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Exploring the barriers and facilitators which influence mHealth adoption among older adults: A literature review

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Abstract

Background: The SARS-CoV-2 2019 pandemic highlighted the challenges of providing high-quality healthcare to older adults during a public health emergency. Mobile health (mHealth) quickly gained recognition as a cost-effective way to deliver healthcare and provide patients with tools to manage acute and chronic illnesses in their own homes. However, despite the increasing availability of this technology, some older adults may encounter barriers to accessing this type of care.
Objective: This review aims to explore the factors that influence the adoption of mHealth among older adults.
Method: A search of the existing literature was conducted using Scopus and PubMed which uncovered 3124 studies. After applying our inclusion criteria, 23 original studies were identified for review.
Results: Technology adoption by older adults is multifactorial with three overarching themes, these being: (1) dispositional barriers, (2) usability features of mobile devices, and (3) social influence. Dispositional barriers including low self-efficacy and mistrust of technology lead to anxiety surrounding mHealth uptake among older adults. Furthermore, age-related physical and cognitive impairment may also impede the use of mHealth. Older adults who overcome these barriers rely on social support from family and healthcare providers to recognise mHealth as a potential health-optimization tool. Involving older adults in the designing process is recommended to anticipate and overcome the obstacles to mHealth adoption that are unique to this group.
Conclusion: Research into technology adoption has elucidated various targets for initiatives and areas of research to improve mHealth adoption. Future research should include experimental models with older adults to look at interventions that enable regular and ongoing use of mHealth. Seeking input from end-users will ensure that modifications in healthcare delivery do not inadvertently disadvantage the same populations they are intended to serve.

Keywords: mHealth, mobile health, older adults, technology adoption

Introduction

Background

Most adults as they age would opt to maintain their independence and continue to participate in their local communities (EuroStat Report, 2019). However, part of growing older may involve adjusting to a progressive loss of independence and varying degrees of physical and cognitive decline. Given that older adults are living longer than before, healthcare challenges are an important consideration, especially in those living with multiple chronic conditions (Atella et al., 2018). Healthcare systems must be adaptable to meet their unique needs, focusing on structured assessment and management of chronic disease to reduce health complications and the need for acute hospitalization (Komisar et al., 2012).

The impact of the novel SARS-CoV-2 2019 (COVID-19) virus on global healthcare delivery is still evolving. COVID-19 has had a profound impact, disproportionately affecting older individuals and those with underlying comorbid health conditions (Lithander et al., 2020; Centers for Disease Control and Prevention COVID Data, 2020). To protect vulnerable populations and prevent hospitals from becoming depleted of resources, governments resorted to nationwide shutdowns (Barrett et al., 2020). In response to an uncertain situation with social and physical distancing policies, numerous sectors such as education and commerce have rapidly shifted to digital technology, embracing virtual classrooms and office solutions (Ting et al., 2020). Similarly, the healthcare sector is employing digital tools that minimize community spread, such as telehealth consultations, remote triage, remote disease monitoring, and tools for the dissemination of validated information (Chauhan et al., 2020; Iyengar et al., 2020). Despite increasing vaccination rates of COVID-19 and the reduction of public health restrictions, the use of digital systems and remote healthcare delivery is expected to continue (Kannampallil and Ma, 2020).

mHealth in the care for older adults

While there is no standardized definition of mobile health (mHealth), it is generally understood to be the utilization of mobile technologies to realize medical and public health objectives through the use of a variety of smartphone applications, wireless devices, wearable technologies, and electronic health record (EHR) systems (World Health Organization, 2011; Fox and Connolly, 2018). mHealth provides a wide variety of services such as the reporting of health information, monitoring of clinical signs, patient observation, and educational support for individuals and their caregivers (Gell et al., 2013). It has been suggested that because mobile devices are portable, affordable, and widely available, they are a promising avenue for cost-effective care for older adults (Kansal et al., 2014). With projections that 28.5% of the European population will be over 65 years by 2030 (EuroStat Report, 2019), harnessing the potential of mHealth may improve illness detection, early intervention, and ongoing monitoring for an aging population (Creber et al., 2016; Wood et al., 2019).

Assistive technologies to support older adults maintain their independence are already in place, with continuous improvements in sophistication and functionality (Steinkamp et al., 2019). These include wearable devices such as AppleWatch which detects falls, monitors abnormal heart rhythms, and provides information for health promotion (Osborn et al., 2017); mobile applications like PillBoxie which reminds individuals to take their medication; virtual telehealth consultations; and numerous other applications dedicated to specific medical conditions like osteoarthritis (Bellamy et al., 2011). Through these mHealth applications, older adults can connect with their healthcare providers and contribute valuable self-monitoring information (Wolf et al., 2012; Swedberg et al., 2011).

With such diverse potential for mobile health applications, developers along with healthcare systems and technology companies have saturated the market with upwards of 325,000 different smartphone health applications available to consumers (mHealth Economics, 2017). Despite the surplus of available health technology, older adults have consistently been identified as the lowest adopters of mHealth (Anderson, 2019). As global healthcare systems increase the use of technology, vulnerable populations who have not actively embraced them could be left behind.

Research objective

Recent advancements made in mHealth have led to the widespread availability of smartphones and a growing impetus to integrate healthcare services through mHealth. The term 'older adults' is used to describe adults who are 50 years and older. The objective of this review is to examine and appraise the current literature to understand:
1. What barriers influence the adoption of mHealth technology among older adults?
2. What conditions enable mHealth adoption among older adults?

Methods

Stage 1: Develop the research question

An initial scoping search was conducted on EBSCO Host to broadly identify research in consumer-focused electronic health (eHealth) strategies used in the care of older adults. From this scoping search, the main theme noted was older adults on a global scale are consistently reported to have lower technology adoption. The keywords for the review were then developed based on this theme. The keywords are Gerontechnology, elderly, older adults, technology adoption, technology acceptance, technology use, mobile health, and mHealth.

Gerontechnology is a rapidly growing area of research with increased focus due to an aging global population and advancements in everyday technology systems. To encompass these ideals and this expanding area of research, *"Gerontechnology"* was included as the keyword in our literature search.

The key words 'technology adoption' and 'technology acceptance' are common terms in Information Systems (IS) and social and behavioural sciences to describe the interaction of factors involved in technology use (Taherdoost, 2018). These terms are frequently cited in frameworks for considering features of technology acceptance and rejection, including the widely accepted models, 'Technology Acceptance Model' (TAM) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTUAT) (Venkatesh et al., 2003). As part of an interdisciplinary approach to this literature search, 'technology adoption' and 'technology acceptance' were chosen as keywords. For completeness, 'technology use' was also incorporated into the search.

Stage 2: Search strategy

In February 2021, two of the largest scientific research databases, PubMed and Scopus, were searched. The keywords were used to search for

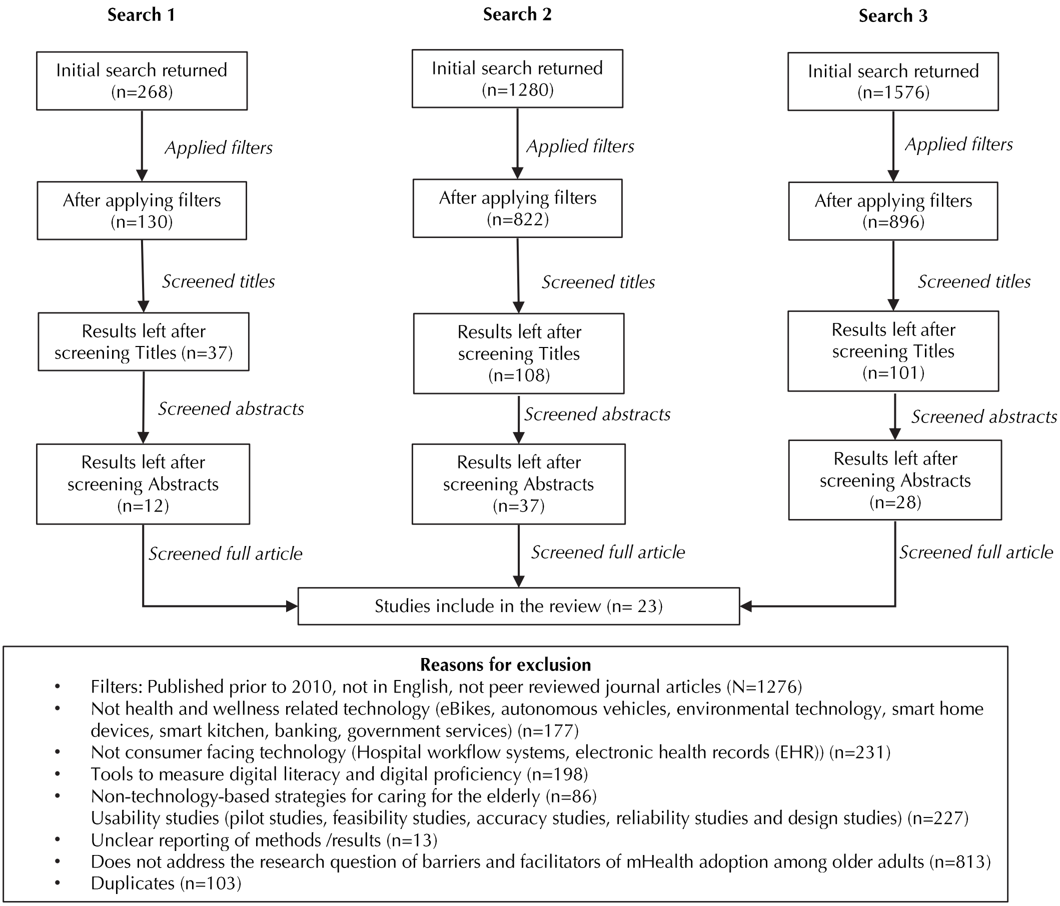

Figure 1. Flow chart of literature searches and study selection.

relevant literature, limited to title and abstract only, using Medical Subject Heading (MeSH) as part of the search.

Three searches were conducted on each database. Search 1 looked for health-related Gerontechnology; Search 2 looked for technology adoption, acceptance, and use amongst older adults; and Search 3 looked for mHealth applications in the care of older adults. This initial search returned 3124 studies, to which the following filters were applied: articles published from January 1st, 2010 to December 31st, 2020; available in English; peer-review journal articles.

The search process is depicted in *Figure 1*, and the search strings with keywords are outlined in *Table 1*. Details of the search strategy are provided in *Appendix I*.

Stage 3: Choosing the appropriate literature

The selection process is based on the work done by Ahmad and colleagues (2020b) who developed a protocol for conducting a review to investigate barriers and motivators in adopting mobile applications for health-related interventions among older adults. From the 1848 studies, we screened the titles and abstracts using our inclusion and exclusion criteria. The summarized inclusion and exclusion criteria for selecting articles are detailed in *Table 2*. This process left 77 original studies in which the full paper was screened to select articles for this review.

Included studies were English, peer-reviewed journal articles published from January 1, 2010 to December 31, 2020. This period was selected due to the widespread availability of smartphones with improvements to user interface and functionality, along with the rapid growth of mHealth applications seen in the last decade (mHealth Economics, 2017). Studies were then selected based on their ability to address the research questions. Articles were included if they described or reported on older adult's opinions and willingness to use mHealth applications as well as the motivators and barriers which influence this decision.

Studies were excluded if they were not in English, did not include opinions of older adults above

Table 1. Common search strings used to search the databases.

Search 1	"Gerontechnology" AND "health"
Search 2	("Elderly" OR "Older Adults") AND ("Technology adoption" OR "Technology acceptance" OR "Technology use")
Search 3	("Mobile health" OR "mHealth") AND ("Elderly" OR "Older Adults")

the age of 50, or discussed mHealth applications which are not affected by attitudes and perceptions of older adults, despite being used in their care. For example, non-consumer-based technology including electronic health records (EHR) and in-hospital artificial intelligence (AI) systems was excluded. Additionally, non-health-based technology such as autonomous vehicles, smart kitchens, and environmental ecosystems were also excluded. Studies were also excluded which outlined the potential benefits and outcomes of using mHealth through experimental or pilot studies but failed to discuss potential barriers, facilitators, or the perception held by older adults regarding acceptance or use. Non-journal articles including book chapters, conference papers, notes, opinion pieces, and editorials were excluded. Finally, studies that are not original empirical studies, such as literature reviews, systematic reviews, and scoping reviews, were also excluded. No duplicates studies were included.

Stage 4: Critical appraisal process

The literature was critically appraised using the Evidence-Based Librarianship and Information Practice (EBLILP) checklist (Glynn, 2006). The EBLILP is a tool used to structure the critical appraisal analysis process, evaluating each section within a body of research for validity, applicability, and appropriateness. This results in a score for each section and an overall score. To be considered 'acceptable', an overall score of 75% must be achieved (Glynn, 2006). All studies included in this review scored above 75% indicating appropriate methods for study design and reporting of data. The summarized calculations for the EBLIP scores are found in *Table 3* and the complete EBLIP critical appraisal checklist can be found in *Appendix II*. 13 studies were removed due to unclear reporting of methods or results, and 23 studies were included in this review.

Results

Study population

The 23 studies included in this review involved a total of 5,274 participants. These studies performed different types of analysis comprising of 7 qualitative, 11 quantitative, and 5 mixed methods analyses. They were conducted in various countries: 8 in Europe, 8 in North America, 6 in Asia, and 1 in Australia. All participants were over the age of 50 years old, with a mean approximated age of 67.6 years across all studies. The majority of participants were community-dwelling. Five studies recruited participants from a non-community-dwelling setting. Tsai and colleagues (2017) recruited from an assisted/ independent living facility, Wang and colleagues (2019) from a retirement home, Ha and Park (2020) from a community senior centre, Tsai and colleagues (2020) from a hospital, and Parker and colleagues (2013) from a primary care clinic. The study design and population characteristics for each article are described in *Table 4*.

Summary of findings

From the review of the literature, three key categories of barriers and facilitators of mHealth adoption among older adults were identified. These include an overall attitude toward technology, social influence, and usability features of the mHealth system itself. A thematic synthesis with reference to the relevant literature is presented in *Table 5*.

All 23 studies(1-23) considered the attitude toward technology as a prominent feature in older adults' intention to use technology. Eighteen studies(1,3-9,11-13,15,18-23) mentioned self-efficacy as a factor. Both high self-efficacy and low-self efficacy were significantly associated with high and low willingness to adopt technology respectively. Different studies that investigated levels of self-efficacy among participants reported there to be vastly differing levels of self-efficacy. Van Houwelingen and colleagues found equal proportions of individuals with high and low self-efficacy and DeVeer and colleagues found that 48% of participants had very high self-efficacy and 25% had very low self-efficacy. Tsai and colleagues (2017) found most of their participants to have high self-efficacy, with 62% saying they feel very comfortable with computers and 90% saying they found tablet computers easy to learn and use.

A theme of mistrust of technology was present in 14 studies (1-10,13,15,19) selected, with the reasons being multi-fold. In 9 studies(1,3,8-10,13,16,18,21) participants expressed apprehension with technology due to privacy concerns, and 11 studies(1-2,4-9,12,15,19) showed participants had anxiety due to perceived difficulty of learning or using technology. Participants in 7 studies(2,5,9,12,15,19,21) reported that despite initial anxiety they would be willing to adopt technology given it is useful to them.

Social circumstances influenced participants' decision to adopt and continue to use technology. In 14 studies(1,3,7,10-14,16-21) participants reported that communication with their family was the initial stimulus to consider adopting technology. Of these, 8(1,7,12,14,16-18,20) showed that continued use of technology was supported by

Table 2. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Published in the last 10 years (2010-2020)	Not available in English
Peer Reviewed Journal Articles	Participants younger than 50yrs old
Health and wellness related digital technology	Non-original empirical studies (e.g. systemic reviews, literature reviews, scoping reviews)
Original research articles	Non-research journal articles (notes, opinion pieces and editorials etc.)
Included mobile health technology	Non- heath based technology
	Non- end-used based system (e.g. hospital workflow systems, electronic health records (EHR))

the family through encouragement and technical support. Recommendations from health experts were discussed in 9 papers (2,4,10, 11,16,19-22). While 86% of participants in a study2 noted their doctor's advice mattered most when considering mHealth, these experts were least often cited as sources of information regarding mHealth apps by participants in another study10. Six authors(11,16,19-21,23) recommended an increased presence of healthcare providers in the mHealth decision-making process for it to be accepted as a useful and trustworthy technology.

Changes brought about by the aging process and the influence of usability characteristics on acceptance were mentioned in 13 studies(2,3,5,7-10,11,15-16,19-21). Physical limitations were cited by 11 studies(2,3,5,7-10,15,16,20,21) and cognitive limitations were cited by 11 studies(2,3,5,7-9,11,16,19, 21). Participants in Wang et al. (2019) study emphasized the need to address the accessibility features in mHealth by calling for co-design in the development process of Gerontechnology.

Discussion

mHealth adoption by older adults is multifactorial with three recurring themes throughout the literature: (1) The overall attitude older adults have toward technology, (2) social influences, and (3) usability features of mobile devices.

Attitudes toward mHealth adoption

Self-efficacy

Self-efficacy is an individual's belief in their ability to accomplish a task (Van Houwelingen et al., 2018). Although it is a highly subjective measure, it provides useful insight as to how individuals perceive the use of different technologies. High self-efficacy is a facilitator while low self-efficacy is a barrier to technology adoption (Van Houwelingen et al., 2018; Berkowsky et al., 2017). Older adults have varying degrees of self-efficacy which depends on the technology in question and can sometimes manifest as an ambivalent attitude toward technology as a whole (Van Houwelingen et al., 2018; De Veer et al., 2015). Pywell and colleagues (2020) found that older adults with low self-efficacy believe that limited ability to use mobile devices successfully might impact the effectiveness of the clinical care they receive. Participants worry that they may not be able to navigate the interface to engage with services, may accidentally enter incorrect information or information in the incorrect location, provide unnecessary disclosures and access information irrelevant to their care (Pywell et al., 2020). Believing that their healthcare can be compromised due to a lack of technical skills is a major deterrent to mHealth (Pywell et al., 2020). Smartphone training programs may be useful in enhancing mobile device competency and self-efficacy among older adults but more work is required to understand how to effectively implement this type of intervention (Zhao et al., 2019; Tellier et al., 2020). Older adults are enthusiastic about the possibility of training programs to help them use mHealth, hoping that competence with smartphones can mitigate some of their daily health-related challenges (Parker et al., 2013).

When individuals already have higher self-efficacy, they tend to view technology as highly useful (Chen and Chan, 2013). They leverage broader features and increased functionality from their devices, and therefore are more willing to engage with mHealth applications (Fox and Connolly, 2018). Bridging the gap of self-efficacy between older adults may be pivotal in acceptance and use.

Technology anxiety

Participants in nine studies expressed a degree of anxiety when discussing technology. Some reported a general aversion to a technology originating from negative past experiences in the early days of personal computing, such as frustrating with frequent software updates, slow processing speeds, and risk of data loss (DeVeer et al., 2015; Tsai et al., 2017). This has left a lasting negative impression and has dissuaded further interest in interacting with new devices or software (Van Houwelingen et al., 2018; Chen and Chan, 2013). This anxiety associated with frustrating experiences will negatively impact participation in technology in general (Cimperman et al., 2016). This is a well-studied phenomenon in the literature around computer-related anxiety (Venkatesh et al., 2003; Or et al., 2011) and continues to be relevant with the use of mHealth (Cimperman et al., 2016).

Table 3. EBLIP critical appraisal checklist.

	Population	Data collection	Study design	Results	Total validity
Van Houwelingen *et al.* (2018)[1]	100.00	100.00	100.00	100.00	**100.00**
Cajita *et al.* (2017)[2]	83.33	75.00	80.00	83.33	**80.42**
Chen& Chan (2013)[3]	66.67	100.00	80.00	100.00	**86.67**
DeVeer *et al.* (2015)[4]	87.50	100.00	100.00	100.00	**96.88**
Berkowsky *et al. (2017)*[5]	83.33	100.00	80.00	100.00	**90.83**
Wang *et al.* (2019)[6]	83.33	83.33	100.00	100.00	**91.67**
Tsai *et al.* (2017)[7]	83.33	80.00	80.00	100.00	**85.83**
Wildenbos *et al.* (2019)[8]	83.33	100.00	80.00	80.00	**85.83**
Mostaghel & Oghazi, (2017)[9]	100.00	100.00	80.00	100.00	**95.00**
Rasche *et al.* (2018)[10]	83.33	60.00	100.00	83.33	**81.65**
Ha *et al.* (2020)[11]	100.00	83.33	100.00	80.00	**90.83**
Kim and Chaudry (2020)[12]	83.33	75.00	100.00	75.00	**83.33**
Askari *et al.* (2020)[13]	83.33	100.00	100.00	100.00	**95.83**
Ahmad *et al.* (2020a)[14]	66.67	80.00	80.00	100.00	**81.67**
Tsai *et al.* (2020)[15]	83.33	100.00	100.00	100.00	**95.83**
Li *et al.* (2019)[16]	66.67	100.00	80.00	80.00	**81.67**
Portz *et al.* (2019)[17]	100.00	80.00	100.00	66.67	**86.67**
Puri *et al.* (2017)[18]	62.50	100.00	100.00	100.00	**90.63**
Cimperman *et al.* (2016)[19]	66.67	100.00	80.00	100.00	**86.67**
Hsiao *et al.* (2015)[20]	83.33	100.00	80.00	100.00	**90.83**
Parker *et al.* (2013)[21]	83.33	83.33	100.00	100.00	**91.67**
Russell *et al.* (2015)[22]	83.33	80.00	100.00	100.00	**90.83**
Pywell *et al.* (2020)[23]	100.00	83.33	100.00	80.00	**90.83**

For some, when they use technology and it does not perform the way they expected, feelings of self-blame may arise (Kim and Choudhury, 2020). This may contribute to the anxiety surrounding mHealth (Tsai et al., 2020). These feelings might stem from a deeper sense of vulnerability, as older adults are being pushed to use devices and systems that they find challenging to use and understand (Wang et al., 2019). As a result, individuals may be hesitant to use novel technology, especially considering the time and effort that may be required to understand a seemingly nuanced system. Individuals with decades of lived experience will tend to rely on patterns they already know and recognize. The anxiety associated with novel and unfamiliar systems combined with an inability to manipulate the technology as intended significantly reduces the use and acceptance of mHealth services (Guo et al., 2012).

It can be argued these attitudes will fade over time as current generations understand the simplicity and convenience of faster technology, and the perception of difficulty reduces (Wildenbos et al., 2019; Tsai et al., 2020). However, the concern is that technology appears to be evolving faster than the attitude towards it, which risks leaving older adults behind.

Trust

Older adults place a significant value on trust within their healthcare system. Thus, they are often hesitant to engage with platforms that have the potential to breach this trust (Rasche et al., 2018; Meng et al., 2019). Older adults prefer face-to-face interactions with their healthcare providers to facilitate a deeper human connection when discussing sensitive topics (Pywell et al., 2020). Virtual consultations are believed to hinder the ability of both the provider and the patient to engage emotionally (Pywell et al., 2020). Much of the therapeutic relationship that physicians and healthcare providers have with their patients is grounded in mutual trust, and older adults worry that this may be lost with the rise of health technology.

Concerns of privacy may also prove to be a deterrent to the acceptance mHealth (Gao et al., 2015). Wang and colleagues (2019) found that 80% of participants had at least a moderate level of concern about privacy. These are often specif-

Table 4. Thematic synthesis of the included studies.

Studies	Attitude toward technology			Social influence		Usability factors	
	Self-efficacy	Usefulness	Privacy	Family and friends	Health-care provider	Physical	Cognitive
Van Houwelingen *et al.* (2018)[1]	X	X	X	X			
Cajita *et al.* (2017)[2]		X			X	X	X
Chen & Chan (2013)[3]	X		X	X		X	X
DeVeer *et al.* (2015)[4]	X	X			X		
Berkowsky *et al. (2017)*[5]	X	X				X	X
Wang *et al.* (2019)[6]	X	X					
Tsai *et al.* (2017)[7]	X	X		X		X	X
Wildenbos *et al.* (2019)[8]	X	X	X			X	X
Mostaghel & Oghazi (2017)[9]	X	X	X			X	X
Rasche *et al.* (2018)[10]			X	X	X	X	
Ha and Park (2020)[11]	X	X		X	X		X
Kim and Choudhury (2020)[12]	X	X		X			
Askari *et al.* (2020)[13]	X	X		X			
Ahmad *et al.* (2020a)[14]		X	X	X			
Tsai *et al.* (2020)[15]	X	X				X	
Li *et al.* (2019)[16]		X	X	X	X	X	X
Portz *et al.* (2019)[17]				X			
Puri *et al.* (2017)[18]	X	X	X	X			
Cimperman *et al.* (2016)[19]	X	X	X	X	X		X
Hsiao *et al.* (2015)[20]	X	X		X	X	X	
Parker *et al.* (2013)[21]	X	X	X	X	X	X	X
Russell *et al.* (2015)[22]	X	X	X				
Pywell *et al.* (2020)[23]	X	X	X		X		

ic concerns related to the way data is being collected or the content of the data itself. For example, some older adults expressed discomfort with continuous home monitoring systems (Parker et al., 2013), while others expressed concerns that sensitive medical information regarding mental health may become public knowledge (Pywell et al., 2020). Revealing this health information, even to close family members, may be perceived as a risk to their independence (Puri et al., 2017). Conversely, others believe that data sharing is largely harmless. Measurements of sleep, physical activity, heart rate, and blood pressure are not considered personal health information and can be shared freely without concern (Puri et al., 2017). These same individuals hold the belief that much of their information—both healthcare and otherwise—is already being shared online and on other platforms. One participant noted, *"all my information is already on my doctor's computer which is linked to the hospital and various other places I'm sure"* (Puri et al., 2017). Parker and colleagues (2013) explained that those who have more health problems, live alone, or see themselves at increased risk of an acute event, are more willing to accept some privacy risks because much of their health information has already been gathered and stored over the years. They accept it as a trade-off to feel less isolated and are comforted in knowing that they are being looked after (Parker et al., 2013). This is echoed by previous work where the need for independence among older adults outweighs potential privacy issues (Mynatt et al., 2004).

The discrepancy between the above findings may be due to a reduced understanding of privacy implications and insufficient information to make an informed decision (Puri et al., 2017). Li and colleagues (2019) propose that one way to mitigate this is for mHealth to be clear about how physical signs are gathered and shared with healthcare providers. There is also an opportunity for education and training programs that mentor safe online practices and increase self-efficacy. This will acknowledge and respect their concerns while attempting to curb their anxiety around technology (Zhao et al., 2019). Attempting to garner more trust in technology may have a positive influence on perceived usefulness, perceived ease of use (McClosekey, 2008), and intention to use mHealth (Cimperman et al., 2016).

Overall, the degree to which trust and privacy affect the opinions of older adults regarding mHealth remains inconclusive. This is an ongoing issue on a global scale, with researchers and legislators employing still unraveling the privacy issues around the use of emerging technologies. Reassuring older adults that trust will transfer over from a traditional healthcare delivery system to an online system is key to maintaining confidence in their healthcare provider and demonstrates the value of mHealth services (Meng et al., 2019). Older adults who feel the platform is trustworthy are more likely to adopt applications like telehealth in their homes (Russell et al., 2015). Concerted efforts should be made to ensure older adults feel comfortable using mHealth.

Perceived usefulness of mHealth

Older adults are a diverse group of individuals with varying levels of frailty and functional independence and tend to be more accepting of

Table 5. Study design and population characteristics of the included studies.

Authors (Year)	Design	Country	Setting	No. of participants	Average age (years)
Van Houwelingen *et al.* (2018)[1]	Mixed methods Cross-sectional: Survey and In-home observation	Netherlands	Community-dwelling	N= 288 (Survey) N= 15 (Home)	Median: 71
Cajita *et al.* (2017)[2]	Cross-sectional	USA	Community-dwelling	N=129	Mean: 71
Chen & Chan (2013)[3]	Mixed methods: Interview and Focus groups	China	Community-dwelling	N=26 (Focus group) N= 24 (Interview)	Mean: 67
DeVeer *et al.* (2015)[4]	Cross-sectional	Netherlands	Community-dwelling	N= 1014	Mean: 67
Berkowsky *et al.* *(2017)*[5]	Mixed methods: Questionnaire and Focus group	USA	Community-dwelling	N= 52	Mean: 77
Wang *et al.* (2019)[6]	Focus group	USA	Retirement home	N=31	Mean: 80
Tsai *et al.* (2017)[7]	Semi-structured interviews	USA	Assisted/ Independent living facilities	N=21	Median: 71
Wildenbos *et al.* (2019)[8]	Usability evaluation	Netherlands	Community-dwelling	N=23	Mean: 66
Mostaghel, & Oghazi (2017)[9]	Cross-sectional	Sweden	Community-dwelling	N=811	87% are 67-74
Rasche *et al.* (2018)[10]	Cross-sectional	Germany	Community-dwelling	N= 576	Mean: 69
Ha *and* Park (2020)[11]	Cross-sectional	Korea	Community senior centre	N=226	Mean: 79.44
Kim and Choudhury (2020)[12]	Mixed methods: Semi-structured interview and questionnaire	USA	Community- dwelling	N=15	Mean: 71.5
Askari *et al.* (2020)[13]	Cross-sectional	Netherlands	Community-dwelling	N=364	Mean: 75
Ahmad *et al.* (2020a)[14]	Cross-sectional	Bangladesh	Community- dwelling	N=223	41.7% are 60-64
Tsai *et al.* (2020)[15]	Usability evaluation	Taiwan	Residential community and hospital	N= 81	28% are 60-69
Li *et al.* (2019)[16]	Cross-sectional	China	Community- dwelling	N=146	39% are 60-64
Portz *et al.* (2019)[17]	Focus group	USA	Community- dwelling	N=24	Mean: 78.4
Puri *et al.* (2017)[18]	Mixed methods: Cross-over design with questionnaire and interview	Canada	Community- dwelling	N=20	Mean: 64
Cimperman *et al. (*2016)[19]	Cross-sectional	Slovenia	Community-dwelling	N=400	Median: 61.13
Hsiao *et al.* (2015)[20]	Cross-sectional	Taiwan	Community-dwelling	N=390	46% are 60-65
Parker *et al.* (2013)[21]	Focus group	USA	Primary care clinic	N=41	Mean: 76.2
Russell *et al.* (2015)[22]	Cross-sectional	Australia	Community-dwelling	N=306	50-68 years old (distribution not reported)
Pywell *et al.* (2020)[23]	Semi-structured interviews	United Kingdom	Community-dwelling	N=10	Mean: 68

technology that addresses these needs (Cajita et al., 2017). Those who require frequent hospital visits live with multiple chronic conditions, or experience daily challenges due to functional limitations are more accepting of technology (Ha and Park, 2020). As such, services and applications need to be tailored to the needs of the individual. For example, an individual with Alzheimer's Disease who struggles with memory impairment may derive benefit from using a medication reminder to improve compliance (Tellier et al., 2020).

The perception of the usefulness of mHealth is a subjective experience for each older adult and has a profound influence on its acceptance. Askari and researchers (2020) detailed that perceived usefulness makes participants 6 times more likely to use it, making this a significant driver of intention to use. Older adults are willing to overlook prior negative attitudes if they perceive this application to improve their quality of life (Parker et al., 2013). Research suggests that individuals with chronic illness are willing to use mHealth systems in their care despite experiencing some anxiety around technology usage (Parker et al., 2013). Ultimately, older adults recognize the distinction between mHealth that is 'interesting' versus mHealth that is useful (Puri et al., 2017). They are not drawn to the features of apps or specifications of these devices, but rather the degree of usefulness to their own needs (Cajita et al., 2017).

It is important to note that even when older adults perceive technology to be beneficial, there are conditions that may reduce its perceived usefulness. Kim and Choudhury (2020) found that when technology is perceived as too difficult to learn, older adults may avoid engaging with it. This may relate closely to their self-efficacy. When faced with an apparently difficult technology system, an older adult who feels incapable of learning new systems would encounter a significant barrier to engagement (Kim and Choudhury, 2020). If the performance of the mHealth system also falls short of expectation with low accuracy or low quality, engagement would be even more challenging (Li et al., 2019). Ultimately, the usefulness of mHealth to older adults is a complex measure and speaks to the whole user experience, not just the available features.

Social influence

Family and friends

For most older adults, communication with their family via a smartphone was their introduction to mobile technology (Van Houwelingen et al., 2018). The ability to stay connected with loved ones gives older adults a sense of mattering which lowers feelings of social isolation and improves psychological wellbeing (Tsai et al., 2017). Many older adults also find that the time spent in the learning process with their children and grandchildren helps strengthen their relationship (Portz et al., 2019).

Therefore, families play an important supportive role in encouraging use and promoting positive attitudes toward health technology (Tsai et al., 2017). Ha and Park (2020) found that there was a correlation between older adults who perceived technology as more difficult to use and those with reduced social support. This is consistent with previous research, which emphasises the demand for support as part of the technology adoption process (McGaughey et al., 2013). Social influences from family and close peers also encourage older adults to realize the potential utility of adopting these devices (Kim and Choudhury, 2020). It is important to remember that as most older adults do not readily engage in social interaction through education or employment, they largely depend on support from family and caregivers (Tsai et al., 2017).

While familial support is integral in reducing obstacles to acceptance, there may be some barriers to attaining this help. Some older adults were hesitant to ask for help as they did not want to bother their families (Peek et al., 2015). Others were less inclined to ask for help because they did not want to appear incapable (Kang et al., 2010) and wanted to display an ability to be self-sufficient (Knight and Winterbotham, 2019). Additionally, some were met by resistance when asking for help using mHealth. Older adults describe low approval from their family, with their children using words like 'hypochondriac' when they explore mHealth like activity trackers (Puri et al., 2017). Even when older adults were able to get assistance, younger family members would find it frustrating to slow down and fully explain tasks (Portz et al., 2019).

Social support, especially family support, is an important feature in the initial consideration to use mHealth but more importantly in facilitating ongoing use. Hsiao and colleagues (2015) recommend that healthcare providers and industry marketers should leverage this relationship in their strategies to ensure that older adults feel supported and motivated to be successful using mHealth. Previous research has shown that some older adults would prefer settings that allow multiple users like caregivers and family members to be able to remotely access devices and monitor health data to improve acceptance (Desteghe et al., 2017). While the influence of family may be useful, the end goal is to equip older adults with a sense of self-sufficiency so they do not feel dependant on their families to enjoy the benefits of mHealth.

Healthcare providers

The use of mHealth can be influenced by individuals who are involved in the care of the elderly (Cajita et al., 2017). When suggested by a physician, older adults are more likely to consider mHealth as useful (Cajita et al., 2017). As discussed earlier, older adults emphasise trust as a central component of their healthcare and as such defer healthcare decision-making to their doctors (Cimperman et al., 2016; Pywell et al., 2020). Almost all participants in the study conducted by Cajita and colleagues (2017) stated the advice given to them by their doctors was the most important factor when considering the use of technology to monitor their health conditions. This is consistent with previous work, showing that participants were willing to use daily health apps to provide their doctors with more information for more individualized care (Mercer et al., 2016). Interestingly, this emphasis on doctors as primary influencers of mHealth is seen across the world in both Eastern and Western cultures (Hsiao et al., 2015; Dorin et al., 2014; Wu et al., 2011). Therefore, despite different cultures and healthcare systems, doctors play an integral part in the adoption of these systems.

Interestingly, Rasche and colleagues (2018) showed that among the current cohort of elderly mHealth users, doctors were seldom cited as a resource for health app information. General practitioners (GP), when asked about their views on recommending mHealth to their patients, explain that their reluctance stems from an overwhelming surplus of apps and devices which has made it challenging to identify tools that are both trustworthy and effective for their patients (Byambasuren et al., 2019). This highlights the challenges doctors face when striving to be advocates of mHealth.

In the future, it is of utmost importance that healthcare providers be well-versed in emerging technologies, so they can provide accurate information to their aging patients (Cajita et al., 2017). Doctors need to be aware of some emerging mHealth services and platforms entering the market to effectively evaluate their patients' needs, and connect them to the appropriate services (Ha and Park, 2020). They may also play a role in connecting older adults who may be apprehensive using mHealth to educational programs, technical support, and financial aid services which may provide specific support (Li et al., 2019; Parker et al., 2013).

Usability features

Physical limitations

Technology is only worth adopting if the value it adds is underpinned by the ease of use and convenience (Berkowsky et al., 2017). Mobile devices fit this role, as vast functionality is possible with devices small enough to fit in your hand. Older adults, especially those with functional mobility limitations, prefer mobile devices as they provide the same user experience without limiting those individuals who cannot sit at a desk for long periods (Tsai et al., 2017). Even individuals who are unable to attend clinics may be able to collect and share health measurements like electrocardiography (ECG) with their doctors without leaving their homes (Tsai et al., 2020). Conversely, while adding convenience through portability, the compact size of mobile devices can also in turn serve as an obstacle (Wang et al., 2019). Elderly individuals with impaired fine motor function and decreased hand-eye coordination can find mobile devices non-practical to use (Wang et al., 2019). To account for this, the implementation of accessibility features like digital zoom and speech-activated tools enables older adults with impaired senses who want to engage with their devices (Wang et al., 2019).

Older adults who report diminished physical health may also find reassurance in systems that monitor their physical signs (Li et al., 2019). To a group living with impaired senses and concern that they may not be able to access care in an emergency, wearable devices that offer vitals monitoring, fall detection, and emergency service contact, instill a sense of security and make mHealth more readily accepted (Parker et al., 2013). Understanding the experience and or concerns of each individual allows services to be tailored to their needs and functional abilities (Hsiao et al., 2015).

Cognitive limitations

Mobile devices can accommodate for some of the physical limitations in age, but developers must also keep in mind the cognitive changes in their target population. Old age is associated with an overall decrease in cognitive function which increases the effort required to learn new skills, such as operating new technology. Thus, older adults with declining working memory and attention deficits find navigating through complex interfaces difficult (Wang et al., 2019; Wildenbos et al., 2019). Mobile devices with minimal setup and intuitive interfaces are preferred as users get a more seamless experience (Tsai et al., 2017). Additionally, many older adults have cognitive decline and reduced speed of information processing, forcing them to rely on a heuristic approach to decisions making (Cimperman et al., 2016). Technology that is intuitive will be more readily accepted as it will require less mental effort to learn and effectively operate (Cimperman et al., 2016; Hsiao et al., 2015). For example, using a medication reminder app to help with inconsistent memory could be beneficial only if the app is simple enough to operate in the context of a decreased working and semantic memory. Cognitive deterioration has an overall negative impact on daily activities, and implementing mHealth with complicated interfaces as part of the care plan for these individuals may serve to increase frustration without providing the intended benefit (Wang et al., 2019).

Co-designing process

Various usability issues were pointed out in the literature, as all age-related challenges tend to be amplified with increasing age. Elderly adults want to contribute to a co-designing process, ensuring usability issues are addressed prior to the development of technology (Wang et al., 2019).

After all, older users are the principal stakeholders; it is logical to have a clear line of communication between them and developers. This may prevent a discrepancy between what older adults need from mHealth and what developers think will be useful (Bruggencate et al., 2019; Davidson and Jensen, 2013).

David and Jensen (2013) showed that older adults offer valuable insight into their needs and priorities despite a lack of technical knowledge. The development of a participatory design process can be an important step to de-mystify mHealth and dispel misinformation around health technology (Davidson and Jensen, 2013). mHealth has incredible potential and engaging older adults in this process could yield novel applications that directly address their needs while maximizing accessibility and use among this group.

Strengths and limitations

Adapting mHealth for the aging population is a growing area of research. With many studies still in the pre-experimental stage, this review emphasises the abundance of qualitative analysis in the literature. Due to smaller sample sizes in qualitative studies, the internal and external validity of these studies is reduced. Moreover, mHealth encompasses a broad field of mobile technologies, so understanding the barriers to some applications of mHealth will not necessarily be generalizable to other applications, or even different versions of the same application. To address this, our review looked at literature published globally, including work done in countries across Europe, North America, and Asia. Additionally, by incorporating literature published globally, we can help support the case that these trends will persist in the face of different healthcare system models, cost of mHealth, and to some extent cultural norms. Finally, it is of note that the search was performed by a single reviewer which may have contributed to bias in screening search results.

Conclusion

In response to the COVID-19 pandemic and preparation for the future, healthcare systems are employing mHealth in healthcare delivery (Iyengar et al., 2020). mHealth has shown to augment health-related behavior in older adults improving adherence to medication, nutritional programs, and exercise regimens which minimizes complications for individuals with chronic disease (Changizi and Kaveh, 2017). However, older adults are at risk of low mHealth adoption, with research striving for a better understanding of their needs in regard to the acceptance of mHealth in this group.

The aim of this review is to explore the factors that influence the use of mHealth among older adults. mHealth has the potential to support independence and optimize healthcare which is especially important for those with accessibility issues and chronic disease. This literature review uncovered attitudinal and dispositional barriers that are impeding widespread utilization of mHealth in this population. Low self-efficacy and reduced trust in technology are causing anxiety and deterring older adults from considering adopting mHealth. Along with motivating older adults toward adopting this technology, their current perceptions around mHealth might need to be challenged and ongoing education provided to enable them to make informed decisions. Families, caregivers, and healthcare professionals must also be encouraged to support digital literacy and promote mHealth use. Finally, having shared input as part of a co-design process will allow older adults to make recommendations to developers, minimizing avoidable usability issues.

Future research should aim to explore the lifecycle of technology adoption, with a focus on compliance and adherence to digital or virtual healthcare programs and ongoing use among older adults. Additionally, as the recent global pandemic unfolds, it is prudent to better understand the changing perceptions of mHealth among these individuals. The literature overwhelmingly indicates that engagement of older adults as end-users is integral to the implementation of mHealth. As care and management of disease in the elderly is a growing concern, it is important to understand how older adults perceive digital health tools and how they chose to interact with them. Without a meaningful contribution from them, healthcare systems risk disadvantaging the population they intend to serve.

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Appendix I: Search strategy details

Search 1: Search strategy for Health research in Gerontechnology

PubMed:

("Gerontechnology"[Journal] OR "gerontechnology"[All Fields]) AND ("health"[MeSH Terms] OR "health"[All Fields]) AND ("2010/01/01"[PDat] : "2020/12/31"[PDat])

Scopus:

TITLE-ABS-KEY (“Gerontechnology” AND “health”) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

Search 2: Search strategy for Technology Adoption by Older Adults

PubMed:

("technology adoption"[All Fields] OR “technology acceptance"[All Fields] OR "technology use"[All Fields]) AND ("older adults"[All Fields] OR ("aged"[MeSH Terms] OR "aged"[All Fields] OR "elderly"[All Fields])) AND ("2010/01/01"[PDat] : "2020/12/31"[PDat])

Scopus:

TITLE-ABS-KEY ("technology adoption" OR “technology acceptance” OR “technology use”) AND (elderly OR "older adults")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

Search 3: Search strategy for mHealth and older adults

PubMed:

"Mobile health"[All Fields] OR “mHealth”[All Fields] AND ("older adults"[All Fields] OR ("aged"[MeSH Terms] OR "aged"[All Fields] OR "elderly"[All Fields])) AND ("2010/01/01"[PDat] : "2020/12/31"[PDat])

Scopus:

TITLE-ABS-KEY ("mobile health" OR “mHealth”) AND (“elderly” OR "older adults")) AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2010)) AND (LIMIT TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

Appendix II – EBLIP critical appraisal

P1: Is the study population representative of all users, actual and eligible, who might be included in the study?
P2: Are inclusion and exclusion criteria definitively outlined?
P3: Is the sample size large enough for sufficiently precise estimates?
P4: Is the response rate large enough for sufficiently precise estimates?
P5: Is the choice of population bias free?
P6: Were participants randomised into groups?
P7: Were the groups comparable at baseline?
P8: If groups were not comparable at baseline, was incomparability addressed by the authors in the analysis?
P9: Was informed consent obtained?
D1: Are data collection methods clearly described?
D2: If a face to face survey, were inter-observer and intra-observer bias reduced?
D3: Is the data collection instrument validated?
D4: If based on regularly collected statistics, are the statistics free from subjectivity?
D5: Does the study measure the outcome at a time appropriate for capturing the intervention's effect?
D6: Is the instrument included in the publication?
D7: Are questions posed clearly enough to be able to elicit a precise answer?
D8: Were those involved in data collection not involved in delivering a service to the target population?
S1: Is the study type/methodology utilized appropriate?
S2: Is there face validity?
S3: Is the research methodology clearly stated at a level of detail that would allow its replication?
S4: Was ethics approval obtained?
S5: Are the outcomes clearly stated and discussed in relation to the data collection?
R1: Are all the results clearly outlined?
R2: Are confounding variables accounted for?
R3: Do the conclusions accurately reflect the analysis?
R4: Is subset analysis a minor, rather than a major, focus of the article?
R5: Are suggestions provided for further areas to research?
R6: Is there external validity?

	Population									Data collection								Study design					Results					
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**S1**	**S2**	**S3**	**S4**	**S5**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**
Van Houwelingen *et al.* (2018)	Y	Y	Y	Y	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Cajita *et al.* (2017)	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	N	U	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	N
Chen& Chan (2013)	Y	N	Y	U	Y	NA	NA	NA	Y	Y	Y	NA	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y
DeVeer *et al.* (2015)	Y	N	Y	Y	Y	Y	Y	NA	Y	Y	NA	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Berkowsky *et al. (2017)*	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y
Wang *et al.*(2019)	N	Y	Y	NA	Y	NA	NA	NA	Y	Y	Y	U	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tsai *et al.* (2017)	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	U	NA	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	Y	Y
Wildenbos *et al.* (2019)	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	NA	NA	NA	NA	NA	NA	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	N
Mostaghel & Oghazi, (2017)	Y	Y	Y	Y	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	Y
Rasche *et. al.* (2018)	N	Y	Y	Y	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	N	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Ha *et. al.* (2020)	Y	Y	Y	Y	Y	NA	NA	NA	Y	N	Y	NA	NA	NA	N	NA	Y	Y	Y	Y	Y	Y	Y	U	Y	NA	Y	N
Kim and Chaudry (2020)	Y	N	Y	Y	Y	NA	NA	NA	Y	N	Y	NA	NA	NA	N	NA	Y	Y	Y	Y	Y	Y	Y	NA	Y	NA	Y	N
Askari *et al.* (2020)	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Ahmad *et al.* (2020)	Y	N	Y	Y	U	NA	NA	NA	Y	Y	U	Y	NA	NA	N	NA	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	Y
Tsai *et al.* (2020)	Y	Y	Y	U	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Li *et al.* (2019)	Y	N	Y	U	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	N
Portz *et al.* (2019)	Y	Y	Y	Y	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	N	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N
Puri *et al.* (2017)	Y	N	Y	U	N	Y	Y	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Cimperman *et al.* (2016)	Y	N	Y	U	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	Y
Hsiao *et al.* (2015)	Y	N	Y	Y	Y	NA	NA	NA	Y	Y	Y	Y	NA	NA	Y	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	NA	Y	Y
Parker *et al.* (2013)	Y	Y	Y	Y	N	NA	NA	NA	Y	Y	Y	N	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Russell *et al.* (2015)	N	Y	Y	Y	Y	NA	NA	NA	Y	Y	NA	Y	NA	NA	N	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y
Pywell *et al.* (2020)	Y	Y	Y	Y	Y	NA	NA	NA	Y	Y	Y	U	NA	NA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NA	Y	N

To each of these questions regarding the study design, the methods and the reporting of data, a response of Yes (Y); No (N). Unknown (U), Not applicable (NA) is given. Total number of Y is dividing by total Y, N and U, to give a score out of 100, for each section and the study as a whole.