Title: The use of mobile health technology in the management of osteoarthritis: a scoping review with scientometric analyses

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Abstract

Introduction

Although mHealth technology is an emerging approach for enabling self-management/education of hip/knee osteoarthritis (OA) that may reduce burdens in primary and secondary care, no scoping review has been conducted to comprehensively review the scope of mHealth technology in managing hip/knee OA. This scoping review and scientometric analyses aimed to summarize the current state of research on the use of mHealth technology (mobile applications/web-based interventions) for self-management/education of adults with hip/knee OA, identify key research activities, and provide future directions on the development/usage of mHealth technology.

Methods

The Arksey and O'Malley methodological framework was employed, augmented with scientometric analyses. Six databases were searched from inception to 31 May 2021. Findings were reported according to the PRISMA extension for scoping review. Co-word, co-author, and co-citation scientometric analyses were conducted to examine the social and intellectual connections of the research field (e.g., research hotspots and researcher collaborations).

Results

Twenty mHealth programs for promoting self-management of hip/knee OA were identified. The programs mainly included exercises or directives on performance of exercises. Compared to no interventions, mHealth technology was usable and might be more effective in improving pain, physical function, and quality of life in individuals with OA. The scientometric analyses identified

multiple co-occurring keywords that reflected conceptual properties of this research domain. Although some intellectual connections among authors, research articles, and journals were noted, there were insufficient international collaborations in this field.

Discussion

While individual small-scale studies highlighted promising short-term effects of mHealth technology in self-managing hip/knee OA, many mHealth technologies were developed without clinicians' and/or patients' contributions. Future mHealth programs should be developed based on a strong theoretical background and professional inputs. The long-term benefits and cost-effectiveness of mHealth technologies, user experience, as well as cross-cultural adaptation of these technologies should be evaluated.

Summary/Highlights

- Prior reviews have shown that mHealth technologies (web and app-based) were effective in managing short-term OA symptoms, however, there was mixed evidence regarding their effects on physical disability and quality of life.
- Although 10 web-based and nine app-based programs were identified, each program was only evaluated by one to two studies. Moreover, there was no mHealth program for managing hip/knee osteoarthritis targeting Africans or East Asians.
- Scientometric analyses revealed limited author co-citation or collaborations in the field.
- Future studies should evaluate the long-term benefits and cost-effectiveness of mHealth technologies, as well as cross-cultural adaptation of these technologies. Moreover, qualitative studies exploring mHealth user experiences are warranted.

1.0 Introduction

Osteoarthritis (OA) is the most prevalent degenerative joint disease affecting approximately seven percent of people globally.[1, 2] Knee and hip OA are the most common ones, and are ranked as the 11th most common cause of disability worldwide, mainly affecting older adults.[3] Women are more susceptible to OA than men, with a lifetime prevalence of 18% and 10%, respectively.[4] Individuals with OA usually experience joint pain, swelling, stiffness, and crepitation.[1, 3] Given the increasing life expectancy worldwide, the prevalence of OA is anticipated to rise exponentially that will pose tremendous burdens on individuals and the society.

Various guidelines have recommended therapeutic exercises, weight management, self-management education, assistive devices, and thermal modalities to manage mild to moderate OA.[5-8] Self-management education is thought to be an effective evidence-based approach to empower patients in managing OA.[8, 9] Self-management education included patient education, behavioral modification, and management strategies to inspire individuals to actively manage their condition and augment direct healthcare provision.[10] Given the technological advancement and popularity of mobile devices (e.g., smartphones and tablets), mobile applications and web-based programs have become a novel mode to deliver self-management education.[11, 12]

Mobile health (mHealth) delivers healthcare services via mobile applications and/or websites to help patients better understand their health conditions, enhance self-management strategies, and modify health behaviors.[6, 11] It overcomes geographical, temporal, and/or organizational barriers to access healthcare services.[6, 13-15] In situations like a pandemic, mHealth technology offers a promising mode of healthcare delivery without undue face-to-face interactions between users and clinicians. Preliminary evidence suggests that mHealth for OA management is cost-effective and helps users overcome barriers associated with primary care delivery.[15-19] Studies also found that mHealth was comparable to face-to-face physiotherapy in improving pain and function among patients with hip/knee OA,[18, 20] and attained good patients' and practitioners' satisfaction.[21]

Although several systematic reviews have separately synthesized evidence regarding applications, satisfaction, efficacy, or cost-effectiveness of mHealth technology in OA care,[12, 21-26] no review has summarized the extent of developments, applications, and interrelations among various research papers or research groups. This information can help researchers identify knowledge gaps and provide direction for future research initiatives for health caregivers. To bridge this gap, a scoping review can provide an overview of the nature and characteristics of relevant primary studies, while scientometric analyses can statistically analyse publications and graphically present the social and intellectual connections of relevant literature (e.g., researcher collaborations).[27] Therefore, this scoping review and scientometric analyses aimed to: (i) assess the current state of research regarding the social and intellectual dimensions of mHealth applications for self-management of hip/knee OA in adults; (ii) identify key research activities; and (iii) recommend future research directions.

2.0 Methods

2.1 Design

This review adopted the Arksey and O'Malley methodological framework[28] with some modifications.[29] It was conducted in five steps: (i) identifying the research question; (ii) developing the search strategy; (iii) identifying and selecting relevant studies; (iv) data charting; and (v) collating and reporting the finding. We chose scoping review over systematic review for several reasons. The extant literature on mHealth and OA care is complex and heterogeneous, comprising various study designs from quantitative and qualitative paradigms. [30, 31] Moreover, pre-existing systematic reviews focused solely on synthesizing and summarizing evidence of the effectiveness of mHealth technology on some selected outcomes such as functioning and quality of life.[12, 21-26] Additionally, unlike a systematic review, scoping review typically addresses a broadly stated focused research question to map key concepts and evidence of a given topic.[28] For instance, in this review, our goal is to map evidence regarding the use of mHealth in OA care (utility and user experience), explore the contents of available mHealth technology, and explicate the nature of the existing body of knowledge. Thus, the scoping review seems more congruent with the main objective of this study compared to the systematic review. On the contrary, the scientometric analyses were conducted using VOS viewer (Universiteit Leiden, Netherlands, version 1.6.16), to construct and visualize the mHealth research network in OA care, which cannot be achieved using scoping review alone.[27, 32]

2.2 Research question

Our research question was 'what are the extant literature on the use of mHealth technology in managing hip/knee OA among adults?' This review summarized the scope of research on the application of mHealth in managing patients with radiographic or clinical hips/knees OA, and evidence regarding the effectiveness/cost-effectiveness of these mHealth programs, as well as user experiences. mHealth technology was defined as the use of wireless or mobile technologies in healthcare to attain healthcare objectives (e.g., improved clinical outcomes, healthcare services).[33]

2.3 Search strategy

MEDLINE, Web of Science, CINAHL, AMED, PEDro, and Google Scholar were searched from inception to 31 May 2021. Relevant medical subject headings (mesh terms) and keywords were used to capture multiple domains of mHealth and OA (Appendix 1). The search strategy was varied among the databases because each database has a unique set of mesh terms. We used only mesh terms and keywords that are indexed in the respective databases. For google scholar, which is a search engine, we used commonly reoccurring keywords to generate manageable output. Grey literature was searched on the Grey Literature Report and Open Grey. Manual search and forward citation tracking of the selected studies were conducted. Corresponding authors of the included studies were contacted by emails to identify additional relevant studies.

2.4 Study selection

Studies were included if: (i) they are English/Chinese articles reporting the use of mobile applications or web-based programs to treat adults (≥18 years) with hip/knee OA, (ii) they are experimental studies (randomized controlled trials (RCTs), quasi-experimental studies, and case-control studies) reporting the effectiveness/feasibility of mobile applications or web-based programs in the management of adults with hip/knee OA, and (iii) they are qualitative studies reporting user experiences on the use of mobile applications or web-based programs in the management of adults with hip/knee OA. Reviews, editorials, conference proceedings, and studies reporting about text message-based intervention, telephone-based interventions, and wearable devices were excluded.

Studies identified from literature searches were imported into Covidence. Two authors (SKS and LL) independently screened titles and abstracts to identify studies for full-text screening. Between-reviewer disagreements were resolved by discussion. If disagreements persisted, a third reviewer (AW) was consulted for arbitration. The full-text screening procedure was identical.

To generate a more international view of the literature we included articles with full-text published in English or in Chinese, provided the latter's' titles and abstracts were available publicly in English translation. All but one of the authors are fluent in both languages, enabling us as a team to do full-text screening in both. The inclusion of Chinese articles did not affect our search strategy. None of the Chinese articles we identified qualified for inclusion in any case.

2.5 Data extraction

Data extraction was conducted using the Cochrane collaboration data extraction form. SKS and LL independently extracted relevant data (authors, year of publication, country, study design, participants, objectives, type of intervention, outcomes, duration of follow-up, attrition rate, results, interpretations of findings, and user experience). Their results were compared. Any between-reviewer discrepancies were resolved by consensus through discussion or consultation with AW.

2.6 Data synthesis

The nature and extent of available evidence were summarized by narrative synthesis. Evidence of effectiveness (including cost-effectiveness), usability aspects (including acceptability and adherence), and user satisfaction were synthesized using content analysis of information extracted from the primary studies. Scientometric analyses (co-word, co-author, co-citation) were conducted using the VOS viewer software[34] to provide a visual representation of the conceptual, social, and intellectual networks of mHealth research in OA management.[27, 32] The co-word analysis investigated the conceptual structure of the field using the most important words or keywords in the included studies. The co-author analysis determined the social structure and collaboration networks among authors, while the co-citation analysis summarized the interrelations among cited documents based on authors, documents, or journals.[27]

Scientometric analyses were conducted in two steps. First, networks were constructed through keyword co-occurrence analysis, author co-occurrence analysis, author co-citation analysis, journal co-citation analysis, and document co-citation analysis. Second, maps were generated to mine useful information regarding the conceptual, social, and intellectual properties of mHealth research for hip/knee OA management (Table 1). [27, 35]

3.0 Results

3.1 Characteristics of the included studies

Literature searches identified 732 articles (Figure 1). After removing duplicates, 682 titles and abstracts were screened. Twenty-eight out of 42 screened full-text articles were included. These studies were conducted in Australia, Germany, India, Netherlands, Norway, Saudi Arabia, Sweden, the UK, and the USA (Table 2). They included 17 RCTs,[4, 9, 15-19, 36-45] five quasi-experimental studies,[39, 46-49] two prospective studies,[4, 50] three pilot studies,[43, 50, 51] and one feasibility study.[40] These studies recruited 4,854 individuals (sample sizes ranging from 12 to 499). Interventions lasted from one to 52 weeks, with variable follow-up durations. Conversely, we could not identify any qualitative study that reports user experience (acceptability and user satisfaction) of mHealth technology in OA care.

3.2 Contents of mHealth interventions

Eleven web-based and nine app-based programs were identified (Appendix 2). Web-based programs mainly include exercises or directives on exercises, except for *eHealth*, *iCBT* (internet-based Cognitive Behavioral Therapy), *My Joint Pain*, *and PainCoach*. Notably, the *eHealth* program contains general information about OA, patient consultation routines, medication orders, and future orthopaedic appointments.[14] *My Joint Pain* program includes OA factsheets, information on available healthcare providers, treatment options, and a peer support function.[47] The *PainCoach* comprises eight training modules lasting for 30-45 minutes each (progressive muscle relaxation, brief relaxation practices, activity-rest cycling, scheduling of pleasant activity, cognitive restructuring, pleasant imagery, distraction techniques, and problem-solving skills).[37, 44] The *iCBT* is a self-managing program for depression targeting people with knee OA and concomitant major depressive disorder. It comprises six online CBT lessons, homework assignments, an online discussion forum, and regular email contacts with a mental healthcare provider.[52] The *iCBT* teaches behavioural activation, cognitive restructuring, problem solving, and assertiveness skills.

Exercises and/or guidance on exercise performance are the most common contents for all app-based programs, except *OA-GO*, *Patient Journey,* and *Vett* apps. The *OA-GO* app solely provides motivational messages and requires users to enter daily pain and mood data to tailor motivational messages for greater functional mobility. It works with a wearable activity monitor to summarize users' daily step counts, calories burnt, and sleep.[17] The *Patient Journey* app provides knee OA education, conservative and surgical treatment options, surgical risks, as well as rehabilitation and expectations after total knee arthroplasty.[9] The *Vett* app comprises a mapping function of personal goals, tasks to be performed, and self-evaluation functionality in order to help attain behavioral modification.[40]

Only some mHealth approaches were developed based on theories or guidelines. Specifically, five (*e-Exercise*, *Engage Program*, *iCBT*, *Join2move*, and *PainCoach*) and three web-based programs (*eHealth, Joint Academy,* and *My Knee Exercise*) were developed based on the cognitive learning theory and pre-existing self-management guidelines, respectively. Three web-based programs (*IBET*, *My Joint Pain*, and *TERC*) did not report their theoretical bases. Likewise, only four app-based programs provided their theoretical underpinnings. Notably, *Hinge*, *PAHCO*, and *Vett* were grounded in the cognitive learning theory, while the *dr. Bart* app was based on the Fogg model of behavioral change.

Some mHealth technology programs are freely available on Google play, Apple store, or developer's website (e.g., the *Vett* app, *My Knee Exercise*), while others are commercially available (i.e., *OA-GO* app). However, five app-based and nine web-based programs did not disclose their public availability. Appendix 3 summarizes details about identified mHealth interventions.

3.3 Usability aspects and satisfaction with mHealth intervention

Eleven studies reported usability aspects (including acceptability and adherence) of mHealth technology and user satisfaction with mHealth interventions.

3.3.1 Web-based programs

Five included studies reported that web-based interventions (*Engage*, *Joint Academy*, *Join2move, PainCoach,* and *TERC*,) were acceptable and usable (Tables 2 and 3).[19, 39-41, 51] Users' adherence to the *PainCoach*[19] *Joint Academy,*[4] and *Join2move*[53] were 91%, 62%, and 55%, respectively. Users' satisfactions for *Engage* and *TERC* were 97% and 94%, respectively.[43, 50]

3.3.2 App-based programs

Studies reported that three app-based programs (*Dr. Bart*, *OA-GO*, and *Vett*) were usable, acceptable, and widely recommended by users (Tables 3 and 4).[17, 40, 41] Users' adherence to *Dr. Bart* was 71%,[41] and users' acceptability for *Vett* was 48%.[40] Users' satisfaction with the OA GO was 65%.[17]

3.4 Effectiveness of mHealth interventions

Twenty-six studies investigated the effects of mHealth interventions on pain, physical function, muscle strengths, health-related quality of life (HRQOL), self-efficacy, and/or patient education.

3.4.1 Web-based programs

Six RCTs found that web-based programs were significantly better than other treatments or non-treatments in improving clinical outcomes (Table 3). Specifically, *eHealth tool* was more effective than usual care in educating patients and promoting positive beliefs toward physical activities and pain medication among individuals with hip/knee OA.[14] *iCBT* was more effective than usual care in improving pain, physical function, and HRQOL in people with concomitant depression and knee OA.[52] *Join2move* users yielded significantly better hip/knee OA-related pain reduction, physical function, and self-efficacy than waitlist controls,[53] although their pilot cohort study found no significant clinical improvements.[44] *My Knee Exercise* was more effective than Knee education only in relieving knee OA pain, improving physical function and promoting quality of life. [45] Further, *PainCoach* was significantly better than educational materials in reducing pain, and enhancing physical function and HRQOL among individuals with knee OA.[37] It was also more effective than assessments alone in improving pain and self-efficacy of people with hip/knee OA.[19]

Three RCTs reported that three web-based programs were similar to alternative care. *e-Exercise* and usual care had comparable effects on clinical outcomes (pain, physical function, and HRQOL) among people with hip/knee OA.[36] *PainCoach* was similar to education and exercise in improving pain, physical function, and HRQOL in patients with hip OA, although both interventions significantly improved pain and physical function.[54] *IBET* was comparable to physiotherapy or waitlist in improving pain and physical function among individuals with knee OA.[20]

Three case series studies (including a pilot study) consistently found that *Joint Academy* was effective in improving pain,[4, 51] physical function,[4, 46] and HRQOL (pain/discomfort and mobility domains)[46] in patients with hip/knee OA. Likewise, a case series study revealed that *TERC* significantly alleviated pain, and improved self-efficacy and HRQOL in people with knee OA.[50] A non-RCT with 12- and 24-month follow-ups found that *My Joint Pain* was more effective than non-user controls in improving self-management skills for hip/knee OA (lifestyle, physical activity, and weight reduction) at both follow-ups,[39, 47] although there was no significant between-group difference in patients' health knowledge.[39] A pilot RCT also found that compared to usual care, *Engage* yielded significantly better pain and physical function in individuals with knee OA.[43]

3.4.2 App-based programs

Six RCTs reported that app-based programs were significantly better than other treatments in improving clinical outcomes of patients with hip/knee OA (Table 3). Specifically, *Dr. Bart* was more effective than usual care in improving pain and activities of daily living among individuals with hip/knee OA.[41] Similarly, *iBEAT-OA* was superior to routine self-management in improving pain and functional performance among people with knee OA.[38] *My Dear Knee* was also significantly better than exercises alone in relieving pain, as well as improving physical function and lower limb muscle strength among women with knee OA.[16] *Hinge Health Digital Care or OAGO* was significantly better than usual treatment and/or knee care education in alleviating pain and improving physical function among people with knee OA.[15, 17] *Patient Journey* was also more effective than standard education in promoting patient education and satisfaction among individuals with knee OA.[9] However, one RCT revealed that *PAHCO* was less effective than physiotherapist-guided exercises in promoting exercise-specific self-efficacy or the competence of physical training among people with hip OA.[42]

A non-RCT found that compared to supervised exercises, *Telephysiotherapy* yielded significantly better pain reduction and balance control in individuals with knee OA.[48] A quasi-experimental study found that people with knee OA demonstrated significant improvements in pain and physical function after using *Hinge Health Digital Care.*[49]

3.4.3 Cost-effectiveness of mHealth intervention

Only two studies evaluated the cost-effectiveness of mHealth interventions for OA (*e-Exercise* and *telephysiotherapy*) (Table 3).[18, 48] The costs of intervention and medication were significantly lower among users of *e-Exercise* (a web-based program) than usual physiotherapy,[18] although there was no significant between-group difference in total societal costs and healthcare costs. Another study reported significantly less treatment expenditure in *telephysiotherapy* (a mobile app) users than those performing primary care clinician-supervised exercises.[48]

3.5 Scientometric analyses

5.5.1 Publication trends

Between 2013 and 2016, there were only six articles investigating the use of mHealth technology in managing OA,[19, 44, 47, 50, 51, 53] indicating the beginning of this research domain (Figure 2). It was followed by a sharp increase in annual publications in 2017 and 2018, a temporary decrease in 2019, and a sharp rise in 2020.

3.5.2. Journal sources

This review identified 18 journals publishing relevant studies (Appendix 3). The *Journal of Medical Internet Research* (*JMIR*) has the highest number of relevant publications (five articles; 18.5% of the publications), followed by *BMC Musculoskeletal Disorders, BMC medical informatics and decision making, Osteoarthritis and Cartilage, JMIR mHealth and uHealth, and Pain* that published two articles each.

3.5.3 Keyword co-occurrence analysis

Fifteen commonly used keywords were grouped into five clusters connected by 46 links, illustrating the conceptual fabric of the research activity (Figure 3, Appendix 4). Keywords reflected the concepts related to the disease/region/symptoms (e.g., osteoarthritis, knee, and chronic pain), the technology (e.g., eHealth, digital health, internet), and treatments (e.g., exercise, physical activity, and physical therapy).

3.5.4 Author co-occurrence analysis

Figure 4 and Appendix 5 delineate the network of co-occurrence of authors. Figure 4 reveals that a network of 24 authors was grouped into four clusters and connected via 73 links with a total link strength of 139. There was no connection among these clusters, although there were collaborations among authors within three clusters. The largest cluster involves 14 authors from 10 academic/medical organizations in Australia, Canada, New Zealand, and the USA. The second biggest cluster involves six authors from three research institutes in Holland. The third cluster comprises three authors from an American company. One author from a Swedish university formed the fourth cluster. Fiona Dobson is the most prominent author who collaborated with 13 other authors, with 25 co-publications.

3.5.5 Author co-citation analysis

An author should have at least two publications and 18 citations to be qualified for this analysis. Twenty-four out of 143 authors met the criterion. Authors were grouped into four clusters with different colors (Figure 5). For example, Dinny de Bakker, Daniel Bossen, Joost Dekker, and Cindy Veenhof belonged to the same cluster, highlighting their mutual citations. The size of the bubble and font of an author’s name indicate the number of individual author’s citations. The line linking two authors shows a connection between them, while the thickness of the line illustrates the extent of connection. Table 4 ranks authors based on the strengths of their connections. Hakan Nero and Kim Bennell received the highest average normalized citation scores.

3.5.6 Document and journal co-citation analyses

Seventeen of the 27 included studies were cited at least 12 times (Appendices 6 and 7). They mainly evaluated the effectiveness of various web-based interventions in improving pain and functional outcomes of individuals with knee/hip OA. Six out of 18 identified journals published at least two relevant articles with 21 or more citations. Appendices 8 and 9 show the journal co-citation map and network analysis, respectively.

4.0 Discussion

This review revealed that web-based programs were more commonly investigated than app-based programs, which might be attributed to the earlier development of web-based self-management programs.[13] Most studies included in this review were RCTs that investigated the effectiveness of web- or app-based programs. Evidence from this review suggests that both types of programs were feasible and effective in improving the short-term pain, physical function, and HRQOL of people with hip/knee OA. However, no studies have directly compared the effectiveness/cost-effectiveness between web- and app-based programs in managing hip/knee OA. Further, we could not identify qualitative studies reporting user experiences, particularly acceptability and user satisfaction, which could be used to promote the uptake of mHealth technology in OA management. However, this evidence of user experience was reported in some clinical studies.[19, 39-41, 51] Our findings support the existing literature on the effectiveness of web- and app-based interventions on some functional and quality of life outcomes, specifically, pain, physical function, and HRQOL. Earlier systematic reviews revealed that mHealth programs are effective in both short-term and long-term management of OA symptoms, especially in pain and physical functioning.[12, 21-26] However, there is a mixture of evidence regarding their benefits on disability and quality of life.[12, 21-26] Variation in sample characteristics and intensity and duration of the mHealth intervention could account for the mixed findings regarding the benefits of the web- and app-based interventions on disability and quality of life. Unlike systematic reviews, scoping review cannot synthesize concrete evidence of effectiveness but rather maps the existing evidence to identify a knowledge gap for future research engagement.[29]

Technological advancements facilitate mHealth development. Approximately 7 billion people are using mobile phones globally,[55] and over 65% of the global population is covered by wireless communication.[56] Therefore, mHealth technology has a great potential to reach many people worldwide to overcome the barriers of time/space of in-person healthcare.[13, 57] Web- and app-based programs are well accepted by users because they empower patients to self-manage their health, promote users' autonomy, and provide accurate health information. However, mHealth may not benefit underprivileged individuals given their poor technological literacy, difficulty in accessing affordable internet services, or health insurance policy.[58]

Both web- and app-based programs for OA management offer unique advantages and limitations. Different electronic devices can access web-based programs. Computers and tablets have big screens to facilitate users to watch videos or read articles. However, web-based programs are internet dependent and may require users to log in every time.[13, 57, 59] Conversely, app-based programs may allow offline usage. It also facilitates users to record and forward audiovisual information to healthcare providers for comments.[13, 57] However, app users may need to subscribe a data plan to access the content when wireless connection is unavailable. Further, the small cellphone screen may hinder old people in watching videos or reading texts.[13, 57]

Most of the mHealth programs identified in this review focused on exercises and education although they differed in the content, user interface, and usability. However, these programs usually did not involve clinicians or patients in the content development.[60] Only the *e-Health tool* (a web-based program) incorporated users' perspectives during the program development. Most existing mHealth apps for pain self-management lack a theoretical underpinning.[61] Only a few identified apps adopted evidence-based strategies for self-management of pain.[62] This highlights the importance of involving clinicians and patients in future mHealth program development.

Unlike prior reviews, our scoping review included more relevant studies and summarized the intellectual and social dimensions of mHealth literature on OA management. A prior narrative review reported that web-based self-management interventions for OA were effective in improving pain, joint stiffness, and physical function among adults with OA.[63] Similar systematic reviews[22-26] showed that mHealth programs were effective in managing short-term OA symptoms (especially pain, and physical functioning), although there was mixed evidence regarding their effects on physical disability and HRQOL. The current and prior reviews consistently highlighted that most primary studies were limited by small sample sizes and no long-term follow-ups, which may limit their clinical usage.

Our scientometric analyses delineate social and intellectual dimensions of mHealth technology literature in OA self-management. There is a growing interest in investigating the adoption of mHealth technology for hip/knee OA care. The author's co-occurrence analysis revealed the social dimension (collaboration networks among authors) of mHealth research for OA management.[34] Many authors involved in the mHealth domain were interrelated, although they had unbalanced interconnections. The lack of collaboration among the four identified clusters might be because these authors used different mHealth technologies. Theoretically, more collaborations among authors from different backgrounds and institutions could advance relevant research. The absence of African or Asian researchers in existing clusters highlights the unknown benefits or feasibility of using mHealth technology in these populations.

The intellectual dimension of mHealth research in OA management was analyzed by three co-citation analyses (i.e., author, document, and journal). The influence of an author, or a document/journal is determined by either the normalized citation or average normalized citation. Normalized citation is calculated by dividing the number of citations of a document by the expected citation rate for similar documents published in the same year.[34] The average normalized citation denotes the average normalized number of citations received by documents published by an author or a journal.[34] Our author co-citation analysis indicated that only a few authors were engaged in mHealth research, prompting the urgent need of global collaborations (e.g., Africa and Asia researchers' involvements) to evaluate the effects of mHealth for OA care globally.

The document co-citation analysis showed that the most impactful articles were from four teams (Bennell,[37] O'Moore,[52] Bossen,[53] and Rini et al.[19]). These studies usually cited one another, except that O'Moore et al did not cite any of the three articles. This may be because Bennell and Bossen teams determined the clinical effectiveness of web-based programs among adults with hip/knee OA, whereas O'Moore et al only evaluated the effects of internet-delivered CBT on depression in older adults with knee OA. The journal co-citation analysis investigates influences and connections among journals.[34] Our journal co-citation analysis showed that authors preferred to publish their works in journals focusing on mHealth technology (e.g., JMIR). However, the lack of publications in traditional medical journals (e.g., *Rheumatology*) may limit the knowledge translation to clinicians.

4.1 Limitations

The current review has several limitations. First, only clinical studies were included, other sources of evidence such as qualitative research were not considered because we could not identify eligible studies. Moreover, our search strategy in Google Scholar was restricted to clinical trials only, hence we might have missed some relevant studies. Additionally, quality appraisal of the included studies was not done because our goal was not to synthesize evidence of the effectiveness of mHealth intervention, however, we believe that quality appraisal could have added to the rigor of our study. Hence information in this review about the effect of mHealth intervention on functional and quality of life outcomes should be interpreted with caution. Second, our scientometric analyses included fewer studies because of our scoping review approach to the literature search. Further, the VOS viewer did not allow the analysis of different authors' specific collaborations. Future scientometric analysis should use other scientometric analysis software to address this limitation. Third, since smartphone and internet users tend to seek health information,[64] or have a higher health literacy,[65] existing findings may not be generalized to the general public.

The included studies also had several limitations. The attrition rate of some studies was high (up to 32%). Participants were lost due to technical problems or other unforeseeable reasons during the trial periods.[14, 15, 20, 36, 38, 39, 41, 47] Other limitations included non-representative sample,[17, 19, 46, 54] small sample sizes,[16, 40, 42, 50] unblinding of participant,[49, 53] and a non-specific intervention for OA management.[52] Despite these limitations, these studies provided valuable insight into the benefits and drawbacks of web- and app-based self-management programs.

4.2 Future research directions

Although this review identified 19 web- and app-based interventions for OA care, the effectiveness of each program was evaluated by one or two studies. Future RCTs should involve large representative samples to evaluate the long-term effectiveness and cost-effectiveness of these approaches on various clinical outcomes.[66] Qualitative exploration of user experience, particularly acceptability and user satisfaction are warranted to promote the uptake of this technology in OA care. The development of mHealth programs should be based on a robust theoretical background and the perspectives of clinicians/end-users to enable evidence-based patient-centered interventions. Machine learning algorithms may be adopted to develop artificial intelligent-embedded web- or app-based programs for better individualized patient-centered care. An international taskforce should also be established to determine the research agenda and/or develop strategies to provide evidence-based mHealth for OA management to disadvantaged individuals and communities. This is paramount for the actualization of the World Health Organization response to musculoskeletal health by making rehabilitation services accessible and available for all population.[67]

4.3 Conclusions

This is the first scoping review incorporating scientometric analyses to summarize the current state of research on the use of mHealth technology for hip/knee OA management (including contents of interventions, and their feasibility, effectiveness, and cost-effectiveness), It also highlights the social and intellectual dimensions of mHealth literature in OA management. While preliminary evidence supports the effectiveness of web- and app-based programs in reducing pain among people with hip/knee OA, future studies should determine the long-term effects of these approaches on patients' clinical outcomes. User experiences should be studied to promote the use of mHealth technology in OA management.

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Table 1. Scientometric technique procedures

Technique	Objective	Description/Procedure
Co-occurrence of keywords	To determine the conceptual structure of the research domain by establishing the relationship between author keywords	We selected “co-occurrence” as the type of analysis and “author keywords” as the unit of analysis. We opted for author keyword to present a reproducible visualization. We used full counting and set the minimum number of co-occurrence to two. Of the 118 keywords, 27 met the threshold from the dataset. We removed 12 redundant keywords before generating the network map. Finally, 15 keywords were connected through 46 links with a total link strength of 72.
Author co-occurrence analysis	To determine the social structure of the research domain by establishing the relationship between authors	We used “co-occurrence” as the type of analysis and “author” as the unit of analysis, while the counting method was set to “full counting”. The minimum number of documents of an author was set at 2. Consequently, 24 of 143 authors met the thresholds. Overall, the network of author co-occurrence analysis showed 24 authors, 5 clusters, and 73 links with a total link strength of 139.
Author co-citation analysis	To determine the intellectual structure of the research domain by establishing the relationship between cited authors	We used “citation” as the type of analysis, “authors” as the unit of analysis, and “full counting” as the counting method. We set the minimum number of documents of an author and minimum number of citations of an author to 2 and 18 respectively, to generate a strong network. Twenty-four out of the total 143 authors met the threshold.
Document co-citation	To determine the intellectual structure of the research domain by establishing the relationship between cited documents	We used “citation” as the type of analysis, “documents” as the unit of analysis, and “full counting” as counting method. We set the minimum number of citations of a document to 12, to generate a strong network. Of the 27 documents, 17 met the threshold.
Journal co-citation network	To determine the intellectual structure of the research domain by establishing the relationship between cited journals	We used “citation” as the type of analysis, “sources” as the unit of analysis, and “full counting” as counting method. We set the minimum number of documents of an author and minimum number of citations of an author to 2 and 21 respectively, to generate a strong network. Six out of the total 18 sources met the threshold.

Note: For detail description of the procedure and terms employed, please see van Eck & Waltman [34]

Table 2. Characteristics of the included studies

Author, Year, Country	Study objective	Study design	Participants characteristics	Type of arthritis/ Mode of diagnosis	Duration of intervention/ Follow-up times	Funding Sources
Web-based programs						
Nelligan et al., 2021; Australia	To evaluate the effects of a self-directed web-based strengthening exercise and physical activity program supported by automated behavior-change text messages on knee pain and function for people with knee OA.	Parallel two arm superiority randomized clinical trial	Sample (N=206) M/F: 97/109 Mean age (SD): 60 (8.4) yrs Dropout: 26 Study groups: Experimental (N=103) M/F: 58/60% Mean age (SD): 60.3(8.2) yrs Dropout: 13 Control (N=103) M/F: 64/66% Mean age (SD): 59.0 (8.5) yrs Dropout: 13	Knee/ Clinical	24 weeks/ Baseline and 24-weeks	Funding was provided by the NHMRC (Grant No. 1091302). Two authors (Bennell and Hinman) were supported by NHMRC Fellowships (No. 1058440 and No. 1154217, respectively). A third author (Nelligan) was supported by an Australian Government Research Training Program Scholarship.
Claassen et al., 2020; Netherlands	To evaluate the effect of a stand-alone web-based educational intervention (eHealth tool) compared to usual preparation of a first orthopedic consultation of patients with hip or knee OA on patients' satisfaction.	Two-armed unblinded randomized controlled trial	Sample (N=286) M/F: 120/166 Mean age (SD): NR Dropout: 19 Study groups: Experimental (N=144) M/F: 63/81 Mean age (SD): 61.7(10.4) yrs Dropout: 6 Control (N=142) M/F: 57/85 Mean age (SD): 63.3(10.1) yrs Dropout: 13	Hip or knee/ Self-reported	6 weeks/ Baseline, 2-5 weeks before scheduled consultation	Stichting Landelijk Katholiek Reumacentrum, Netherlands

Dahlberg et al., 2020; Sweden	To investigate the long-term pain and functional outcomes of people with hip or knee OA after participating in a digital self-management program	Observational longitudinal cohort study	Sub-Sample A (completed 24 weeks) (N= 499) M/F: M/372 Mean age (SD): Hip OA-63 (9) / Knee OA- 64 (9) yrs Dropout: 0 Sub-Sample B (completed 48 weeks) (N=138) M/F: M/96 Mean age (SD): Hip OA-64 (8) / Knee OA-65 (9) yrs Dropout: 0	Hip/ Knee/ Clinical	48 weeks/ baseline, 12-, 24- and 48-week	Vinnova - Sweden's Innovation Agency (grant no: 2016-04187) and Stiftelsen fo¨r Bistånd åt Ro¨relsehindrade i Skåne (grant no: 2019-01-20)
Wang et al., 2020; Australia	To evaluate the effects of the updated version of an evidence-based OA resource and consumer hub, '*My Joint Pain*' website compared to non-program users, on health education and quality of care over 12 months	A quasi-experimental study	Sample (N=277) M/F:NR (125/152) Mean age (SD): NR Dropout: 82 Study groups: Experimental (N=104) M/F: 25/79 Mean age (SD): 60.5 (8.3) yrs Dropout: 38 Control (N=91) M/F: 18/73 Mean age (SD): 60.9 (9.1) yrs Dropout: 35	Hip/ Knee/ Clinical	24 weeks/ Baseline, 12 months and 24 months	Australian Research Council discovery grant (#DP130104407)
Allen et al., 2018; USA	To compare the effectiveness of standard physical therapy (PT) and internet-based exercise training (IBET), each vs a wait list (WL) control, among individuals with knee OA	Pragmatic randomized controlled trial	Sample (N=350) M/F: 99/251 Mean age (SD): 65.3 (11.1) yrs Dropout: 46 Study groups: Experimental-1 (PT) (N=142) M/F: 44/98	Knee/ Clinical	12 months/ Baseline, 4- and 12-month	Patient-Centered Outcomes Research Institute Award (CER-1306-02043)

			Mean age (SD): 65.3 (11.5) yrs Dropout: 30 Experimental-2 (IBET) (N=140) M/F: 40/100 Mean age (SD): 65.7 (10.3) yrs Dropout: 11 WL control (N=68) M/F: 15/53 Mean age (SD): 64.3 (12.2) yrs Dropout: 5			
Bennell et al., 2018; Australia	To evaluate the effects of an automated internet-based pain coping skills training (PCST) program before home exercise compared to alternate care (exercise and education) for people with clinically diagnosed hip OA	Two-arm parallel group randomized controlled superiority trial	Sample (N=144) M/F: 62/82 Mean age (SD): NR Dropout: 17 Study groups: Experimental (N=73) M/F: 28/45 Mean age (SD): 61.2 (7.2) yrs Dropout: 8 Control (N=71) M/F: 34/37 Mean age (SD): 61.3 (7.1) yrs Dropout: 9	Hip/ Clinical	8 weeks/ Baseline, 8-, 24-, and 52-week	National Health and Medical Research Council Program grant (#631717)
Kloek & Bossen et al., 2018; Netherlands	To investigate the short- and long-term effectiveness of *e-Exercise* compared to usual physical therapy in people with hip/knee OA	Cluster randomized controlled trial	Sample (N= 208) M/F: 67/141 Mean age (SD): NR Dropout: 73 Study groups: Experimental (N= 109)	Hip/Knee/ Clinical	12 weeks/ Baseline, 3, 6, 9, and 12 months	ZonMw (ZonMw Research Program Sport, ref. no. 525001007), the Dutch Rheumatoid Arthritis Foundation, and the

			M/F: 35/74 Mean age (SD): 63.8 (8.5) yrs Dropout: 43 Control (N= 99) M/F: 32/67 Mean age (SD): 62.3 (8.9) yrs Dropout: 30			Royal Dutch Society for Physiotherapy.
Kloek & van Dongen et al., 2018; Netherlands	To investigate whether the integration of a web-application (e-exercise) within physiotherapeutic treatment for patients with hip and/or knee OA can substitute a part of the face-to-face sessions in comparison with usual care	Cluster randomized controlled trial	Sample (N= 208) M/F: 67/141 Mean age (SD): NR Dropout: 73 Study groups: Experimental (N= 109) M/F: 35/74 Mean age (SD): 63.8 (8.5) yrs Dropout: 43 Control (N= 99) M/F: 32/67 Mean age (SD): 62.3 (8.9) yrs Dropout: 30	Hip/Knee/ Clinical	12 weeks/ Baseline and 12 week	ZonMw, the Dutch Rheumatoid Arthritis Foundation and the Royal Dutch Society for Physiotherapy
Murphy et al., 2018; USA	This study assessed the feasibility and preliminary efficacy of an online-assisted, occupational therapist–delivered, cognitive–behavioral therapy intervention to promote physical function compared to usual care in patients with knee OA	A pilot randomized controlled trial	Sample (N= 57) M/F: 22/35 Mean age (SD): 63.5 (8.3) yrs Dropout: 11 Study groups: Experimental (N= 38) M/F:14 /24 Mean age (SD): 64.8 (8.0) yrs Dropout: 7 Control (N= 19) M/F: 8/11 Mean age (SD): 60.7 (8.5) yrs Dropout: 4	Knee/ Clinical	6 weeks/ Pre and post	Michigan Institute of Clinical and Health Research, National Center for Advancing Translational Sciences (2UL1TR000433), and National Institute on Aging (K01 AG050706-01A1)

O'Moore et al., 2018; Australia	To determine the efficacy of an internet-based cognitive behavioral therapy (iCBT) program for depression in older adults with knee OA and concomitant major depressive disorder compared to usual care	A randomized controlled trial	Sample (N= 77) M/F: 14/55 Mean age (SD): 62(7.07) yrs Dropout: 11 Study groups: Experimental (N= 49) M/F: 6/38 Mean age (SD): 63.16(7.38) yrs Dropout: 7 Control (N= 28) M/F: 8/17 Mean age (SD): 59.68(6.01) yrs Dropout: 4	Knee/ Clinical	10 weeks /Baseline, week 5, week 11 (1 week following iCBT, post intervention end point), and 3-month follow-up (week 24).	Not reported
Bennell et al., 2017; Australia	To evaluate the effectiveness of internet-delivered, physiotherapist-prescribed home exercise and pain-coping skills training (PCST) compared to internet-based educational material among individuals with knee OA	Pragmatic parallel group randomized controlled trial	Sample (N=148) M/F: 65/83 Mean age (SD): NR Dropout: 15 Study groups: Experimental (N=74) M/F: 31/43 Mean age (SD): 60.8(6.5) yrs Dropout: 8 Control (N=74) M/F: 34/40 Mean age (SD): 61.5(7.6) yrs Dropout: 7	Knee/ Self-reported	12 weeks/ Baseline, 3- and 9-month	Australian National Health and Medical Research Council (program grant 1091302)
Nero et al., 2017; Sweden	To evaluate joint pain, physical function, and health-related quality of life (HRQoL) over time of users of the *Joint Academy* program and to investigate whether the use of the 6-week program is associated with	Observational quasi-experimental study	Sample (N= 350) M/F: 111/239 Mean age (SD): 62 (10) yrs Dropout: 100	Hip/Knee/ Clinical	6 weeks/ Baseline and post six weeks	Vinnova, Sweden's Innovation Agency, Lund University, and Arthro Therapeutics AB

	decreases in fear of physical activity and desire for surgery, and improve self-reported difficulties in walking					
Dahlberg et al., 2016; Sweden	To describe the effect of a newly developed web-based OA self-managing program (*Joint Academy*) on joint pain of the first-time users with hip/knee OA, and to examine whether these first-time user would recommend the program to other patients with OA .	Non-randomized pilot study	Sample (N=53) M/F: 14/39 Mean age (SD): 57(14) yrs Dropout: 5	Hip/Knee/ Clinical	6 weeks /Baseline, 3- and 12-month	Lund Innovation System
Rini et al., 2015; USA	To evaluate the potential efficacy and acceptability of an 8-week, automated, Internet-based version of PCST (*Pain COACH)* compared to assessment only	Two-arm randomized controlled trial	Sample (N= 113) M/F: 22/91 Mean age (SD): 67.62(9.45) yrs Dropout: 4 Study groups: Experimental (N=58) M/F: 12/46 Mean age (SD): 68.52(7.65) yrs Dropout:1 Control (N=55) M/F:10/45 Mean age(SD):66.67(11.02) yrs Dropout:3	Hip/ Knee/ Clinical	8 weeks/ Baseline, mid-point, post intervention	National Institute of Arthritis and Musculoskeletal and Skin Diseases, part of the National Institutes of Health, under Award Number R01 AR057346.
Umapathy et al., 2015; Australia	To evaluate outcomes in users of *My Joint Pain* on the quality of care and self-management in people with hip and/or knee OA compared to non-users	A quasi-experimental study	Sample (N=277) M/F: 65/212 Mean age (SD): 61.0 (8.6) yrs Dropout: 82 Study groups: Experimental (N=104) M/F: 25/79	Hip/ Knee/ Self-reported	12 weeks/ Baseline and 12 months	ARC discovery grant (#DP130104407)

			Mean age (SD): 60.5 (8.3) yrs Dropout: NR Control (N=91) M/F: 18/73 Mean age (SD): 60.9 (9.1) yrs Dropout: NR			
Brooks et al., 2014; USA	To investigate use of a web-based Therapeutic Exercise Resource Center (TERC) as a tool to prescribe strength, flexibility and aerobic exercise as part of knee OA treatment	Prospective cohort pilot study	Sample (N=65) M/F: 40/25 Mean age (SD): 61(9.4) yrs Dropout: 13	Knee/ Clinical	8 weeks/ Baseline and 8-week	NIH SBIR Phase I grant 1R43HD065358-01A1 Increasing Physician Use of Exercise for Treating OA of the Knee.
Bossen et al. 2013; Netherlands	To investigate whether a fully automated web-based physical activity (PA) intervention in patients with knee and/or hip OA would result in improved levels of PA, physical function, and self-perceived effect compared with a waiting list control group	Two-armed randomized controlled trial	Sample (N=199) M/F: 70/129 Mean age (SD): NR Dropout: 29 Study groups: Experimental (N=100) M/F: 40/60 Mean age (SD): 61(5.9) yrs Dropout: 24 Control (N=99) M/F: 30/69 Mean age (SD): 63(5.4) yrs Dropout: 25	Hip and/or Knee/ Self-reported	9 weeks/ Baseline, 3- and 12-month	Not reported
App-based programs						
Gohir et al., 2021; United Kingdom	To compare the effect of an internet-based treatment for knee OA (*i-beat OA*) with routine self-management (i.e., usual care)	Parallel-group randomized clinical trial	Sample (N=146) M/F: NR Mean age (SD): NR Dropout: 9 Study groups: Experimental (N=74) M/F: 14/34 Mean age (SD): 65.2 (9.7) yrs	Knee/ Clinical	6 weeks/Baseline and 6-week	Grants 21960 and 18769 from the Versus Arthritis UK Pain Centre and by the National Institute for Health Research Nottingham Biomedical Research Centre respectively. The study was also funded by

			Dropout: 17 Control (N=63) M/F: 20/37 Mean age (SD): 68.0 (8.6) yrs Dropout: 15			Pfizer Global medical grant No. WI243608
Alasfour et al., 2020; Saudi Arabia	To examine the effects of an Arabic smartphone application (My Dear Knee) on the adherence to home exercise programs (HEPs) and the effectiveness of mobile-based HEPs on pain, physical function, and lower-limb muscle strength among older women with knee OA compared to exercise program alone	Two-arm parallel randomized controlled trial	Sample (N=40) M/F: All females Mean age (SD): 54.4(4.33) yrs Dropout: 5 Study groups: Experimental (N=20) M/F: All females Mean age (SD): 53.65(3.96) yrs Dropout: 2 Control (N=20) M/F: All females Mean age (SD): 55.15(4.64) yrs Dropout: 3	Knee/ Clinical	6 weeks/ Baseline, 3- and 6- week	Graduate Students Research Support (via Deanship of scientific research funds)
Dighe et al., 2020; India	To investigate the effect of a 4-week *telephysiotherapy* program on impairments and quality of life of patients with knee OA using a smartphone application (*telephysiotherapy*) and to compare the cost effectiveness of the *telephysiotherapy* program with supervised therapy (exercise) group	Quasi experimental study	Sample (N=64) M/F: 18/46 Mean age (SD): NR Dropout: NR Study groups: Experimental (N=33) M/F: 12/21 Mean age (SD): 52.06(6.30) yrs Dropout: NR Control (N=31) M/F: 6/25	Knee/ Clinical	4 weeks/ Pre-treatment, 2nd week, and 6th week post treatment	Not reported

			Mean age (SD): 54.87(8.69) yrs Dropout: NR			
Durst et al., 2020; Germany	To evaluate whether instruction and guidance via a digital app (PAHCO) is not inferior to supervision by a physiotherapist with regard to movement quality, control competence for physical training, and exercise-specific self-efficacy	Randomized non-inferiority crossover trial	Sample (N= 54) M/F:22 /32 Mean age (SD): 62.4 (8.2) yrs Dropout: 7 Study groups: Experimental (N= 28) M/F: 12/16 Mean age (SD): 62.3(8.5) yrs Dropout: 4 Control (N=26) M/F: 10/16 Mean age (SD): 62.5(8.0) yrs Dropout: 3	Hip/ Self-reported	12 weeks/ baseline, 3- and 12-month	Leibniz-Wissenschafts Campus Tuebingen “Cognitive Interface” with funds from the Ministry of Science, Research and the Arts Baden Wuerttemberg
Pelle et al., 2020; Netherlands	To compare the short-term effects of use of the *dr. Bart* app with usual care on the number of secondary health care consultations and clinical outcomes in people with knee/hip OA in the Netherlands	A randomized controlled trial	Sample (N= 427) M/F: 121/306 Mean age (SD): NR Dropout: 131 Study groups: Experimental (N= 214) M/F: 67/147 Mean age (SD): 62.1 (7.7) yrs Dropout: 84 Control (N= 213) M/F:54/159 Mean age (SD): 62.1 (7.0) yrs Dropout: 47	Hip/ Knee/ Self-reported	26 weeks/ baseline, 3- and 6-month	This project is funded within the INTERREG-programme and received financial support by the European Union, the Ministry of Economic Affairs, Innovation, Digitalisation and Energy of the State of North Rhine-Westphalia, the Ministry of Economic Affairs and Climate Policy of the Netherlands, and the Dutch Provinces of Gelderland and Limburg.
Støme et al., 2019; Norway	To investigate the acceptability, usability and utility of *Vett* as a	A feasibility study	Sample (N=12) M/F: 2/10 Mean age (R): 65(61-70) yrs	Hip, Knee, Foot,	12 weeks/ Baseline, 12 weeks	Norwegian Research Council (grant number:237766/O30)

	personalized application for goal achievement		Dropout: 1	Shoulder/ Clinical		
Mecklenburg et al., 2018; USA	To assess the efficacy of a remotely delivered digital care program compared to usual care for chronic knee pain	A two-armed, randomized, controlled, unblinded trial	Sample (N= 162) M/F: 105/61 Mean age (SD): NR Dropout: 68 Study groups: Experimental (N= 101) M/F: 58/43 Mean age (SD): 46(12) yrs Dropout: 43 Control (N= 54) M/F: 40/14 Mean age (SD): 47(12) yrs Dropout: 18	Knee/ Self-reported	6 months/ Baseline, 6 months	Not reported
Timmers et al., 2018; Netherlands	To determine whether providing patients with information in a subdivided, categorized, and interactive manner via an educational app for smartphone or tablet might increase the knowledge of their illness compared to standard education	A surgeon-blinded randomized controlled trial	Sample (N=213) M/F: 101/112 Mean age (SD): NR Dropout: 58 Study groups: Experimental (N=91) M/F: 45/46 Mean age (SD): 62.3(8.3) yrs Dropout:17 Control (N=122) M/F: 56/66 Mean age (SD):61.8(8.5) yrs Dropout:41	Knee/ Self-reported	1 week/ baseline, 2 days before consultation, and 1 day after consultation	Not funded
Skrepnik et al., 2017; USA	To evaluate the impact of a mobile app (*OA GO*) plus wearable activity monitor/ pedometer (Jawbone UP 24) used for 90 days on the mobility of patients with knee OA treated with	Open-label, multicenter, randomized, parallel-group study	Sample (N=211) M/F: 105/106 Mean age (SD): 62.6 (9.4) yrs Dropout: 4	Knee/ Clinical	90 days/ 5 visits: screening and baseline (days −7 and 1) with follow-up visits at	Sanofi Biosurgery LLC

	hylan G-F 20 compared to activity monitor alone		Study groups: Experimental (N=107) M/F: 48/59 Mean age (SD): 61.6 (9.5) yrs Dropout:3 Control (N=104) M/F: 57/47 Mean age (SD): 63.6 (9.3) yrs Dropout:1		days 7, 30, and 90, and the last visit (day 180, post study adherence check).	
Smittenaar et al., 2017; USA	To investigate the effect of the Hinge Health 12-week digital care program (DCP) for chronic knee pain on knee pain and function, with secondary outcomes of surgery interest and satisfaction, at 12 weeks and 6 months after starting the program.	Single-arm experimental design	Sample (N=41) M/F: 9/32 Mean age (SD): 52 (9) yrs Dropout: 12	Knee/ Self-reported	12 weeks/ Baseline, 3- and 6-month	Hinge Health, Inc
Bossen et al., 2013; Netherlands	To investigate the preliminary feasibility, acceptability, and effectiveness of *Join2move* in patients with knee and/or hip OA	Non-randomized pilot study	Sample (N=20) M/F: 5/15 Mean age (SD): 64(6.6) yrs Dropout: 0	Hip and/or Knee/ Self-reported	9 weeks/ Baseline, 6- and 12-week	Not reported

yrs=years

Table 3. Effects of various web- and app-based interventions on various outcomes measures (OMs)

Authors	Intervention vs Comparator	Outcome Measured and Results			Authors' Remark	
		Pain	**Function**	**Other**	**Effectiveness**	**Cost-Effectiveness**
Randomized Controlled Trial (Web-based intervention)						
Nelligan & Hinman 2021	My Knee Exercise Website Plus Text Messages (n=103) vs My Knee Education Website (n=103)	**OM:** 11-point Numeric Rating Scale **Results:** **Between-group analysis:** There was evidence of greater improvements in overall pain (mean difference, 1.6 units; 95% CI, 0.9-2.2 units; P < .001) in favor of intervention group.	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index **Results:** **Between-group analysis:** There was evidence of greater improvements in WOMAC physical function (mean difference, 5.2 units; 95% CI, 1.9-8.5 units; P = .002) favouring the intervention group.	**OM:** Knee Injury and Osteoarthritis Outcome Score (knee-related quality-of-life subscales) **Results:** Between-group analysis: There was evidence of improvement in quality of life (mean difference (95% CI): −7.4 (−12.6 to −2.2), P = .005) favouring the intervention group.	The study found that the self-directed web-based strengthening exercise regimen and physical activity guidance supported by automated behavior-change text messages to encourage exercise adherence improved knee pain and function at 24 weeks compared to the control.	Not Applicable
Claassen & Schers, 2020	Educational eHealth tool (n = 144) vs Usual hospital procedure (n =142)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Satisfaction with the consultation, measured with Consumer Quality Index (CQI) Knowledge of participants measured with Self-administered questionnaire Treatment belief measured with Treatment beliefs in OA (TOA) **Results**: ***Between-group analysis:*** No differences between groups were observed on the 3 subscales of the CQI (group difference (95% CI): communication 0.009 (− 0.10, 0.12), conduct − 0.02 (− 0.12, 0.07) and information provision 0.02 (− 0.18, 0.21)).	The study showed that preparing a first orthopedics consultation for hip or knee OA using the intervention does not result in higher satisfaction with the consultation. However, participants using the intervention did have more knowledge and less negative beliefs about physical activities and pain medication as compared to the control.	Not Applicable

				Between group differences (95% CI) were in favor of the intervention group for knowledge (1.4 (0.6, 2.2) negative beliefs regarding physical activities (− 0.19 (− 0.37, − 0.002) and pain medication (− 0.30 (− 0.49, − 0.01)).		
Allen & Arbeeva, 2018	IBET program (n = 140) vs Standard Physiotherapy (PT) (n = 142) vs Waitlist (WL) (n = 68)	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index-Pain Subscale **Results**: ***Between-group analysis:*** Pain did not Differ significantly between either intervention group or control at 4 months (PT: –0.45 (CI= –1.33, 0.42), p = 0.31; IBET: -0.93 (CI= –1.82, –0.03), p = 0.04) or 12 months (PT: –0.05 (CI= –0.92, 0.81), p = 0.90; IBET: –0.51 (CI= –1.39, 0.38), p = 0.26).	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index-Function Subscale **Results**: ***Between-group analysis:*** Function did not differ significantly between both intervention (IBET or PT) group and control at 4 months (PT: –2.48 (CI= –5.02, 0.07), p=0.06; IBET: -1.44 (CI= –4.03, 1.15), p=0.27) or 12 months (PT: –1.79 (CI= –4.45, 0.87), p=0.19; IBET: –1.90 (CI= –4.61, 0.82), p=0.17).	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index-Total **Results**: ***Between-group analysis:*** At 4-months, improvements in WOMAC score did not differ significantly for either the intervention group compared with control (WL) (IBET: 2.70, CI = –6.24, 0.85, P = 0.14; PT: 3.36, CI = 6.84, 0.12, P = 0.06). Similarly, at 12-months mean differences compared to WL were not statistically significant for either group (IBET: 2.63, CI = 6.37, 1.11, P = 0.17; PT: 1.59, CI = 5.26, 2.08, P = 0.39). IBET was non-inferior to PT at both time points.	Improvements in WOMAC score following the interventions did not differ significantly from the control group.	Not Applicable
Bennell & Nelligan, 2018	PainCoach (n = 73) vs Education and exercise (n = 71)	**OM:** Numeric Rating Scale **Results**: ***Between-group analysis:*** There were no significant between-group differences in pain at week 24 (change in walking-pain [mean difference 0.5 units; 95% confidence interval, 20.3 to	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index - physical function **Results**: ***Between-group analysis:*** There were no significant between group differences in function at week 24 [20.9	**OM:** Assessment of Quality of Life Instrument **Results**: ***Between-group analysis:*** There was no significant between-group difference in quality of life scores at week 24 (Exp.: Mean	The intervention did not provide better clinical outcomes for people with hip OA compared with the control group.	Not Applicable

		1.3]), with both groups showing clinically relevant improvements.	units; 95%confidence interval, 24.8 to 2.9]), with both groups showing clinically relevant improvements.	(SD) = 0.8 (0.1) Cont.: Mean (SD) = 0.8 (0.2)).		
Kloek & Bossen, 2018	e-Exercise (n = 109) vs Usual Care (n = 109)	**OM: :** Knee/hip OA outcome Score (KOOS/HOOS)-Pain Subscale **Results**: ***Between-group analysis:*** There was no significant difference between experimental and control group (Mean=−2.0, 95%CI −8.9 to 4.8, p=.56). However, there was a significant improvement within both experimental group (Mean=65.9, 95%CI 54.3 to 77.5, p<0.01) and control group (Mean=61.6, 95%CI 49.9 to 73.4, p<0.01).	**OM:** HOOS and KOOS, Function Subscale **Results**: ***Between-group analysis:*** There was no significant difference between experimental and control group (Mean= −0.2, 95CI −6.4 to 6.0, p=.95). However, there was a significant improvement within both experimental (Mean=59.8, 95%CI 51.4 to 68.1, p<0.01) and control (Mean=58.0, 95%CI 49.6 to 66.5, p<0.01) groups.	**OM:** HOOS and KOOS, Quality of life subscale **Results**: ***Between-group analysis:*** There was no significant difference between experimental and control group (Mean= -4.3, 95CI −10.3 to 1.8, p=.16). However, there was a significant improvement within both experimental (Mean=52.5, 95%CI 43.6 to 61.4, p<0.01) and control (Mean=56.1, 95%CI 47.0 to 65.1, p<0.01) groups.	The experimental group was not superior to the control group, however, both interventions were effective.	Not Applicable
Kloek & Dongen, 2018	e-Exercise (n = 109) vs Usual Physiotherapy (n = 109)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Knee/hip OA outcome Score (KOOS/HOOS)-Physical functioning and Actigraph Accelerometer- Physical activity **Results**: ***Between-group analysis:*** There were no significant differences between the experimental group and the control group on physical functioning (ΔE = 1.49; 95%CI: − 4.70 to 7.69) and physical activity (ΔE = − 3.46; 95%CI: − 11.66 to 4.73).	**OM:** Quality-adjusted life years (QALYs) according to the EuroQol (EQ-5D-3 L) **Results**: ***Between-group analysis:*** No significant difference between the e-Exercise group and the usual physiotherapy group on health-related quality of life (ΔE = 0.01; 95%CI: − 0.03 to 0.04). For QALYs, the probability of the intervention (e-Exercise) being cost-effective compared to the control was 0.68/0.84 at a willingness to pay of	Intervention costs and medication costs were significantly lower in experimental group compared to control group. Total societal costs and total healthcare costs did not significantly differ between groups.	e-Exercise itself was significantly cheaper compared to usual physiotherapy in patients with hip/ knee OA, but not cost-effective from the societal- as well as healthcare perspective. The decision between both interventions can be based on the preferences of the patient and the physiotherapist.

				10,000 Euro and 0.70/0.80 at a willingness to pay of 80,000 Euro per gained QALY from respectively the societal and the healthcare perspective.		
O'Moore & Newby, 2018	Internet-based CBT (iCBT) (n = 49) vs Treatment as Usual (TAU) (n = 28)	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) **Results**: ***Between-group analysis:*** Findings indicated between-group superiority of iCBT over TAU on WOMAC (Hedges g = 0.56–0.65, 95% CI 0.04, 1.18) at the 3-month follow-up.	**OM:** Arthritis Self-Efficacy Scale (ASES) **Results**: ***Between-group analysis:*** Results indicated between-group superiority of iCBT over TAU on ASES (Hedges g = -0.81, 95% CI -0.29, -1.33) at the 3-month follow-up.	**OM:** Short Form health survey (SF-12) **Results**: ***Between-group analysis:*** The iCBT group had significantly improved scores with a large between group effect size for the SF-12 mental component score (Hedges g = 0.87, 95% CI 0.34, 1.40).	The study indicate that iCBT is acceptable and efficacious for older patients with depression and OA. The benefits extend beyond reduced depressive symptoms, distress, and mental well-being to include improved arthritis-related self-efficacy, pain, stiffness, and physical function.	Not Applicable
Bennell & Nelligan, 2017	PainCOACH (n = 74) vs Internet based educational material (n = 74)	**OM:** Numeric Rating Scale **Results**: ***Between-group analysis:*** The intervention group reported significantly more improvement in pain (mean difference, 1.6 units [95% CI, 0.9 to 2.3 units]) than the control group at 3 months, and improvements were sustained at 9 months (mean differences, 1.1 units [CI, 0.4 to 1.8 units].	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index **Results**: ***Between-group analysis:*** The intervention group reported significantly more improvement in physical function (mean difference, 9.3 units [CI, 5.9 to 12.7 units]) than the control group at 3 months, and improvements were sustained at 9 months 7.0 units [CI, 3.4 to 10.5 units].	**OM:** Assessment of Quality of Life instrument **Results**: ***Between-group analysis:*** The intervention group had significant improvement in quality of life than the control group at both 3 and 9 months (Experimental: mean difference, −0.1 units [CI, −0.1 to 0)]; (Control: mean difference, 0 units [CI, 0 to 0)]).	The study showed a greater improvement for pain, function, and quality of life, supporting the short and long-term effectiveness of the intervention.	Not Applicable
Rini & Porter, 2015	*PainCOACH* (n = 58) vs Assessment only (n = 55)	**OM:** Arthritis Impact Measurement Scale-2 (AIMS2) **Results**: ***Between-group analysis:*** Women in the intervention group had significant reductions in pain from	**OM:** Pain-related interference with functioning (AIMS2) **Results**: ***Between-group analysis:*** There was no significant effect of intervention, F (1,102) = 1.55, P= 0.216.	**OM:** Self-efficacy for pain management (Arthritis Self-Efficacy Scale) Acceptance **Results**: ***Between-group analysis:***	Women who used the intervention reported lower pain than that of women in the control group, with an effect size in a range considered to be clinically significant. Besides, the experimental group self-	Not Applicable

		baseline (mean = 4.74) to midpoint (mean = 4.11; Tukey adjusted P = 0.028) and from baseline to post-intervention (mean = 4.02; Tukey adjusted P = 0.036). The Cohen's d effect size for the group difference at post-intervention was 0.33	The Cohen's d effect size for the group difference at post-intervention was 0.13.	Self-efficacy in the experimental group increased significantly from baseline (mean= 6.66) to post-intervention (mean = 7.52; Tukey adjusted P = 0.023), although increases from baseline to midpoint (mean = 7.21) and from midpoint to post-intervention did not reach significance (Tukey adjusted P = 0.193 and 0.650, respectively). The Cohen's d effect size for the group difference at post-intervention was 0.43. Among the experimental group, adherence to the program was high: 53 of the 58 (91%) completed all 8 training modules.	efficacy for pain management increased from baseline to post-intervention compared with the control group, suggesting potential for sustained benefits. These findings, along with strong evidence for the program's acceptability, highlight the clinical promise of delivering the intervention through the internet.	
Bossen & Veenhof, 2013	*Join2move* (n = 100) vs Wait List (n = 99)	**OM:** Numerical Rating Scale **Results**: ***Between-group analysis:*** *At 3 months* There is a significant difference between the intervention and control group with respect to pain (P=.002; d=−0.2). *At 12 months* However, there was no difference at 12 months.	**OM:** Physical Activity Scale for the Elderly (PASE) Knee/hip OA outcome Score-physical function **Results**: ***Between-group analysis:*** *At 3 months* Participants in the intervention group reported a significantly improved physical function (P=.006, d=0.20). No effect was found for physical activity measured with the PASE questionnaire (P=.84, d=−0.01).	**OM:** Arthritis Self-Efficacy Scale (ASES) **Results**: ***Between-group analysis:*** *At 3 months* There is improvements in self-efficacy for pain (P=.008, d=0.17) in favor of the intervention group. *At 12 months* Subjects in the intervention group reported better passive pain coping scores (P=.008, d=−0.18).	The study demonstrated that the intervention has the potential to improve physical activity behavior and showed significant short-term improvements in physical function and self-perceived effect. However, there are no significant effects for physical function and self-perceived effect over the long term.	Not Applicable

			At 12 months The intervention group showed higher levels of subjective and objective physical activity (P=.02, d=0.18 and P=.045, d=0.19) compared with the control group. No effect was found for physical function (P=.10, d=0.17).			
Randomized Controlled Trial (App-based intervention)						
Gohir & Eek, 2021	*iBEAT-OA* (n = 74) vs Routine Self-Management vs usual care (n = 63)	**OM:** Numeric Rating Scale (NRS) **Results**: ***Between-group analysis:*** *Baseline to 6 weeks* The intervention group showed significantly greater decreases in the NRS score than the control group (between-group difference, −1.5 [95% CI, −2.2 to −0.8]; P < .001). ***Within-group analysis:*** *Baseline to 6 weeks* Statistically significant improvement in pain score in the intervention group (mean change, −1.8 [95%CI, −2.4 to −1.3]; d = −0.83) but not in the control group (mean change, −0.3 [95% CI, −0.8 to 0.2]; d = −0.2).	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) **Results**: ***Between-group analysis:*** *Baseline to 6 weeks* The intervention group had significantly better improvements in the WOMAC subscales for pain (between-group difference, −1.1 [95% CI, −2.0 to −0.2]; P = .02), stiffness (between-group difference, −1.0 [95% CI, −1.5 to −0.5]; P < .001), and physical function (between-group difference, −3.4 [95% CI, −6.2 to −0.7]; P = .02). ***Within-group analysis:*** *Baseline to 6 weeks* The intervention group had significant improvements in the 3 WOMAC subscales (pain change, −2.2 [95% CI, −2.9 to −1.6]; d = −0.60; stiffness change, −0.8 [95% CI, −1.2 to −0.4]; d = −.51; and	**OM:** Arthritis Research UK Musculoskeletal Health Questionnaire (MSK-HQ)-OA symptoms and quality of life **Results**: ***Between-group analysis:*** No statistically significant between-group differences. ***Within-group analysis:*** No statistically significant within-group changes in MSK-HQ over time.	The intervention was superior to routine self-managed care in pain score and functional performance.	Not Applicable

			function change, −7.8 [95% CI, −9.8 to −5.7]; d = −0.60).			
Alasfour & Almarwani, 2020	My Dear Knee vs Exercise program	**OM:** Arabic Numeric Pain Rating Scale **Results**: ***Between-group analysis:*** *Baseline to 6 weeks* The intervention group had significantly better pain reduction (mean= –1.08, p=.015, effect size = 0.165). ***Within-group analysis:*** *Baseline and the 6 weeks* There was a significant reduction in pain within-group for the intervention group over time, the mean difference (mean (95%CI) =2.22 (0.73 to 3.72)) (p<.001).	**OM:** Arabic version of the reduced Western Ontario and McMaster Universities Osteoarthritis Index - ArWOMAC **Results**: ***Between-group analysis:*** *Baseline to 6 weeks* No significant between-group difference (p=.619). ***Within-group analysis:*** *Baseline and the 6 weeks* There were significant reduction in physical function scores for the intervention group (mean (95%CI) = 5.11 (2.45 to 7.77), p<.001) and control group (mean (95%CI) = 1.29 (–0.83 to 3.42), p<.095) over time.	**OM:** Lower limb muscle strength (Five-Times Sit-to-Stand Test) **Results**: ***Between-group analysis:*** *Baseline to 6 weeks* No significant between-group difference (p=.397). ***Within-group analysis:*** *Baseline and the 6 weeks* There were significant increases in lower limb muscle strength scores for the intervention group [mean (95%CI) = –0.83 (–1.52 to –0.15), p=.001) and control group (mean (95%CI) = –0.77 (–1.25 to –0.28), p=.001) over time.	There was significant pain reduction and improvement in physical function and lower-limb muscle strength with the intervention.	Not Applicable
Durst & Roesel, 2020	Physical activity-related health competence (PAHCO) model (n = 28) vs Physiotherapist guided exercises (n = 26)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Movement Quality assessed by independent raters Multidimensional Self-Efficacy for Exercise Scale Control Competence for Physical Training assessed with Self-rating Scale **Results**: ***Between-group analysis:*** Movement quality: The intervention was better than the control (Hedges g	Exercise-specific self-efficacy and control competence for physical training improve using the intervention, and movement quality is acceptable for exercises that are easy to perform. The intervention might be a supplementary tool to support patients' independent home training for less complex exercises. However, it cannot replace a physiotherapist with an equivalent effect.	Not Applicable

				–0.13, 95% CI –0.41-0.16). Exercise-specific self-efficacy showed a strong effect in favor of the control group (Hedges g 0.84, 95% CI 0.46-1.22). Control competence for physical training: The intervention was only slightly inferior to the control group (Hedges g 0.18, 95% CI –0.14-0.50).		
Pelle & Bevers, 2020	Dr. Bart app (n = 214) vs usual care (n = 213)	**OM:** Knee/hip OA outcome Score (KOOS or HOOS) **Results**: ***Between-group analysis:*** Overall treatment effect of the intervention for pain was 3.5 (95% CI: 0.9; 6.0).	**OM:** Short Questionnaire to Assess Health-enhancing Physical Activity KOOS/HOOS- Functional Limitations **Results**: No significant differences in physical activity was reported. Treatment effect of the intervention for activities of daily living in the experimental group was 2.9 (95% CI: 0.2; 5.6).	**OM:** HRQOL ((EQ-5D-3L) Usage of the app **Results**: No significant differences in HRQOL Of the 214 participants allocated to the intervention group, 171 (80%) opened the app at least once. Of all participants, 151 (71%) chose at least one goal. A total of 113 (53%) participants achieved at least one goal.	dr. Bart app is effective with respect to symptoms, pain, and activities of daily living, although these benefits were small.	Not Applicable
Mecklenburg & Smittenaar, 2018	Hinge Health Digital Care Program (n = 101) vs Knee Care Education and Usual Treatment (n = 54)	**OM:** Knee Injury and Osteoarthritis Outcome Score (KOOS)-Pain subscale **Results**: ***Between-group analysis:*** The intervention group had a significantly greater reduction in KOOS-Pain compared to the control group at the end of the program (greater reduction	**OM:** KOOS Physical Function Short-form (KOOS-PS) **Results**: ***Between-group analysis:*** The intervention group had a significantly greater improvement in physical function compared to the control group at the end of	**OM:** Visual analog scales (VAS) for pain and stiffness respectively **Results**: ***Between-group analysis:*** The intervention group had a significantly greater reduction in the VAS pain (12.3, 95% CI 5.4 to 19.1, P<.001) and VAS stiffness	Findings demonstrated large improvements in knee pain, physical function, and stiffness in individuals with CKP on the Hinge Health DCP.	Not Applicable

		of 7.7, 95% CI 3.0 to 12.3, P=.002).	the program (7.2, 95% CI 3.0 to 11.5, P=.001).	(13.4, 95% CI 5.6 to 21.1, P=.001).		
Timmers & Janssens, 2018	Patient Journey App (n = 91) vs Standard Education (website and information event) (n = 122)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Knowledge of illness, Satisfaction with knowledge provided, Mobile device proficiency **Results**: Knowledge was 52% higher in the app group, Knowledge satisfaction was higher in app group (app: mean 6.8 [SD 2.7], No difference in mobile device proficiency between groups (app: mean 59.3 [SD 19.73] control: mean 60.3 [SD 18.77])	In comparison with standard educational tools, using an app to actively educate patients with subdivided, categorized, and interactive content significantly increased their level of perceived knowledge and satisfaction with the knowledge.	Not Applicable
Skrepnik & Spitzer, 2017	*OA GO* plus Wearable Activity Monitor (n =107) vs Standard care (n = 104)	**OM:** Numeric Pain Rating Scale **Results**: ***Between-group analysis:*** The experimental group experience significantly more improvement than the control group. The least squares mean percentage change in pain is −55.3% (experimental) versus −33.8% (control) (mean difference: −21.5%, 95% CI −37.8 to −5.2; P=.007)	**OM:** Mobility (Steps/Day) **Results**: ***Between-group analysis:*** The experimental group experience significantly more improvement than the control group. The least squares mean change in number of steps per day was 1199 (experimental) vs 467 (control), a mean difference of 732 steps (95% CI 127-1337; P=.03) ***Within-group analysis:***	**OM:** Satisfaction with treatment (Patient Activation Measure-PAM)-13 **Results**: ***Between-group analysis:*** PAM-13 scores improved from baseline to day 90 in both groups. The least squares mean change from baseline was 5.0% in experimental versus 6.9% in control (mean difference –1.9%, 95% CI –6.8% to 3.1%; P=.99). A greater number of experimental group participants (68/104, 65.4%) reported they would be likely or very likely to use the devices compared with patients (36/104, 34.6%) who reported that they would be somewhat likely or not at all likely to do so.	This study shows there is a significant improvement in mobility, reduction in pain and increase satisfaction with the intervention.	Not Applicable

Quasi Experimental Studies (web-based intervention)						
Wang & Urban, 2020	*My Joint Pain* (n = 104) vs Non program users (n = 91)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Health Education Impact Questionnaire (HEIQ) and the OA Quality Indicator (OAQI) questionnaire. **Results**: ***Between-group analysis:*** Between-group (experimental versus control) differences did not show favourable statistical significance in HEIQ. The experimental group demonstrated higher improvements on several items in the OAQI, including appropriate information about self-management, treatment alternatives and the use of NSAIDs (effects and side-effects). ***Within-group analysis:*** There were no significant changes in health education measured by the HEIQ from 12 to 24 months in the experimental group.	The study doesn't show significant improvements in terms of health education, however may help deliver useful information about self-management and appropriate use of pharmacological treatments.	Not Applicable
Nero & Dahlberg, 2017	*Joint Academy* (n = 350)	**OM:** Numerical Rating Scale **Results**: Change in mean numerical rating scale was larger than the minimal clinical difference (5.4 vs 4.1; P<.001).	**OM:** 30-second chair-stand test **Results**: Physical function increased from 10.88 to 13.14 (P<.001)	**OM:** Health-related quality of life (HRQoL; EQ-5D-3L) Self-report difficulty walking and afraid of physical activity due to OA	Findings suggest that participation in the intervention is associated with a clinically relevant decrease in pain and an increase in physical function and HRQoL, as well as a decreasing fear of physical activity.	Not Applicable

				Results: Separate analysis of each dimension of the EQ-5D-3L showed that mobility and pain or discomfort were significantly improved from baseline to follow-up, while changes in self-care, usual activities, and anxiety or depression were not significant. The percentage of participants having walking difficulties decreased from 81.7% (196/240) to 62.1% (149/240; P<.001), those afraid of being physically active decreased from 22.1% (53/240) to 6.7% (16/240; P<.001), and 22.0% (55/250) reported that they had reduced the amount of OA-related medication		
Umapathy & Bennel, 2015	*My Joint Pain* (n = 104) vs Non-users (n = 91)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Self-management (Health Evaluation Impact Questionnaire, HEIQ) and Quality of care (Osteoarthritis Quality Indicator, OAQI) **Results**: ***Between-group analysis:*** With the exception of health service navigation, mean effect sizes from all other HEIQ domains showed a positive trend for the experimental group compared to control, although the differences between groups were not statistically significant.	Findings indicated that the intervention did not improve all aspects of HEIQ or OAQI, but highlighted benefits that included improvements in health-directed activity, positive and active engagement in life, self-monitoring and insights, skill and technique acquisition, and social integration within the HEIQ. Improvements in self-management, lifestyle, physical activity, and	Not Applicable

				Compared to control, the intervention group showed significant improvements in self-management (change scores 15.2% vs 1.7%, P=.001) and weight reduction (change scores 2.5% vs –6.3%, P=.03) measured on the OAQI after 12 months.	weight reduction were observed in the OAQI.	
Quasi Experimental Studies (app-based intervention)						
Dighe & Dabholkar, 2020	*Telephysiotherapy* (n = 33) vs Supervised exercises (n = 31)	**OM:** Numeric Pain Rating Scale **Results**: ***Between-group analysis:*** There is more pain reduction in the experimental group (Mean±SD: 0.66±0.82) than in control group (Mean±SD: 0.86±0.93) however, not statistically significant (p=0.32). ***Within-group analysis:*** Both groups recorded improvement in pain scores from baseline.	**OM:** Western Ontario and McMaster Universities Osteoarthritis Index - WOMAC **Results**: ***Between-group analysis:*** There was no significant difference in WOMAC scores for the experimental group (Mean±SD: 10.68±8.363) compared to the control group (Mean±SD: 12.22±9.45) (p=0.49) ***Within-group analysis:*** Both groups recorded improvement in function.	**OM:** Balance (Single Leg Stance) **Results**: ***Between-group analysis:*** There is significant difference in balance scores for the experimental group (Mean±SD: 33.09±(NR)) compared to the control. group (Mean±SD: 29.67±(NR)) (p=0.00) The experimental group incurred less expenditure than control. The cost expenditure for treatment is (Mean±SD: 1367.±812) in experimental group and (Mean±SD: 2541±1419) in control group.	The study showed more improvements in balance in the intervention group than in the control group. Moreover, there is improvement in pain and functional outcomes associated with the intervention.	The cost expenditure for treatment was lower in experimental group compared to control group.
Smittenaar & Erhart-Hledik, 2017	*Hinge Health Digital Care Program* (n = 41)	**OM:** Knee OA outcome Score (KOOS)-Pain Subscale **Results**: Participants reported clinically significant improvements in the KOOS pain subscale of 16 points (95% CI 12-21, P<.001).	**OM:** KOOS Physical Function Short Form (KOOS-PS) **Results**: Participants reported clinically significant improvements in the KOOS-PS function	**OM:** VAS pain and function **Results**: There is a significant reductions of 57% (mean difference 30, 95% CI 21-38, P<.001) and 51% (mean difference 25, 95% CI 16-33, P<.001) in VAS	Participants' KOOS pain and function scores improved by clinically significant 16 and 10 points, respectively, at the end of the 12-week program. Similarly, VAS pain and stiffness scores improved by clinically significant 58% and 50%	Not Applicable

			subscale of 10 points (95% CI 6-14, P<.001).	knee pain and stiffness, respectively.	at the end of the 12-week program.	
Cohort Studies (web-based intervention)						
Dahlberg & Dell'Isola, 2020	*Joint Academy* (n =637)	**OM:** Numerical Rating Scale **Results**: Pain decreased by -0.43 units (95% CI -0.51, -0.35) and -0.39 units (95% CI -0.43, -0.36) per month for the 24- and 48-weeks respectively.	**OM:** 30 Second Chair Stand Test (30CST) **Results**: Physical function increased by 0.76 repetitions (95% CI 0.64, 0.89) and 0.72 repetitions (95% CI 0.65, 0.79) per month, for the 24- and 48-weeks respectively.	**OM:** Not Applicable **Results**: Not Applicable	Continuously participating in the intervention program for 6 or 12 months was associated with a clinically important decrease in joint pain and increased physical function, in individuals with hip/knee OA.	Not Applicable
Brooks & Beaulieu, 2014	*Therapeutic Exercise Resource Center (TERC)* (n = 65)	**OM:** Modified Short Form Western Ontario and McMaster Universities Osteoarthritis Index (mSF-WOMAC) **Results**: mSF-WOMAC scores decreased (indicating better pain and function) (p < .001; large effect, pr = 0.70) (pr= partial point biserial r)	**OM:** Knee Self-Efficacy Scale (KSES) **Results**: K-SES scores increased (p < .001; large effect, pr = 0.54)	**OM:** World Health Organization Quality of Life scale (WHO-QOL) User Satisfaction **Results**: WHO-QOL physical scores increased (p = .015; medium effect, pr = 0.33) The overall satisfaction score was 3.1 ± 0.5 indicating participants found a high degree of satisfaction with the intervention. The participants reported very positive evaluation of the intervention (94% indicated the website was easy to use; 90% specified the exercise animations were especially helpful).	The study demonstrated the intervention to be both feasible and efficacious in improving clinical outcomes for patients with mild to moderate knee OA. The participants reported improved physical function, pain, quality of life related to physical health, and self-efficacy to perform daily activities.	Not Applicable
A Pilot Randomized Controlled Trial (web-based intervention)						
Murphy & Janevic, 2018	*Engage* Program (n = 38) vs Usual Care (n = 19)	**OM:** Brief Pain Inventory (BPI) **Results**: ***Between-group analysis:***	**OM: :** Modified Short Form Western Ontario and McMaster Universities Osteoarthritis Index – Physical Function (WOMAC-PF)	**OM:** Intervention Feasibility and Acceptability (open-ended questions)	Findings of the study suggest that the intervention is feasible; it was well received by the participants and associated with a small,	Not Applicable

		The mean scores dropped slightly in the experimental group (M(SD) = 2.7(1.9) to 2.2(2.0); effect size=0.04) and increased slightly in the control group (M(SD) = 2.8 (1.5) to 2.9 (2.2); effect size = 0.04)	**Results**: ***Between-group analysis:*** The mean WOMAC–PF score in the experimental group (representing difficulty in daily activities) decreased from M(SD)=21.0(11.1) at baseline to M(SD)=15.3(11.1) at follow-up (effect size=0.01), with a smaller decrease in the control group (from 22.9(9.8) to 18.5(11.3)).	**Results**: Satisfaction was high, 30 of 31 participants attended six sessions.	positive effect on self-reported physical function at the 6-mo follow-up.	
A Pilot Single Arm (Non-Randomized) Experimental Studies (web-based intervention)						
Dahlberg & Grahn, 2016	*Joint Academy* (n = 53)	**OM:** Numeric Rating Scale **Results**: The mean weekly change in pain was –0.074 (95% CI –0.118 to –0.030, P=.002)	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Acceptance **Results**: 33 out of 53 (62.3%) patients voluntarily continued using the program after 6 weeks, utilizing the same weekly instructions.	This study shows that the intervention has the potential to successfully deliver individualized digital treatment.	Not Applicable
Bossen & Veenhof, 2013	*Join2move*	**OM:** Knee Osteoarthritis Outcome Score (KOOS) and the Hip Injury Osteoarthritis Outcome Score (HOOS) **Results**: At 6 weeks, patients did report significantly higher levels of pain compared to the baseline - from 5.3 to 6.6 (p=0.04). After twelve weeks the differences were no longer statistically significant (p=0.5).	**OM:** Short Questionnaire to Assess Health-enhancing Physical Activity (SQUASH) **Results**: Over the twelve week period, the total time spent on PA increased from 1,697 to 2,044 min/week, and the time spent on moderate intensity increased from 323 to 553 minutes a week. These results, did not however, attain statistical significance (p= 0.3 and p=0.43, respectively)	**OM:** Program usage, and User satisfaction (System Usability Scale) were used to assess Feasibility and acceptability **Results**: Overall, 55% (n=11) of the participants completed at least 75% of the program (≥7 week assignments). 70% (n=14) achieved 60% program exposure and 30% (n=6) were exposed to at least 30% of the intervention. Participants perceived the website as an additional motivation to perform physical activity.	Results from this study indicate that Join2move is a plausible, feasible and acceptable program for patients with knee and/or hip OA. Although effectiveness was not proved due to the lack of power, results do indicate that Join2move has the potential to increase physical activity levels in individuals with knee and/or hip OA.	Not Applicable

				However, the interviews also revealed an important usability issue. It became clear that patients were dissatisfied with the rigid character of the intervention.		
A Feasibility Study (app-based intervention)						
Stome & Pripp, 2019	*Vett app*	**OM:** Not Applicable **Results**: Not Applicable	**OM:** Not Applicable **Results:** Not Applicable	**OM:** Acceptability, Utility, and Usability **Results:** Increase in Acceptability (48%), Utility (32%), and Usability (13%)	The study shows that the use of Vett app was feasible and acceptable.	Not Applicable

Table 4. Summary of author co-citation analysis

Authors	Number of articles	Total citations	Norm. citation	Avg. pub. year	Avg. citations	Avg. norm. citations	Total link strength
Dekker, J	4	152	4.00	2016	37.25	1.00	36
Rini, C	3	175	4.94	2017	55.33	1.65	36
Veenhof, C	4	152	4.00	2016	37.25	1.00	36
Dobson, F	4	147	4.22	2018	34.50	1.05	35
Bossen, D	3	126	3.56	2016	41.00	1.19	34
De Bakker, D	2	112	2.74	2016	55.50	1.37	32
Keefe, F	2	70	2.36	2017	32.50	1.18	29
Bennel, K. I.	3	122	3.58	2018	37.67	1.19	27
Abbott, H	2	122	3.58	2018	56.50	1.79	21
Dalwood, A	2	122	3.58	2018	56.50	1.79	21
French, S	2	122	3.58	2018	56.50	1.79	21
Hinman, R	2	122	3.58	2018	56.50	1.79	21
Kasza, J	2	122	3.58	2018	56.50	1.79	21
Dahlberg, L	2	40	1.39	2017	20.00	0.70	16
Erhart-Hledik, J	2	28	1.24	2018	14.00	0.62	16
Hunter, S	2	28	1.24	2018	14.00	0.62	16
Mecklenburg, G	2	28	1.24	2018	14.00	0.62	16
Smittenaar, P	2	28	1.24	2018	14.00	0.62	16
Dickson, C	2	25	0.64	2018	12.50	0.32	14
Fransen, M	2	25	0.64	2018	12.50	0.32	14
Jones, G	2	25	0.64	2018	12.50	0.32	14
Nero, H	2	18	3.89	2019	9.00	1.95	14
Bennell, K	2	53	2.29	2017	26.50	1.94	10
Hunter, D	2	28	1.65	2019	14.00	0.82	6

Note: Norm. citation = Normalized citation (number of citations of a document divided by the average number of citations of all documents published in the same year); Avg. pub. year = Average publication year; Avg. citations = Average citations; Avg. norm. citations = Average normalized citations (the average normalized number of citations received by the documents published by a source, an author, an organization, or a country); Total link strength= Total number of co-citation of an author

Figure legends

Figure 1. PRISMA flow chart

Figure 2. Temporal distributions of publications

Figure 3. A network of co-occurring keywords related to the use of mHealth technology in the management of OA among adults.
Note: 15 keywords were commonly used by researchers investigating mHealth technology for osteoarthritis management. These keywords were grouped into five clusters, connected by 46 links with a total strength of 72, indicating the number of times the keywords were used. The bubbles (nodes) represent various keywords that were used in the included studies, while the connecting lines show the interrelatedness among keywords. A shorter distance between two keywords indicates a stronger interrelatedness. For example, mobile health and mobile apps are closely related. The size of the bubble denotes the weight/significance of the keyword. The font size indicates the frequency of using the keyword. The color of the bubble is determined by the corresponding year of its usage.

Figure 4. A network of co-authorship for publications related to the use of mHealth technology for managing osteoarthritis among adults

Figure 5. A network of author co-citation for publications related to the use of mHealth technology for managing osteoarthritis