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,2,3 Suzana Shahar,1 Shahrul Azman Mohd Noah,4 Noorlaili Mohd Tohit4

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.


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 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. 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.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.36-34 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.42 The implementation of technology targeting older adults requires change and improvements over time at an individual, organisational and/or community level.42 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.42 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) social influence; (11) negative emotions; (12) beliefs about consequences; (13) goals; (14) knowledge of others’ expectancies.
(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. 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. 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, detailing the search strategy and method used. We primarily followed the Joanna Briggs Institute guidelines on scoping reviews and the framework by Arksey and O’Malley, with improvements suggested by Levac et al. Further, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews. 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.

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>
<thead>
<tr>
<th>Table 1</th>
<th>List of keywords and synonyms generated as search terms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mobile application</strong></td>
<td><strong>Older adults</strong></td>
</tr>
<tr>
<td>Mobile app*</td>
<td>Elderly</td>
</tr>
<tr>
<td>mHealth</td>
<td>Ageing population</td>
</tr>
<tr>
<td>Mobile health</td>
<td>Older population</td>
</tr>
<tr>
<td>Telehealth</td>
<td>Aging</td>
</tr>
<tr>
<td>Mobile technology*</td>
<td>Geriatric</td>
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</tbody>
</table>
Using the information collected from the data extracted were listed in our previously published protocol paper. The types of study characteristics that were selected. The types of study characteristics that were included. The eligibility and exclusion criteria were detailed in our protocol paper that has been published previously.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>List of search strings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search string 1</td>
<td>“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”</td>
</tr>
<tr>
<td>Search string 2</td>
<td>“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”</td>
</tr>
<tr>
<td>Search string 3</td>
<td>“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”</td>
</tr>
</tbody>
</table>

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

**Stage 3: study selection**

According to Arksey and O’Malley’s framework, the third stage 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.

**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. 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 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. 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. The six studies consisted of four studies from Europe and two studies 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.
but for the two\textsuperscript{32,35} 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.\textsuperscript{49–53} Only one study\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{49}

Willingness
Table 4 summarises the details of selected studies with regards to willingness, 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\textsuperscript{30} explored the willingness of older adults to use mobile applications to monitor
<table>
<thead>
<tr>
<th>No</th>
<th>Study</th>
<th>Location</th>
<th>Study design</th>
<th>Sample, N</th>
<th>Participant characteristic</th>
<th>Main findings</th>
</tr>
</thead>
</table>
| 1  | Askari et al²⁸ | 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 al²² | 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 al²⁰ | 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 Sushmitha²⁹ | 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 al³³ | 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, refill medications, and links within the app to additional medication information such as indication and potential side effects |
Open access

and manage their health. This study has shown that older adults are 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 did not want to spend so much time using the app.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.49 This means that a positive attitude towards the usage of mobile applications may provide digital interventions such as mHealth apps and encourage older adults to use mobile applications.

Within the TDF domain number 14, which is behavioural regulation, various motivators were identified within the elements of this domain. Motivators that were identified within this domain include the intention to use, the perceived usefulness of using mobile applications, and the perceived ease of use.54

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**Table 3 Continued**

<table>
<thead>
<tr>
<th>No</th>
<th>Study Location</th>
<th>Study design</th>
<th>Sample, N</th>
<th>Participant characteristic</th>
<th>Main findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Wildenbos et al</td>
<td>Netherlands</td>
<td>Qualitative</td>
<td>23</td>
<td>Age: 50–80 years old and above Sex: 12 males, 11 females (n=23)</td>
</tr>
</tbody>
</table>

mHealth, mobile health; TDF, Theoretical Domains Framework.
<table>
<thead>
<tr>
<th>No</th>
<th>TDF domain</th>
<th>Description</th>
<th>Study context</th>
<th>Willingness</th>
<th>Barriers</th>
<th>Motivators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Knowledge</td>
<td>Awareness of existence of something</td>
<td>Knowledge domain is described as the awareness of the existence of mobile applications that can manage and monitor the older adults’ health.</td>
<td>None identified</td>
<td>Older adults’ eHealth awareness</td>
<td>None identified</td>
</tr>
<tr>
<td>2</td>
<td>Skills</td>
<td>Ability of someone to use something</td>
<td>Skills domain is described as the older adults’ ability to use mobile applications that can manage and monitor their health.</td>
<td>None identified</td>
<td>Computer literacy skills and/or technology skills</td>
<td>None identified</td>
</tr>
<tr>
<td>3</td>
<td>Social/professional role and identity</td>
<td>A coherent set of behaviours and displayed personal qualities of an individual or the need of professional role in social or work setting</td>
<td>Social/professional role and identity domain is described as the older adults’ need to receive health advice through mobile applications from certified healthcare professionals.</td>
<td>None identified</td>
<td>App has valid credentials</td>
<td>None identified</td>
</tr>
<tr>
<td>4</td>
<td>Belief about capabilities</td>
<td>Acceptance of the truth, reality or validity about an ability, talent or facility that a person can put to constructive use</td>
<td>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.</td>
<td>None identified</td>
<td>Lack of confidence or ability to complete task using technology</td>
<td>None identified</td>
</tr>
<tr>
<td>5</td>
<td>Optimism</td>
<td>Confidence that things will happen for the best or that desired goals will be attained</td>
<td>Optimism domain is described as the older adults’ level of confidence towards the use of mobile applications in achieving their health goals.</td>
<td>None identified</td>
<td>None identified</td>
<td>None identified</td>
</tr>
<tr>
<td>6</td>
<td>Belief about consequences</td>
<td>Acceptance of the truth, reality or validity about outcomes of a behaviour in a given situation</td>
<td>Belief about consequences domain is described as the older adults’ concern about negative outcomes when using mobile applications to manage and monitor their health.</td>
<td>None identified</td>
<td>Older adults would not use the app if it does not give sufficient or accurate education/information</td>
<td>None identified</td>
</tr>
<tr>
<td>7</td>
<td>Reinforcement</td>
<td>Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus</td>
<td>Reinforcement domain is described as the older adults’ need for continuous improvement of the mobile applications in order to gain more engagement.</td>
<td>None identified</td>
<td>None identified</td>
<td>Design element or feature enhancement of the existing apps</td>
</tr>
<tr>
<td>8</td>
<td>Intentions</td>
<td>A conscious decision to perform a behaviour or a resolve to act in a certain way</td>
<td>Intentions domain is described as the older adults’ attitude to maximise the use of mobile applications to monitor and manage their health.</td>
<td>None identified</td>
<td>None identified</td>
<td>Attitude to using technology significantly influenced the intention to use medical health apps</td>
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<table>
<thead>
<tr>
<th>No</th>
<th>TDF domain</th>
<th>Description</th>
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<th>Willingness</th>
<th>Barriers</th>
<th>Motivators</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Goals</td>
<td>Mental representation of outcomes or end states that an individual wants to achieve</td>
<td>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.</td>
<td>None identified</td>
<td>None identified</td>
<td>None identified</td>
</tr>
<tr>
<td>10</td>
<td>Memory, attention, decision process</td>
<td>The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives</td>
<td>Memory, attention and decision process domain is described as the older adults’ ability to retain and use health information delivered via mobile applications.</td>
<td>None identified</td>
<td>Incompetence or inability to complete tasks, enter data, explore things using digital platforms[^40][^51]</td>
<td>None identified</td>
</tr>
<tr>
<td>11</td>
<td>Environmental context and resources</td>
<td>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</td>
<td>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.</td>
<td>None identified</td>
<td>Time[^40]</td>
<td>None identified</td>
</tr>
<tr>
<td>12</td>
<td>Social influences</td>
<td>Interpersonal processes that can cause individuals to change their thoughts, feelings or behaviours</td>
<td>Social influences domain is described as the older adults’ interpersonal process that can influence mobile applications’ usage to manage and monitor their health.</td>
<td>None identified</td>
<td>No face-to-face social interactions, digital interventions may be inferior due to the absence of interpersonal communication and encouragement/support from professionals[^40]</td>
<td>None identified</td>
</tr>
<tr>
<td>13</td>
<td>Emotion</td>
<td>A complex reaction pattern, involving experiential, behavioural and physiological elements, by which the individual attempts to deal with a personally significant matter or event</td>
<td>Emotion domain is described as the older adults’ physiological behaviours and feeling towards the use of mobile applications to manage and monitor their health.</td>
<td>None identified</td>
<td>None identified</td>
<td>None identified</td>
</tr>
<tr>
<td>14</td>
<td>Behavioural regulations</td>
<td>Anything aimed at managing or changing objectively observed or measured actions</td>
<td>Behavioural regulations domain is described as older adults’ behavioural view towards the use of mobile applications to manage and monitor their health.</td>
<td>None identified</td>
<td>None identified</td>
<td>Personalised features of the app as a self-monitoring tool for older adults[^49][^53]</td>
</tr>
</tbody>
</table>

[^40]: 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.56 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.56 59 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.\(^1\) 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.\(^2\) 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.\(^3\)\(^4\)

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.

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Contributors NAA and AFML were responsible for developing the concepts of the study. NAA wrote the manuscript with support from AFML. AFML, SS, NMT and SAMN were responsible for reading and approving this manuscript's final version and giving final approval for the version that will be published, ensuring the integrity in all aspects of the work as well as making sure all research questions were addressed accordingly. SS was responsible for approving the design of the study; doing a thorough review to ensure intellectual content; reading and approving the final manuscript; giving the approval for the version that will be published, and ensuring all research questions were analysed accordingly. SS and SAMN contributed to the design of the study and acquired data for the research. AFML responsible for the overall content as the guarantor for this article.

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Ethics approval Since the data used in this study were from publicly available sources, this study does not require any ethical approval. Findings from this review will be disseminated through academic journals, seminars and conferences. We anticipate that our findings regarding older adults’ perspectives towards the use of mobile applications to monitor and manage health conditions will be useful to guide the direction of future research and aid technology developers as well as health professionals who are working in the area of ageing and rehabilitation.

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