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A scoping review of digital health technologies in multimorbidity management: mechanisms, outcomes, challenges, and strategies

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Abstract

Introduction Multimorbidity amplifies healthcare burdens due to the intricate requirements of patients and the pathophysiological complexities of multiple diseases. To address this, digital health technologies play a crucial role in effective healthcare delivery, requiring comprehensive evidence on their applications in managing multimorbidity. Therefore, this scoping review aims to identify various types of digital health technologies, explore their mechanisms, and identify barriers and facilitators within the context of multimorbidity.

Methods This scoping review follows the Preferred Reporting Items for Scoping Reviews guidelines. PubMed, Scopus, Web of Science, EMBASE, and Google Scholar were used to search articles. Data extraction focused on study characteristics, types of health technologies, mechanisms, outcomes, challenges, and facilitators. Results were presented using figures, tables, and texts. Thematic analysis was employed to describe mechanisms, impacts, challenges, and strategies related to digital health technologies in managing multimorbidity.

Results Digital health technology encompasses smartphone apps, wearable devices, and platforms for remote healthcare (telehealth). These technologies work through care coordination, collaboration, communication, self-management, remote monitoring, health data management, and tele-referrals. Digital health technologies improved quality of care and life, cost efficiency, acceptability of care, collaboration, streamlined healthcare delivery, reduced workload, and bridging knowledge gaps. Patients' and healthcare providers' resistance and skills, lack of support (technical, financial, and infrastructure), and ethical concerns (e.g., privacy) barred digital health technologies implementation. Arranging organization, providing technical support, employing care coordination strategies, enhancing acceptability, deploying appropriate technology, considering patient needs, and adhering with ethical principles facilitate digital health technologies implementation.

Conclusions Digital health technology holds significant promise in improving care for individuals with multimorbidity by enhancing coordination, self-management, and monitoring. Successful implementation requires

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addressing challenges such as patient resistance and infrastructure limitations through targeted strategies and investments. It is also essential to consider usability, privacy, and trustworthiness when adopting these tools.

Keywords Digital health, Multimorbidity, Technology, Review

Introduction

Multimorbidity poses a global public health challenge. The term multimorbidity has been used by World Health Organization (WHO) to mean the presence of two or more health conditions in the same individual, mainly referring to long-term health conditions that require complex and ongoing care [1]. Factors such as increasing life expectancy, lifestyle changes, urbanization, genetic predisposition, and sedentary habits contribute to the rising prevalence of multimorbidity [2, 3]. It is associated with the high prevalence of chronic non-communicable diseases (NCDs). The most common NCDs are cardiovascular diseases (heart disease and stroke), cancer, diabetes and chronic respiratory diseases, caused about three quarters of deaths word wide [4]. Every year 17 million people under the age of 70 die due to NCDs; 86% of them live in low- and middle-income countries [4]. Around 37.2% of adult population is diagnosed with multimorbidity globally [5], including 45.7% in South America, 43.1% in North America, 39.2% in Europe, 35% in Asia, and 28.2% in Africa [6]. Due to the rising prevalence of NCDs, low- and middle-income countries, thus, face a dual burden of NCDs and infectious diseases (e.g., HIV and tuberculosis) [4].

The challenge of multimorbidity is exacerbated by inadequate functioning of health systems, including poor governance, insufficiently skilled workforce, lack of health technology, conflicts, and limited capital [7, 8]. Moreover, polypharmacy, specialization, treatment burden, resource shortages, and the presence of various diseases imply the complex health needs of multimorbidity [9, 10]. These require an interoperable health system that leverages digital health technologies (DHTs) [11, 12]. Digital health technologies have been grown, and smart technologies innovation have emerged over time, as well as their applications may vary due to diseases nature and infrastructure. Digital health technologies offer several advantages in strengthening healthcare systems. For instance, it improves care delivery, reduces healthcare costs, enhances efficiencies, and coordinates service provisions [13–15]. The use of DITs may vary based on emerging types of technologies and disease conditions [16, 17].

Countries around the world have established systems for organization of DHTs [18] due to its contributions to the sustainable development goal 3 [19]. The WHO emphasizes the necessity of integrating health technology products into health systems [20], emphasizing the importance of investigating digital technologies in managing multiple diseases [21]. Previous research explores various types and aspects of digital health technologies to enhance services for people with multimorbidity in different settings [22–24]. However, there remains a gap in synthesising the role of DHTs, including mechanisms of action, their significance in managing and preventing multimorbidity, and successes and challenges in implementing these DHTs.

Therefore, this review examines the various types and applications of DHTs explores the significance of utilizing DHTs and identifies the barriers and facilitators in the context of multimorbidity worldwide. The findings from this research will benefit health systems, including healthcare workers, and individuals with multiple health conditions.

Methods

Reporting the findings

This scoping review is presented based on the guide of Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). This guide served as a checklist which contains 20 essential and 2 optional items (PRISMA-SCR-checklist) [25]. We followed the Arksey and O'Malley framework in conducting this scoping review. The framework comprises specify the research question; identify relevant literature; select relevant studies; extract, map, and chart the data; summarize, synthesize, and report the results; and consult with stakeholders (optional) [26].

Eligibility criteria

We applied the Population, Concept, and Context (PCC) framework in conducting this scoping review, which allowed us to clearly define inclusion and exclusion criteria [27]. The study population in this review consisted of individuals with chronic or long-term multimorbidity, regardless of their age, gender, residence status, education level, employment status, socioeconomic status, religion affiliations, and other social classes status. Based on the concept dimension of the PCC framework, studies were deemed eligible if they enrolled individuals with multimorbidity from different level of care, using various DHTs. Regarding the context, studies were included if they were published in English and employed different approaches, including qualitative and/or quantitative methods, as well as reviews, provided that individual articles from those reviews were not included separately. The search was not limited to any specific target population, country, or year of publication. The initial publication date was not restricted, but the recent search date was 15 June 2024. Pre-prints, editorials, conference proceedings, and published in languages other than English were excluded.

Information sources and search strategy

Articles were searched in PubMed, Scopus, Web of Science, EMBASE, and Google Scholar. Search strategies in using databases were built using Boolean operators (Asterisk/*/, AND, OR) (Supplementary file). We conducted a search in Google Scholar by writing "digital health technologies and multimorbidity" on the search interface. We employed a snowball sampling technique within Google Scholar. This involved reviewing the articles we deemed eligible based on their titles and then checking related studies through the "cited by" links to identify further relevant articles. We repeated this process for up to the first 10 pages of Google Scholar. To identify the types of DHTs, examine the role of DHTs with its mechanisms in achieving the desired outcomes, and identify barriers and facilitators in the context of multimorbidity, search terms were based on two main topics: multimorbidity and digital health technologies. The search terms related to DHTs were adapted from previous review on digital health interventions to improve access to and quality of primary healthcare services [28]. The terminologies related to multimorbidity and DHTs are presented (Table 1).

Table 1 Search terms related to multimorbidity and DHTs

Keywords Related to multimorbidity	Keywords Related to DHTs
Multiple condition*, multimorbidit*, complex patient*, multiple disease*, multiple illness*, comorbidit*, co-occurring disorder*, co-occurring illness*, coexisting condition*, coexisting illness*, comorbid condition*, complex health issue*, concomitant condition*, concomitant disease*, concurrent disorder*, concurrent illness*, multiple disorder*, overlapping condition*, overlapping disease*	ehealth, e-health, electronic health, digital health, digital technolog*, digital intervention*, electronic care, telemedicine, tele medicine, telehealth, tele health, telecare, tele care, telemonit*, tele monit*, teleconsultation, tele consultation, videoconsult*, video consult*, text messag*, text*, mobile health, mobile car*, mhealth, m health, m-health, android*, app, audio*, cell phone, cellphone, computer*, mobile, multi-media, multimedia, personal digital assistant, PDA, SMS, social medi*, software, telecomm*, e-Ptal, ePtal, eTherap*, e-therap*, fum*, information technolog*, instant messag*, internet*, ipad, i-pad, iphone, i-phone, ipod, i-pod, web, smart phone, smartphone, mobile phone, e-mail*, email*, electronic health record, personal health record, electronic medical record, computer-based patient record, health information system, internet of medical thing*, robot*, artificial intelligence*, e-pharmac*, e-pharmac*

Selection of sources of evidence

The first and last authors framed the research questions and developed the search strategy. The second and third authors provided feedback on the search terms and strategy during weekly meetings. After the authors developed the search strategy, AE applied it to PubMed, Web of Science, EMBASE, and Scopus. The retrieved articles were then exported to EndNote 20 reference manager for citation management, duplicate removal, and title and abstract screening. Articles that passed the title and abstract screening had their full texts retrieved from each database or were found through a simple search on Google. The full texts were then assessed for final inclusion. Two reviewers screened the articles. Any disagreements were resolved with discussion. Articles with only citations, abstracts, conference presentation, those published in non-English languages, expert opinions, and errata were excluded. To minimize bias and information redundancy, the lists of articles from any types of review articles were searched in search engines, and their full texts were evaluated for inclusion. When the articles included in the review did not meet the inclusion criteria for the current objectives, but the review itself satisfied the current objectives, data was extracted from the review.

Data charting process and data items

A data extraction considers the author, year of publication, study country, study design, disease condition and/or study population, types of digital intervention, and findings. AE handled the data extraction, while other authors provided feedback during weekly meetings. Any extracted data with ambiguity or unclear presentation was discussed, and the team cross-checked it against the full text reports of the included articles. The types of digital health technologies, the mechanisms of actions, and its impacts were presented from the extracted data.

Collating, summarizing, and reporting the results

Based on the Arksey and O'Malley framework [26], we organized the data into themes based on common features (e.g., types of DHTs, mechanisms, barriers, and facilitators) that followed qualitative content and thematic analysis. First, we carefully reviewed the findings and extracted them. Next, we categorized similar ideas or findings into the closest themes. We presented the findings using figures, tables, and text to summarize the extracted data. Figure was used to present the article selection process and the number of eligible articles, while table created to display the characteristics of the included articles. The mechanisms of action, the importance, challenges, and strategies of DHTs were synthesised and presented with texts.

Results

Search results

A total of 7,816 articles were collected from databases and Google Scholar. A total of 3,042 were found in Scopus, followed by PubMed (1,684), EMBASE (2,588), Web of Science (378), and Google Scholar (124). After title, abstract, and full text screening, a total of 67 articles were included (Fig. 1).

Digital health technologies for individuals with multimorbidity

Studies evaluated various DHTs in improving service delivery and health outcomes for individuals with multimorbidity in different countries. Most of the studies (20 articles) were from the USA, four articles from Spain, three articles each from Canada, the UK, and Sweden, two articles each from Australia, South Korea, and Taiwan, one article each from Brazil, Denmark, France, German, Switzerland, Thailand, Norway, Netherlands, Italy, India, and United Arab Emirates. Majority (21 studies) were conducted using experimental study designs, including quasi-experimental, interventional, and randomized control trails.

Digital health technologies for individuals with multimorbidity encompass a variety of digital tools such as electronic prescription, messaging between clinicians and patients, educational platforms, telemonitoring, and multichannel centers [29]. Digital technologies also include wearable devices or sensors like blood pressure monitors, glucometers, smartwatches (activity trackers), and pulse oximeters [30–32]. Other digital applications are mHealth [33–37], involving health apps [33] and

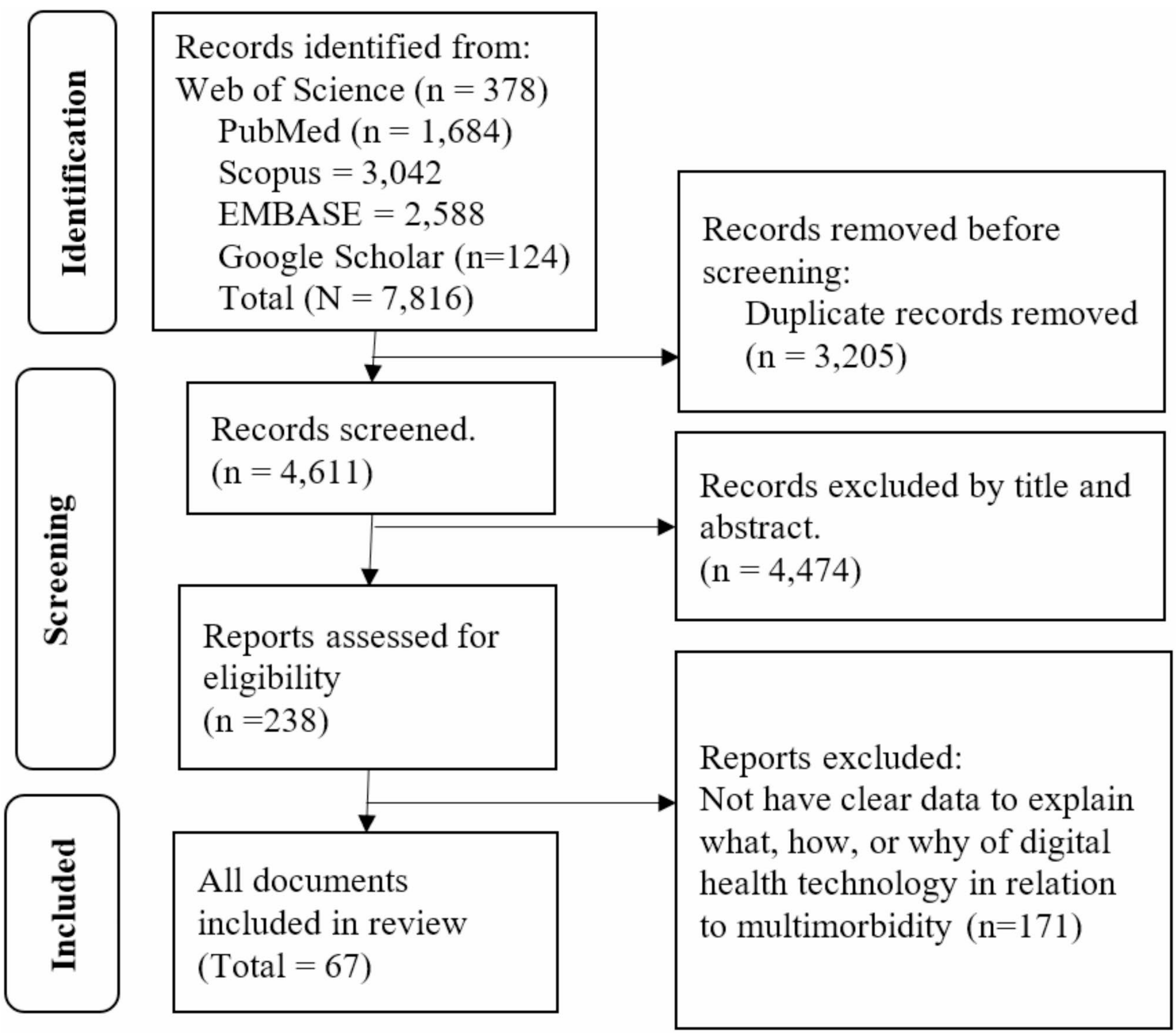

Fig. 1 Article selection process

tablet [34]; telehealth and telemedicine [38–45]; EHRs [29, 46, 47]; artificial intelligence [48–51]; and integrating websites [52–54]. Web-based applications often require combined usage (Mobile and Website) [55, 56], such as QR codes and websites [57], ambient assisted living technologies [58], and smart home technology [59], incorporating computers with internet access and X10-based smart home technology (Table 2).

Mechanisms and outcomes of DHTs for multimorbidity

Digital health technologies are delivered through electronic prescriptions, messaging, educational platforms, data storage, telemonitoring, video conferencing, and on-call consultations. These specific activities can be broadly categorized as the mechanisms of action for DHTs: coordination, collaboration, and communication [22, 29, 36, 38–44, 46, 47, 59–64, 67, 71], self-management (client empowerment) [30–37, 58, 59, 61, 63, 64, 72], remote monitoring and caring [22, 30–32, 45, 52, 53, 59, 61–63, 66, 69, 70], and managing client's health data [22, 29–32, 35, 48–51, 60, 63, 66, 68, 71, 73]. These mechanisms were evaluated as interventions aimed at the desired outcomes.

These desired outcomes reflect the role of digital and information technologies for individuals with multimorbidity. Positive outcomes resulting from the application of DHTs through their mechanisms of action with utilizing specific activities include improvements in quality of care [22, 24, 31, 40, 45, 60, 62–64, 66, 69, 70, 72, 74], quality of life [63] as measured by RAND-36 [75] (reduce frailty and improved exercise [37], minimize unintentional falling at home [45], prevent functional loss [58], maintain physical and cognitive status [59]), cost-efficiency (eHealth [63] and telemedicine [38]), increased acceptability of services ([38, 39, 57, 59, 76–78], enhance healthcare delivery (e.g., increased PHC service utilization) [29, 54, 63, 77], improve collaboration and coordination [53, 55, 59, 71, 80], reduce workload on healthcare providers [58, 61] (e.g., ambient Assisted Living technologies), and close knowledge gap [54]. In contrast, artificial intelligences have reported as causing administrative burden [51]. Other contradictions include mortality was higher in the telemonitoring group than in the usual care group with the cause of greater mortality in the telemonitoring group was unknown [42], while mortality was lower among those under telemonitoring in another study [41]. Other contradicted evidence on adherence reported that there was no difference in adherence between control and intervention groups [60], whereas ALICE App improved adherence, reduced rates of forgetting and of medication errors, and increased perceived independence in managing medication [72] and higher self-reported adherence to medication [67] (Table 3).

Challenges and strategies

Challenges of implementation of digital health technologies were patients and healthcare provider-related barriers (e.g., lack of skills among both patients and healthcare providers and health conditions) [32, 56, 59, 63], lack of technical, financial and infrastructure support [43, 52, 59, 63, 70], ethical issues [51, 63], inequalities in utilization due to age difference [77, 78]. Strategies in designing eHealth to meet the needs of individuals with multimorbidity requires accommodating both clients and health workers' interest, technical and ethical issues, as well as financial supports. These include organizational arrangement [46, 54, 76], technical support [44, 59], care coordination support [33, 55, 81, 86], enhance acceptability of technologies [32, 36, 43, 82, 83], appropriate use of telemedicine [53, 81–83], satisfy the needs of the patients [33, 81–83, 85], and addressing ethical issues [53, 63, 82, 87] (Table 4).

Discussion

The review summarized the various roles of DHTs with related challenges and strategies in managing multimorbidity. Most available DHTs were successfully implemented for individuals with multimorbidity. mHealth, webpage, the IMTs, artificial intelligence, and their combination were applied in preventing, controlling, and managing multimorbidity. The implementation of DHTs was not without challenges, including issues with flexibility, interoperability, infrastructure, ethics, the skills of both clients and health workers, resistance to change, and dependence on the clients' health status. Strategies to some of the challenges were enhance clients' willingness to use DHTs, real-time feedback, technical and financial support, and e-health education.

Digital health technologies have several benefits for individuals with multimorbidity. It improved quality of care [40, 63] and quality of life [62, 63, 75], reduced healthcare costs [63], enhanced healthcare delivery [63, 77], increased acceptability of care [57], improved client's recovery from illness [22, 64, 69, 70], decreased hospital admission [61], and reduced mortality [41]. Digital health technologies (e.g., ambient assisted living technologies) also reduced workload on healthcare providers and care givers by enhancing clients' self-management skills and minimizing healthcare providers involvement in routine care, health education, and medication reminders [58, 61]. Web-based educational resources and healthcare tools support both patients and providers [52, 53]. However, rarely, the application of telemonitoring found contradictory, revealing mortality was higher in the telemonitoring group than in the usual care group with the unexplored reasons [42] and caused administrative burden (e.g., artificial intelligence) [51].

Table 2 Characteristics of included studies and outcomes

Author/Year	Country	Study design	Diseases condition	Digital intervention	Findings
Mateo-Abad M et al. 2020 [29]	European regions	Quasi-experimental study	chronic patients aged 65 or older	Twelve relevant ICT tools for Integrated Care support*	Reduce emergency visit, while increase visits of general practitioners & primary care nurses
Atalla S et al. 2022 [31]	UAE & India	Implementation study	Multimorbidity	Wearable sensor networks	Involved stakeholders: End users. Healthcare authorities, healthcare providers, and application integrators
Kenning C et al. 2024 [32].	United Kingdom (UK)	Qualitative study	18 + with multimorbidity	Smartwatch app	More 'real-time' feedback from the app should be available to maintain engagement over a longer period; the presence of severe or chronic pain was a barrier
Parvaneh S et al. 2017 [30]	USA	Quantitative: cross-sectional	older adults with multimorbidity	Wearable technology	Help to identify frailty status by monitoring postural transition
Haverhals LM et al. 2011 [33]	USA	Qualitative study	Older adults with multi-morbidity	Personal health applications	Self-medication management processes challenges: seeking reliable medication information, maintaining autonomy in medication treatment decisions, worrying about taking too many medications, reconciling information discrepancies between allopathic and alternative medical therapies, and tracking and coordinating health information between multiple providers
Siek KA, et al. 2010 [34]	USA	Implementation study	Older adults with multi-morbidity	Interoperable Personal Health Application	Designed an application based on the real-world artifacts and workflows for medication management
Bousquet J et al. 2018 [35]	European regions	Interventional study	allergic rhinitis and asthma multimorbidity in the elderly	ICT tools	Deployed the apps
Reeder B et al. 2013 [36]	USA	Qualitative study	Older adults with multi-morbidity	Medication dispensing device in home care	Clients responded the tool is very easy to use, very reliable and helpful in the management of their medications, as well as participants expressed a desire to use the machine in the future
Lee S-C et al. 2019 [37]	Taiwan	Quasi-experimental study	Middle-Aged and Older Adults	Health Promotion Program Combining Smart Phone Learning and Exercise	Reduced frailty and improved exercise
Pariser P et al. 2019 [38]	Canada	Mixed-methods study	People with multimorbidity	Telemedicine	Clients responded that telemedicine improved their access to interdisciplinary resources, feeling hopeful their conditions would improve as a result, they would use it again, and improved confidence in managing their patient's care, and the cost was about 22% less than that of a 1-day hospital admission through the emergency department.
Wiseman JT et al. 2015 [39]	USA	Quantitative: survey	People with multimorbidity	Smartphone	Older patient cohort with significant comorbidity is able and willing to adopt a smartphone-based postoperative monitoring program
Valdivieso B et al. 2018 [40]	Spain	Interventional study	high-risk patients with multiple chronic conditions	Telehealth, telephone support	Improved quality of life, but no differences in mortality or utilization were found
Martín-Lesende I et al. 2016 [41]	Spain	Descriptive longitudinal study	Patients with multimorbidity (heart failure and/or lung disease)	Telemonitoring	Telemonitoring studies; technology help to collect data
Takahashi PY et al. 2012 [42]	USA	A randomized controlled trial	older adults with multiple health issues	Telemonitoring	Reduced hospitalizations and emergency department visits

Table 2 (continued)

Author/Year	Country	Study design	Diseases condition	Digital intervention	Findings
Schmidt S et al. 2019 [43]	German	Qualitative study	older people with multimorbidity	Personal-online case management (video conferences)	Offers formative and organisational support in various life-domains.
Berner J et al. 2016 [44]	Sweden	Qualitative study	frail older adults	Ablet computers and Skype	Conflicting feelings did emerge to adopt in the future; skype needs to be tested; technical support and well-functioning technology are important
Tchalla AE et al. 2012 [45]	France	Prospective cohort study	frail elderly population	Home-based technologies combined with a monitoring assistive center (light path coupled with tele-assistance service)	Reduced the incidence of unintentional falling at home
Wang H et al. 2023 [46]	USA	Cross-sectional study	adult emergency department patients with multimorbidity.	Patient portal use (MyChart)	One in five adults used patient portals; having primary care physicians and insurance promote patient to use MyChart
Williams TB et al. 2022 [47]	USA	Cross-sectional study	Multimorbidity	Electronic health records (EHRs)	EHRs used for research purpose
Cesario A et al. 2021 [48]	Not specified	Not clear	Multimorbidity and cancer	Artificial intelligence	Integrate and manage heterogeneous data
Hassaine A et al. 2020 [49]	Non-specific	Review	Multimorbidity	Machine learning	Improved the complex relationships between diseases;
Majnarić LT et al. 2021 [50]	Non-specific	Review	Multimorbidity	Artificial intelligence	Managed big data
Ambagtsheer R et al. 2020 [51]	Australia	Cross-sectional study	frailty within a residential aged care	Artificial intelligence	Identified frailty within a residential aged care using administrative data; potential benefits will need to be weighed against administrative burden, data quality concerns and presence of potential bias
Portz JD et al. 2019 [52]	Not specified	Qualitative study (Focus group discussion)	older adults with multiple chronic conditions	Patient portal user interface and user experience	The portal was seen to be easy to use, simple, and quick, challenges related to log-ins, user interface design (color and font), and specific features; Older adults are interested in using patient portals because the portal improved patient-provider communication, saved time and money, and provided relevant health information.
Macdonald GG et al. 2018 [53]	Canada	Qualitative study (interview of nurses & physician)	Multimorbidity	eHealth technologies	Ethical issues raised
Martínez-García A et al2013 [54]	Spain	Implementation study	Multimorbidity	Social network and open-source tools	Professionals valued positively all the items; Open source with the social network encourages adoption and facilitates collaboration; allow communication and coordination
de Jong CC et al. 2016 [55]	Netherlands	Implementation study & survey from professionals	home-dwelling elderly patient	E-communication tool	An e-communication tool (Congredi) was usable for improving multidisciplinary communication among professionals
Levine DM et al. 2018 [56]	USA	Longitudinal cohort	Seniors in declining health	Digital health technology	Seniors with new dementia, relocation to a nursing home, and declining physical performance seem especially poor candidates for technology interventions
Tseng M-H et al. 2014 [57]	Taiwan	Implementation study	Elders in outpatients	QR code and Web services	Highly accepted by the elderly

Table 2 (continued)

Author/Year	Country	Study design	Diseases condition	Digital intervention	Findings
Dupuy L et al. 2017 [58]	Not specified	Experimental study	Frail older adults and their caregivers	Ambient assisted living technologies (AAL) (includes sensors, online store applications, tablets)	AAL is a relevant environmental support for preventing both functional losses in Frail older Individuals and objective burden professional caregiver.
Tomita MR et al. 2007 [59]	USA	Random controlled trail	Frail elders	A computer with Internet access and X10-based smart home technology	Almost all participants recommended its use by others, and it maintained physical and cognitive status of intervention groups
Wakefield BJ et al. 2012 [22]	USA	A single center randomized controlled clinical trial	Patients with diabetes and hypertension	Telehealth	Improved knowledge, but no significant differences were found across the groups in self-efficacy, adherence, or patient perceptions of the intervention mode
Wakefield BJ et al. 2011 [60]	USA	A single center randomized controlled clinical trial	Comorbid diabetes and hypertension	Telehealth	Enhanced earlier detection of key clinical symptoms requiring intervention
Lear SA et al. 2021 [61]	Canada	A randomized Clinical Trial	Multiple chronic conditions	Interactive Digital Health–Based Self-management Program	Reduced hospitalizations
Bernocchi P et al. 2018 [62]	Not specified	A randomized controlled trail	older patients with chronic obstructive pulmonary disease and heart failure	Home-based telerehabilitation	It was feasible and effective
Melchiorre MG et al. 2018 [63]	European region	Qualitative study (survey of programmers0	People with multimorbidity	eHealth	eHealth improved care integration/management, quality of care/life and cost-efficiency, whereas inadequate funding represents a major barrier
Yoo H et al. 2009 [64]	South Korea	A randomized controlled clinical trial	Type 2 diabetes and hypertension	Cellular phones and the internet	Improved multiple metabolic parameters
Park MJ et al. 2009 [65]	South Korea	a quasi-experimental design	obese patients with hypertension	Web-based intervention by way of cellular phone and Internet	Improved blood pressure, body weight, waist circumference, and HDL-C
Schiff GD et al. 2019 [66]	Not specified	A randomized trail	hypertension, diabetes, depression, and insomnia	Automated calls coupled with phone-based pharmacist counseling	Identified a substantial number of previously unidentified potentially drug-related symptoms
Prabhakaran D et al. 2019 [67]	India	A randomized trail	multiple chronic conditions (hypertension, diabetes mellitus, current tobacco and alcohol use, and depression)	mHealth-based electronic decision support system	No differences observed between intervention and control groups
Zheng H et al. 2021 [68]	USA	Retrospective cohort	Multimorbidity	Reinforcement learning of electronic health records	Substantial improvements in glycemia, blood pressure, and CVD risk outcomes
Rifkin DE et al. 2013 [69]	USA	A randomized trail	older patients with kidney disease and hypertension	Wireless blood pressure monitoring	Led to greater sharing of data between patients and clinic and produced a trend toward improvements in BP control over usual care

Table 2 (continued)

Author/Year	Country	Study design	Diseases condition	Digital intervention	Findings
Donesky D et al. 2017 [70]	USA	A controlled nonrandomized trial	chronic obstructive pulmonary disease and heart failure	Home-based TeleYoga	Patients perform yoga safely in the home setting; TeleYoga was acceptable, and adherence was good, while technical issues were a barrier.
Fried TR et al. 2017 [71]	Not specified	A randomized clinical trial	Veterans aged 65 and older	A web tool linking EHRs	Improved communication about medications and accuracy of documentation
Mira JJ et al. 2014 [72]	Spain	A randomized clinical trial	elderly patients taking multiple medications	A Spanish pillbox app	Improved adherence, helps reduce rates of forgetting and of medication errors, and increases perceived independence in managing medication
Jennings MV et al. 2022 [73]	USA	Cross-sectional study	High-risk comorbidities	EHRs	EHR prescription can serve as a platform to characterize complex risk markers
Orlandoni P et al. 2016 [74]	Italy	A randomized prospective study	Frail older patients	Video consultation	A video consultation between home visiting staff and hospital physicians reduced metabolic complications in a population of frail older patient
Persson HL et al. 2020 [75]	Sweden	Longitudinal study	Elderly multimorbid COPD and chronic heart failure	telemonitoring and hospital-based home care	Improved quality of life
Kay-Lambkin FJ et al. 2009 [24]	Australia	a randomized controlled trial	comorbid depression and problematic alcohol and/or cannabis use	Computer-based psychological treatment	Computer-based integrated interventions could be involved for managing depression and cannabis use
Marcolino MS et al. 2021 [76]	Brazil	Mixed-methods study	Hypertension and diabetes	Clinical decision support system	Applicable in the context of primary health care settings in low-income regions, with good user satisfaction and potential to improve adherence
Manning SE et al. 2023 [77]	USA	Cross-sectional study	Multimorbidity	Health information technology (HIT0	Disparities by age and multimorbidity in using HIT
Seifert A et al. [78]	Switzeralnd	Cross-sectional study	Older adults	mobile device use (smartphone, tablet, fitness tracker, and smartwatch), health app use (e.g., health insurance apps, fitness apps),	75.0% of the participants used at least one mobile device; 22.9% used health-related apps. Younger individuals and those with a strong interest in new technology had a higher likelihood of using health apps. Participants were more often willing to share their data with doctors than with health insurance companies or researchers
King BL et al. 2022 [79]	USA	Cross-sectional study	Multimorbidity in patients with heart failure	EHRs	The EHR-based problem list captures multimorbidity with moderate to-good accuracy
Vos J et al. 2018 [80]	England	Mixed-methods study	Older adults with multimorbidity	Care Navigation	Navigating one's personal care network rested mainly on patients' shoulders
Ekstedt M et al. 2021 [81]	Sweden	Implementation study	Older adults with chronic diseases	A web-based application electronic Patient Activation in Treatment at Home)	Feasibility study revealed redesign and highlighted the importance of adequately addressing not only varying user needs but also the complex nature of healthcare organizations when implementing new services and processes in chronic care management.
Buawangpong N et al. [82]	Thailand	Qualitative study	Older Adults with multimorbidity	Telemedicine	perceived benefit of telemedicine among older adults with multimorbidity, appropriate use of telemedicine for multimorbid care, telemedicine system catering to the needs of older patients, and respect patients' decision to decline to use telemedicine
Wathne H et al. 2023 [83]	Norway	Qualitative study	Post-hospitalization long-term illness	eHealth service	Expecting information, reassurance, and guidance when using eHealth for heart failure and colorectal cancer self-management; expecting eHealth to be comprehensible, supportive, and knowledge promoting; and recognizing both the advantages and disadvantages of eHealth for heart failure and colorectal cancer self-management

Table 2 (continued)

Author/Year	Country	Study design	Diseases condition	Digital intervention	Findings
Ancker JS et al. 2015 [84]	USA	Qualitative study	Patients with multimorbidity	HIT for data tracking	Overload on patients, provoke strong positive and negative emotions, value judgments, and diverse interpretations, and patients often notice that physicians trust technologically measured data such as lab reports over patients' self-tracked data.
Zulman DM et al. 2015 [85]	USA	Qualitative study	patients with multiple chronic conditions	eHealth technology	Patients with multiple chronic conditions manage a high volume of information, visits, and self-care tasks; they need to coordinate, synthesize, and reconcile health information from multiple providers and about different conditions; their unique position at the hub of multiple health issues requires self-advocacy and expertise. Focus groups identified desirable eHealth resources and tools that reflect these themes
Greenhalgh T et al. 2015 [86]	United Kingdom	Qualitative study	Clients with multimorbidity and key informants	Telehealth	Quality telehealth or telecare is 1) ANCHORED in a shared understanding of what matters to the user; 2) REALISTIC about the natural history of illness; 3) CO-CREATIVE, evolving and adapting solutions with users; 4) HUMAN, supported through interpersonal relationships and social networks; 5) INTEGRATED, through attention to mutual awareness and knowledge sharing; 6) EVALUATED to drive system learning
Runz-Jørgensen SM et al. [87]	Denmark	Qualitative study	People living with multimorbidity	eHealth	Patient-perceived value of eHealth varied, depending on their burden of illness and treatment: those with a greater burden had more positive perceptions of eHealth, and expressed more intention to use it.

*Electronic prescription, Messaging clinician and Patients, Electronic Health Record, Interconsultation, Call Center, Virtual Conference, Personal Health Folder, Nurse Information System, Educational Platform, Collaborative Platform, Telemonitoring and Multichannel Centre

Digital health technologies improved quality of life of clients with multimorbidity, for example, by enhancing cognitive and physical wellness, and by preventing falling and functional loss. This may work for clients with a single NCDs or advanced medical conditions. For instance, smartphone applications, including short message services, were associated with better glycaemic control, unlike website-based interventions [88]. Website-based interventions, according to the current review, closed knowledge gaps, reduced emergency visits, increased primary care visits, and enhanced coordination. Further research may be needed to assess its unseen long-term health outcomes for clients with multimorbidity. Digital health technologies also work comparably for individuals with single health problems, with improving diabetes distress, self-efficacy and HbA1c levels [89–91]. To illustrate with specific DHTs type, mobile phone interventions lowered systolic blood pressure and reduced hospitalizations among patients with heart failure [92]. Digital health technologies also enhanced the quality of life of individuals who are unable to speak and walk by converting thoughts to text, and by assisting them to walk [93, 94]. However, telemedicine might not be always effective in reducing HbA1c among women with diabetes in pregnancy (e.g., telemedicine) [95].

Digital health technologies managed data and maintained records, with variation in complexity and applicability. Electronic health records and AI involve the collection and entry of clients' health data, analyzing health data, receiving responses, registering patient health parameters, and identified multimorbidity cases from big dataset [22, 30–32, 35, 63, 71]. There are essential indicators related to data and information management but were not addressed in the included articles of this review. With three main themes (usability, informativeness, and availability), conformance, consistency, maintainability, accuracy, plausibility, provenance, relevance, accessibility, portability, security, timeliness, completeness, and interpretability are dimensions of information quality for DHTs [96].

Digital health technologies enhanced shared understanding, and promoted care coordination, collaboration, and communication in caring clients with multimorbidity [22, 29, 60–62, 71]. Clarification of roles and responsibilities between clients and providers are essential [81]. Considering the interests and needs of clients is also essential. Clients with type 2 diabetes, for example,

Table 3 Types of DHTs tools and equipment with the mechanisms of actions and its outcomes for individuals with multimorbidity

Types of DHTs tools and equipment	Mechanisms of actions and/or activities in implementing DHTs	Outcomes of DHTs Resolved problems
Electronic health records [29, 46, 47, 68, 71]	• Electronic prescription [29] • Data entry and record [71] • Reinforcement learning algorithms within EHRs [68]	• Timely communication [71] • Information sharing [71] • Manage clients' health data, enhanced person-centered care [68] • Improve accuracy of documentation [71]
Internet of medical things (wearable devices or sensors) [30–32, 64]	• Glucose monitors attached to patients' phones equipped with web-based physician communication [64] • Make appointment & monitor their own health [30–32, 63, 64] • Wireless Bluetooth-enabled blood pressure cuffs paired with internet hubs [69]	• Tele communication [64] • Data management (collect, record), client empowerement [63] • Telemonitoring and caring [30–32] • Minimize the unexpected health complications [31] • Enhance recovery from illness [64] • Integration/management of care [63]
Websites [52–54]	• Web-based educational resources and healthcare tools [29, 52, 53]	• Closing knowledge gap [52–54], • Reduce emergency visits and increased primary care visits [29] • Improved coordination between health workers and clients & care providers [53, 54]
mHealth or telehealth or mobile lines/health apps [22, 29, 33–44, 55, 60–63, 66, 70, 81]; tablet computer [34, 67]; computer [24]	• Electronic messaging and health information exchange [29, 33] • Video conferencing (e.g., Skype), ePrescriptions [38–44, 63] • On-call consultations or video conference [22, 61, 70] • Electronic reminders and computerized self-management tools or online decision supports [61, 63] and telemonitoring [29] • Displays medication images and sounds an alarm at medication times [72] • Clients enter health data [63] • Conduct weekly nurse phone calls [62] • Tele-assistance services using light paths [45] • Patients enter their data, access and print information [22, 35] • Smart phone learning of and the moderate exercise [37] • Facilitate post-treatment discharge [29] • A real-time phone referral of clients to a pharmacist [66] • Nurses enter patient data [67] • Computer-based therapy combined with motivational and cognitive behaviour [24]	• Collaboration [36] • Generate decision support recommendations [33, 63] • Communication [29, 33, 63] • Closing knowledge gap [61, 63] • Remote monitoring & caring [62, 63, 66] • Unidentified potentially drug-related symptoms [66] • Clients' data management [22, 35] • Quality of care [40, 63], safety (reduced medication errors) [72] • Reduced the incidence of unintentional falling at home [45] • Reduced metabolic complications [74] • Recovery from illness [64, 67] • Improved management of care [63] • Enhance detection of key clinical symptoms [22, 60] • Quality of life [62, 63, 75] • Improved cognitive & physical wellness and preventing functional loss [45] • Maintained physical and cognitive status [37] • Cost-efficiency [63], reduced travelling, direct and indirect costs [38], • Increased service acceptability [38, 39] • Improves care integration/management [63] • Reduced number patients admitted in hospitals [61] • Enhance acceptability of services [43] • Reduce cannabis and substance use [24]
Artificial intelligence [48–51, 73]	• Analyze pattern [48–51, 73] • Recommend treatment options [48–51, 73] • Identify high-risk comorbidities [48–51, 73]	• Client's health data management [48–51]
Ambient assisted living technologies [58]	• Client follow their own health condition [58]	• Client empowerment [58] • Improve cognitive & physical wellness [58] • Prevent functional loss [58] • Reduce workload on health care providers [58]
X10-based smart home technology [59]	• Remote monitoring and caring [59]	• Client empowerment [59] • Increased service acceptability [59] • Maintained users' physical and cognitive status [59] • Supports social interactions [59]
Combined (Mobile and Website, QR codes) [55–57]; A web tool linking an HER [71]	• Data input for automated algorithms [71] • Clinician feedback reports [71] • Patient feedback reports [71]	• Acceptability of technologies [57] • Improved communication among professionals [55] • Communication [71] • Correction of medication discrepancies but had no effect on number of medications or reduction in PIM [71]

Table 4 Barriers and strategies of DHTs implementation for individuals with multimorbidity

Types of DHTs tools and equipment	Barriers	Strategies to address barriers
Electronic health records [29, 46, 47, 68, 71]		• Technology resource (internet connection, mobile & landline telephony) [76] • Financial support (increase health insurance coverage) [46] • Presence of primary care physicians [46]
Internet of medical things (wearable devices or sensors) [30–32, 64]	• Clients health condition [32]	• Enhance patient willingness to wear and utilize it [32] • Real-time feedback from the app [32] • Patient longevity in engagement [32] • Enabling standardized exchange of electronic information [63] • Inequality in utilization due to age [78]
Websites [52–54]	• Problems-related to log-ins and user Interface design (colour and font) [52]	• Organizational arrangement [54] • Interoperability [54] • Patient engagement in two-way communication [53]
mHealth or telehealth or mobile/health apps [33–44, 55, 63, 81]	• Lack of skills (both clients and providers) [63] • Resistance from both clients and providers [63] • Inadequate infrastructure (e.g., poor internet) [43, 63] • Lack of technical support [63, 70] • Incompatibility between different eHealth tools [63] • Lack of financial support [63] • Privacy/security issues [63] • Inadequate legislative framework for using eHealth tools [63]	• Technical support [44] • Clarification of roles and responsibilities [81] • Information exchange between providers are essential [81] • Enhance shared understanding [86] • Self-management support [55] • Delivery system design [55] • Clinical decision support [55] • Clinical information system [55] • eHealth education [55] • Previous exposure [43] • Provide comprehensive information [33, 81, 83, 85] • Patient engagement in two-way communication [83] • Perceived benefits [82] • Apply among stable clients [82] • Skills and knowledge development for clients and providers [82] • Self-management support [81, 83] • Addressing ethical issues [53, 82, 87]
Artificial intelligence [48–51, 73]	• Data quality issues and bias, and causing administrative burden [51]	
X10-based smart home technology [59]	• Clients' unfamiliarity with computers and inability to learn how to use them [59] • Hidden running programs [59] • Computer virus computer [59] • Bad RAM chip or conflict [59] • Unable to connect to the Internet [59] • Old phone lines and/or old electricity lines interfered with the use of X10 via computer [59]	• Technical support [59]

require simple and positively framed communication when using mHealth [97]. Professionals utilized e-care in caring elders at primary care level by considering delivery system design, clinical decision support, clinical information system, and eHealth education [55]. Using technology-enabled care coordination for youths with mental health problems, similar to clients with multimorbidity, underscored the benefits of introducing a smart healthcare infrastructure [98].

There were challenges emerged during DHTs implementation, including issues with flexibility, interoperability, infrastructure, ethics, the skills of both clients and health workers, resistance to change, and dependence on the clients' health status. Clients' sociodemographic status influences the DHTs use. For instance, aged 70 and above were less comfortable to internet-based home care compared to aged 70 and less [99]. Older clients may have several cognitive and psychomotor impairment so that they could not accept and able to adhere with telemedicine system [82]. There have been differences between clients, as some viewed e-health as something makes things easier or undesirable and worthless [87]. Individuals with multimorbidity were less likely to accept e-health than individuals with single disease [99], revealing how client's health status impacts DHTs applicability. Telemedicine system better be practised as like as in-person care, and should allow in-person home visits when necessary and supports knowledge and skills development for clients and caregivers [82]. Clients may need diagnostic-specific but comprehensive information, which is easily accessible, evidence-based, understandable, and satisfy their needs [33, 81, 83, 85]. When the patients are in a stable condition, they can maintain the stability of the telemedicine and practice self-management [82].

Patient-engagement is necessary in the two-way communication [53, 83]. Providing guidance and motivational support, connecting with other patients, and inviting caregivers are crucial [81, 83].

Challenges that arose from DHTs side hindered implementation. Wearable devices remain with challenges related to data quality, balanced estimations, and fairness [100, 101]. Ethical and legal challenges have been also raised [102] due to the concern of safety and effectiveness, cybersecurity, poor protection of privacy, liability, data protection and privacy, patients unwillingness to provide their data, data quality issues (including bias), and intellectual property law [51, 63, 103, 104]. Inadequate legislative framework was one of the barriers for using eHealth tools [63]. Naik et al. addressed that there are no well-defined regulations in place to address the legal and ethical issues that arise from using AI in healthcare settings [105]. Maintaining local standards of quality and interoperability is crucial [101, 106], and it is essential to respect client's rights and adhere with ethical standards [63]. A critical understanding and engagement is valuable to the ethical development of technologies for people living with MLTCs [107]. For instance, understanding epistemic injustice serves as a conceptual tool for mapping gaps in knowledge reproduction in the design of data-driven health technologies [107] because unconscious epistemic injustice might be happen when healthcare team reused client's data [107].

The findings from this review will contribute to digital health initiatives. World health organization and UNs provided great attention for telehealth and telemedicine alongside strengthening innovation and infrastructure, as it is one of the SDGs agenda [108].The Global Initiative on Digital Health, managed by WHO, aims to assess and prioritize country needs for sustainable digital health transformation. It also seeks to align country-level digital health resources with unfunded priorities, accelerate the achievement of strategic objectives outlined in the Global Strategy on Digital Health, and enhance capacity-building efforts. The goal is to encourage local development, maintenance, and adaptation of digital health technologies to meet evolving needs from 2020 to 2025 [109].

Limitation of the study

This scoping review only included studies published in English. By excluding non-English language studies, we may limit the comprehensiveness of the findings and overlook valuable data and insights from diverse cultural contexts. Future research could benefit from incorporating studies in multiple languages to enhance the diversity and richness of the data.

Conclusions

This review highlights the essential aspects of DHTs in managing multimorbidity, focusing on their adoption, benefits, challenges, and strategies for improvement. The widespread usage of DHTs across various countries and healthcare settings demonstrate their potential to enhance service delivery and health outcomes. The benefits of DHTs include improved care coordination, patient empowerment, and cost-efficiency However, the effective implementation of these technologies is accompanied by several challenges, including patient and provider resistance, technical issues, financial constraints, and ethical concerns. To fully realize the potential of DHTs, strategic measures are necessary to address existing barriers and enhance the design and implementation of these technologies for individuals with multimorbidity.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2. Search strategy.

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