BMJ Open

Willingness, perceived barriers and motivators in adopting mobile applications for health-related interventions among older adults: a scoping review

Nurul Asilah Ahmad ,[1] Arimi Fitri Mat Ludin ,[1,2] Suzana Shahar,[1] Shahrul Azman Mohd Noah,[3] Noorlaili Mohd Tohit[4]

For numbered affiliations see end of article.

Correspondence to
Dr Arimi Fitri Mat Ludin; arimifitri@ukm.edu.my

ABSTRACT

Objectives This scoping review aims to identify the level of willingness, the existing barriers, and motivators among older adults in using mobile applications to monitor and manage their health conditions. The secondary aim of this paper is to categorise these willingness, barriers and motivators using the Theoretical Domains Framework (TDF).

Design Scoping review.

Data source PubMed, Embase, CINAHL, Cochrane Library, Google Scholar and Science Direct (January 2009– December 2020).

Study selection Studies that describe older adults' perspectives with regard to their willingness, barriers or motivators towards the use of mobile applications in monitoring and managing their health condition were included.

Data extraction Titles and abstracts were initially screened by two reviewers. Articles agreed by both reviewers were proceeded to full-text screening. One reviewer extracted the data, which were verified by a second reviewer. Findings were further classified according to the 14 TDF domains by two researchers.

Results Six studies were included in the final scoping review. Barriers to adopting mobile applications for health-related interventions among older adults were the most common topic identified in the included studies. Barriers included being unaware of the existence of mobile health applications, lack of technological skills, lack of perceived ability and time, absence of professional involvements, and violation of trust and privacy. With regard to willingness, older adults are willing to use mobile applications if the apps incorporated features from a trusted source and have valid credentials. Motivators included continuous improvements of mobile applications' design interface and personalised features tailored to older adults' needs.

Conclusions With the constant research for more diversified technology, the development of mobile applications to help older adults to manage and monitor health is seen as feasible, but barriers have to be addressed. The most prominent barriers linked to TDF domains were: (1) technological skills, (2) belief about consequences, and (3) memory, attention and decision

Strengths and limitations of this study

► We conducted a scoping review of older adults' perspectives in using mobile applications for health, using a broad and inclusive search strategy and prepublished protocol.

► We followed a systematic approach based on guidance for carrying out a scoping review and reported our findings thoroughly based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses scoping review checklist.

► A significant strength of this paper is that a comprehensive result analysis was used in which all of the findings were linked to the Theoretical Domains Framework domains that can be replicated by other interventionists for a specific population.

► As this is a scoping review, critical appraisal of the study quality and the risk of bias were not conducted.

process. Future interventions should use behaviour change techniques that target these three TDF domains in order to improve the ability to engage older adults with mobile technology.

INTRODUCTION

The world's ageing population continues to grow at an unprecedented rate. To date, there are 703 million people aged 65 years or over around the world.[1,2] By 2050, it is projected there will be 1.5 billion older adults globally with the proportion of one in six people in the world will be aged 65 years or over.[1] Malaysia's ageing population, in particular, the number of this subpopulation has increased gradually since 1970s.[3,4] It is expected to triple from 2.0 million today, to more than 6.0 million by 2040.[3,4] This world phenomenon is a result of one of the most remarkable achievements of mankind's history with regard to health, social and economic improvements over

time.[1] This improvement has contributed to the sustained increases in life expectancy across the globe.[5–7]

Despite of this success history of human life expectancy, it does not come with a proportionate increase in the quality of life for older adults. As widely discussed in the literature, with increased life expectancy, there will be an increased risk of developing chronic diseases, disability and dementia especially among older adults.[8–10] This explains the higher use of health services and greater demand for specialised services among this subpopulation.[11–13] The increased complexity of health services required and increased health costs have always been linked to the increased pressure on the economy and social systems in most countries.[10 14–16]

With advanced technological innovations nowadays, we are able to carry out many tasks effectively and efficiently. Technology-supported healthcare is now growing remarkably and provides new means of health self-management. While older adults may be seen as technological laggards, the internet usage among this subpopulation has been reported to increase significantly from year to year.[17] For example, the internet usage among older adults in the UK aged 65–74 years has increased gradually over the last 8 years, from 52% in 2011 to 83% in 2019.[18 19] To add, the trend of smartphone ownership is reported to grow rapidly across the globe.[20–22]

With the rapid growth of technology, particularly in smartphones and internet use, mobile health (mHealth) is seen as a promising tool to minimise health problems as well as to support and improve healthcare services. To date, no standardised definition for mHealth has been established, but the WHO defines mHealth as 'medical and public health practice supported by mobile devices, personal digital assistants and other wireless devices'.[23] There are more than 325 000 identified mHealth applications covering various fields of health, medical and fitness topics.[24 25] There is substantial evidence that has shown the effectiveness of mHealth applications in improving self-care, self-management, self-efficacy medication adherence as well as in improving health behaviours with regard to quality of sleep, diet, physical activity and mental health.[26–29] Numerous studies also demonstrated the benefits of mHealth towards older adults.[30–37] Research shows that by using mHealth technology alongside medical advice from healthcare professionals, we can help the older adults to develop a healthy lifestyle, such as improving their daily food intake, sleep quality and physical activity.[17 25 26] This will consequently improve their self-efficacy in managing and monitoring their health, especially for those with chronic diseases. For example, a web-based education programme for older adults was found to be cost-effective in self-perceived disability and informational support score.[36] Other benefits that have been documented include helping to address existing barriers to treatment such as long waiting times at hospitals, poor access to transportation and increased cost of healthcare services.[30–34] Despite the numerous benefits of mHealth among older adults, barriers faced by this subpopulation have been reported. The most prevalent barriers reported in the literature were usability issues, decreased sensory perception and lack of familiarity when using such technology.[38–40]

Although there has been a steady increase in the number of studies exploring mHealth adoption among older adults, few have focused on the usage of mobile applications alone. Many studies have focused on the combination of mHealth and electronic health (eHealth) technology, such as the adoption or acceptance of particular websites, telehealth conferences, wearable devices such as fitness trackers and other types of gadgets.[26 27 35–37] Moreover, few studies have explored the perceptions of older adults towards the use of mobile applications for health-related purposes including the willingness to use mHealth, as well as perceived motivators and barriers.[26] To our knowledge, there are no studies that have examined the combination of willingness, barriers and motivators among older adults towards the use of mobile applications to monitor and manage their health conditions. Despite the potential of mobile applications to improve the health of older adults, their efficacy ultimately relies on their adoption and sustained use by the intended users.[41]

While usage of mobile applications is increasing among the older adult population, they continue to lag behind their younger counterparts when it comes to technology adoption. Therefore, it is essential to explore the perceptions with regard to willingness, barriers and motivators among older adults towards the use of mobile applications in order to increase the rate of adoption of such technology. A better understanding of these three main components that might influence older adults' intention to use mobile applications to monitor and manage their health could guide the development and implementation of future mobile applications for health intervention. Thus, the primary purpose of this study is to identify the level of willingness, the existing barriers, and motivators among older adults in using mobile applications to monitor and manage their health conditions.

Furthermore, implementing health interventions using a technology, especially among older adults, is associated with many factors such as concerns regarding technology use (usability factors), expected benefits of technology (perceived usefulness), social influences and a lot more.[40] The implementation of technology targeting older adults requires change and improvements over time at an individual, organisational and/or community level.[40] Organising and analysing these factors into broader theories of behaviour change can help to improve health interventions targeting older adults. The Theoretical Domains Framework (TDF) is an integrative framework of behaviour change that can be used to identify modifiable factors.[2] There are 14 domains in the TDF as follows: (1) knowledge; (2) skills; (3) memory; (4) attention and decision process; (5) behavioural regulation; (6) social/professional role and identity; (7) beliefs about capabilities; (8) optimism; (9) beliefs about consequences;

(10) intentions; (11) goals; (12) reinforcement; (13) emotions, environmental context and resources; and (14) social influences. TDF has been used in previous studies to understand barriers and facilitators related to health behaviour.[2] Furthermore, TDF is also a part of the Behaviour Change Wheel that guides the intervention developers to target appropriate behaviour change techniques (BCTs). TDF also provides a behavioural diagnosis of what needs to improve or change in order for a specific behaviour to change. Hence, a TDF analysis of a behaviour is crucial, in which it provides the initial step in implementing any behaviour change interventions.[2] Thus, the secondary aim of this study is to categorise and analyse the willingness, barriers and motivators within the TDF to provide detailed insights for healthcare professionals as well as mobile application developers working with this subpopulation.

METHODS AND ANALYSIS
Protocol and overall scoping review methodology
The study protocol was as previously published,[42] detailing the search strategy and method used.

We primarily followed the Joanna Briggs Institute guidelines[43] on scoping reviews and the framework by Arksey and O'Malley,[44] with improvements suggested by Levac et al.[45 46] Further, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews.[47] The checklist is shown in online supplemental appendix 1. We also followed the journal guidelines for the preparation of the manuscript. The major methodological steps for the systematic scoping review comprised determining the research question; identifying relevant studies; selecting studies; charting the data; collation; summarisation and reporting of the results; and consulting with stakeholders.

Stage 1: identifying the research question
The present scoping review sought to answer one overarching research question: 'What is known about the perspectives in adopting mobile applications for health-related interventions among older adults?' We then further sought to answer these subquestions:
1. What is the level of willingness among older adults in using mobile applications to monitor and manage their health conditions?

2. What are the existing barriers among older adults in using mobile applications to monitor and manage their health conditions?
3. What motivates older adults to use mobile applications to monitor and manage their health conditions?

Stage 2: identifying relevant studies
A comprehensive search to identify studies on the willingness, perceived barriers and motivators in adopting mobile applications among older adults from January 2009 to December 2020 was performed using different resources. In our previously published protocol, the searches were limited from January 2009 to April 2020. In this scoping review, we decided to extend this time frame up to December 2020 to cover possible research studies around perspectives among older adults in using mobile applications to monitor and manage their health that were released in this particular year. The identification of relevant literature consisted of a three-stage approach: (1) searching electronic databases, (2) searching the reference lists of literature that meet all inclusion criteria and (3) hand searching specific key publications such as identified white papers or conference presentations. These stages have been detailed in our protocol paper that has been published previously.[42] The electronic searches included several electronic databases, which were PubMed, Embase, CINAHL, Cochrane Library, Google Scholar and Science Direct. We have also conducted manual hand searches on additional key electronic journals such as the Journal of the American Medical Informatics Association, the Journal of Medical Internet Research, the International Journal of Digital Healthcare and Digital Health (SAGE) in order to maximise the search coverage. However, the Journal of mHealth was excluded from our search, as our institution is not subscribed to this journal. We also searched relevant grey literature databases (eg, Grey Literature Report, OpenGrey, Web of Science Conference Proceedings, government documents, academic theses/dissertations) to identify studies, reports and conference abstracts of relevance to this review.

Subject headings, and list of keywords and synonyms were developed as search terms by the research team members to capture potential studies in the resources (table 1). After several revisions, a list of search strings

Table 1 List of keywords and synonyms generated as search terms

Mobile application	Older adults	Perspective	Barrier	Facilitator
Mobile app*	Elderly	View	Limitation	Motivate*
mHealth	Ageing population	Attitude	Difficulty	Promote*
Mobile health	Older population	Mindset	Restriction	Help
Telehealth	Aging	Willingness	Drawback	Ease
Mobile technolog*	Geriatric	Readiness		Aid
		Acceptability		

Table 2	List of search strings
Search string 1	"Mobile application*" OR "mobile app" OR "mHealth" OR "mobile health" OR "telehealth" OR "mobile technology" AND "Older adults" OR "Elderly" OR "Ageing population" OR "Older population" OR "Aging" OR "Geriatric" AND "Perspective*" OR "View" OR "Attitude" OR "Mindset" OR "Willingness" OR "Readiness" OR "Acceptability"
Search string 2	"Mobile application*" OR "mobile app" OR "mHealth" OR "mobile health" OR "telehealth" OR "mobile technology" AND "Older adults" OR "Elderly" OR "Ageing population" OR "Older population" OR "Aging" OR "Geriatric" AND "Barrier*" OR "Limitation*" OR "Difficulty" OR "Restriction*" OR "Drawback*"
Search string 3	"Mobile application*" OR "mobile app" OR "mHealth" OR "mobile health" OR "telehealth" OR "mobile technology" AND "Older adults" OR "Elderly" OR "Ageing population" OR "Older population" OR "Aging" OR "Geriatric" AND "Facilitate*" OR "Motivate*" OR "Promote*" OR "Help" OR "Ease" OR "Aid"

(table 2) was corrected and finalised, with only three instead of four search strings, as was used in our previous protocol paper.[42]

Stage 3: study selection
According to Arksey and O'Malley's framework, the third stage[43] aims to identify the studies that will be included in the scoping review. The screening process consisted of two stages: (1) a title and abstract/summary and (2) full-text screening. A PRISMA flow chart was used in the selection process of the study. In the first stage, two reviewers (NAA and AFML) screened the titles and abstracts of the articles. During this process, the following decisions were undertaken: (1) for articles that both reviewers agreed to include, the article was then read in full by each reviewer, (2) for any article that both reviewers agreed to exclude, the article was then excluded from the study, (3) for any article that did not achieve agreement between both reviewers on whether to include or to exclude it, the article was then proceeded onto the second stage of the screening process, to be read in full by each reviewer before a final decision was made. In the second stage, both reviewers have performed a full-text review of the included articles. The eligibility and exclusion criteria have been detailed in our protocol paper that has been published previously.[42]

Stage 4: charting the data
A data extraction table has been developed to gather and tabulate all relevant data from the studies that have been selected. The types of study characteristics that were extracted were listed in our previously published protocol paper.[42] Using the information collected from the data extraction process, the key characteristics of included studies were summarised qualitatively and tabulated. We reviewed each full-text article and extracted the following study characteristics into Excel spreadsheets: publication years, authors, sample size, age, study design (qualitative, quantitative, mixed) and study location. Data regarding willingness, barriers and motivators were extracted from the selected studies if they were mentioned by the authors in the results or discussion as being relevant to older adults' usage of mobile applications to monitor and manage their health. A combination of EndNote V.X9

and Covidence software was used to organise and track relevant data.

Stage 5: collating, summarising and reporting the results
After the initial extraction, the TDF[2] was used to categorise the willingness, barriers and motivators. AFML and NAA independently categorised the extracted willingness, barriers and motivators into the most predominant of the 14 TDF domains, as per the definition of each domain.[2] This approach was agreed on by the first and second authors prior to the categorisation to ensure parsimony. Upon completing the extraction and categorisation, AFML and NAA met to determine agreement on: (1) the presence or absence of willingness, barriers and motivators within each paper, and (2) the TDF domain categorisation. The discussion was structured based on the TDF domain that emerged.
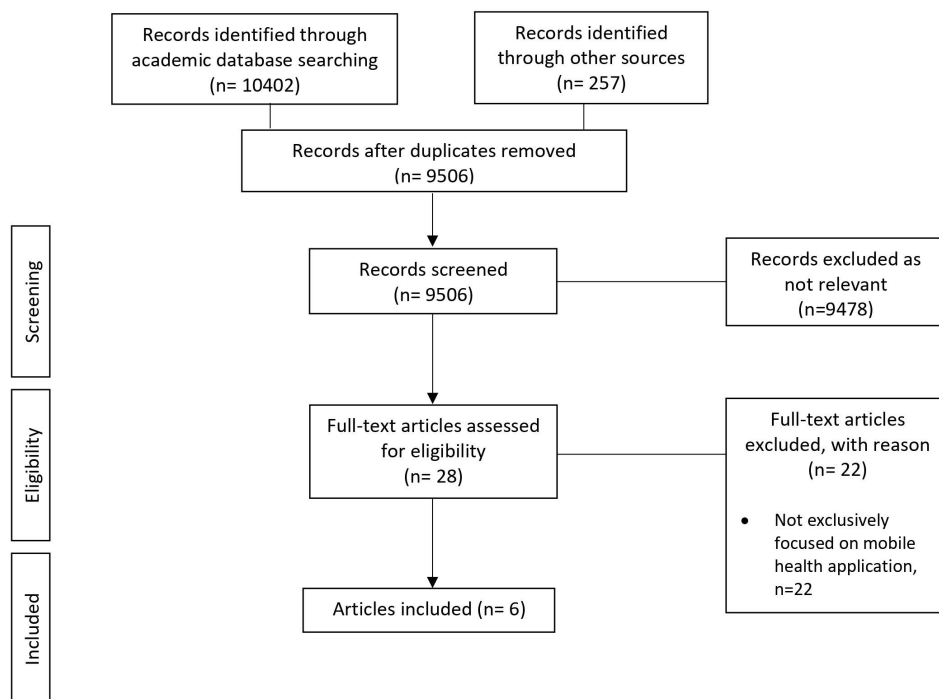
RESULTS
Literature search
The search yielded a total of 10 659 articles from 9 different sources and identified 9506 articles after removal of duplicates (figure 1). After screening these articles on title and abstract, the large majority of articles were not relevant (n=9478), as a result of our deliberately overinclusive search strategy. We identified 28 articles that on title and abstract met our inclusion criteria. This in-depth screening excluded a further 22 articles leaving only 6 articles that met the predefined inclusion criteria. Reasons for exclusion at full-text screening referred to: studies that combined multiple eHealth and mHealth interventions (n=22). As a result, we were left with six articles that included research evidence on the older adults' perspectives towards the use of mobile application to manage and monitor their health condition.

Characteristics of the included studies
All publications included (N=6) in the final data extraction were published between 2017 and 2020.[48–53] The six studies consisted of four studies[48–51] from Europe and two studies[52 53] from the USA. These studies involved a total of 472 participants who were older adults aged 60 years and over. Ethnicity was not reported in all articles,

Inclusion criteria
- Describes or reports older adults' perspectives either their willingness, barriers or motivators towards the use of mobile application in monitoring and managing their health condition.
- Published in English language.
- Contains only older population aged 60 years old as its study population.
- Is a peer-reviewed literature or grey literature.
- Is dated 1 January 2009-April 2020

Exclusion criteria
- Provides summaries and do not introduce any new knowledge (e.g., literature review, scoping review, systematic review, topical review, commentaries, opinion papers).

Figure 1 PRISMA flow diagram. The PRISMA diagram details the search and selection process applied during our systematic literature search for this scoping review. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

but for the two[52 53] that did, participants were white and African-American.

Table 3 summarises the details of the studies that met the inclusion criteria. Five studies employed qualitative methods of data collection.[49–53] Only one study[49] used a mixed-methods approach involving interviews where data relevant to identifying the motivators of the older adults using mHealth apps were presented both quantitatively and qualitatively, and were thus included in the analysis and discussion as part of qualitative studies.

Furthermore, only one study used quantitative methods of data collection.[48] In this cross-sectional study, a questionnaire was distributed to determine the relationship of technology acceptance factors and intention to use mobile medical apps and the data were presented quantitatively.[48] The data were collected from November 2018 to June 2019 and this study has shown that almost half of the respondents (49.7%) had no intention to use

medical apps.[48] This was further explored by acceptance factors, and it was revealed that the attitude toward usage appeared to be the most significant factor that has influenced the intention to use medical apps among older adults.

The qualitative studies included a total of 107 participants, 57 of which were female. One study did not report gender and mean age, though the participants ranged from 50 years or above who were suffering from type 2 diabetes.[49]

Willingness

Table 4 summarises the details of selected studies with regards to willingess, barriers and motivators according to TDF domains. Older adults' willingness to use mobile applications for health-related interventions is the least discussed topic. Only one study[50] explored the willingness of older adults to use mobile applications to monitor

Table 3 Overview of included studies

No	Study	Location	Study design	Sample, N	Participant characteristic	Main findings
1	Askari et al[48]	Netherlands	Quantitative	364	Age: 75 years (SD 7 years) Sex: 155 males, 209 females	▲ Almost half of the respondents (49.7%, n=181) had no intention to use medical apps. ▲ Acceptance factors significantly related to intention to use were: perceived usefulness, perceived ease of use, attitude toward use, subjective norm, sense of control, feelings of anxiety, personal innovativeness, social relationships, self-perceived effectiveness, service availability and facilities. ▲ Feelings of anxiety about using new technology may negatively affect the intention to use medical apps. This might be caused by factors such as a lack of self-efficacy, a desire for a greater sense of control, privacy issues or a lack of trust.
2	Park et al[52]	USA	Qualitative	28	Age: 69.5 (SD 10.8 years) for non-veterans (50% male) and 70 (SD 8.6 years) for veterans (100% male) Sex: 7 females, 21 males	▲ Facilitators of using the app: participants preferred the idea of being able to interact with the apps as medication reminder, comprehensive features like drug information, interactions and side effects and repository of wide range of health measurements, the ability to track and monitor health indicators on a long-term basis ▲ Desired app features: a link to their medical providers would help in medication adherence ▲ Barriers: violations of privacy
3	Pywell et al[50]	North East England, UK	Qualitative	10	Age: 50 years or older who experienced periods of low mood Sex: 7 females, 3 males	▲ Six distinct barriers to older adults' uptake of mobile-based mental health interventions: mental electronic health awareness, interaction with technology, discontinuation, 'seeing' facilitates therapeutic alliance, incongruent role of the general practitioner and privacy and confidentiality.
4	Kalimullah and Sushmitha[49]	Sweden	Quasi-experimental	6	Age: older adults aged 50 years or above, suffering from type 2 diabetes Sex: not stated	▲ The participants from the control group were exposed to the Glucosio application integrated with QoE probe to study user experience and the experimental group was exposed to the prototype of Glucosio to measure UX. ▲ It was observed that much of the difference in the user experience may not be observed with a change in any one of the user interface design elements of the mHealth application, but when the changes were made (user interface design) as per the convenience of the elders, a considerable increase in the UX of the older adults can be seen after they use the application.
5	Russell et al[53]	USA	Qualitative	46	Age: the mean age was 65 years (SD=9) Sex: 32 females, 14 males Race: 61% (n=28) of participants were white	▲ Preferences: medication interaction warning, double dose warning, comprehensive medication list, reminder alerts, caregiver friendly ▲ Main theme desired features/facilitators: medication education, regimen identification, refill management, provider and pharmacy information, reminders and alerts, cost comparisons ▲ Most desired features: drug interaction warnings, a comprehensive medication list, reminders to take medication, reminder to refill medications, and links within the app to additional medication information such as indication and potential side effects

Continued

Table 3 Continued

No	Study	Location	Study design	Sample, N	Participant characteristic	Main findings
6	Wildenbos et al[51]	Netherlands	Qualitative	23	Age: 50–80 years old and above. Sex: 12 males, 11 females (n=23)	Barriers: – Motivational barriers: low computer literacy, low trust in a patient's own ability to use the app, efficiency in seeing benefits summarises the willingness, barriers and motivators among older adults towards the use of mobile applications to monitor and manage their health conditions according to TDF domains. – Perception level: visual acuity oversaw important icons or feedback messages and had difficulties with reading the small fonts – Cognitive barriers: working memory, dynamic/selective attention, semantic fluency, reasoning – Physical abilities: hand–eye coordination

mHealth, mobile health; TDF, Theoretical Domains Framework.

and manage their health. This study has shown that older adults were willing to use a particular mHealth app if the app reflects the authenticity of a trusted source and has valid credentials such as healthcare professionals' involvement.

Barriers

Barriers to adopting mobile applications for health-related interventions among older adults are the most common topic identified in the included studies. One study has shown that knowledge was a common barrier where the participants did not know or did not realise the existence of mHealth applications.[50] There were two studies that reported the lack of technological skills or low computer literacy skills as one of the barriers towards the use of mHealth among older adults.[50 51] Within the TDF domain number 6, which is belief about consequences, one study reported that older adults would stop using the app if they were unable to gain a better understanding or education.[50] Violation of trust and privacy has also been identified to be one of the barriers within this domain.[53] Within the TDF domain number 10, which is memory, attention and decision process, two studies reported that older adults' limited ability to complete tasks using the computer was identified to be one of the barriers within this theme.[50 51] Time has been identified to be one of the barriers within the TDF domain of environmental context and resources. In one study, the participants reported that the use of mHealth application was a waste of time as they would not want to spend so much time to engage with it.[50] Barriers that emerged within the social influences domain are the absence of interpersonal communication and/or encouragement from professionals. Older adults also perceived digital interventions such as mHealth apps may provide less communication due to the absence of support and non-verbal cues to be picked on if they used digital platforms.[50]

Motivators

There are several motivators for using mobile applications to monitor and manage health among older adults that were identified within various TDF domains. The reinforcement domain was identified to be one of the motivators that influenced older adults to use mobile applications. Continuous improvements of the interface designs of mobile applications will increase the rate of technology adoption among the older adults.[49] The intentions domain has also been identified as one of the motivators. Acceptance factors that were positively related to intention to use were identified as one of the motivators within this domain.[48] Attitude towards use (which is one of the elements in acceptance factors) has been shown to be the most significant factor that influenced older adults to use medical mobile applications.[48] This means that older adults will use mobile applications if they have a positive attitude towards the usage of mobile applications. Within the TDF domain number 14, which is behavioural regulation, various motivators were identified within

Table 4 Willingness, barriers and motivators according to TDF domains

No	TDF domain	Description General	Study context	Willingness	Barriers	Motivators
1	Knowledge	Awareness of existence of something	Knowledge domain is described as the awareness of the existence of mobile applications that can manage and monitor the older adults' health.	None identified	Older adults' eHealth awareness[50]	None identified
2	Skills	Ability of someone to use something	Skills domain is described as the older adults' ability to use mobile applications that can manage and monitor their health.	None identified	Computer literacy skills and/or technology skills[50–52]	None identified
3	Social/professional role and identity	A coherent set of behaviours and displayed personal qualities of an individual or the need of professional role in social or work setting	Social/professional role and identity domain is described as the older adults' need to receive health advice through mobile applications from certified healthcare professionals.	App has valid credentials[50]	None identified	None identified
4	Belief about capabilities	Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use	Belief about capabilities domain is described as the older adults' perceived ability to use mobile applications that can help them to manage and monitor their health.	None identified	Lack of confidence or ability to complete task using technology[50]	None identified
5	Optimism	Confidence that things will happen for the best or that desired goals will be attained	Optimism domain is described as the older adults' level of confidence towards the use of mobile applications in achieving their health goals.	None identified	None identified	None identified
6	Belief about consequences	Acceptance of the truth, reality or validity about outcomes of a behaviour in a given situation	Belief about consequences domain is described as the older adults' concern about negative outcomes when using mobile applications to manage and monitor their health.	None identified	Older adults would not use the app if it does not give sufficient or accurate education/information[50 52]	None identified
7	Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus	Reinforcement domain is described as the older adults' need for continuous improvement of the mobile applications in order to gain more engagement	None identified	None identified	Design element or feature enhancement of the existing apps[49]
8	Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way	Intentions domain is described as the older adults' attitude to maximise the use of mobile applications to monitor and manage their health.	None identified	None identified	Attitude to using technology significantly influenced the intention to use medical health apps[48]

Continued

Table 4 Continued

No	TDF domain	Description		Willingness	Barriers	Motivators
		General	**Study context**			
9	Goals	Mental representation of outcomes or end states that an individual wants to achieve	Goals domain is described as the older adults' determination to use mobile applications to monitor and manage their health as well as to achieve their health goals.	None identified	None identified	None identified
10	Memory, attention, decision process	The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives	Memory, attention and decision process domain is described as the older adults' ability to retain and use health information delivered via mobile applications.	None identified	Incompetence or inability to complete tasks, enter data, explore things using digital platforms[50 51]	None identified
11	Environmental context and resources	Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence and adaptive behaviour	Environmental context and resources domain is described as the older adults' life situation or environmental experiences when using mobile applications to manage and monitor their health.	None identified	Time[50]	None identified
12	Social influences	Interpersonal processes that can cause individuals to change their thoughts, feelings or behaviours	Social influences domain is described as the older adults' interpersonal process that can influence mobile applications' usage to manage and monitor their health.	None identified	No face-to-face social interactions, digital interventions may be inferior due to the absence of interpersonal communication and encouragement/ support from professionals[50]	None identified
13	Emotion	A complex reaction pattern, involving experiential, behavioural and physiological elements, by which the individual attempts to deal with a personally significant matter or event	Emotion domain is described as the older adults' physiological behaviours and feeling towards the use of mobile applications to manage and monitor their health.	None identified	None identified	None identified
14	Behavioural regulations	Anything aimed at managing or changing objectively observed or measured actions	Behavioural regulations domain is described as older adults' behavioural view towards the use of mobile applications to manage and monitor their health.	None identified	None identified	Personalised features of the app as a self-monitoring tool for older adults[49 53]

eHealth, electronic health; TDF, Theoretical Domains Framework.

this domain that are mostly related to having a tool for personalised health monitoring. This includes personalised features of the app, such as providing education, health/medication regimen, and involvement/communication with the experts via the app.[49 53]

DISCUSSIONS

The purpose of this study was to identify the willingness, perceived barriers and motivators in adopting mobile applications for health-related interventions among older adults. To the best of our knowledge, this is the first review combining willingness, barriers and motivators among older adults in adopting mobile applications for health-related interventions. The findings of the present review could give a better understanding in this area of research field.

It appears that there is an emerging trend across the globe on research publications about technology uptake among older adults in the past 10 years.[17 18] Our findings could inform other mHealth application interventions and resource development addressing these three factors in accordance with the TDF domains. The present review also found that in the last 5 years, there has been an increasing trend in the number of studies exploring mHealth adoption among older adults, though only a small number have focused on the usage of mobile applications alone.[48–53] When comparing the three main factors, that is, willingness, barriers and motivators in adopting mobile applications for health-related interventions among older adults, barriers appeared to be the most common factor discussed in the included studies. The present study found that there were three main TDF domains linked with barriers, which were: (1) skills, that is, technological skills, (2) belief about consequences, and (3) memory, attention and decision process.

Half of the studies (50%) reported the lack of technological skills and/or lack of confidence to complete tasks digitally, as well as to explore things using digital platforms.[50–52] For older adults, integrating these devices into their lifestyle may be difficult or simply unwanted, particularly for those who have functional deficits or who are not as technologically savvy. This computer literacy or commonly reported as technological skill is not a 'new' barrier for older adults in adopting mobile applications. This type of barrier remains as one of the crucial factors to take note of in ensuring continued technology engagement among this subpopulation. For instance, previous studies suggested that older adults are likely to have technical challenges while engaging and interacting with digital interventions.[53–56] Another study addressed the need for more guidance and precise instructions on how to use such interventions.[54] Therefore, it is imperative for technological interventions, particularly mobile application providers and/or developers, to ensure that older adults are given a thorough demonstration on how to use and maximise their mobile applications' uptake as well as to provide a continuous technical support throughout the

engagement. This approach will provide the opportunity for older adults to ask questions and gain sufficient knowledge on how to use such mobile applications. Furthermore, this approach will also help to increase the older adults' technological skills. This is supported by one study where the participants reported positive effects from the early demonstration session conducted regarding the use of the particular apps.[54] The older adults' self-efficacy in using computers and technology was also improved when technical training was provided and thus, shows a promising approach to overcome this type of barrier.[57]

Belief about consequences domain is among the most commonly discussed TDF domains within the included studies.[50 52] One study has found that difficulties interacting with the digital interface and other technical problems can bring negative psychological effects to older adults.[50] Older adults have doubts over how they may engage with such technology and some of them felt that if the technology did not work properly or was presented nicely, it would actually be seen as an added stress and therefore, they may not see the technology as a worthy time investment.[50]

The capability of a mobile application to collect and store a wealth of health and personal information is seen to be a downside towards their adoption among older adults. Among the highlighted concerns, possible violation of privacy was often brought up by the older adults. Older adults felt that it is not safe to use and to store their personal information in the mobile applications as they are worried that their information might be misused. Most of them felt that they have little or no control over how these technology entities use their personal information.[58] Breaches of client privacy are a commonly cited barrier to mHealth technology use.[59] Given that privacy concerns have been one of the major reasons for discontinuation or low engagement with a digital intervention, failure to highlight this as a crucial factor can cripple the scalability of mobile applications' uptake among older adults. Despite numerous studies that have highlighted this barrier,[50 52] there are still quite a number of mental health mobile applications that do not have privacy policies for their intended users.[58] Moreover, there are currently insufficient privacy protection rules around personal health information and cyber-security in online interventions, particularly in mental health mobile applications.[60] A key recommendation to address these potential concerns of privacy and security is perhaps to assess the degree to which older adults perceive mobile applications as a threat and by providing them with a customised privacy setting where they have the power to modify and control it on their own.[56 59]

Memory, attention and decision process domain of the TDF also has a strong link to barriers among older adults in adopting mobile applications for health-related interventions.[50 51] Usability issues such as being unable to complete tasks digitally, and difficulties in navigating through the mobile applications' functions are among the most reported barriers in our study.[50 51] Further, prior

studies have highlighted the importance of specific user interface designs for older people, such as avoiding the use of small-sized numbers/wordings and overloaded characters.[61] These findings further confirm the association between generating cognitive skills due to ageing and usability issues that arise due to a complexity in functionalities and navigation of the apps.[62] A key recommendation that could address this type of barrier might be to provide older adults with simple coloured information visuals. This might include sending a hardcopy manual or book that explains how to use the particular mobile application. This will help older adults to better engage with the mobile applications. In addition, coloured information visuals have been identified to provide a positive effect on the accuracy of the decisions made by older adults in eHealth tools.[62 63]

Hence, future research within this area should focus on these TDF domains to ensure a better understanding in developing mHealth applications targeted to older adults. A significant strength of this scoping review is that it was conducted using a systematic approach and presented a comprehensive result analysis that is linked to the TDF domains. This approach can be replicated by other health interventionists for a specific population in the future. However, as this study is a scoping review, a quality assessment of included articles was not performed as well as an evaluation of the risk of bias of the included studies was not conducted. In addition, the developers of the TDF acknowledge that the domains are not mutually exclusive.[2] However, in categorising willingness, perceived barriers and facilitators into the TDF domains for this review, we adopted a conservative approach by identifying the single most relevant domain for a more comprehensive data presentation. Lastly, experts were consulted regarding the selection of studies, but it is always possible that some studies were not located and our database search was limited to English-language articles only.

CONCLUSIONS

With the constant research and demand for more diversified and advanced technologies, the development of mobile applications to help older adults to manage and monitor their health is seen as feasible, but certain conditions have to be addressed. Barriers to adopting mobile applications for health-related interventions among older adults are the most common topic identified in the included studies when compared with the other two components (willingness and motivators). The most prominent barriers were classified within these three TDF domains: (1) technological skills, (2) belief about consequences, and (3) memory, attention and decision process. Future interventions should use the BCTs that target these three TDF domains to promote greater interactivity and better engagement among older adults. Mobile application developers and/or mHealth interventionists should consider conducting demonstration sessions for older adults prior to the adoption of their mobile applications

in order to increase their users' skills and to incorporate more secure in-app features to increase their users' trust to use mobile applications for health-related purposes.

Author affiliations
¹Center for Healthy Ageing and Wellness, National University of Malaysia, Faculty of Health Sciences, Kuala Lumpur, Wilayah Persekutuan, Malaysia
²Biomedical Science Programme, Universiti Kebangsaan Malaysia Faculty of Health Sciences, Kuala Lumpur, Malaysia
³Faculty of Information, Science and Technology, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia
⁴Department of Family Medicine, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia

ORCID iDs
Nurul Asilah Ahmad http://orcid.org/0000-0002-5727-1237
Arimi Fitri Mat Ludin http://orcid.org/0000-0003-1517-2115

REFERENCES

1 Nations U. *World population ageing 2019: highlights*. New York: department of economic and social Affairs PD, 2019. https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2019-Highlights.pdf

2 Cane J, O'Connor D, Michie S. Validation of the theoretical domains framework for use in behaviour change and implementation research. *Implement Sci* 2012;7:37.

3 Department of Statistics Malaysia. Population and Demographics : Ageing [press release], 2017. Available: https://www.dosm.gov.my/v1/index.php?r=column/ctwoByCat&parent_id=115&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09

4 Karim HA. The elderly in Malaysia: demographic trends. *Med J Malaysia* 1997;52:206–12.

5 Wilmoth JR. Demography of longevity: past, present, and future trends. *Exp Gerontol* 2000;35:1111–29.

6 Hedin RJ. The contribution of public health and improved social conditions to increased life expectancy: an analysis of public awareness. *Journal of Community Medicine & Health Education* 2014 https://www.omicsonline.org/open-access/the-contribution-of-public-health-and-improved-social-conditions-to-increased-life-expectancy-an-analysis-of-public-awareness-2161-0711-4-311.php?aid=35861

7 Davies AM. Epidemiology and the challenge of ageing. *Int J Epidemiol* 1985;14:9–21.

8 Brayne C. The elephant in the room - healthy brains in later life, epidemiology and public health. *Nat Rev Neurosci* 2007;8:233–9.

9 Brown G. *The living end: the future of death, aging and immortality*. London: Palgrave Macmillan The Limited, 2008.

10 Roziana Baharin SS. Ageing population and health care expenditure: evidence using time series analysis. *Geografia Malaysian Journal of Society and Space* 2018;14.

11 Institute of Medicine (US) Committee on the Future Health Care Workforce for Older Americans. *Retooling for an Aging America:Building the Health Care Workforce*. Washington (DC: National Academic Press, 2008.

12 Acharya S, Ghimire S, Jeffers EM, *et al*. Health care utilization and health care expenditure of Nepali older adults. *Front Public Health* 2019;7:24.

13 Zhu X, Cai Q, Wang J, *et al*. Determinants of medical and health care expenditure growth for urban residents in China: a systematic review article. *Iran J Public Health* 2014;43:1597.

14 Wolff JL, Starfield B, Anderson G. Prevalence, expenditures, and complications of multiple chronic conditions in the elderly. *Arch Intern Med* 2002;162:2269–76.

15 Hoffman C, Rice D, Sung HY. Persons with chronic conditions. their prevalence and costs. *JAMA* 1996;276:1473–9.

16 Barnett K, Mercer SW, Norbury M, *et al*. Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet* 2012;380:37–43.

17 Hunsaker A, Hargittai E. A review of Internet use among older adults. *New Media Soc* 2018;20:3937–54.

18 Prescott C. Internet users, UK-Office for national statistics, 2019. Available: https://www.ons.gov.uk/businessindustryandtrade/itandinternetindustry/bulletins/internetusers/2019 [Accessed 17 Nov 2021].

19 Kyle T, Laura S. *Smartphone ownership is growing rapidly around the world, but not always equally*. Pew research center, 2019.

20 Kontos E, Blake KD, Chou W-YS, *et al*. Predictors of eHealth usage: insights on the digital divide from the health information national trends survey 2012. *J Med Internet Res* 2014;16:e172.

21 Estacio EV, Whittle R, Protheroe J. The digital divide: examining socio-demographic factors associated with health literacy, access and use of Internet to seek health information. *J Health Psychol* 2019;24:1668–75.

22 Flynn KE, Smith MA, Freese J. When do older adults turn to the Internet for health information? findings from the Wisconsin longitudinal study. *J Gen Intern Med* 2006;21:1295–301.

23 Ryu S. Book review: mHealth: new horizons for health through mobile technologies: based on the findings of the second global survey on eHealth (global Observatory for eHealth series, volume 3). *Healthc Inform Res* 2012;18:231–3.

24 West JH, Hall PC, Hanson CL, *et al*. There's an APP for that: content analysis of paid health and fitness apps. *J Med Internet Res* 2012;14:e72.

25 Heart T, Kalderon E. Older adults: are they ready to adopt health-related ICT? *Int J Med Inform* 2013;82:e209–31.

26 Changizi M, Kaveh MH. Effectiveness of the mHealth technology in improvement of healthy behaviors in an elderly population-a systematic review. *Mhealth* 2017;3:51.

27 Kobu T. Evaluation of mobile health application (mHealth) from the pharmacist perspective. *Journal of Information System and Technology Management* 2017;2:0128–6666.

28 Nasir S, Goto R, Kitamura A, *et al*. Dissemination and implementation of the *e-MCH H andbook*, UNRWA's newly released maternal and child health mobile application: a cross-sectional study. *BMJ Open* 2020;10:e034885.

29 Barber T, Sharif B, Teare S, *et al*. Qualitative study to elicit patients' and primary care physicians' perspectives on the use of a self-management mobile health application for knee osteoarthritis. *BMJ Open* 2019;9:e024016.

30 Syed ST, Gerber BS, Sharp LK. Traveling towards disease: transportation barriers to health care access. *J Community Health* 2013;38:976–93.

31 Agyemang-Duah W, Peprah C, Peprah P. Barriers to formal healthcare utilisation among poor older people under the livelihood empowerment against poverty programme in the Atwima Nwabiagya district of Ghana. *BMC Public Health* 2019;19:1185.

32 Fitzpatrick AL, Powe NR, Cooper LS, *et al*. Barriers to health care access among the elderly and who perceives them. *Am J Public Health* 2004;94:1788–94.

33 Doetsch J, Pilot E, Santana P, *et al*. Potential barriers in healthcare access of the elderly population influenced by the economic crisis and the troika agreement: a qualitative case study in Lisbon, Portugal. *Int J Equity Health* 2017;16:184.

34 Chang AY, Skirbekk VF, Tyrovolas S, *et al*. Measuring population ageing: an analysis of the global burden of disease study 2017. *Lancet Public Health* 2019;4:e159–67.

35 Alley S, van Uffelen JG, Schoeppe S, *et al*. Efficacy of a computer-tailored web-based physical activity intervention using Fitbits for older adults: a randomised controlled trial protocol. *BMJ Open* 2019;9:e033305.

36 Vanoh D, Shahar S, Razali R, *et al*. The effectiveness of a web-based health education tool, WESIHAT 2.0, among older adults: a randomized controlled trial. *Journal of Alzheimer's Disease* 2019;70:S255–70.

37 Mohamad H, Shahrul A. Mobile application on healthy diet for elderly based on persuasive design. *International Journal on Advanced Science Engineering Information Technology* 2017.

38 Anderson K, Burford O, Emmerton L. Mobile health Apps to facilitate self-care: a qualitative study of user experiences. *PLoS One* 2016;11:e0156164.

39 Free C, Phillips G, Galli L, *et al*. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: a systematic review. *PLoS Med* 2013;10:e1001362.

40 Muessig KE, Pike EC, Legrand S, *et al*. Mobile phone applications for the care and prevention of HIV and other sexually transmitted diseases: a review. *J Med Internet Res* 2013;15:e1.

41 Zhao J, Freeman B, Li M. Can mobile phone Apps influence people's health behavior change? an evidence review. *J Med Internet Res* 2016;18:e287.

42 Ahmad NA, Mat Ludin AF, Shahar S, *et al*. Willingness, perceived barriers and motivators in adopting mobile applications for health-related interventions among older adults: a scoping review protocol. *BMJ Open* 2020;10:e033870.

43 Aromataris E, Munn Z. *Joanna Briggs Institute Reviewer's Manual*. The Joanna Briggs Institute, 2017.

44 Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol* 2005;8:19–32.

45 Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci* 2010;5:69.

46 Daudt HML, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Med Res Methodol* 2013;13:48.

47 Tricco AC, Lillie E, Zarin W, *et al*. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;169:467–73.

48 Askari M, Klaver NS, van Gestel TJ, *et al*. Intention to use medical Apps among older adults in the Netherlands: cross-sectional study. *J Med Internet Res* 2020;22:e18080.

49 Kalimullah K, Sushmitha D. Influence of design elements in mobile applications on user experience of elderly people. *Procedia Comput Sci* 2017;113:352–9.

50 Pywell J, Vijaykumar S, Dodd A, *et al*. Barriers to older adults' uptake of mobile-based mental health interventions. *Digit Health* 2020;6:2055207620905422.

51 Wildenbos GA, Jaspers MWM, Schijven MP, *et al*. Mobile health for older adult patients: using an aging barriers framework to classify usability problems. *Int J Med Inform* 2019;124:68–77.

52 Park LG, Ng F, K Shim J, *et al*. Perceptions and experiences of using mobile technology for medication adherence among older adults with coronary heart disease: a qualitative study. *Digit Health* 2020;6:2055207620926844:205520762092684.

53 Russell AM, Smith SG, Bailey SC, *et al*. Older adult preferences of mobile application functionality supporting medication self-management. *J Health Commun* 2018;23:1064–71.

54 Vaportzis E, Clausen MG, Gow AJ. Older adults perceptions of technology and barriers to interacting with tablet computers: a focus group study. *Front Psychol* 2017;8:1687.

55 Crabb RM, Cavanagh K, Proudfoot J, *et al*. Is computerized cognitive-behavioural therapy a treatment option for depression in late-life? a systematic review. *Br J Clin Psychol* 2012;51:459–64.

56 Mohd Yusof A, Norizan A, Noor F. Issues Affecting the Use of Information and Communication Technology among the Elderly : A Case Study on JENII. *Malaysian Journal of Communication* 2012.

57 Mohadisdudis HM, Ali NM. A study of smartphone usage and barriers among the elderly. 2014 3rd International Conference on user science and engineering (i-USEr). *2014 3rd International Conference on User Science and Engineering (i-USEr)*, 2014:109–14. doi:10.1109/IUSER.2014.7002686

58 Kuerbis A, Mulliken A, Muench F, *et al*. Older adults and mobile technology: factors that enhance and inhibit utilization in the context of behavioral health. *Ment Health Addict Res* 2017;2.

59 Torous J, Nicholas J, Larsen ME, *et al*. Clinical review of user engagement with mental health smartphone apps: evidence, theory and improvements. *Evid Based Ment Health* 2018;21:116–9.

60 Treskes RW, Van der Velde ET, Schoones JW, *et al*. Implementation of smart technology to improve medication adherence in patients with cardiovascular disease: is it effective? *Expert Rev Med Devices* 2018;15:119–26.

61 Wozney L, Newton AS, Gehring ND, *et al*. Implementation of eMental health care: viewpoints from key informants from organizations and agencies with eHealth mandates. *BMC Med Inform Decis Mak* 2017;17:78.

62 Or C, Tao D. Usability study of a computer-based self-management system for older adults with chronic diseases. *JMIR Res Protoc* 2012;1:e13.

63 Price MM, Crumley-Branyon JJ, Leidheiser WR, *et al*. Effects of information visualization on older adults' decision-making performance in a Medicare plan selection task: a comparative usability study. *JMIR Hum Factors* 2016;3:e16.