*, vol. 5, no. 2, p. 1, Jul. 2015, doi: 10.5296/ijafr.v5i2.8004.
[17] M. Z. Ansaar et al., "The mHealth Applications Usability Evaluation Review," in *2020 International Conference on Information Networking (ICOIN)*, Barcelona, Spain: IEEE, Jan. 2020, pp. 70–73. doi: 10.1109/ICOIN48656.2020.9016509.
[18] Q. Wang *et al.*, "Usability evaluation of mHealth apps for elderly individuals: a scoping review," *BMC Med. Inform. Decis. Mak.*, vol. 22, no. 1, Dec. 2022, doi: 10.1186/s12911-022-02064-5.
[19] M. K. I. Ahmad et al., "Closed-loop Functional Electrical Stimulation (FES) – cycling rehabilitation with phase control Fuzzy Logic for fatigue reduction control strategies for stroke patients," *SINERGI*, vol. 28, no. 1, pp. 63-74, 2024, doi: 10.22441/sinergi.2024.1. 007.
[20] Moh. Khairudin *et al.*, "Early detection of diabetes potential using cataract image processing approach," *SINERGI*, vol. 28, no. 1, pp. 55-62, 2024, doi: 10.22441/sinergi. 2024.1.006.
[21] J. C. S. Hvidt et al., "Translation and validation of the system usability scale in a Danish mental health setting using digital technologies in treatment interventions," *Int. J. Hum.-Comput. Interact.*, vol. 36, no. 8, pp. 709–716, 2020, doi: 10.1080/10447318.2019. 1680922.
[22] M. Hägglund and I. Scandurra, "User evaluation of the swedish patient accessible electronic health record: system usability scale," *JMIR Hum. Factors*, vol. 8, no. 3, 2021, doi: 10.2196/24927.
[23] J. Balsa *et al.*, "Usability of an intelligent virtual assistant for promoting behavior change and self-care in older people with type 2 diabetes," *J. Med. Syst.*, vol. 44, no. 130, pp.

1–12, 2020, doi: 10.1007/s10916-020-01583-w.
[24] M. N. Islam et al., "Investigating usability of mobile health applications in Bangladesh," *BMC Med. Inform. Decis. Mak.*, vol. 20, no. 19, pp. 1–13, 2020, doi: 10.1186/s12911-020-1033-3.
[25] J. W. Dexheimer et al., "Usability evaluation of the SMART application for youth with mTBI," *Int. J. Med. Inf.*, vol. 97, pp. 163–170, 2017, doi: 10.1016/j.ijmedinf.2016.10.007.
[26] J. Choi et al., "Steps to develop a mobile app for pain assessment of cancer patients: A usability study," *CIN - Comput. Inform. Nurs.*, vol. 38, no. 2, pp. 80–87, 2019, doi: 10.1097/CIN.0000000000000581.
[27] H. N. C. Fu et al., "Usability evaluation of four top-rated commercially available diabetes apps for adults with type 2 diabetes," *CIN - Comput. Inform. Nurs.*, vol. 38, no. 6, pp. 274–280, 2020, doi: 10.1097/CIN.0000000000000596.
[28] R. J. Holden *et al.*, "Usability and feasibility of consumer-facing technology to reduce unsafe medication use by older adults," *Res. Soc. Adm. Pharm.*, vol. 16, no. 1, pp. 54–61, 2020, doi: 10.1016/j.sapharm.2019.02.011.
[29] B. R. Eapen and B. Chapman, "Mobile access to clinicalconnect: A user feedback survey on usability, productivity, and quality," *JMIR MHealth UHealth*, vol. 3, no. 2, 2015, doi: 10.2196/mhealth.4011.
[30] C. Panagopoulos et al., "Increasing usability of homecare applications for older adults: A case study," *Designs*, vol. 3, no. 2, pp. 1–18, 2019, doi: 10.3390/designs3020023.
[31] V. A. Miller et al., "The healing hearts at home© mobile application usability and influence on parental perceived stress: A pilot study," *Int. J. E-Health Med. Commun.*, vol. 12, no. 3, pp. 90–105, 2021, doi: 10.4018/IJEHMC.20210501.oa6.
[32] H. G. de O. Cavalcanti et al., "Evaluation of the usability of a mobile application in early detection of pediatric cancer," *Rev. Gaucha Enferm.*, vol. 42, 2021, doi: 10.1590/1983-1447.2021.20190384.
[33] S. Subramaniam and J. S. Dhillon, "Assessing the usability of a prediabetes self-care application: A multi-method approach," *Int. J. Eng. Technol.*, vol. 7, no. 4.35, p. 66, Nov. 2018, doi: 10.14419/ijet.v7i4.35.22325.
[34] B. R. Vargas *et al.*, "Usability and acceptability of a comprehensive HIV and other sexually transmitted infections prevention app," *J. Med. Syst.*, vol. 43, no. 175, pp. 1–5, 2019, doi: 10.1007/s10916-019-1323-4.
[35] K. Hsieh, J. Fanning, M. Frechette, and J. Sosnoff, "Usability of a fall risk mhealth app for people with multiple sclerosis: Mixed methods study," *JMIR Hum. Factors*, vol. 8, no. 1, 2021, doi: 10.2196/25604.
[36] M. van der Velde *et al.*, "Usability and preliminary effectiveness of a preoperative mHealth app for people undergoing major surgery: Pilot randomized controlled trial," *JMIR MHealth UHealth*, vol. 9, no. 1, 2021, doi: 10.2196/23402.
[37] P. S. de M. C. Valente *et al.*, "Development and usability evaluation of an application for patients with glaucoma," *Int. Ophthalmol.*, vol. 41, no. 10, pp. 1–10, 2021, doi: 10.1007/s10792-021-01905-y.
[38] Y. S. Liu, J. Hankey, N. M. Lou, P. Chokka, and J. M. Harley, "Usability and emotions of mental health assessment tools: Comparing mobile app and paper-and-pencil modalities," *J. Technol. Hum. Serv.*, vol. 39, no. 2, pp. 1–19, 2021, doi: 10.1080/15228835.2021.1902457.
[39] R. Bergquist, B. Vereijken, S. Mellone, M. Corzani, J. L. Helbostad, and K. Taraldsen, "App-based self-administrable clinical tests of physical function: Development and usability study," *JMIR MHealth UHealth*, vol. 8, no. 4, 2020, doi: 10.2196/16507.
[40] J. Y. Lee *et al.*, "Development and usability of a life-logging behavior monitoring application for obese patients," *J. Obes. Metab. Syndr.*, vol. 28, pp. 194–202, 2019, doi: 10.7570/JOMES.2019.28.3.194.
[41] M. Y. Alkawaldeh, C. S. Jacelon, and J. Choi, "Usability testing of a tablet-based self-management application for older adults with T2DM: The ASSISTwell application," *Gerontechnology*, vol. 20, no. 1, pp. 1–13, 2020, doi: 10.4017/GT.2020.20.1.399.08.
[42] M. Fuller-Tyszkiewicz *et al.*, "A mobile app-based intervention for depression: End-user and expert usability testing study," *JMIR Ment. Health*, vol. 5, no. 8, 2018, doi: 10.2196/mental.9445.
[43] F. Ehrler, T. Weinhold, J. Joe, C. Lovis, and K. Blondon, "A mobile app (BEDSide mobility) to support nurses' tasks at the patient's bedside: Usability study," *JMIR MHealth UHealth*, vol. 6, no. 3, 2018, doi: 10.2196/mhealth.9079.
[44] K. Khowaja and D. Al-Thani, "New checklist for the heuristic evaluation of mHealth apps (HE4EH): Development and usability study," *JMIR MHealth UHealth*, vol. 8, no. 10, 2020, doi: 10.2196/20353.
[45] E. Sarzynski *et al.*, "Beta testing a novel smartphone application to improve

medication adherence," *Telemed. E-Health*, vol. 23, no. 4, pp. 1–10, 2017, doi: 10.1089/tmj.2016.0100.
[46] M. Georgsson and N. Staggers, "Quantifying usability: An evaluation of a diabetes mHealth system on effectiveness, efficiency, and satisfaction metrics with associated user characteristics," *J. Am. Med. Inform. Assoc.*, vol. 23, no. 1, pp. 5–11, 2016, doi: 10.1093/jamia/ocv099.
[47] W. Martinez, A. J. Hackstadt, G. B. Hickson, S. T. Rosenbloom, and T. A. Elasy, "Evaluation of the my diabetes care patient portal intervention: Protocol for a pilot randomized controlled trial," *JMIR Res. Protoc.*, vol. 10, no. 5, 2021, doi: 10.2196/25955.
[48] C. H. Liao *et al.*, "An image-based mobile health app for postdrainage monitoring: Usability study," *J. Med. Internet Res.*, vol. 22, no. 8, 2020, doi: 10.2196/17686.
[49] M. D. Sung, S. J. Park, S. Jung, E. Lee, J. Lee, and Y. R. Park, "Developing a mobile app for monitoring medical record changes using blockchain: Development and usability study," *J. Med. Internet Res.*, vol. 22, no. 8, 2020, doi: 10.2196/19657.
[50] S. Sigle et al., "Evaluating online consumer medication information systems: Comparative online usability study," *JMIR MHealth UHealth*, vol. 8, no. 6, 2020, doi: 10.2196/16648.
[51] A. Clebone *et al.*, "Development and usability testing of the society for pediatric anesthesia pedi crisis mobile application," *Anesth. Analg.*, vol. 129, no. 6, pp. 1635–1644, 2019, doi: 10.1213/ANE.0000000000003935.
[52] L. Zhou et al., "The mhealth app usability questionnaire (MAUQ): Development and validation study," *JMIR MHealth UHealth*, vol. 7, no. 4, 2019, doi: 10.2196/11500.
[53] S. Bhattacharjya et al., "Usability, usefulness, and acceptance of a novel, portable rehabilitation system (mRehab) using smartphone and 3D printing technology: Mixed methods study," *JMIR Hum. Factors*, vol. 8, no. 1, 2021, doi: 10.2196/21312.
[54] U. Müssener *et al.*, "Development of an intervention targeting multiple health behaviors among high school students: Participatory design study using heuristic evaluation and usability testing," *JMIR MHealth UHealth*, vol. 8, no. 10, pp. 1–12, 2020, doi: 10.2196/17999.
[55] A. T. Nguyen, E. K. Somerville, S. M. Espín-Tello, M. Keglovits, and S. L. Stark, "A mobile app directory of occupational therapists who provide home modifications: Development and preliminary usability evaluation," *JMIR Rehabil. Assist. Technol.*, vol. 7, no. 1, 2020, doi: 10.2196/14465.
[56] M. van Beukering *et al.*, "Usability and usefulness of a mobile health app for pregnancy-related work advice: mixed-methods approach," *JMIR MHealth UHealth*, vol. 7, no. 5, 2019, doi: 10.2196/11442.
[57] G. Ferrara, J. Kim, S. Lin, J. Hua, and E. Seto, "A focused review of smartphone diet-tracking apps: Usability, functionality, coherence with behavior change theory, and comparative validity of nutrient intake and energy estimates," *JMIR MHealth UHealth*, vol. 7, no. 5, 2019, doi: 10.2196/mhealth.9232.
[58] C. C. Quinn, S. Staub, E. Barr, and A. Gruber-Baldini, "Mobile support for older adults and their caregivers: Dyad usability study," *JMIR Aging*, vol. 2, no. 1, 2019, doi: 10.2196/12276.
[59] D. George, M. A. Hassali, and H. S. S. Amar-Singh, "Usability testing of a mobile app to report medication errors anonymously: Mixed-methods approach," *JMIR Hum. Factors*, vol. 5, no. 4, 2018, doi: 10.2196/12232.
[60] Y. C. Liu et al., "Usability of food size AIDS in mobile dietary reporting apps for young adults: Randomized controlled trial," *JMIR MHealth UHealth*, vol. 8, no. 4, pp. 1–17, 2020, doi: 10.2196/14543.
[61] E. Meinert et al., "Acceptability and usability of the mobile digital health app noobesity for families and health care professionals: Protocol for a feasibility study," *JMIR Res. Protoc.*, vol. 9, no. 7, 2020, doi: 10.2196/18068.
[62] H. H. Kim et al., "User-dependent usability and feasibility of a swallowing training mhealth app for older adults: Mixed methods pilot study," *JMIR MHealth UHealth*, vol. 8, no. 7, 2020, doi: 10.2196/19585.
[63] M. F. M. Marzuki et al., "Usable mobile app for community education on colorectal cancer: Development process and usability study," *JMIR Hum. Factors*, vol. 6, no. 2, 2019, doi: 10.2196/12103.
[64] C. E. Mauch et al., "Commercially available apps to support healthy family meals: User testing of app utility, acceptability, and engagement," *JMIR MHealth UHealth*, vol. 9, no. 5, 2021, doi: 10.2196/22990.
[65] S. M. Kim *et al.*, "User experience of mobile personal health records for the emergency department: Mixed methods study," *JMIR MHealth UHealth*, vol. 8, no. 12, 2020, doi: 10.2196/24326.
[66] F. O. Babatunde et al., "Development and usability testing of a web-based and therapist-

assisted coping skills program for managing psychosocial problems in individuals with hand and upper limb injuries: Mixed methods study," *JMIR Hum. Factors*, vol. 7, no. 2, 2020, doi: 10.2196/17088.

[67] A. L. Beatty et al., "VA fitheart, a mobile app for cardiac rehabilitation: Usability study," *JMIR Hum. Factors*, vol. 5, no. 1, 2018, doi: 10.2196/humanfactors.8017.

[68] A. A. B. Ramadan, J. Jackson-Thompson, and C. L. Schmaltz, "Usability assessment of the missouri cancer registry's published interactive mapping reports: Round one," *JMIR Hum. Factors*, vol. 4, no. 3, 2017, doi: 10.2196/humanfactors.7899.

[69] K. A. Grindrod, M. Li, and A. Gates, "Evaluating user perceptions of mobile medication management applications with older adults: A usability study," *JMIR MHealth UHealth*, vol. 2, no. 1, 2014, doi: 10.2196/mhealth.3048.

[70] A. Newton *et al.*, "A mobile phone-based app for use during cognitive behavioral therapy for adolescents with anxiety (MindClimb): User-centered design and usability study," *JMIR MHealth UHealth*, vol. 8, no. 12, 2020, doi: 10.2196/18439.

[71] B. Langlet *et al.*, "Formative evaluation of a smartphone app for monitoring daily meal distribution and food selection in adolescents: Acceptability and usability study," *JMIR MHealth UHealth*, vol. 8, no. 7, 2020, doi: 10.2196/14778.

[72] O. B. Kristjansdottir *et al.*, "Mobile app to help people with chronic illness reflect on their strengths: formative evaluation and usability testing," *JMIR Form. Res.*, vol. 4, no. 3, 2020, doi: 10.2196/16831.

[73] C. H. Teo et al., "A mobile web app to improve health screening uptake in men (Screenmen): Utility and usability evaluation study," *JMIR MHealth UHealth*, vol. 7, no. 4, 2019, doi: 10.2196/10216.

[74] K. Morawski, C. Monsen, S. Takhar, and A. Landman, "A novel information retrieval tool to find hospital care team members: Development and usability study," *JMIR Hum. Factors*, vol. 5, no. 2, 2018, doi: 10.2196/humanfactors.6781.

[75] T. Stütz *et al.*, "Mobile phone-supported physiotherapy for frozen shoulder: Feasibility assessment based on a usability study," *JMIR Rehabil. Assist. Technol.*, vol. 4, no. 2, pp. 1–25, 2017, doi: 10.2196/rehab.7085.

[76] R. Z. Franco et al., "A Web-based graphical food frequency assessment system: Design, development and usability metrics," *JMIR Hum. Factors*, vol. 4, no. 2, 2017, doi: 10.2196/humanfactors.7287.

[77] P. S. Sullivan *et al.*, "Usability and acceptability of a mobile comprehensive hiv prevention app for men who have sex with men: A pilot study," *JMIR MHealth UHealth*, vol. 5, no. 3, 2017, doi: 10.2196/mhealth.7199.

[78] K. P. Loh *et al.*, "Novel mhealth app to deliver geriatric assessment-driven interventions for older adults with cancer: Pilot feasibility and usability study," *JMIR Cancer*, vol. 4, no. 2, 2018, doi: 10.2196/10296.

[79] K. Gupta et al., "Usability Evaluation and Classification of mHealth Applications for Type 2 Diabetes Mellitus Using MARS and ID3 Algorithm," *Int. J. Environ. Res. Public. Health*, vol. 19, no. 12, p. 6999, Jun. 2022, doi: 10.3390/ijerph19126999.

[80] J. H. Kim et al., "Formative Usability Evaluation of a Three-Way Digital Healthcare System for the People with Disabilities and Their Caregivers: A Cross-Sectional Study," *Healthcare*, vol. 10, no. 11, p. 2325, Nov. 2022, doi: 10.3390/healthcare10112325.

[81] S. Mortezaei, R. Rabiei, F. Asadi, and H. Emami, "Development and usability evaluation of a mHealth application for albinism self-management," *BMC Med. Inform. Decis. Mak.*, vol. 23, no. 1, p. 106, Jun. 2023, doi: 10.1186/s12911-023-02202-7.

[82] M. I. Ismaei et al., "Chatbot System for Mental Health in Bahasa Malaysia," *Journal of Integrated and Advanced Engineering (JIAE)*, vol. 2, no. 2, pp. 135-146, 2022, doi: 10.51662/jiae.v2i2.82

[83] E. Nasr, W. Alsaggaf, and D. Sinnari, "Developing Usability Guidelines for mHealth Applications (UGmHA)," *Multimodal Technol. Interact.*, vol. 7, no. 3, p. 26, Feb. 2023, doi: 10.3390/mti7030026.

[84] Z. Hu et al., "Three-dimensional electromagnetic method in shallow surface exploration in complex piedmont belt," *Proquest*, vol. 660, no. 1, pp. 3–7, 2021, doi: 10.1088/1755-1315/660/1/012129.