Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

International Journal of Osteopathic Medicine 41 (2021) 37–44

Contents lists available at ScienceDirect

International Journal of Osteopathic Medicine

journal homepage: www.elsevier.com/locate/ijosm

Review

Digital health technologies for osteopaths and allied healthcare service providers: A scoping review

C. Mastronardo [a,*], L.S. Muddle [a], S. Grace [b], R.M. Engel [c], A. Fazalbhoy [a]

[a] School of Health and Biomedical Sciences, RMIT University, Melbourne, VIC, 3000, Australia
[b] School of Health and Human Sciences, Southern Cross University, Lismore, NSW, 2480, Australia
[c] Department of Chiropractic, Macquarie University, Sydney, NSW, 2000, Australia

A R T I C L E I N F O

Keywords:
Allied health
Capabilities
Digital health
Limitations
Mobile apps
Technology
Telehealth
Wearables

A B S T R A C T

Background: Digital health technologies are poised to revolutionise the healthcare industry by improving accessibility to services and patient outcomes. The novel coronavirus disease-19 (COVID-19) pandemic has presented unprecedented challenges for the delivery of allied healthcare and has catalysed rapid adoption of telehealth. As such, allied healthcare consumers and providers stand to benefit from the capabilities of the digital health movement, ultimately justifying a scoping review of current and emerging technologies.
Objective: To provide decision makers with up-to-date information on the allied health applications of new and emerging digital health technologies; their evidence of efficacy, scope of use, and limitations.
Methods: A scoping review of the literature was conducted, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews. To synthesise original research, MEDLINE, CINAHL, and EMBASE databases were searched from 2010 to June 2020 and reference lists were examined for randomised control trials analysing the efficacy of these technologies in allied health applications.
Results: A total of 14 articles were included with a focus on common musculoskeletal conditions managed by allied health service providers. Studies were selected for data extraction after abstract and full-text screening by three independent reviewers. The results of this review indicate that telehealth technology effectively monitors and progresses patient care, while mobile health applications provide remote support and enable data collection.
Conclusion: Emerging trends suggest that digital technologies serve as promising adjuncts to allied healthcare. Further research is warranted regarding the safety and efficacy of digital health technologies in this context.

Implications for practice

- Technological advances have revolutionised the allied healthcare service industry;
- Digital health technologies are poised to improve the delivery of healthcare by facilitating greater accessibility, improving healthcare outcomes, and potentially reducing the cost of care; and
- Allied healthcare consumers and providers stand to benefit from the capabilities of the digital health movement, particularly during the novel coronavirus disease-19 (COVID-19) pandemic.

Introduction

The shift towards remote and patient-generated healthcare may allow service providers to better support active self-management of chronic musculoskeletal conditions, monitor and provide timely feedback, and deliver services remotely and to regional areas [1,2]. Never has this been more pivotal than during the novel coronavirus disease-19 (COVID-19) pandemic, where digital health technologies (DHTs) are used to substitute for face-to-face encounters. Although it may be argued that aspects of the clinical encounter (for example efficacy of clinical examination and palpation) are not readily replaceable by DHTs, the use of these technologies presents unparalleled opportunities to overcome access barriers, increase patient engagement, and reduce healthcare costs.

Both providers and consumers stand to benefit from the digital health movement; the use of information and communication technologies to collect and share health information remotely and instantly, overcoming the traditional barriers of distance and time [3]. Technologies including telehealth, wearables, and mobile health (mHealth)

* Corresponding author. 264 Plenty Road, Mill Park, PO Box 71, Bundoora, VIC, 3083, Australia.
E-mail address: chanelle.mastronardo@rmit.edu.au (C. Mastronardo).

https://doi.org/10.1016/j.ijosm.2021.05.002
Received 13 February 2021; Received in revised form 27 April 2021; Accepted 8 May 2021
Available online 17 May 2021
1746-0689/© 2021 Elsevier Ltd. All rights reserved.

applications allow consumers to access information and monitor their own health status, thereby promoting autonomy and informed decision-making. In turn, healthcare providers are given greater access to patient health data to support continuity and quality of care [3].

The allied healthcare industry in Australia includes 21 healthcare professions with expertise in preventing, diagnosing, and treating a range of health conditions and illnesses [4]. The industry itself represents almost 20% of the Australian health workforce and delivers an estimated 200 million health services annually [4]. Consumers are significant drivers of the digital health movement with 88% of Australians aged 18–75 years owning a digital health device and 78% of them using it to track their personal health data [3,5]. According to the World Health Organization (WHO), the increasing popularity and broadening capabilities of DHTs among consumers suggests that healthcare providers will need to innovate and adapt [6]. As such, enterprising healthcare providers are exploring strategies to leverage this technology by incorporating DHTs into their practices. This is reflected in market projections suggesting that over 70% of global healthcare organisations will invest significantly in digital health within the next few years. This includes allied healthcare providers [6].

As telehealth, wearables, and mHealth applications become increasingly available, so does the need for evidence supporting the clinical use of such devices [7]. Important questions arise: (1) how are DHTs being adopted by the patient, allied health provider, and healthcare system as a whole? (2) what aspects of digital health are most effective? (3) what are the outcomes for the patient? and (4) will user-generated data stand up against controls for data quality, safety and reliability? Several small-scale studies have appeared in the literature exploring individual technologies in areas of musculoskeletal care such as exercise rehabilitation, remote consultation (assessment and advice), and biofeedback/physical activity tracking. These studies are yet to be collated and interpreted with an allied healthcare lens to determine their potential uses and limitations within this context. The objective of this review is to identify promising technologies for further research and map the current capabilities of DHTs for allied healthcare purposes.

Methods

Methodological basis

A scoping review was performed to examine the breadth of research activity on DHTs for allied healthcare applications. The review was conducted using methods specified in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement for reporting. The methodological framework was based on the earlier framework by Arskey and O'Malley [8]. This framework outlines a number of steps: (1) identifying a broad research question to search the literature, (2) selecting studies using an inclusion or exclusion criteria based on familiarity with the topic of interest, (3) sorting the extracted data from studies into themes and patterns, and (4) collating key themes and issues.

Data sources

The overall search strategy was designed to capture a wide breadth of literature related to the primary research question guiding this scoping review: *What digital health technologies are available for musculoskeletal care within the allied healthcare industry?* Key questions were formulated regarding the efficacy of current and emerging DHTs. Selected medical subject headings (MeSH) terms and keywords were combined using Boolean operators (e.g. Or, AND). Proceeding with this strategy, a structured literature search was conducted using three scientific databases: MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Excerpta Medica database (EMBASE) to identify relevant studies from 2010 to June 2020.

Search terms

Used include: (1) modalities, physical therapy (MeSH), manual therapy, (2) rehabilitation (MeSH), rehab, (3) mobile applications (MeSH), mobile device, (4) telemedicine (MeSH), telehealth, (5) allied health occupation (MeSH), physiotherapist, osteopathic medicine, chiropractic, (6) remote monitoring (MeSH), clinical decision support systems. The detailed search strategy used for the database MEDLINE has been provided as an example (Appendix 1).

Eligibility criteria

All studies retrieved through the search strategy were screened using the following inclusion criteria: (1) reported on common musculoskeletal conditions seen by allied health practitioners, (2) utilised DHTs for the purpose of remote treatment/management or to supplement face-to-face treatment, (3) published in English, and (4) published between 2010 and June 2020. Studies were excluded if they did not report the use of DHTs, reported on health conditions not commonly managed by allied health practitioners, particularly manual therapists, did not facilitate remote access to the digital health technology, were editorials or reviews for editorials, epidemiological studies, and protocols or feasibility studies, or if full texts were unavailable. Screening of reference lists with a focus on systematic reviews was also conducted.

Identifying relevant studies

A two-stage screening process was developed and employed by the authors. All search results were initially imported to an EndNote X8 library accessible to all reviewers. AF reviewed all titles and abstracts identified by the searches and CM then independently reviewed all titles and abstracts. Full-text articles were then further reviewed independently by both reviewers and any conflicts were resolved through discussion. If discussions failed to achieve a consensus, LM was available for resolution.

Quality appraisal

Aligning to the guidelines of a scoping review, no formal assessment of methodological quality of the included studies was performed [8].

Data extraction and analysis

An analysis of relevant information on the allied health applications of new and emerging DHTs was performed, with emphasis on their evidence of efficacy, scope of use, and limitations. A technology category system was developed consisting of two technology categories utilised in a previous environmental scan for DHTs conducted as part of the 'Strategic plan for the osteopathy profession 2030': (1) telehealth (n = 6); and (2) wearables and mHealth applications (n = 8). These technology categories were identified via the environmental scanning process as the most relevant, popular, and accessible among consumers, yet their allied healthcare applications were not fully elucidated in current research. Studies were categorised into this system by AF and CM. Within these categories, included studies reported on DHTs for (1) common musculoskeletal conditions seen by allied health practitioners, and (2) the purpose of remote treatment/management or to supplement face-to-face treatment. Types of DHTs with potential applications for the management of musculoskeletal conditions included those in subcategories such as remote consultation (assessment and advice), exercise rehabilitation, and biofeedback/physical activity tracking.

Results

Search results

A total of 8743 articles were retrieved for this review from both databases and hand searching. After removing duplicates, 6165 remained for title screening. A total of 6108 were excluded (3757 not musculoskeletal; 2124 not technology; 122 qualitative; 62 protocol and feasibility studies; 43 gaming for rehabilitation). A remainder of 57 articles underwent full-text screening, with 43 then excluded (13 not musculoskeletal; 3 not technology; 5 qualitative; 17 protocol and feasibility studies; 5 gaming for rehabilitation), leaving a total of 14 articles to be included (Fig. 1). A complete list of all included studies can be found in Tables 1 and 2.

Technology categories

Several studies were analyzed within the two broad categories: telehealth and mHealth/wearables. An overview of the distribution of included studies in terms of technology categories and subcategories is presented in Table 3.

Telehealth

The most widely researched technology category is telehealth technology ($n = 8$) for the purposes of exercise rehabilitation ($n = 5$), remote consultation ($n = 2$), and clinician training ($n = 1$). Five studies described the use of telehealth technology for providing post-trauma/operative exercise rehabilitation [9–13], two studies examined the use of telehealth technology for facilitating remote consultation/assessment/advice for musculoskeletal pain [14,15], and one study examined the practical applications of telehealth technology for providing injury prevention training to clinicians [16] (Tables 1 and 3). Of these, two focused on general musculoskeletal pain [9,14], two on knee osteoarthritis [11,12], one on knee pain [10], one on lower back pain [15], one on recovery post total knee arthroscopy [13], and one on falls risk [16]. Telephone consults were an interventional component in all studies; the next most common being interactive virtual technology (IVT) and computer-based modules. The approach and constitution of telehealth teams varied between studies: some provided virtual physiotherapy alone [9,12–14], while others involved additional 'health coaching' [11,15] or 'pain coping skills training' [10]. Some interventions were delivered by a single group of practitioners [9,10,12–15], while others involved a multidisciplinary team of clinicians trained in health coaching and pain management [11].

Studies involving exercise rehabilitation and remote consultation had mixed results. Positive outcomes for patients with musculoskeletal pain/injury were represented by patient-reported decreases in pain and improved function above that observed with conventional physiotherapy alone [9,15] or internet-based educational materials [10]. In contrast, two studies [13,14] found equivalent benefits in these measures when compared to conventional physiotherapy alone, while another two studies [11,12] found no significant improvement in these measures with the addition of telephone-based intervention or coaching. Furthermore, one study noted a reduction in patient satisfaction with the telephone-based alternative to conventional physiotherapy, despite

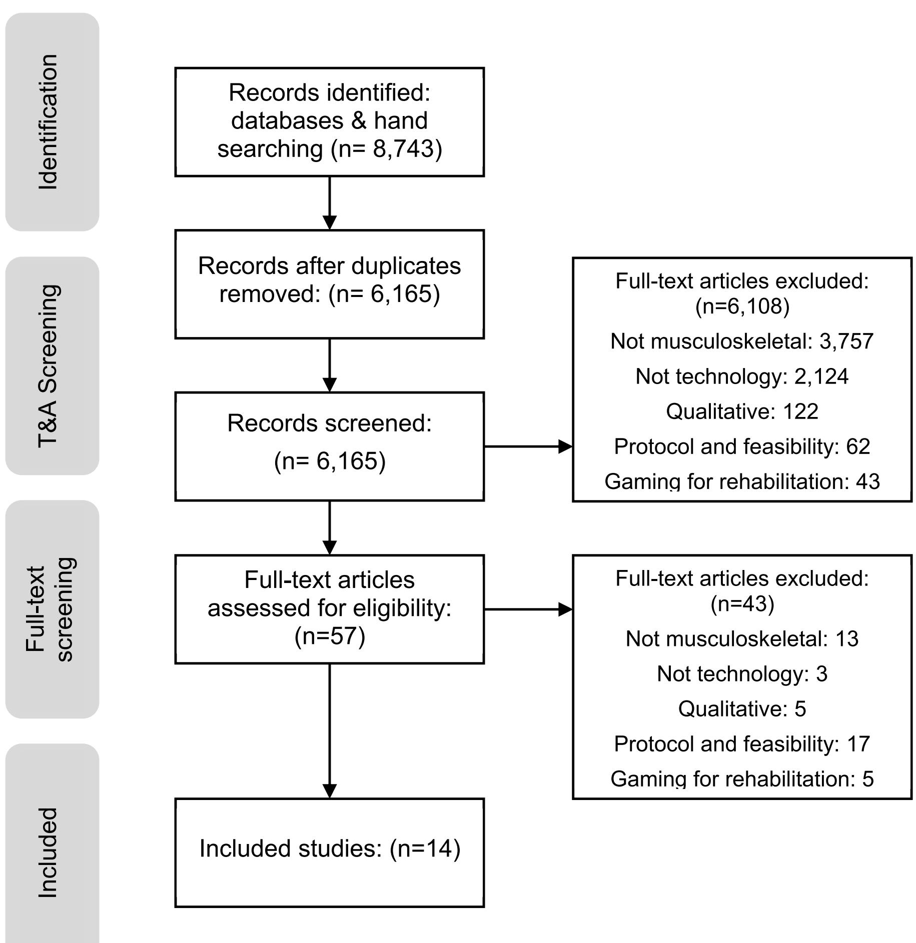

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. T&A: title and abstract.

Table 1
Summary of studies utilising telehealth.

Study identifiers: First author (year), category/ subcategory (sample size) [reference]	Study purpose	Intervention characteristics	Outcomes
Adhikari et al. (2020), telehealth/exercise rehabilitation ($n = 15$) [9]	• Telephone-based physiotherapy for the management of musculoskeletal pain of various origins in rural patients, compared with conventional physiotherapy	• Weekly telephone consults with a physiotherapist to educate, correct, modify, and progress exercises over 4 weeks	• Significant reduction in pain caused by various musculoskeletal problems with the addition of telephone physiotherapy
Bennell et al. (2012), telehealth/exercise rehabilitation ($n = 168$) [11]	• Telephone-based physiotherapy with/without coaching for physiotherapist-prescribed home-based physical activity program for knee osteoarthritis	• Five consults with a physiotherapist over 6 months for education, home exercise, and physical activity advice • Additional 6–12 telephone coaching sessions with clinicians trained in behavioral-change support for exercise and physical activity	• No significant improvements in pain and function with the addition of telephone coaching to the physiotherapist-prescribed home-based physical activity program
Bennell et al. (2017), telehealth/exercise rehabilitation ($n = 148$) [10]	• Telehealth-based physiotherapy for home-based exercise rehabilitation and pain coping skills training (PCST) for chronic knee pain, compared with internet-based educational material	• Seven videoconferencing (Skype [Microsoft]) sessions with a physiotherapist for home exercise and a PCST program over 3 months	• Clinically meaningful improvements in pain and function that are sustained for at least 6 months
Iles et al. (2011), telehealth/remote consultation ($n = 26$) [15]	• Telephone coaching in addition to usual physiotherapy for non-chronic low back pain and low to moderate recovery expectations	• Five telephone coaching sessions with a physiotherapist trained in health coaching techniques in addition to usual physiotherapy over 12 weeks	• Clinically important improvements in activity and recovery expectation with the addition of telephone coaching
Maloney et al. (2011), telehealth/remote consultation training ($n = 135$) [16]	• Telehealth-delivered training on exercise prescription for falls prevention for physiotherapists, exercise physiologists, nurses, and occupational therapists, compared to face-to-face training	• Seven hours of telehealth-delivered training modules provided over 4 weeks, compared with a 1-day face-to-face training seminar with additional video and written support material	• Equivalent results were seen with telehealth-delivered and face-to-face approaches
Odole et al. (2013), telehealth/exercise rehabilitation ($n = 50$) [12]	• Telephone-based physiotherapy for the management of knee osteoarthritis, compared with conventional physiotherapy	• Thrice weekly telephone consults with a physiotherapist to monitor self-administered osteoarthritis-specific exercises over 6 weeks	• No significant improvements in pain and function with the addition of telephone physiotherapy compared with conventional physiotherapy
Piqueras et al. (2013), telehealth/exercise rehabilitation ($n = 142$) [13]	• Interactive virtual tele-rehabilitation (IVT) program for recovery post total knee arthroplasty, compared with conventional physiotherapy	• Ten IVT sessions (5 physiotherapist-led and 5 independently performed) over 2 weeks post-surgery	• As effective as conventional physiotherapy for improving pain and function
Salisbury et al. (2013), telehealth/exercise rehabilitation ($n = 1506$ for PhysioDirect & $n = 743$ usual care) [14]	• Clinical effectiveness, effect on waiting times, and patient acceptability of PhysioDirect services in patients with musculoskeletal problems, compared with usual care	• Initial telephone consult with a physiotherapist for initial assessment and advice with/without follow-up conventional physiotherapy consults	• Comparable effectiveness and safety with reduced waiting times compared with usual care, however slightly reduced patient satisfaction

effectiveness being comparable [14].

Additionally, one study found that telehealth-delivered and face-to-face training modules produced equivalent results for allied healthcare professionals (physiotherapists, exercise physiologists, nurses, and occupational therapists) completing falls prevention training [16].

mHealth/wearables

Six studies examined the use of mHealth applications and wearable technology for the purposes of exercise rehabilitation ($n = 2$), remote mobility/activity monitoring ($n = 2$), and pain management for musculoskeletal issues ($n = 2$). Two studies described the use of mHealth applications/wearables for providing exercise rehabilitation for lower back pain [17] and upper/lower limb musculoskeletal complaints [18], two studies examined the accuracy of these technologies for remote mobility/activity monitoring for both healthy individuals [19] and those post neurosurgical intervention [20], and two studies determined the effectiveness of these technologies in managing pain associated with non-specific chronic low back pain [21,22] (Tables 2 and 3). Wearable devices paired with Smartphone mHealth applications were an interventional component in all studies, excluding those specific applications (Kaia app & Pain Care) which were unpaired. The approach and constitution of these studies varied: those for exercise rehabilitation either directly coached patients (by a virtual physiotherapist) [17] or provided them with a resource for performing exercises [18]. Those for remote mobility/activity monitoring both utilised off-the-shelf activity sensors to monitor both patients and healthy individuals, and those for pain management employed specialised applications with or without additional conventional physiotherapy [21,22], respectively.

Studies involving exercise rehabilitation showed improved adherence and functional outcomes and reduced rate of care-seeking when compared to paper handouts with exercises [18], yet no significant improvements were identified above those provided by conventional physiotherapy [17]. Studies determined that activity sensors accurately recorded and wirelessly transmitted information regarding patient mobility [19,20], however mHealth applications were more precise than wearables by a significant margin thus calling into question their accuracy and reliability. Finally, studies found that the use of pain management applications significantly reduced pain and improved self-efficacy when used both alongside conventional physiotherapy and alone [21,22], respectively.

Discussion

This scoping review sought to analyse the current available evidence on the use of DHTs for allied healthcare applications. We found a limited number of full-scale randomised trials testing these interventions (1) against related allied healthcare modalities outside of physiotherapy such as occupational therapy, exercise physiology, and osteopathy, and (2) for outcomes relevant to allied healthcare other than pain and function, such as treatment reliance, cost-effectiveness, patient self-efficacy and overall satisfaction. Despite numerous forecasted benefits of DHTs within allied healthcare service provision, published research to this end remains sparse. Overall, our results draw attention to the potential benefits and limitations of these technologies and highlight gaps in the knowledge base.

Table 2
Summary of studies utilising wearables and mHealth applications.

Study identifiers: First author (year), category/ subcategory (sample size) [reference]	Study purpose	Intervention characteristics	Outcomes
Amorim et al. (2019), mHealth/ wearables ($n = 68$) [17]	• mHealth application (IMPACT app)-supported coaching for patient-centered physical activity intervention for chronic low back pain, compared with conventional physiotherapy	• Twelve mHealth coaching consults with a physiotherapist following an initial face-to-face assessment, supported by a Fitbit activity tracker and paired internet-based mobile application over 6 months	• Reduced rate of care-seeking yet no significant improvements in pain and function compared with conventional physiotherapy
Appleboom et al. (2015), mHealth/ wearables ($n = 27$) [20]	• Off-the-shelf activity sensors (FitBit Zip) to remotely monitor patient postoperative mobility following neurosurgical intervention, compared with direct observation	• Total steps recorded using several Fitbit Zip devices at various body locations compared with those counted by two blinded researchers	• Activity sensors accurately recorded and wirelessly transmitted information regarding patient mobility, albeit with a slight underestimation bias in more debilitated patients
Case et al. (2015), mHealth/ wearables ($n = 14$) [19]	• Comparison of 10 activity sensors (pedometers, accelerometers, wearables, mHealth apps) to remotely monitor mobility in healthy individuals, compared with direct observation	• Total steps (up to 1500) recorded on a treadmill using 10 different devices compared with those counted by a blinded researcher	• mHealth apps accurately recorded step counts (small relative difference in mean step count) while wearables showed greater variability
Lambert et al. (2017), mHealth ($n = 77$) [18]	• mHealth application for home-based exercise program for upper and lower limb musculoskeletal complaints, compared with hard-copy handouts	• Four-week home-based exercise program delivered using physiotherapyexercises.com, with supplementary telephone calls and motivational text messages	• Significant improvement in adherence and functional outcomes with the use of an app with remote support compared to paper handouts
Toelle et al. (2019), mHealth ($n = 101$) [21]	• Multidisciplinary mHealth back pain application (Kaia App) for the management of non-specific lower back pain (6 weeks–1 year), compared with conventional physiotherapy	• Three months access to Kaia App, compared with 6 physiotherapy consults over 6 weeks with supplementary online education materials	• Significantly lower pain intensity rating with the use of Kaia App compared with conventional physiotherapy
Yang et al. (2019), mHealth ($n = 8$) [22]	• mHealth pain application (Pain Care) plus conventional physiotherapy for the management of chronic lower back pain (>3 months), compared with conventional physiotherapy alone	• Four weeks of conventional physiotherapy plus a self-management program delivered via Pain Care app	• Significant improvements in pain, self-efficacy and mental health with the use of Pain Care app compared with conventional physiotherapy alone

Table 3
Technology categories with included studies.

Category	Subcategory	Definition	Included studies
Telehealth	Exercise rehabilitation	The provision of exercises for the purpose of post-trauma/operative rehabilitation or injury prevention	[9–13]
	Remote consultation (assessment and advice)	The provision of assessment and advice for the management of musculoskeletal pain and dysfunction	[14,15]
	Clinician training	The provision of training modules for the purpose of educating clinicians in injury prevention/ management	[16]
Wearables and mHealth applications	Exercise rehabilitation	As above	[17,18]
	Remote consultation (assessment and advice)	As above	[21,22]
	Biofeedback/ physical activity tracking	The collection of data on body position and physical activity for the management of musculoskeletal pain and dysfunction	[19,20]

Practical considerations for implementing digital health technologies

In considering implementation, our results demonstrated that DHTs have the potential to facilitate accurate remote assessment and activity monitoring, and provide effective patient exercise rehabilitation and clinician training. Overall, this translates to improved outcomes for patients with musculoskeletal issues seeking allied healthcare, typically equal to or in some cases above those outcomes achieved with conventional therapies. Given the current healthcare climate, knowing that allied healthcare services may be delivered just as effectively at a distance provides support for the rapid changes to the provisions of care resulting from the novel coronavirus disease-19 (COVID-19) pandemic. The numerous applications of DHTs in allied health, coupled with their widespread use and user-friendly enhancements, have created an optimal environment for their implementation. However, the use of DHT's in allied health is not straightforward. There are significant barriers for their use which must be considered. These include views about their pervasive nature, limited training and support, available infrastructure, accessibility issues, and inconsistencies in data accuracy and reliability.

Digital health training and support for consumers

Included studies did not report any preparatory training or digital health support service for participants in the use of DHTs. Furthermore, access to participant resources including how-to guides and/or troubleshooting materials were not explicitly mentioned. While this may not be necessary for those studies utilising conventional telephone-based interventions [9,11,12,14,15], other studies involved the use of more advanced technologies including videoconferencing platforms [23] and interactive virtual tele-rehabilitation (IVT) systems [13]. Assuming a greater level of participant prior knowledge and skill with technology, these studies reported no major problems or complaints from participants regarding the use of more advanced technologies. Similarly, those studies utilising mHealth applications and wearables reported high compliance and minimal technical difficulties among participants, suggesting a significant degree of user-friendliness [17,20–22]. Given that participant ages, backgrounds and level of technological skill/aptitude were not well elucidated overall, sufficient training and support should be an important consideration when interpreting the results of such studies and designing future trials.

Digital health infrastructure

When considering implementing DHTs into allied healthcare practices, sufficient infrastructure and technical support is necessary, particularly to facilitate uptake by rural/remote populations and those with limited technology exposure such as older adults. It was often unclear whether there were any infrastructure issues included in the studies, such as technical difficulties with the devices, connectivity deficits, or interoperability problems. Therefore, explicit reporting of these factors in future studies may assist towards addressing this.

Digital health access

The successful implementation of DHTs into allied healthcare hinges upon finding solutions to improve access equality and thereby reduce the digital divide between consumers. Some studies excluded participants who did not have access to the required devices, others provided the necessary hardware to participants [19,20] or required them to download free mHealth applications [21,22]. Exclusion of certain categories of participants reflects larger issues surrounding marginalisation of under-equipped populations from rural/regional or low socioeconomic areas. In order for allied health services to optimise provision of these services in Australia, it is imperative that costs associated with such devices and the location of users be adequately considered.

Data accuracy and reliability

Studies examining the use of mHealth applications and wearable devices for biofeedback and activity tracking produced variable results. Overall, mHealth applications were more precise than wearables by a significant margin [19,20], thus calling into question their accuracy and reliability within a healthcare context. Furthermore, comparisons between various fitness wearables showed significant (25% error margin) variations in accuracy between devices, suggesting a lack of inter-device reliability [19]. While medical-grade devices are designed to record medically reliable data for healthcare providers, more accessible consumer wearables used in the included studies (FitBit and FitBit Zip) typically collect data using trends and algorithms designed and dictated by the preferences of various medical, sporting, and fitness professionals, making the data difficult to validate. As such, the future implementation and benefit of such devices in allied healthcare necessitates further investigation.

Future directions

A promising area of results for this review is the use of DHTs to assist with chronic pain management and pain education/coaching. Across the healthcare landscape, self-management of chronic pain is considered a priority area as the incidence of chronic diseases continues to rise and existing resources become overwhelmed [10–12,17]. For those with chronic musculoskeletal conditions, self-management necessitates proactive patient involvement, disease surveillance, and ongoing care/-maintenance [24]. While theoretically these could be provided with the use of DHTs by allied healthcare providers, included studies showed no improvement of outcomes (e.g. pain or function) for chronic musculoskeletal conditions beyond those achieved with conventional therapies. However, studies showed patient reliance was reduced with the addition of pain coaching [11,15]. This area of research may be of particular relevance for allied health professions, who increasingly service those individuals with pain associated with chronic musculoskeletal conditions and comorbidities. As such, future research priorities could include the applications of DHTs in the field of modern pain science. We recommend a study in the osteopathy profession measuring the implementation of DHTs (such as telehealth technology, wearables, and mobile applications) in chronic pain management, pain coaching, and patient reliance. We also recommend further studies measuring the accuracy, safety and feasibility of utilising DHTs for long-term disease surveillance and management for those individuals with chronic musculoskeletal conditions managed by osteopaths and other related healthcare professions. Furthermore, the osteopathy profession must strategically plan for the coming of new and emerging DHTs when considering the practice of the future. We recommend that technology be a significant research priority within the profession.

Limitations

In our attempt to focus on studies that were directed towards common musculoskeletal conditions often seen by allied health professionals, some studies may have been overlooked or excluded due to our search parameters. This is despite utilising a rigorous search strategy that was developed and refined to yield a breadth of studies. Whilst we used relevant journal databases and hand searched references for inclusion, we did not contact experts in the field to enquire about key studies or projects that should be included for review. Finally, as per scoping review methodology, no quality appraisal was conducted on included studies to ensure a broad overview of evidence was achieved.

Conclusion

In conclusion, DHTs are poised to facilitate the delivery of allied healthcare services and may potentially improve patient outcomes equally or above that achieved by conventional therapies. As such, allied healthcare consumers and providers stand to benefit from the capabilities of digital health platforms including telehealth technology, wearable health devices, and consumer-facing mobile apps. While several barriers exist regarding the implementation of these technologies into practice, this review has highlighted several promising applications and future directions for these technologies within allied healthcare. For future technological advancement, we strongly recommend further randomised trials to test these technologies against a breadth of allied healthcare modalities and outcome measures. Furthermore, researchers should account for implementation barriers such as accessibility and data reliability in their study designs in order to facilitate equality of care.

Funding statement

CM is a Research Assistant employed through RMIT University and supported by a research grant from Osteopathy Australia. LM is supported by an academic appointment as a Lecturer in the Discipline of Osteopathy, School of Health and Biomedical Sciences, RMIT University. RE is supported by an academic appointment as a Senior Lecturer in the Department of Chiropractic at Macquarie University. SG is supported by and academic appointment as Professor at the School of Health and Human Sciences, Southern Cross University. AF is supported by an academic appointment as a Discipline Leader, Senior Lecturer in the Discipline of Osteopathy, School of Health and Biomedical Sciences, RMIT University. This research was supported by a research grant (grant number RE-03425-101) from Osteopathy Australia.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analyzed.

Authors' contributions

Relevant information was acquired by CM who drafted an initial environmental scan report. Eligible research papers for the scoping review were identified and screened by AF with contributions by CM. Relevant information, in addition to its conception and design, were contributed by LM, SG and RE.

Declaration of competing interest

The authors declare that they have no competing interests. RE is an Associate Editor of the *International Journal of Osteopathic Medicine* but had no role in the review process or decision to publish this manuscript.

Acknowledgements

This work was carried out as part of a research project conducted by RMIT University entitled 'Strategic plan for the osteopathy profession 2030'. Within this project, a Steering Committee featuring current leaders in the field determined that an understanding of emerging technologies was essential for the future of osteopathy and allied health in Australia. As such, we would like to acknowledge the Steering Committee for their contribution.

APPENDICES.

Appendix 1. Search strategy

(Rehabilitation [MeSH Terms])) OR (rehab*[Title/Abstract])) OR (manual therapy [MeSH Terms])) OR (modalities, physical therapy [MeSH Terms])) OR (Physical health [Title/Abstract])) AND (Mobile Applications [MeSH Terms]))) OR (cell phones [MeSH Terms])) OR (Computers, Handheld [MeSH Terms])) OR (app [Title/Abstract])) OR (apps [Title/Abstract])) OR (application*[Title/Abstract])) OR (technology [Title/Abstract])) OR (platform*[Title/Abstract])) OR (computer program*[Title/Abstract])) OR (software [Title/Abstract])) AND (smartphone*[Title/Abstract])) OR (phone [Title/Abstract])) OR (phones [Title/Abstract])) OR (tablet*[Title/Abstract])) OR (handheld* [Title/Abstract])) OR (iphone*[Title/Abstract])) OR (ipad*[Title/Abstract])) OR (android*[Title/Abstract])) OR (mobile app*[Title/Abstract])) OR (mobile technolog*[Title/Abstract])) OR (mobile device* [Title/Abstract])) OR (mobile comput*[Title/Abstract])) OR (wearable [Title/Abstract])) OR (clinical decision support systems [MeSH Terms])) OR (telemedicine [MeSH Terms])) OR (telemedicine [Title/Abstract])) OR (telemonitor [Title/Abstract])) OR (remote monitor* [Title/Abstract])) OR (telehealth [Title/Abstract])) OR (mobile health [Title/Abstract])) OR (ehealth [Title/Abstract])) OR (mhealth [Title/Abstract])) OR (connected health [Title/Abstract])) AND (allied health personnel [MeSH Terms])) AND (allied health occupation [MeSH Terms])) OR (physical therapist [MeSH Terms])) OR (physiotherapy [Title/Abstract])) OR (osteopathic medicine [Title/Abstract])) OR (chiropractic [Title/Abstract])) OR (chiropractor [Title/Abstract])

References

[1] Topol E, Steinhubl S, Torkamani A. Digital medical tools and sensors. J Am Med Assoc 2015;313(4):353. https://doi.org/10.1001/jama.2014.17125.

[2] Kumar S, Nilsen W, Abernethy A. Mobile health technology evaluation: mHealth evidence workshop. AJPM 2013;45(2):228. https://doi.org/10.1016/j.amepre.2013.03.017.

[3] AIHW. Australia's Health 2018. Retrieved 20 June 2019, from, https://www.aihw.gov.au/getmedia/fe037cf1-0cd0-4663-a8c0-67cd09b1f30c/aihw-aus-222.pdf.aspx?inline=true; 2019.

[4] AHPA. Increasing access to allied health telehealth services. Retrieved 20 June 2019, from, https://ahpa.com.au/wp-content/uploads/2017/09/170531-Telehealth-Position-Statement.pdf; 2018.

[5] GSHM. The global smart healthcare market report 2018-2022. Retrieved 27 June 2019, from, https://www.technavio.com/blog/top-5-healthcare-technologies-changing-global-smart-healthcare-market; 2018.

[6] WHO. A national telehealth strategy for Australia. Australian National Consultative Committee on Electronic Health; 2018. Retrieved 27 June 2019, from, https://www.who.int/goe/policies/countries/aus_support_tele.pdf.

[7] Bhavnani S, Narula J, Sengupta P. Mobile technology and the digitization of healthcare. Eur Heart J 2016;37(18):1428–38. https://doi.org/10.1093/eurheartj/ehv770.

[8] Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol 2005;8(1):19–32. https://doi.org/10.1080/1364557032000119616.

[9] Adhikari S, Shrestha P, Dev R. Feasibility and effectiveness of telephone-based telephysiotherapy for treatment of pain in low-resource setting: a retrospective pre-post design. Pain Res Manag 2020;2020:1–7. https://doi.org/10.1155/2020/2741278.

[10] Bennell K, Campbell P, Egerton T, Metcalf B, Kasza J, Forbes A, et al. Telephone coaching to enhance a physiotherapist-prescribed home-based physical activity program for knee osteoarthritis: a randomised clinical trial. Osteoarthritis Cartilage 2016;24:S44–5. https://doi.org/10.1016/j.joca.2016.01.105.

[11] Bennell K, Egerton T, Bills C, Gale J, Kolt G, Bunker S, et al. Addition of telephone coaching to a physiotherapist-delivered physical activity program in people with knee osteoarthritis: a randomised controlled trial protocol. BMC Muscoskel Disord 2012;13(1). https://doi.org/10.1186/1471-2474-13-246.

[12] Odole A, Ojo O. A telephone-based physiotherapy intervention for patients with osteoarthritis of the knee. Int J Telerehabilitation 2013;5(2):11–20. https://doi.org/10.5195/ijt.2013.6125.

[13] Piqueras M, Marco E, Coll M, Escalada F, Ballester A, Cinca C, et al. Effectiveness of an interactive virtual telerehabilitation system in patients after total knee arthoplasty: a randomized controlled trial. J Rehabil Med 2013;45(4):392–6. https://doi.org/10.2340/16501977-1119.

[14] Salisbury C, Montgomery A, Hollinghurst S, Hopper C, Bishop A, Franchini A, et al. Effectiveness of PhysioDirect telephone assessment and advice services for patients with musculoskeletal problems: pragmatic randomised controlled trial. BMJ 2013; 346(jan29 3). https://doi.org/10.1136/bmj.f43. f43-f43.

[15] Iles R, Taylor N, Davidson M, O'Halloran P. Telephone coaching can increase activity levels for people with non-chronic low back pain: a randomised trial. J Physiother 2011;57(4):231–8. https://doi.org/10.1016/s1836-9553(11)70053-4.

[16] Maloney S, Chamberlain M, Morrison S, Kotsanas G, Keating J, Ilic D. Health professional learner attitudes and use of digital learning resources. J Med Internet Res 2013;15(1):e7. https://doi.org/10.2196/jmir.2094.

[17] Amorim A, Pappas E, Simic M, Ferreira M, Jennings M, Tiedemann A, et al. Integrating Mobile-health, health coaching, and physical activity to reduce the burden of chronic low back pain trial (IMPACT): a pilot randomised controlled trial. BMC Muscoskel Disord 2019;20(1). https://doi.org/10.1186/s12891-019-2454-y.

[18] Lambert T, Harvey L, Avdalis C, Chen L, Jeyalingam S, Pratt C, et al. An app with remote support achieves better adherence to home exercise programs than paper handouts in people with musculoskeletal conditions: a randomised trial. J Physiother 2017;63(3):161–7. https://doi.org/10.1016/j.jphys.2017.05.015.

[19] Case M, Burwick H, Volpp K, Patel M. Accuracy of smartphone applications and wearable devices for tracking physical activity data. J Am Med Assoc 2015;313(6):625. https://doi.org/10.1001/jama.2014.17841.

[20] Appelboom G, Taylor B, Bruce E, Bassile C, Malakidis C, Yang A, et al. Mobile phone-connected wearable motion sensors to assess postoperative mobilization.

JMIR Mhealth And Uhealth 2015;3(3):e78. https://doi.org/10.2196/mhealth.3785.

[21] Toelle T, Utpadel-Fischler D, Haas K, Priebe J. App-based multidisciplinary back pain treatment versus combined physiotherapy plus online education: a randomized controlled trial. Npj Digital Medicine 2019;2(1). https://doi.org/10.1038/s41746-019-0109-x.

[22] Yang J, Wei Q, Ge Y, Meng L, Zhao M. Smartphone-based remote self-management of chronic low back pain: a preliminary study. Journal Of Healthcare Engineering 2019;2019:1–7. https://doi.org/10.1155/2019/4632946.

[23] Bennell K, Nelligan R, Dobson F, Rini C, Keefe F, Kasza J, et al. Effectiveness of an internet-delivered exercise and pain-coping skills training intervention for persons with chronic knee pain. Ann Intern Med 2017;166(7):453. https://doi.org/10.7326/m16-1714.

[24] Bird M, Li L, Ouellette C, Hopkins K, McGillion M, Carter N. Use of synchronous digital health technologies for the care of children with special health care needs and their families: scoping review. JMIR Pediatrics And Parenting 2019;2(2):e15106. https://doi.org/10.2196/15106.