CO-CREATION OF A PERSON-CENTRED INTEGRATED DIGITAL HEALTH MODEL OF CARE FOR FRAGILITY HIP FRACTURES: A MIXED METHODS PRAGMATIC RESEARCH

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LIST OF SCHOLARLY ACTIVITY

List of Publications

Yadav, L., Haldar, A., Jasper, U., Taylor, A., Visvanathan, R., Chehade, M., & Gill, T. (2019). Utilising Digital Health Technology to Support Patient-Healthcare Provider Communication in Fragility Fracture Recovery: Systematic Review and Meta-Analysis. *Int J Environ Res Public Health,* 16(20), 4047. Retrieved from https://www.mdpi.com/1660-4601/16/20/4047

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THESIS DECLARATION- STATEMENT OF ORIGINALITY

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide.

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LIST OF ABBREVIATIONS

3D	Three-Dimensional
ADL	Activity of Daily Living
AI	Artificial Intelligence
AIHS	American Interprofessional Health Collaborative
AMSEC	Australian Musculoskeletal Education Collaboration
AQoL 8D	Assessment of Quality of Life 8 Dimensions
AUD	Australian Dollar
BCW	Behaviour Change Wheel
BJD	Bone and Joint Decade
BMD	Bone Mineral Density
CALHN	Central Adelaide Local Health Network
CALO-RE	Coventry, Aberdeen and London-Redefined
CIHC	Canadian Interprofessional Health Collaborative
CINAHL	Cumulative Index to Nursing and Allied Health Literature
CME	Continuing Medical Education
COPD	Chronic Obstructive Pulmonary Disease
CORE	Clinically Organised Relevant Exam
COREQ	Consolidated Criteria for Reporting Qualitative Studies
COVID-19	Coronavirus Disease 2019
CRE	Centre for Research Excellence
DHH	Digital Health Hub

DSTs	Decision Support Tools
DVT	Deep Vein Thrombosis
DXA	Dual-energy Absorptiometry
ECHO	Extension of Community Healthcare Outcomes
eHealth	Electronic Health
ePPOC	Electronic Persistent Pain Outcomes Collaboration
FGD	Focus Group Discussion
G-MUSC	Global Alliance for Musculoskeletal Health
GBD	Global Burden of Diseases
GHWN	Global Health Workforce Network
GP	General Practitioner
GSCI	Global Spine Care Initiative
HAT	Home Automated Tele-management
HBCSS	Human Behaviour Change Supporting Systems
HCP	Health Care Provider/Practitioner
HREC	Human Research Ethics Committee
HWF	Health Workforce
i-PARIHS	Integrated-Promoting Action on Research Implementation in Health Services
ICT	Information and Communication Technologies
IDI	In-depth Interview
INT	Intensive
IPCHS	Integrated, People-Centred Health Services

IPE	Interprofessional Education
ISAEC	Interprofessional Spine Assessment and Education Clinics
JBI	Joanna Briggs Institute
JBI SUMARI	Joanna Briggs Institute Systems for the Unified Management, Assessment and Review of Information
LBP	Low Back Pain
LMIC	Low- and Middle-Income Country
LMS LoS	Learning Management System Length of Stay
MAPS	Mobile health Assessment and Planning for Scale
MD	Doctor of Medicine
MEDLINE	Medical Literature Analysis and Retrieval System Online
MeSH	Medical Subject Headings
mHealth	Mobile Health
MIN	Minimum
ML	Machine Learning
MoC	Model of Care
MOOCs	Massive Open Online Courses
MRI	Magnetic Resonance Imaging
MSK	Musculoskeletal
Multi-D	Multidisciplinary team
MyHR	My Health Record
NCD	Non-Communicable Diseases

NGO	Non-Governmental Organisation
NHMRC	National Health and Medical Research Council
NHS	National Health Service
NICE	National Institute for Health and Care Excellence
NoF	Neck of Femur
OA	Osteoarthritis
OARSI	Osteoarthritis Research Society International
OPD	Out-patient Department
OR	Odds Ratio
PCEHRs	Personally Controlled Electronic Health Records
PCP	Primary Care Physician
pDHH	personalised Digital Health Hub
PEP	Physical activity Enhancing Program
PEPA	Patient Empowerment and Physician Alerting
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analysis
RAH	Royal Adelaide Hospital
RCT	Randomised Controlled Trials
RGB	Red, Green and Blue
RMO	Resident Medical Officer
ROM	Range of Motion
SA	South Australia
SDGs	Sustainable Development Goals

SF-36	36-items Short Form health survey
SF-MPQ	Short form of the McGill Pain Questionnaire
TLC	Telehealth Liaison Carer
TQEH	The Queen Elizabeth Hospital
U of T	University of Toronto
UN	United Nations
US	United States
USD	United States Dollar
WHO	World Health Organization
WHO-ICOPE	World Health Organization- Integrated Care for Older People
WSC	World Spine Care
XAI	Explainable Artificial Intelligence

ABSTRACT

Hip fracture is among the most devastating events faced by older people. These *fragility fractures* often occur due to trivial or low trauma falls. Current treatment efforts have led to best practice management guidelines and clinical audits at the level of the acute hospital setting and, to a certain extent, immediate post-hospital discharge. However, concerns still exist in the areas of prevention and rehabilitation outcomes including quality of life, and functional independence. Based on emerging evidence, a more nuanced approach is required for future health services delivery which incorporates: 1) musculoskeletal health; 2) increasing burden of multimorbidities; and 3) societal influences and circumstances shaping individual's health literacy including access to digital technology.

The aim of this thesis work is to conduct a program of research focused on establishing a person-centred and integrated model of care for older people with hip fractures assisted by digital health technology and modern educational approaches. The goal is to improve outcomes such as health literacy, access, functional rehabilitation, and quality of life.

Objectives

1. To map out digital health interventions by conducting a comprehensive systematic review, which evaluates the effectiveness of digital health supported targeted patient communication versus usual provision of health information, on the recovery from fragility fractures.

2. To determine different phases of a research program for the development of a digital health hub enabled model of care focused on hip fracture rehabilitation through a dynamic conceptual framework.
3. To understand the perspective of older people with hip fractures, their family members, and residential aged carers, to inform the development of a personalised digital health hub and factors impacting the likelihood of potential usage.
4. To understand the perspectives of clinicians from various medical and surgical disciplines, allied health, and other relevant non-health stakeholders to inform the development of a digital health enabled model of care for fragility fractures.
5. To examine the process and management of innovation, and the strategic directions required to improve musculoskeletal healthcare at macro (policy), meso (service delivery), and micro (clinical practice) levels and discuss the critical role of different stakeholders in driving innovations in healthcare.
6. To describe a vision for future health care to address increasing population multimorbidity through the co-creation of personalised digital health hubs that recognise the importance of patient agency in driving the evolution of health services.

This study emphasises that digital health solutions must be co-created and co-implemented by engaging relevant stakeholders including end consumers at the local contextual level. Developed countries such as Australia are emerging global leaders in contemporary research focused on advancing knowledge and filling gaps within existing health service delivery for older people.

CHAPTER 1

INTRODUCTION

This chapter has been divided into four sections. Section 1.1 provides an overview around fragility hip fractures among older people as an important health issue for South Australia. Section 1.2 explains the rationale for undertaking the research, which is followed by the aims and objectives in Section 1.3. In conclusion, Section 1.4 is the outline and introduction of the remaining thesis chapters.

1.1 Background

The state of South Australia has among its population the second highest number of older people in Australia, next to Tasmania. According to the latest population projections, the number of individuals aged 65 and above in the state will increase to around half a million by 2041. This will account for almost 25% of the total population of the state. In particular, the number of people aged 80 and above is projected to increase by 117% (1), which corresponds to an increase in the burden of non-communicable diseases and the long-term consequences due to ageing (2, 3).

Among non-communicable diseases, musculoskeletal (MSK) conditions represent more than 150 diagnoses affecting the locomotor system, including fractures of the bone. Sound MSK health enables mobility, dexterity, and the ability to actively participate in all aspects of life. This is in turn supports economic, social, and functional independence, as well as human capital across the life course. Deterioration in MSK health contributes to significant loss of productivity resulting in financial insecurity and early retirement (4, 5). The most common presenting complaints with these conditions are pain and reduced physical function which are often accompanied by significant declines in mental health, a greater risk of developing other chronic health conditions, and increased all-cause mortality (5).

The co-occurrence of two or more chronic conditions in an individual is termed as multimorbidity (6-8), and is a concerning phenomenon globally due to people's longer life expectancy (3). More than half of the older population experiences multimorbidity with associated risk factors, the prevalence of which varies from 38-76% in person aged 60-74 years to 76-88% among persons aged 85 years and older (9-11). Those in lower socioeconomic groups have the highest burden (12). MSK conditions are commonly embedded within multimorbidity clusters representing one-third to more than one-half of all non-communicable, multimorbidity disease presentations (5). There are common risk factors shared across MSK and other multimorbid conditions, including a sedentary lifestyle, obesity, and poor nutrition. Moreover, the highest burden of persistent pain across countries and ages is attributable to MSK conditions (13). Chronic pain at the back and neck, osteoarthritis, rheumatoid arthritis, and fractures are among the most disabling conditions experienced (14).

1.1.1 Fragility hip fractures

In older people a low energy trauma, such as a fall from a standing height or less, can result in a *fragility fracture*. This is usually associated with reduced bone density (15) as identified by dual-energy X-ray absorptiometry (DXA) which can be categorised as osteopenia (T-score -1 to -2.5) and osteoporosis (T-score >-2.5), the latter reflecting more severe bone loss or poor bone health. Both categories are recognised as increasingly prevalent conditions that have significant health consequences for individuals who sustain fractures (16, 17).

It is predicted that osteoporosis/osteopenia will increase by 31% in 2022, equating to 6.2 million Australian people over the age of 50 years (17). The direct cost of osteoporosis in Australia in 2017 was estimated to be $3.44 billion (USD 2.77 billion); treatment of fractures accounted for 68% of total direct costs. Overall, 32% of the burden of disease attributable to osteoporosis was due to the cost of management and prevention of further bone loss. This cost estimate does not include indirect costs, such as productivity loss and the impact on disability and quality of life (17).

According to a study in the United States, which predicted the burden of incident osteoporosis-related fractures and costs, hip fractures only accounted for 14% of the total incident burden, but more than 70% of the associated costs (18). Another study reported that the combined health and social care costs in the first year following hip fractures to be $43,669. This is higher than equivalent estimates for ischaemic stroke and acute coronary syndrome (19).

Hip fractures are considered to have the most devastating outcomes due to the complexity associated with the treatment and care. The financial cost of hip fracture management is just one side of the story (20). More than 50% of hip fracture patients are forced into permanent residential aged care within 12 months of sustaining the injury (21). Due to their pre-existing functional and medical vulnerability, some will also require integration with geriatric palliative care (22).

Patient cognition and sarcopenia are additional important variables. An individual with dementia is up to three times more likely than a cognitively intact older adult to sustain a hip fracture (23). Sarcopenia can be defined as the progressive loss of skeletal muscle mass and strength and is usually associated with ageing. It can be found in 17-74% of hip fractures among older people (24).

Frailty is a more generalised multidimensional geriatric syndrome characterised by decline of physical and cognitive reserves that leads to increased vulnerability. Sarcopenia and dementia are therefore often features of frailty. Frailty increases with age and is associated with falls, increased hospital length of stay (LoS), poorer recovery from illness and injury, and increased mortality. Frailty, sarcopenia, osteoporosis, and falls have close links epidemiologically, biologically, and clinically (24).

1.2 Rationale for this thesis

Older people with hip fractures clearly represent a complex patient cohort and optimising outcomes is a major challenge that requires multimodal management. Current treatment efforts have led to best practice hip fracture management guidelines and clinical audits at the level of the acute care and immediate post-hospital discharge. However, concerns still exist in the area of prevention and rehabilitation, including improving quality of life and functional independence post-fracture (24). It is crucial to address fragility hip fractures among older people, including multimorbidity clusters, in a whole-person, integrated manner rather than managing individual conditions in isolation or silos (25).

1.2.1 Rehabilitation and person-centred integrated care

Rehabilitation is the care process involving a unique set of interventions that is needed when a person is experiencing or likely to experience limitations in everyday functioning. These limitations may be physical, mental, and/or social and due to ageing or a health condition, including chronic diseases or disorders, injuries, or trauma (26). These limitations could adversely impact an individual's ability to think, see, hear, communicate, move around, have relationships, retain a job or undertake any other fulfilling life activities (27).

The core goal of rehabilitation is to improve functioning and well-being, yet rehabilitation services are often under resourced, underdeveloped, and undervalued (26). There is a constant rise in the demand for rehabilitation services with as much as 74% of years lived with disability (YLDs) attributable to the failure to provide optimal rehabilitation (3). Rehabilitation is integral to realising the full potential not only for fragility hip fractures but healthcare overall (26).

After surgical intervention, hip fracture recovery is dependent on modifiable determinants which are common with rehabilitation pathways of other MSK conditions and non-communicable diseases (17, 23). If these modifiable determinants, such as diet and physical activity could be tailored around individual needs along with support from family members in the community then improved rehabilitation outcomes are likely to follow (17, 28).

Services also need to provide appropriate assessment of falls risk and bone health along with the implementation of secondary fracture management as required (17).

As previously stated, the management of hip fractures broadly has two components – acute hospital care and community rehabilitation – which both require involvement of several stakeholders including multiple healthcare providers, GPs, allied health, patients, family members, and formal carers (29). In developed countries, management of hip fractures in acute hospital settings has improved disproportionately and become better coordinated over time than rehabilitation. The latter often occurs in community settings where patients and their carers need to navigate and negotiate the varied and complex care options which may not align with best practice evidence (30). Therefore to achieve optimal outcomes among older patients with hip fractures, person-centred and integrated care is essential to address their specific individual needs (31).

To achieve integrated care in older patients, delivery models need to extend beyond traditional clinical approaches and include more holistic and socially based aged care services (21). Patient and carer empowerment is required to navigate this complex landscape and cannot be achieved without an effective education strategy. Often, the supportive information provided is complex and beyond the comprehension of patients and/or their carers. Therefore, it is critical to consider the impact of information delivery on a patient's care pathway and ultimate recovery outcomes (32).

1.2.2 Health literacy

Health literacy has evolved from a poorly recognised 'silent epidemic' to becoming part of discussions involving health policy and major reforms (33, 34). Health literacy comprises a wide range of skills which influence an individual's ability to navigate the healthcare system in alignment with their personal circumstances. This includes reading, writing, numeracy, communication, and use of technology (35).

Adequate health literacy means patients can: 1) express their needs, signs and symptoms, identify appropriate health services and when to seek them; 2) confidently work in partnership with health professionals and navigate complex healthcare processes; and 3) understand health professionals' recommendations and ask questions concerning their anxieties and apprehension (36). Thus, health literacy is the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions (37).

Health professionals often overlook a patient's health literacy during routine practice by incorrectly assuming that the health information and instructions provided to patients and their family members have been understood (38, 39). It has been reported that the average US adult reads at an eighth-grade level. However, more than 75% of the educational materials meant for patients are written at a high school or college reading level (35). Limited health literacy would mean difficulty in reading, understanding, and applying health information. This could include wording on- prescribed medications, food labels, appointments slips, discharge instructions, informed consent process, hospital admission and medical forms, insurance applications, medical bills, interpretation of pathology and other investigative reports, and health education materials (35).

Any rehabilitation intervention strategy could be severely compromised if the health professionals have difficulty in communicating with patients who are limited by their ability to understand, evaluate, and communicate (36). The process of rehabilitation is closely linked to health literacy through the capacities, functioning, participation, and empowerment of patients in their everyday lives. Rehabilitation should ideally be considered a holistic and person-centred approach to teach patients about new methods to enhance their abilities or adapt their daily activities (36). Moreover, equitable access to rehabilitation services must also be considered without discrimination and prejudices where improved health literacy could address vulnerabilities linked to race, culture, religious differences, or sexual orientation (36, 40).

1.2.3 Digital health literacy and learning management system

According to the latest guideline provided by the World Health Organization (WHO) on digital health interventions, any application of information and communication technologies to further advance the improvement of healthcare can be categorised under digital health (41). These interventions can range from clinical decision support systems, to patient education, big data analytics and wider genomic studies (41).

Digital health literacy uses the same operational definitions within health literacy, while aligning with digital health solutions, and encompasses advances in information and communication technologies. Digital solutions can increase access and improve transparency of information, facilitating communications between the patients and the healthcare professionals. Potentially, information to patients can be presented in a more engaging way and provide ongoing, dynamic, and highly personalised plans (42).

While designing any digital health solutions to improve health literacy one must consider barriers relating to groups that may not be able to afford, or may not have access to devices, such as smart phones and wearables (42). Potential solutions must go beyond building literacy and numeracy skills to incorporating functional and critical skills, such as navigating the healthcare system, communication with healthcare providers, and shared decision making (43). The associated improvement in health literacy skills would impact health outcomes positively in patients with chronic conditions by embracing the use of new technologies, patient-centred care plans, and better research and evaluation models (44).

Learning management systems (LMS) are cloud-based, web-based or installed software programs designed to assist with learning and teaching. Initially targeting higher education, they have now evolved to cater different sectors including workforce training. Many current LMS platforms are open-access, personal, social, flexible, support learning analytics, and move to mobile computing (45). With medical education advancing rapidly, LMS such as Moodle^{TM} have been used extensively in continuing medical education, including interdisciplinary learning (46) and have improved clinicians' performance (47).

Similarly, LMS could be used to educating patients and their carers. They may be particularly useful if there was also provision to utilise a trained educator (facilitator), with additional coaching/motivational/behavioural change skills. Currently, digital health technology solutions are at the cutting edge due to rapid and iterative software developments. Most digital health interventions have evolved in just over a decade and the number are likely to increase exponentially (48).

A consequence of the coronavirus disease 2019 (COVID-19) pandemic has been an unparalleled surge in digital health adoption, including tele-rehabilitation where face-to-face consultations had been a standard practice (48). There have been some successful digital health solutions developed to promote healthy lifestyles for people with chronic conditions, such as multiple sclerosis (49) and to aid multidisciplinary exercise rehabilitation for low back pain. These have demonstrated their potential to improve outcomes with reduced pain, disability, and opioid use (50). However, the effective translation of knowledge to patients has been limited due to the challenges associated with the unique characteristics inherent within the contexts of stakeholders and health service delivery models (48).

At this juncture, digital health research could be used to facilitate 'partnership models' of decision-making that bring together health professionals, consumers and software developers to drive superior outcomes with reduced clinical risks (51). To fully realise its potential, health literacy should be an integral part of the design and development of digital health solutions.

This will require a conceptual model that incorporates the innovative nature of technology and the scientific nature of researchers and clinicians (52).

1.3 Aims and objectives of the research

The aim of this thesis work is to conduct a program of research focused on establishing a person-centred and integrated model of care for older people with hip fractures assisted by digital health technology and modern educational approaches. The goal is to improve outcomes such as health literacy, access, functional rehabilitation, and quality of life. The model envisages an emphasis on the patient, their family members and carers as networked units to be supported through healthcare providers, ranging from specialist services, GPs, allied health and social care services. This will incorporate advances in software development and computer science, modern education technologies, ethics and law.

1.3.1 Objectives

- To map out digital health interventions by conducting a comprehensive systematic review, which evaluates the effectiveness of digital health-supported, targeted patient communication versus the usual provision of health information on the recovery from fragility fractures.
- To determine different phases of a research program for the development of a digital health hub enabled model of care focused on hip fracture rehabilitation through a dynamic conceptual framework.
- To understand the perspectives of older people with hip fractures, their family members, and residential aged carers, to inform the development of a personalised digital health hub and factors impacting the likelihood of potential usage.
- To understand the perspectives of clinicians from various medical and surgical disciplines, allied health, and other relevant non-health stakeholders to inform the

development of a digital health enabled model of care for fragility fractures.

- To examine the process and management of innovation, and the strategic directions required to improve musculoskeletal healthcare at macro (policy), meso (service delivery), and micro (clinical practice) levels and discuss the critical role of different stakeholders in driving innovations in healthcare.
- To describe a vision for future health care to address increasing population multimorbidity through the co-creation of personalised digital health hubs that recognise the importance of patient agency in driving the evolution of health services.

1.4 Outline of the thesis

Subsequent to this introduction, there are six chapters outlining individual publications, all of which have been published. The final chapter is a discussion of the collective research undertaken and conclusions including recommendations for clinical practice and future direction of the research.

Chapter 2 addresses the first objective to explore existing digital technology. It is a comprehensive systematic review which includes mapping of digital health interventions and a meta-analysis. This research was focussed specifically on the evidence that exists around the use of digital health interventions to improve recovery and rehabilitation of patients with fragility fractures, post hospital discharge. A WHO guideline on digital health interventions was used to classify and group different intervention strategies. These ranged from simple targeted patient communication to involving GP practices and the use of more sophisticated interactive modes of digital multimedia. The meta-analysis revealed that targeted digital health interventions with involvement of primary care physicians could be twice as effective in preventing secondary fractures.

Chapter 3 addresses the second objective which is to inform the development of the research program. This is a protocol paper which outlines methods for formative research.

It introduces a dynamic conceptual framework which outlines different stages of the research program, alongside embedding multidisciplinary theoretical frameworks and demonstrating how they are interrelated.

Chapter 4 addresses the third objective which is to understand the usage of information technology among patients and carers. The paper focusses on mixed methods research involving patients, their family members and residential aged carers. A survey tool was administered to study participants which assessed their current use of computers and access to digital technology and likelihood of using potential digital health hub for patient education. Further, a behaviour change wheel framework was used to understand the factors influencing behaviour, such as capability, opportunity and motivation.

Chapter 5 addresses the fourth objective which examines stakeholders' perspectives from multiple disciplines. This paper involves qualitative in-depth interviews conducted with stakeholders from multiple clinical disciplines, allied health and other disciplines. These stakeholders represented front line staff to senior administration levels, including those who could influence policy and research agendas. The findings from this study were categorised into content, context and systems with embedded thematic constructs. These represent interplay of factors that could influence the ultimate design of a digital health hub enabled model of care for hip fractures and its subsequent implementation.

Chapter 6 addresses the fifth objective, which describes innovations to improve access to MSK care. This is a paper based on collaborative work involving experts in musculoskeletal conditions, public health, higher education and computer science to establish a common understanding around what constitutes an innovation, particularly within the context of musculoskeletal conditions (including fragility hip fractures). The paper discusses different approaches, targeting diverse audiences, such as healthcare providers, patients and community members through exemplars reflecting contemporary and innovative practices within the domain of improving musculoskeletal care.

Chapter 7 addresses the sixth objective describing a vision of a healthcare system assisted with digital technology and advanced educational approaches to address the increasing burden of multimorbidity (published). This work was undertaken with collaborators and involved multidisciplinary inputs from orthopaedics, musculoskeletal health, computer science, higher education, and public health. It describes a proof-of-concept developed for a digital health enabled model of care for fragility hip fractures in South Australia. Subsequently, digital health hub enabled models of care can be developed more broadly for musculoskeletal conditions and other multimorbidities/ chronic conditions, across a range of settings, from developed to emerging economies.

Chapter 8 provides a consolidated discussion of this thesis including its strengths and limitations and concludes with recommendations for clinical practice and future direction of the research.

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CHAPTER 2

SYSTEMATIC REVIEW AND META-ANALYSIS

Utilising digital health technology to support patient-healthcare provider communication in fragility fracture recovery: Systematic review and meta-analysis was published in the *International Journal of Environmental Research and Public Health* in 2019.

The published paper will follow summary and statement of authorship.

Summary

This paper addresses the first objective of the thesis work by mapping out digital health interventions and evaluating the effectiveness of digital health supported targeted patient communication versus usual provision of health information on the recovery from fragility fractures.

With the advancement of digital health technologies, it should be possible to seamlessly integrate the provision of different services for older people with fragility fractures from acute hospital care to community rehabilitation and improve care while also reducing costs to the system and patient. To fully realise the potential of digital health solutions, targeted patient communications designed to educate and improve health literacy must be an essential component.

The review considered studies conducted in hospitals, residential aged-care facilities or community dwellings. It included older people, aged 50 and above, with a diagnosis of fragility (osteoporotic) fracture. Studies evaluated digital health supported patient communication and education solutions delivered through any digital device (in the form of voice call/messaging, text messaging, educational videos, or multimedia platforms), and compared the efficacy of digital health communication with usual delivery of health information. There was variation in the use of digital health solutions across the studies included in this review. Therefore, the results from meta-analysis and narrative synthesis were classified and interpreted according to the latest World Health Organization guidelines on digital health interventions.

The primary outcome examined was the prevention of secondary fractures, measured using proxies of 1) bone mineral density tests and/or 2) adherence to osteoporosis medication at six months after discharge from acute care. Findings from this meta-analysis suggest that digital health supported interventions were overall twice as effective when compared with the usual standard care (OR 2.13, 95% CI 1.30-3.48) and statistically significant ($z=3.01$, $p=0.003$), despite the population sample not being homogeneous ($I^2=79$, $p=0.005$). Narrative synthesis of the remaining studies included in this systematic review also suggest improvement in secondary outcomes. These included functional outcomes such as mobility, quality of life, health/ ehealth literacy, knowledge, or perceived service satisfaction.

Findings from this review show that digital health can be used effectively within existing practice for targeted patient communications following fragility fractures. Further, digital health solutions should be considered to support patient education in any area that requires a holistic approach to health care including pain management; physical activity; nutrition; sleep hygiene and mental health.

The paper has been cited in seven publications and findings presented at seven different national, regional and international conferences.

Statement of Authorship

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Name of Principal Author (Candidate)	Lalit Yadav
Contribution to the Paper	Conceptualisation, comprehensive search strategy, database search, finalisation and critical appraisal of the articles, writing of first draft, and addressing reviewers' comments leading to the final publication
Overall percentage (%)	85%
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper
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Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate to include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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Article

Utilising Digital Health Technology to Support Patient-Healthcare Provider Communication in Fragility Fracture Recovery: Systematic Review and Meta-Analysis

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Abstract: The objective of this review is to evaluate the effectiveness of digital health supported targeted patient communication versus usual provision of health information, on the recovery of fragility fractures. The review considered studies including older people, aged 50 and above, with a fragility fracture. The primary outcome was prevention of secondary fractures by diagnosis and treatment of osteoporosis, and its adherence. This review considered both experimental and quasi-experimental study designs. A comprehensive search strategy was built to identify key terms including Medical subject headings (MeSH) and applied to the multiple electronic databases. An intention to treat analysis was applied to those studies included in the meta-analysis and odds ratio was calculated with random effects. Altogether, 15 studies were considered in the final stage for this systematic review. Out of these, 10 studies were Randomised controlled trials (RCT) and five were quasi experimental studies, published between the years 2003 and 2016 with a total of 5037 participants. Five Randomised control trails were included in the meta-analysis suggesting that digital health supported interventions were overall, twice as effective when compared with the usual standard care (OR 2.13, 95% CI 1.30–3.48), despite the population sample not being homogeneous. Findings from the remaining studies were narratively interpreted.

Keywords: digital health; telemedicine; health literacy; patient education; rehabilitation

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1. Introduction

In older people, a low energy trauma, such as a fall from a standing height or less, can result in a fracture. This is known as a “fragility fracture” and is usually due to osteoporosis with its associated reduced bone density [1]. One of the most devastating fragility fractures is the hip fracture. Due to the significant increase in ageing and life expectancy globally, it is estimated that the annual number of fragility hip fractures is likely to reach 6.3 million by 2050. Twenty percent of hip fractures can be fatal and a further 50% cause disability with only 30% of patients able to fully recover. [2–4]. Further, during recovery, older patients with a fragility fracture may exhibit sedentary behaviour and have low physical activity participation [5]. This adds to the complex scenario leading to a loss of independence, decreased mobility, and poor quality of life [6]. In parallel to this, the utilisation of health services and associated costs increases, mainly within the first year of the initial hospitalisation, much of which is attributable to ongoing long-term care [7–10]. Thus, this long-term care process requires an integrated approach that is often delivered by range of care providers, involves management of medication prescription for any coexisting comorbidities, exercise and falls prevention advice, good nutrition, and psychological well-being [11]. On the other hand, recent evidence in Australia suggests that the existing practice must also be applied to other types of fragility fractures that may not require acute hospitalisation or if it does, shorter periods of hospitalisation. Some of these fractures herald the beginning of the 'fragility fracture cascade' towards a hip fracture and include first occurrence of non-hip and non-vertebral minor fragility fractures [12].

Looking at the post-discharge care pathway; patients may need to attend orthopaedic out-patient departments (OPD), located in hospitals where access can be difficult, as they rely on family or ambulance services to provide transport. In addition, for falls prevention, patients may need to access specialist geriatric services and similarly, general practitioners (GP) within community for management of any existing co-morbidities and osteoporosis. For some, there may be involvement of community-based rehabilitation, aged care and allied health services. [13,14]. Shared decision making is enhanced through improved patient and family education where trust can be built, and people motivated to improve adherence to achievable treatment and prevention goals [11].

With the advancement of modern information and communications technologies (ICT), it is possible to integrate seamlessly the different service providers that are involved in the care of older people with fragility fracture and, more importantly, it could also include the patient and their nominated carers. Such technology may assist in the reorientation of services to the community and closer to the patient in their own community. Digital health or Electronic health (eHealth) systems utilise ICT built within computers, mobiles, sensors and web-based applications to support effective delivery of health services and information [15,16]. It involves people from multiple disciplines with expert knowledge and a desire to innovate; including specialties within health sciences, software engineering, communications, social science and legal aspects. However, the influence of human behaviour must be recognised, while interacting with the healthcare systems, as well as the local context in which the digital health platform is intended to be used [17]. This includes crucial components of health systems, such as financing, workforce, access to essential medicine and leadership and governance [15]. Importantly, three critical questions need to be addressed: (i) Does the information delivered through a digital health channel align with the recommended health practices or validated health content? (ii) Does the digital technology promise to achieve broader health sector objectives, as a discrete function? (iii) Are the software systems and communication channels able to facilitate the delivery of digital interventions and health content and demonstrate capability at scale?

Research Question

The question of this review is:

What is the effectiveness of digital health supported and targeted patient communication that is facilitated through healthcare providers in the recovery of older adults with fragility fractures?

The review explores the use of different digital health strategies and its effect on treatment adherence, functional outcomes, quality of life, education, knowledge, and perceived service satisfaction.

2. Methods

This systematic review was conducted in accordance with a standardised methodology for systematic reviews for effectiveness evidence [18] and this review title along with the methodological details has been registered with the Joanna Briggs Institute, The University of Adelaide systematic review database [19].

2.1. Inclusion Criteria

2.1.1. Participants

It is considered that in low- and middle-income countries, or other disadvantaged communities, the initiation of ageing processes could start at a relatively younger age. Therefore, the inclusion criteria involved original studies or research papers including people aged 50 and above with a low trauma or fragility fracture, and conducted within a hospital, residential aged care facility, or community dwelling.

2.1.2. Intervention

Studies were considered that evaluated digital health technology used to support targeted patient communication and education solutions delivered through any digital device in the form of voice call/message, text messages, educational videos or multimedia platforms (e.g., computers, mobile phone applications, telephone, and other audio-visual aids).

2.1.3. Comparators

Studies that compared usual provision of health information to patients delivered through instructions leaflet/booklet or any similar resources either at the point of discharge or as part of standard care.

2.1.4. Outcomes

The primary outcome was prevention of secondary fractures by diagnosis and treatment of osteoporosis, and adherence to treatment. The secondary outcomes included quality of life, health/ehealth literacy, knowledge, or perceived service satisfaction.

2.2. Types of Studies

This review considered both experimental and quasi-experimental study designs including Randomised controlled trials (RCTs), non-Randomised controlled trials, before and after studies and interrupted time-series studies. In addition, analytical observational studies including prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies were considered for inclusion. This review also considered descriptive observational study designs including case series, and individual cases. All studies published in English from the year 2000 until 2018 were included.

2.3. Search Strategy

An initial limited search of MEDLINE was undertaken to identify articles on the topic. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy for PUBMED, CINAHL, SCOPUS, Embase, ProQuest dissertation and thesis global, and Google Scholar (Supplementary 1). The search strategy, including all identified keywords and index terms, was adapted for each included information source. The reference list of all studies selected for critical appraisal was screened for additional studies.

2.4. Study Selection

Following the search, all identified citations were collated and uploaded in EndNote X8/2018 (Clarivate Analytics, Philadelphia, PA, USA) and duplicates removed. Titles and abstracts were then screened by two independent reviewers (LY, AH) for assessment against the inclusion criteria for the review. Potentially relevant studies were retrieved in full and their citation details imported into the JBI

System for the Unified Management, Assessment and Review of Information (JBI SUMARI) [20]. The full text of selected citations was assessed in detail against the inclusion criteria by two independent reviewers. Reasons for exclusion of full text studies that did not meet the inclusion criteria were recorded and reported in the systematic review. Any disagreements that arose between the reviewers at each stage of the study selection process were resolved through discussion, or with a third reviewer [TG]. The results of the search are reported in full in the final systematic review and presented in a Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) [21]. A checklist is provided in Supplementary 2.

2.5. Assessment of Methodological Quality

Eligible studies were critically appraised by the two independent reviewers (LY, AH) for methodological quality using standardised critical appraisal instruments for experimental and quasi-experimental studies from the Joanna Briggs Institute [18,20]. Any disagreements that arose were resolved through discussion, or with a third reviewer (TG).

2.6. Data Extraction

Data were extracted from included studies in the review using the standardised data extraction tool. The data included specific details about the populations, study methods, interventions, and outcomes of significance to the review objective.

2.7. Data Synthesis

Data from five studies were pooled in a statistical meta-analysis using JBI SUMARI. Effect sizes were expressed as odds ratios and heterogeneity was assessed statistically using I^2 tests. Statistical analyses were performed using random effects models [22]. Whereas, statistical findings from the remaining ten studies included in the review were narratively interpreted.

3. Results

3.1. Study Inclusion

Altogether, 3465 records were identified through database searching and additional 4 records from manual and secondary reference searches. After removing duplicates and articles with no clear orthopaedic or fragility/osteoporotic fracture or bone health domain, 1690 articles were screened for title and abstract. Further, 42 were considered for full text review, from which 15 studies were finally considered for this systematic review. The key reasons for excluding the studies were: digital health interventions targeting healthcare providers, other musculoskeletal conditions, falls prevention among older people without fragility fracture in the hospital setting, and digital health solutions aimed at health workforce education or meant for supporting clinical decision at the point of care. Out of the included studies, 10 studies were RCTs [23–32] and 5 were quasi experimental studies [33–37]; including 3 studies with no comparison group [33,35,37]. A PRISMA flowchart is provided as Figure 1.

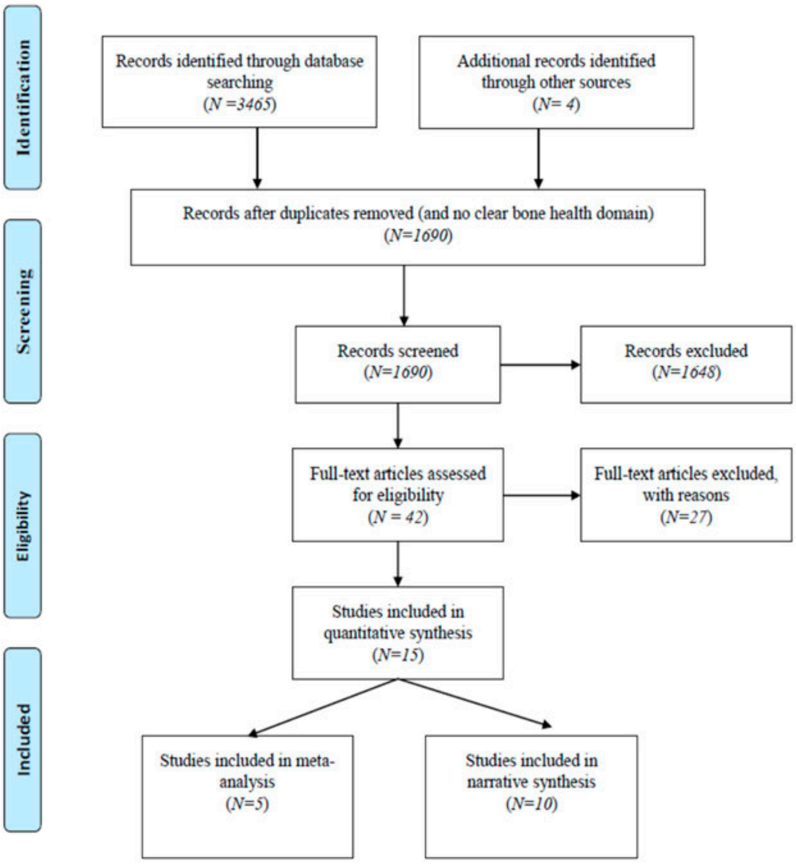


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Flowchart.

3.2. Methodological Quality

Overall methodological quality varied according to the type of studies. Within the RCT group, 2 studies were found to be of high-quality scoring 85% [28,29], 4 rated moderate, scoring between 50–70% [26,27,30,31] and 4 rated low at less than 50% [23–25,32]. The majority of studies scored poorly around questions relating to blinding or description of the intervention.

Within the quasi experimental group, only one study scored around 90% [34] and two studies scored moderate [36,37]. Further, the remaining two scored low at less than 50% [33,35]. The reasons for low or moderate quality were linked to the absence of a control group and/or failure to clarify if follow-ups were completed. The results are summarised in Table 1.

Table 1. Methodological quality assessment.

1A Randomised controlled trials (*N* = *10*).

Study	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Overall Appraisal
Allegrante et al. [23]	2007	Unclear	Yes	Unclear	Unclear	No	Unclear	Yes	No	No	Yes	Unclear	Yes	No	4 (31%)
Davis et al. [25]	2007	Unclear	Unclear	No	Unclear	No	Unclear	Yes	Unclear	Yes	Yes	No	Yes	Yes	5 (38%)
Majumdar et al. [29]	2008	Yes	Yes	Yes	No	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	11 (85%)
Bessette et al. [24]	2011	Yes	No	Yes	No	No	Unclear	No	Yes	No	Yes	No	Unclear	No	4 (31%)
Jaglal et al. [28]	2012	Yes	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	11 (85%)
Roux et al. [31]	2013	No	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Unclear	Yes	Yes	7 (54%)
Suwanpasu et al. [32]	2014	Yes	No	Unclear	No	No	No	Yes	Unclear	No	Yes	Unclear	Yes	Yes	5 (38%)
Langford et al. [27]	2015	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	No	No	7 (54%)
Monaco et al. [26]	2015	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	9 (69%)
O'Halloran et al. [30]	2016	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Yes	Unclear	Yes	Yes	9 (69%)
		70%	60%	70%	0%	10%	50%	90%	70%	30%	100%	20%	80%	70%	

JBI critical appraisal checklist questions for RCTs

Q1	Was true randomisation used for assignment of participants to treatment groups?
Q2	Was allocation to treatment groups concealed?
Q3	Were treatment groups similar at the baseline?
Q4	Were participants blind to treatment assignment?
Q5	Were those delivering treatment blind to treatment assignment?
Q6	Were outcomes assessors blind to treatment assignment?
Q7	Were treatment groups treated identically other than the intervention of interest?
Q8	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
Q9	Were participants analysed in the groups to which they were Randomised?
Q10	Were outcomes measured in the same way for treatment groups?
Q11	Were outcomes measured in a reliable way?
Q12	Was appropriate statistical analysis used?
Q13	Was the trial design appropriate, and any deviations from the standard RCT design (individual randomisation, parallel groups) accounted for in the conduct and analysis of the trial?

Table 1. *Cont.*

1B Quasi-experimental studies (*N* = 5).

SR No	Study	Year	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Overall Appraisal
1	Tappen et al. [36]	2003	Yes	Unclear	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes	6 (67%)
2	Cook et al. [34]	2007	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	8 (89%)
3	Dickson et al. [35]	2008	Yes	Unclear	Unclear	No	No	Unclear	Unclear	Unclear	Unclear	1 (11%)
4	Tousignant et al. [37]	2014	Yes	Yes	Unclear	No	Yes	Yes	Yes	Yes	Yes	7 (78%)
5	Bedra et al. [33]	2015	Yes	Yes	Unclear	No	Yes	Unclear	Yes	No	No	4 (44%)
Response rate			100%	60%	20%	20%	80%	40%	80%	60%	60%	

JBI critical appraisal checklist questions for Quasi-experimental studies

Q1	Is it clear in the study what is the ‘cause’ and what is the ‘effect’ (i.e., there is no confusion about which variable comes first)?
Q2	Were the participants included in any comparisons similar?
Q3	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
Q4	Was there a control group?
Q5	Were there multiple measurements of the outcome both pre and post the intervention/exposure?
Q6	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
Q7	Were the outcomes of participants included in any comparisons measured in the same way?
Q8	Were outcomes measured in a reliable way?
Q9	Was appropriate statistical analysis used?

3.3. Characteristics of Included Studies

Studies included were published between the years 2003–2016 but none published in 2017 and 2018. The majority were conducted in Canada [24,25,27–29,31,35,37], followed by US [23,33,34,36] and one each in Australia, Italy and Thailand, respectively [26,30,32]. Participants were recruited from hospital-based settings in 12 studies [23–29,31,32,35–37] and community-based settings in 3 studies [30,33,34]. There were no studies conducted in the residential aged care facilities. A total of 5037 participants with fragility fractures were recruited to the 15 studies. Eight studies had only hip fractures as a criterion for inclusion [23,25–27,30,32,33,36] and 4 studies had women participants only [24,26,31,35].

3.4. Review Findings

Findings of this review are categorised primarily into meta-analysis and narrative synthesis. Further, these results are presented in three subcategories (Tables 2 and 3 (part A and part B)), which correspond to the definitions suggested by latest WHO guideline on digital health interventions [15].

3.5. Meta-Analysis

Targeted Patient Communication with Primary Care Physician Support

Five of the studies were included in the meta-analysis with a similar intervention strategy and measures of primary outcomes [24,25,28,29,31] (Table 2). Four of the studies involved voice telephone calls as a delivery channel and one [24] involved targeted patient communication using educational videos. Further, in all five studies, respective primary care physicians were also involved. Studies [24,31] having two separate intervention groups were combined as a single intervention as there was no reported difference between each intervention group, individually or combined and when compared with the control group.

Findings from the studies included in this theme suggests that the primary outcome of bisphosphonate treatment for osteoporosis along with BMD test was significantly improved in the intervention group in comparison to the control group [25,28,29,31], except one study reported an increase with respect to osteoporosis treatment but not BMD testing [24]. However, when stratified by sex, men in the intervention group were less likely than women to receive appropriate secondary fracture prevention care at 15% and 44%, respectively [29]. Uptake of calcium and vitamin D improved in the intervention group [28,29] expect in one study [25]. Similarly, the intervention resulted in the majority of patients having a discussion about osteoporosis with their physician (82% vs. 55%, OR-3.8, 95% CI 2.3–6.3, $p < 0.0001$) [28].

Table 2. Meta-analysis: (Targeted patient communication with primary care physician support *).

SR No	Author/Year Methodological Quality (H, M, L) **	Intervention	Outcome	Results
1	Majumdar et al. (2008) [29] H	The intervention consisted of three component intervention; firstly, brief telephonic counselling by an experienced registered nurse. These messages emphasise on at a high risk osteoporosis and future fracture, requiring bone mineral test followed by appropriate treatment through bisphosphonates or other alternative treatments like calcitonin, hormone replacement therapy, raloxifine. Beyond delivering these messages, the registered nurse also answered questions and allayed any concerned expressed by the patients about their treatment. The nurse also emphasised on the importance of speaking to their physician about their health condition. Secondly, patient specific reminder was sent to their respective physician with the same set of messages. Thirdly, summary of evidence-based actionable osteoporosis guideline, with endorsements from 5 local opinion leaders were sent to the physicians	Primary outcome was starting treatment with a bisphosphonate within 6 months after the fracture. This was measured using patient self-report and confirmed through dispensing records of local community pharmacies. There was 100% agreement between self-reporting and dispensing records. Secondary outcome was Bone mineral density (BMD) test and a composite measure of quality, referred to as guideline concordant or "appropriate care" defined as having undergone a BMD test and receiving bisphosphonate treatment if bone mass was low or osteoporosis.	Median age reported was 60 years (IQR 55–68 years). The findings from this study suggests that 22% (30) of the intervention group achieved primary outcome of bisphosphonate treatment for osteoporosis in comparison to only 7% (10) in the control group (RR 2.6, 95% CI 1.3–5.1, $p = 0.008$). By the end of the study, 66% received both calcium and vitamin D in the intervention group verses 43% with control group (RR 1.6, 95% CI 1.2–1.9, $p = 0.001$). Similarly, 52% (71) of the patients in the intervention group undertook BMD test compared to 18% (24) in control group (RR 2.8, 95% CI 1.9–4.2, $p < 0.001$). Of these, who had BMD test, 28% reported to have normal bone mass, 52% osteopenia and 20% osteoporosis at either hip or spine. Appropriate care was received by 38% of patients within the intervention group in compared to 11% in the control group (RR 3.1, 95% CI 1.8–5.3, $p < 0.001$). further, when the results were stratified by sex, men in the intervention group were less likely than women to receive appropriate care as 15% and 44% respectively.
2	Jaglal et al. (2012) [28] H	The intervention involved a physiotherapist as a centralised coordinator for following up patients and their physicians, provided evidence-based recommendations about the fracture risks and treatment of osteoporosis and assist with multidisciplinary consultation for patients with complex need, if needed. Patients received telephonic counselling about the risk of future fractures, BMD test and treatment of osteoporosis and follow-up with their physician. The primary care physician received a letter about the patient around the risk of future fracture, importance of BMD test, osteoporosis treatment using bisphosphonates or other alternative medications and availability of telehealth multidisciplinary consultation at a tertiary care hospital, in case of complex cases. Physicians also received pocket cards containing best-practice recommendations according to the recent Canadian guidelines. Outcomes	The primary outcome in was the proportion of patients self-reporting "appropriate management" defined as receiving within 6 months of fracture, either and osteoporosis medication (bisphosphonate, raloxifen or teriparatide) or normal BMD and prevention advise. Secondary outcomes were; the proportion of patients with a physician visit to discuss osteoporosis after fracture and the proportion for which BMD was scheduled or performed	Mean age was 66 years. The study reported a significant improvement in the osteoporosis management within the intervention group (32% vs. 20%, $p = 0.007$); analysis carried out as intention-to-treat. Further, in the intervention group, 23% had normal BMD, 22% treatment in comparison to 9% and 17% respectively in the control group. Whereas, with straight comparison, proportionately BMD test was reported to be higher in the intervention group than control group (57% vs. 21%, OR-4.8, 95% CI 3.0–7.0, $p < 0.0001$). Similarly, the intervention resulted in the majority of patients having a discussion about osteoporosis with their physician (82% vs. 55%, OR-3.8, 95% CI 2.3–6.3, $p < 0.0001$).

Table 2. *Cont.*

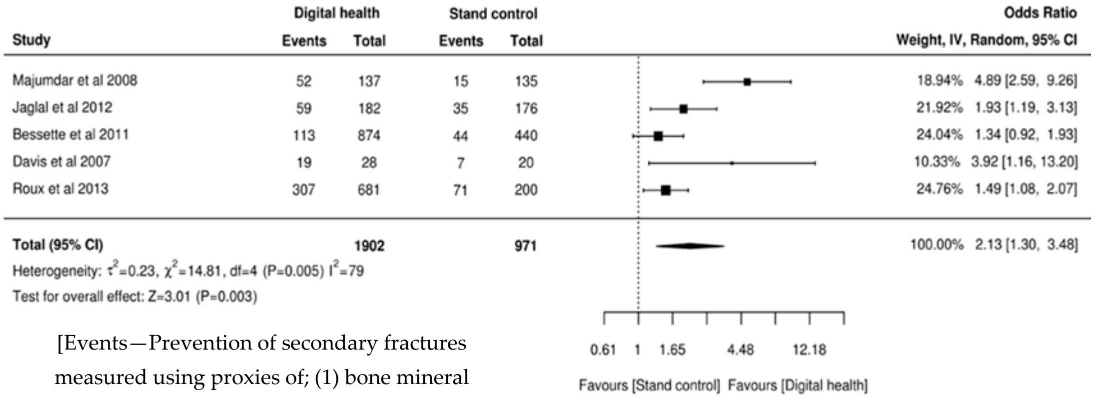
SR No	Author/Year Methodological Quality (H, M, L) **	Intervention	Outcome	Results
3	Bessette et al. (2011) [24] L	There were two intervention groups; written material and videocassette and written material group. The former received educational material on osteoporosis in the form of a two page document with concise information on the elevated risk for a new fracture, the importance of BMD and a summary of non-pharmacological therapies. Participants were invited to provide their respective primary care physician with an official summary of Canadian best practice guideline on osteoporosis. The videocassette group, in addition to written materials, received a 15-min educational video on osteoporosis which consisted of more comprehensive information on osteoporosis diagnosis and treatment as well as complications associated with fragility fractures	The primary objective of the study was to evaluate the impact of the two educational interventions on the diagnosis and treatment rates for osteoporosis after approximately 12 months following randomisation	In the group of women with no diagnosis or treatment at randomization, diagnosis of osteoporosis after follow-up occurred in 12%, 15%, and 16% of women within control, written material and videocassette and written material groups respectively. The rate of diagnosis for both intervention groups combined was 15%. Whereas, treatment rates were 8%,12% and 11% respectively in the same groups and if both interventions combined, it was 11%. In the group, without treatment at randomisation, at the follow-up, osteoporosis therapy was initiated in 10%, 13% and 15% respectively while combining the intervention; it would result in 13%.
4	Davis et al. (2007) [25] L	The intervention consisted of patient empowerment and physician alerting (PEPA) system; usual care for the fracture including surgical treatment, osteoporosis information and a letter for participants that encouraged them to return to their PCPs for further investigation, a request for participants to take a letter from the orthopaedic surgeon to the PCP alerting them to the hip fracture and encourage osteoporosis investigation, and telephonic call at 3 and 6 months to determine whether osteoporosis investigation and treatment had occurred	BMD test and bisphosphonate therapy at 6 months	In the PEPA (intervention) group, 15 (54%) were prescribed bisphosphonates therapy, 8(29%) BMD scan, 11(39%) calcium and vitamin D and 9(32%) exercises. Whereas, within the control group, none of the patients received any intervention, except 30% of them were prescribed calcium and vitamin D

Table 2. *Cont.*

SR No	Author/Year Methodological Quality (H, M, L) **	Intervention	Outcome	Results
5	Roux et al. (2013) [31] M	The intervention included two groups- Minimum (MIN) and Intensive (INT). MIN involved a coordinator to explain the patient, verbally and in writing, the casual link between fragility fracture and osteoporosis and the importance of contacting their primary care physician (PCP). A standard letter notified PCP of their patient's fragility fracture status, explained the rationale and importance of rapid treatment of osteoporosis and outlined the appropriate investigations and treatment available and suggesting investigations and empirical treatments, irrespective of the BMD scores. Trained personnel made follow-up telephone calls at 6 and 12 months. In addition to collection of data, the importance of osteoporosis treatment was stressed and suggestions to increase adherence to osteoporosis medication was discussed. Whereas, within the INT group, same process was followed but in addition screening blood test were prescribed and patients were given a written prescription for BMD test. Blood test were conducted for serum calcium, phosphate, creatinine, alkaline phosphatase, and 25(OH) vitamin D levels, total blood count and plasma protein electrophoresis. Results were sent the respective PCPs with a letter stating that an incident fragility fracture usually indicates a need for treatment, irrespective of BMD results. When lab abnormalities were identified during screening, individualised counselling was given in writing to the PCP. Further, any PCP could contact one of the team members to discuss on how to manage the patient, if required. Similarly, telephonic follow-up was performed at 4, 8 and 12 months.	BMD test and osteoporosis therapy confirmed with the patients' pharmacists at one year	Median age was 65 years (IQR 57–76 years) including 82% as females. At 12 months follow-up, the rates of current osteoporosis treatment were significantly higher in the intervention group than in the control group with no significant differences between the two intervention groups. Further, according to self-reports, around 45% of all patients underwent BMD testing during the first year, including 66% in the INT group whereas, around 34% within control and MIN groups each

* In this group, digital health technology was used to communicate with patients along with engagement of primary care physician through non-digital or conventional forms of communication. The primary care physicians were provided with patients' key information around their disease conditions and future risks around bone health. Thus, such personalised information around their patients' health status would encourage them to support decision making around appropriate investigation and treatment to prevent future falls. ** Methodological quality; H-High > 85%, M-Moderate 50–80%, L-Low < 50%.

This meta-analysis suggests the digital health supported interventions were twice as effective when compared with the usual provision of health information to patients as part of standard care (OR 2.13, 95% CI 1.30–3.48). This is statistically significant (z = 3.01, p = 0.003), despite the population sample not being homogeneous (I^2 = 79, p = 0.005). The results are presented in Figure 2.



[Events—Prevention of secondary fractures measured using proxies of; (1) bone mineral density and/or (2) adherence to osteoporosis medication at 6 months after discharge from the acute care]

Figure 2. Forest plot.

3.6. Narrative Synthesis

Targeted Patient Communication

Studies included under this theme utilised digital health interventions in the form of educational videos and motivational voice telephone calls. These studies included 5 RCTs [23,26,27,30,32] and 2 quasi experimental [34,36] without involvement of primary care physicians as part of the intervention (Table 3, part A). Videos were used in two studies [23,36] whereas four utilized voice calls [26,30,32,34] and one study used both of these modes of delivery [27].

Table 3. Narrative synthesis.

3A Targeted Patient Communication *				
SR No	**Author/Year Methodological Quality (H, M, L) *** **	**Intervention**	**Outcome**	**Results**
1	Allegrante et al. (2007) [23] L	Motivational videotape and a corresponding booklet around falls prevention self-efficacy, in addition an in-hospital peer support visit and 8-weeks out-patient physical therapy consisting of tailored exercises and progressive muscle strengthening training.	Functional status was assessed using 36-item short form health survey (SF-36) as the study's primary outcome at 6-months follow-up	All the intervention patients were exposed to at least one of the three intervention components, i.e., videotape, strength training and peer counselling. However, only 34% of all the participants were able to complete full 6-months follow-up assessments (Intervention 32 vs. control 27). Patients within the intervention group had a significant positive change in the role-physical scale as compared to the control group (mean score, −11 ± 33 Vs −37 ± 41, p = 0.03). No significant post intervention differences were observed in the change on the physical functioning and social functioning scales and other domains like bodily pain, general health, vitality, role-emotional and mental health
2	Tappen et al. (2003) [36] M	Consisted of two parts; videotaping the study participants during their physical therapy sessions and showing one of the two generic educational videos that were produced for this study, depending upon the type of surgical repair, i.e., total hip replacement or arthroplasty, using plates or screws. Generic educational videos depict all aspects of physical recovery through the use of demonstrations and interviews with actual patients. The major focus of these generic tapes was the need to increase activity daily and intended to reinforce instructions that were given during rehabilitation and applied while moving in home or the respective community setting. Symptoms of anxiety and depression after hip surgery were also addressed using psychosocial adjustments. On the other hand, individual videos consisted of intervention participants being videotaped during their respective physical therapy sessions at regular intervals throughout their stay to record their progress. These videos show the therapist instructing the individual participants in the use of assistive devices, ambulance techniques and procedures for transferring. The tapes also document individualised instructions on exercises and show the therapist helping the participant do the prescribed exercises correctly. Participants were given both videotapes to take home for review	Physical activity performance measured through the distance walked in feet and time in seconds at three months post-discharge.	At three months post-discharge, time walked in seconds was significant, intervention [314.79 (SD-139.59)] Vs control [204.77 (179.70)]. Though analysis comparing the two groups did not differ significantly on self-care, functional ability, coping and performance of independent ADLs; results for coping approached statistical significance.

Table 3. *Cont.*

3A Targeted Patient Communication *				
SR No	**Author/Year Methodological Quality (H, M, L) *****	**Intervention**	**Outcome**	**Results**
3	Cook et al. (2007) [34] H	"Scriptassist" telephonic counselling program, intervention delivered telephonically by one of the four registered nurses at the scriptassist call centre. This communication was based upon the principles of motivational interviewing, focused on patient's motivation for treatment, problem solving to resolve barriers to adherence, improve self-efficacy and helping patient practice skills to self-manage their own chronic conditions. Calls focused on relationship building and answering questions to encourage participant's motivation for treatment.	Adherence to osteoporosis medication at 6 months based on pharmacy and clinical interview data	Among the high risk participants for fragility fractures, up to five telephonic contacts (median) were made with average call duration of 15 min. The participants were followed up for an average of 4.1 months after the start of the treatment (range 0–14 months). In terms of 6-months follow-up, 188 patients completed pharmacy data whereas, 255 patients with interview data. Adherence to treatment was reported at 6 months around 70% in this study, by both methods, compared to 46% in the representative population group reported through a national survey.
4	Monaco et al. (2015) [26] M	The intervention included at least 3 h during the stay of the patients, an occupational therapist to assess home hazards of falling based upon a standard checklist to determine future risk of falling and subsequent recommendations were provided. The patients also received a brochure describing falls prevention strategies. Further, geriatric evaluation was conducted for health optimisation and possibility of withdrawing medications in use which may increase the risk of falls and oral supplements of vitamin D and calcium were prescribed to continue after discharge from the hospital. Single telephonic call by an occupational therapist after discharge to check for environmental hazards, behaviour in ADL, use of assistive devices and reinforced targeted modifications to prevent falls.	Proportion of falls between two groups at 6 months	As an outcome measure, no differences were found in the proportion of fallers between the two groups (RR 1.06, CI 0.48–2.34)
5	O'Halloran et al. (2016) [30] M	Telephonic-based motivational interviewing eight times during the study participation period, lasting about 30 min per session and one call per week. The intervention was delivered by a trained physiotherapist in motivational interviewing. The intervention was designed to address issues associated with ambivalence about change in activity, such as beliefs about physical activity, low confidence and fear of falling which may prevent people after hip fracture from being more active.	Participants were asked to wear an accelerometer fitted to the thigh for a seven-day period at baseline and then again after the intervention phase, to measure the amount of physical activity they completed (ActivPal). Physical activity was recorded as the number of steps taken per day, the time spent walking per day and the time spent sitting or lying each day (sedentary behaviour). Secondary outcomes were health-related quality of life assessed through AQOL 8-D	Physical activity seemed to be improved in the intervention group compared with the control group, measured by daily steps and time spent walking; 26% and 22% respectively. Intervention group improved in mobility-related confidence but no difference observed with respect to mobility-related function. Further, the intervention group also demonstrated improvements in health-related quality of life (5.8, CI 1.2 to 10.4, $p = 0.015$), anxiety (−1.8, CI −3.0 to −0.6, $p = 0.004$) and depression scores (−3.7 CI −6.3 to −1.1, $p = 0.010$).

Table 3. *Cont.*

3A Targeted Patient Communication *				
SR No	**Author/Year Methodological Quality (H, M, L) *****	**Intervention**	**Outcome**	**Results**
6	Suwanpasu et al. (2014) [32] L	Physical activity enhancing program (PEP) which composed of four phases, covered five sessions of implementation within seven weeks post-hip fracture surgery, but combined both phone calls and face-to-face interactions. Phase-1 assess existing self-efficacy, outcome expectations for physical activity and being ready to change physical activity. Phase-2 involved preparation for strengthening self-efficacy and outcome expectations offered through individual education and training in structural exercise and daily life physical activity and the benefits of regular behaviour, verbal encouragement by credible sources, seeing others experience and visual cueing (physical activity after hip fracture booklet, poster and flipbook), and short and long-term goal setting. Phase-3 included practice for strengthening self-efficacy and outcome expectations, involved everyday workouts of structural exercises and daily life physical activity, re-evaluating goal setting, self-monitoring and re-interpretation and control of unpleasant sensations associated with physical activity. Phase-4 involved evaluation of physical activity behaviour, including the energy expenditure of physical activity.	Information on physical activity was collected at 6-weeks after discharge.	At 6-weeks post-discharge, there was a significant increase in physical activity in the intervention group compared with the control group after controlling for pre-fracture physical activity with an effect size of 0.18 (<0.01). The amount of overall physical activity of the intervention group significantly increased by 961.37 MET/min/week over the control group. Physical activity was effective in 65% of the PEP (intervention) group. The ratio of efficiency (markedly effective and effective) induced by the PEP was higher than that induced by usual care (65% vs. 48%) and similarly ratio of markedly effective induced by the PEP was significantly higher than that induced by usual care 30% vs. 8%).
7	Langford et al. (2015) [27] M	The intervention included one hour in-hospital educational session with a trained health professional, using the hip fracture recovery manual and four educational videos. The content of this education program followed a standard format as guided by the manual but was individualised for each participant, including a description of the type of fracture sustained, how it was surgically fixated, red flags to watch out for during the recovery phase, an exercise program (home-based reducing both the rate and risk of future falls), practical information about future falls prevention, review of home safety and environmental hazards and mobility and recovery goal setting. The videos were viewed at the bedside using a tablet and headphone. Teach-back method was used which intends to clarify and check participants' understanding of materials and ensured that the participants were able to provide a verbal summary of the education provided to them. After discharge, the trained health professional telephoned participants up to five times in the first 4 months following hip fracture to provide further encouragement, falls prevention information, coaching to remain active, problem solving skills, mobility goal setting, and advise to help participants maintain and increase their prescribed home exercises. The content of the sessions classified according to the CALO-RE (Coventry, Aberdeen and London-Redefined) taxonomy of behaviour change.	This study was a pilot study and the primary outcome of the trial was feasibility measured by recruitment rate and participant retention	The recruitment and retention rate of participants in the study was 42% and 90% respectively

Table 3. *Cont.*

3B Telemedicine, personal health tracking and healthcare provider decision support **				
SR No	**Author/Year**	**Intervention**	**Outcome**	**Results**
1	Bedra et al. (2015) [33] L	Home automated telemanagement (HAT) system to support individualised exercise program which consisted of a home unit, HAT server and a clinician unit. Home unit guides patients at home in routinely following their exercise program in a safe and effective way. The unit sends this information through a landline or wireless connection to the HAT information system. This system is able to monitor progress in terms of patient adherence and compare the results with the prescribed level of activities by the respective clinician. On the other hand, clinician unit can be any web-enabled devise. This system provides tailored feedback to the patients motivates them based on the behavioural profile and notifies clinicians. The system can further empower patients with self-paced interactive multimedia education on the major aspects of hip fracture rehabilitation program. This education module can be individualised to each patient's specific needs and is based on the concepts of social cognitive theory.	Exercise self-efficacy, physical functioning, role limitations due to physical health problems, social functioning, health transition and client satisfaction at 30-day	Overall, 14 patients were recruited to test the telerehabilitation system at their homes. Mean age was around 77 (±9), More than 50% never had any computer experience in their lifetime. The telerehabilitation system was successfully used by the hip fracture patients at their home regardless of their socioeconomic or computer literacy background. At the end of 30-day telerehabilitation program, exercise self-efficacy (9 ± 1 vs. 6 ± 3, $p = 0.01$), physical functioning (71 ± 31 vs. 38 ± 27, $p = 0.009$), role-limitations due to physical health problems (17 ± 12 vs. 6 ± 10, $p = 0.05$), social functioning (85 ± 28 vs. 54 ± 31, $p = 0.01$), health transition (22 ± 18 vs 47 ± 40, $p = 0.05$) and client satisfaction (31 ± 0.46 vs. 27 ± 4, $p = 0.04$) apparently seems to have improved. Also, physical activity in terms of hours per week demonstrated a significant increase (31 ± 14 vs. 24 ± 14, $p = 0.04$). Adherence to the telerehabilitation over a 30-day program was reported to be 90% and above in most domains.
2	Dickson et al. (2007) [35] L	Involved setting up of network studio within the osteoporosis research department at a Women's college hospital. The technology included a set-top videoconferencing system with a 27 inch television. Space was allocated for two desks; one for telehealth coordinator and one for health professionals to allow for them to move and demonstrate various exercises/activities to the patients during the consultation. Each healthcare professional individually consulted the patient via a telehealth, providing them with the same information they would receive in an in-person consult.	Knowledge about osteoporosis, confidentiality, and client satisfaction	The mean age was 56.5 years and the average length of telehealth consultation was around two hours and the length of follow-up was 15-min. The response rate to satisfaction survey questionnaire was 67%. Out of which, 58% rated telehealth consultation as excellent in comparison to in-person specialist consultation and 33% rated as a good experience. Almost all the participants expressed their intent to be using it again and recommend to their friends and family members. Prior to consultation, 73% described their knowledge about osteoporosis as fair and 27% as good but after consultation, only 10% described as fair, 30% good and 60% rated as excellent. When rating confidentiality, 83% patients felt completely comfortable discussing their health problems during their telehealth consultation

Table 3. *Cont.*

3B Telemedicine, personal health tracking and healthcare provider decision support **				
SR No	**Author/Year**	**Intervention**	**Outcome**	**Results**
3	Tousignant et al. (2014) [37] M	The intervention based on a modular design, a generic platform was built, consisting of a videoconferencing unit to provide telerehabilitation program over eight consecutive weeks. The treatment program was delivered twice a day, every day, either supervised by a physiotherapist through telerehabilitation or unsupervised. Patients had two telerehab sessions in week 1, 3 and 5 and only one on weeks 2, 4, 6, 7 and 8.	Three outcome measures were evaluated; pain, shoulder ROM and upper limb function and additional satisfaction with health services received.	Each session lasted for about 30–45 min and divided into three parts; warm-up, treatment program and question period. The treatment program was adjusted for each patient according to the number of weeks, post fracture. Every exercise program involved four exercise types based on the orthopaedic physician's specifications; stretching, pain control, active/active assisted ROM and muscle building. The physiotherapist also adjusted the progression of exercises according to the patient's progress. Pain decreased significantly between pre and post intervention as indicated by the SF-MPQ score (difference of 10.6 ± 12.4, $p = 0.003$) and VAS (difference 26.3 ± 21.8, $p = 0.001$) which was greater than minimal clinically important difference (difference over 5/45 for total descriptors). The shoulder ROM difference was greater than the interrater minimal clinical difference (more than 5–10 degrees) for all. A difference of 42.1 ± 11.4 ($p < 0$) in the upper limb function was observed, greater than the minimal clinical difference (change over 15/100). Further, around 82% was the overall satisfaction, considered to be very good.

* A unidirectional or bidirectional communication initiated by health system customised according to an individual's specific needs, results in "tailored or targeted client or patient communication" whereby message content is matched according to the needs and preferences of an individual. This consists of transmitting targeted health information to patients or client based on health status or demographics, which can include health education, behaviour change communication, client-centred messaging. In this theme, the delivery channels mainly consisted of voice telephone or calls by healthcare providers and educational videos. ** Telemedicine is defined as the provision of health-care services at a distance where patients and providers are separated. This could include consultation between remote client and healthcare providers, real-time telemedicine or interactive telemedicine, remote monitoring of client health or virtual monitoring or telemonitoring. Whereas, personal health tracking involves use of mobile application by clients, phone-based sensors, health records, wearables, web tools and other applications that allow to review and track their health status in terms of self-monitoring of health status and active data capture. Further, healthcare provider (HCP) decision support is defined as digitised job aids that combine an individual's health information with the health-care provider's knowledge and clinical protocols in order to assist HCPs in making diagnosis and treatment decisions. This involves supporting service delivery according to care plans, guidelines and protocols [33] *** Methodological quality; H-High > 85%, M-Moderate 50–80%, L-Low < 50%.

As an outcome, four studies reported exclusively around physical activity [27,30,32,36], and one each around functional status [23], adherence to prescribed treatment [34], proportion of falls [26], feasibility measured by recruitment and retention rate [27], health-related quality of life and anxiety and depression [30]. Physical activity measures varied across four studies. In one study, there was no difference between groups measured through the distance walked in feet; except some improvement in time (seconds) walked at 3-months post-discharge [36] whereas, another study reported improvement in the intervention group measured by daily steps and time spent walking [30]. Similarly, the third study also reported a significant increase in physical activity in the intervention group [32].

Functional status was assessed in one study using 36-item short form health survey (SF-36) at 6 months; no significant post-intervention differences were observed [23]. The study reporting adherence to osteoporosis treatment was effective in 70% of cases as compared to 46% in a representative population national survey [34]. No difference was found in the proportion of falls between two groups at 6 months [26]. However, another study demonstrated improvements in quality of life, anxiety and depression scores [30].

3.7. Telemedicine, Personal Health Tracking and Healthcare Provider Decision Support

Multimedia applications were used in three quasi experimental studies with interactive telemedicine [33,35,37], but real time teleconsultation was provided only in one study [35] (Table 3, part B). Two studies reported good client or service satisfaction [33,37]. Interestingly, in one study, more than 50% of the patients never had any computer experience in their lifetime but successfully participated in the intervention [33]. However, from the outcomes measured (physical activity measured as hours per week, exercise self-efficacy, physical functioning, role-limitations due to physical health problem, social functioning, and health transition), there were no statistically significant differences observed [33]. The remaining studies reported positively around knowledge about osteoporosis and confidentiality issues [35] and other outcomes such as pain, shoulder range of motion (ROM) and upper limb function [37].

4. Discussion

Fragility fractures usually affect older people and they require health care solutions which align with their daily needs and lives [38,39]. This review suggests digital health interventions can range from simple voice call to more sophisticated application of multimedia technologies to motivate and educate patients. Our review consisted of 15 studies including 10 RCTs and five quasi experimental with variation around methodological quality. Of these, there were three assessed as high, six of moderate and six of low methodological quality. The meta-analysis, included five studies, mostly conducted in the developed country setting except one study in Thailand [32]. Findings from the meta-analysis further suggest that digital health supported targeted patient communication with primary care physician involvement could be twice as effective as usual care in prevention of secondary fractures among patients with fragility fractures. In this review, secondary fracture prevention considered bone mineral density testing and osteoporosis treatment initiation and/or its adherence as surrogate endpoints [40,41]. Furthermore, narrative synthesis indicates there could be an improvement in secondary outcomes such as health-related quality of life, self-efficacy including physical mobility and physical activity. Thus, digital health can be incorporated in the design of a comprehensive solution, keeping patients and their carers at the centre. However, technology on its own is unable to work effectively unless key health systems challenges like information provision, availability and quality of services, acceptability to local practice and context, utilisation and efficiency of care provision are considered. Further, patient-side costs and community feedback mechanisms also need to be considered [15].

Our review findings suggest that a voice telephone call is effective during the follow-up recovery period, if provided by motivational and competent staff working with patients to resolve concerns or barriers. In one of the reviewed studies, where a more sophisticated computer system was used for physical exercises without intervention from a healthcare provider, ehealth literacy did not seem to be important in adhering to the intervention [33]. Technology has been used to devise a clinical decision support system, but whether this can be used to improve clinicians' efficiency or for the purposes of task shifting [42,43] is unclear. There remains uncertainty around whether older patients are able to interact with this technology and optimise the benefits in their path to recovery from a disease condition [44]. The WHO report on healthy ageing suggests that ageing must be considered as a continuum of life and not stigmatised, suggesting that there is a decline in the intrinsic capacity of people as determined by the age bracket [38]. However, people within similar age brackets may have different intrinsic capabilities and health and social care services should be targeted to be efficient. With appropriate facilitation, patients can be empowered to utilise new technology and engage with the health system to form a credible information or knowledge exchange process with their health care providers or family and friends within their community [38,39]. For this to happen, we must engage all these stakeholders at different levels from policy to practice including patients and their carers to co-create a model of care using digital health technological solutions [45]. In addition, studies from our review also suggest future research must consider complex nature of clinical interventions in the area of orthopaedics or musculoskeletal issues with respect to ageing. These intervention approaches combine medical/surgical and/or psychosocial components. Thus, deploying range of patient engagement strategies involving their family, caregiver and social networks could help with treatment compliance [23]. Further, resources must be made available for long-term follow-ups [33,34] and larger investigations are required in a real-world setting to optimise delivery of patient education materials reflected through better retention and satisfaction rates [27].

Although, the majority of the studies included in our systematic review were RCTs, the overall methodological quality was not uniform. Some of the studies reported high attrition or small sample sizes [23]. One study was conducted as a RCT but was a pilot study to ascertain recruitment and retention rates, as a primary outcome variable [27]. The usual caveat is in the delivery process detail and must be interpreted carefully as each setting and context might differ [15]. As with conventional clinical trials, dose and response are determined but in cases like these several factors and confounders play a critical role [46]. Therefore, it is difficult to generalise findings and the results need to be interpreted with caution. The meta-analysis of relevant RCTs included an intention-to-treat analysis with random effects. This conservatively estimated the effect size of the intervention using one or more digital health solutions to communicate or educate patients with fragility fractures in order to support their recovery process. Quasi experimental studies were included, with the intention of understanding any novel approaches being tested. Such studies seem promising in order to achieve potential outcomes but as the sample sizes were based on convenience and relatively small, it is difficult to determine whether such solutions can be adopted into mainstream. Moreover, the majority of studies were conducted in developed countries so these findings cannot be generalised to low and middle income countries.

In addition to these limitations, our meta-analysis was based on the assumption that the intervention components were broadly the same. Therefore, we might have neglected the dosing component with respect to how precise it would have been delivered to reach to the desired outcome compared. However, while interpreting, we acknowledge this fact and therefore recommend that any findings that suggest that interventions are effective (including our case of this meta-analysis) must be tested according to the local context. This will require adjustments for dosage and other aspects of technology suited for feasibility before going on a large-scale implementation. Finally, publication bias was not formally tested for as part of the meta-analysis.

4.1. Recommendations for Practice

Dedicated fracture liaison services and community based general practices managing patients with fragility fractures could be improved by implementing targeted digital health strategies adapted for local context.

4.2. Recommendations for Research

Management of older people with fragility fractures is a complex, multidimensional problem which extends beyond the acute care facility and immediate discharge care. Patient recovery is often influenced by factors not related to bone fracture itself, this includes the individual's intrinsic capability and external environment and social determinants. After the immediate discharge period, patients are often left on their own to navigate the health and care system leading to poorer post-fracture outcomes. Future research studies should be designed for fragility fractures with consideration of these factors. Digital health studies should also be undertaken using these principles applied to broader populations with other complex diagnoses requiring more person centred and integrated care.

5. Conclusions

Findings from our review support the view that a person-centred and integrated model of care can be delivered to older people with fragility fractures with the support of digital health technological solutions and achieve desired outcomes. Resources to optimise pain management, physical activity, nutrition, sleep hygiene and mental health could all be integrated. The provision of health information in isolation does not equate to education. Monitoring and feedback of progress are critical. Techniques such as behaviour change and motivational interviewing need to be integral to the service. Importantly, solutions must be co-designed or co-created within the context of a particular practice and with consideration to resource availability to realise a model of care pathway that is fully feasible to implement in practice.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/16/20/4047/s1, Table S1. Logic grid and Table S2 and PRISMA Checklist.

Author Contributions: L.Y., T.G., R.V. and M.C. contributed in the study conceptualisation and discussions leading to comprehensive search strategy for this review. L.Y. and A.H. conducted the literature search and carried the systematic process, independently. Wherever there was any disagreement over study inclusion, TG provided the arbitration. L.Y., A.H., T.G., R.V. and M.C. were involved in the finalisation of results. L.Y. drafted the first version of the manuscript. M.C., T.G., A.H., A.T., U.J., and R.V. reviewed the initial draft and provided critical inputs to improve the quality of manuscript. L.Y. under the guidance of M.C., R.V. and T.G. produced the final draft of the manuscript. This final version of the manuscript incorporates comments and edits from the authors and approved by all.

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CHAPTER 3

CO-CREATION OF A DIGITAL HEALTH HUB

Co-creation of a digital patient health hub to enhance education and person-centred integrated care post hip fracture: a mixed-methods study protocol was published in the *British Medical Journal Open* in 2019.

The published paper will follow summary and statement of authorship.

Summary

This paper addresses the second objective of the thesis work by determining different phases of a research program for the development of a digital health hub enabled model of care focused on hip fracture rehabilitation through a dynamic conceptual framework.

Developing a successful model of care would mean introducing effective intervention strategies that are relevant, acceptable, and could be implemented in real-world settings. The research program involves different phases, incorporating a co-creation or co-design approach involving patients, their carers, primary aged care clinicians, physiotherapists, dieticians, social workers, occupational therapists, other stakeholders from health and non-health backgrounds, such as computer science, education, ethics and law, through an iterative process.

A suite of theoretical frameworks and best practice guidelines was used as part of the conceptualisation process to guide design, development, and conduct of the study in a real-world setting. Frameworks included the National Institute for Health and Care Excellence (NICE) guideline on hip fracture management; the World Health Organization's guideline on community-level intervention to manage declines in intrinsic capacity through an integrated approach for older people (WHO-ICOPE); Health Behaviour Change Support Systems (HBCSS); and integrated-Promoting Action on Research Implementation in Health Services (i-PARIHS). The first phase of the study would inform the development of a prototype, a digital health platform (Phase 2). This would be pilot tested for usability in the next stage (Phase 3).

It was also ensured that this program of research would encompass a pragmatic yet methodologically rigorous process of generating evidence and further research ideas.

This paper is a foundation for an ongoing research program and the conceptualisation was presented at five different national, regional and international conferences and cited by five articles.

Statement of Authorship

Title of Paper	**Co-creation of a digital patient health hub to enhance education and person-centred integrated care post hip fracture: a mixed-methods study protocol**	
Publication Status	☒ Published ☐ Submitted for Publication	☐ Accepted for Publication ☐ Unpublished and Unsubmitted work written in manuscript style
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Contribution to the Paper	Conceptualisation, background literature search around theoretical framework and methodology to guide the conduct of the pragmatic study approach, produced first draft, addressed reviewers' comments leading to final publication of the manuscript	
Overall percentage (%)	85%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper	
Signature		Date: 15 July 2021

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate to include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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Cocreation of a digital patient health hub to enhance education and person-centred integrated care post hip fracture: a mixed-methods study protocol

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ABSTRACT

Introduction Older people with hip fractures often require long-term care and a crucial aspect is the provision of quality health information to patients and their carers to support continuity of care. If patients are well informed about their health condition and caring needs, particularly posthospital discharge into the community setting, this may support recovery and improve quality of life. As internet and mobile access reach every household, it is possible to deliver a new model of service using a digital education platform as a personal health hub where both patients and their providers of care can establish a more efficient information integration and exchange process. This protocol details proposed research, which aims to develop a 'model of care' by using a digital health solution that will allow delivery of high quality and patient-centred information, integrated into the existing process delivered within the community setting.

Methods and analysis This phase of the study uses a pragmatic mixed-methods design and a participatory approach through engagement of patients, their carers and healthcare providers from multiple disciplines to inform the development of a digital health platform. Quantitative methods will explore health literacy and e-health literacy among older people with hip fractures admitted to the two public tertiary care hospitals in Adelaide, South Australia. Qualitative methods will provide an understanding of aspects of content and context required for the digital health platform to be developed in order to deliver quality health information. The study will use appropriate theoretical frameworks and constructs to guide the design, analysis and overall conduct of the research study. The scope of the study intends to ultimately empower patients and their carers to improve self-management and to better use coordinated services at the community level. This could prevent further falls including associated injuries or new fractures; reduce new hospital admissions and improve confidence and engagement by limiting the psychologically restrictive 'fear of falls'.

Ethics and dissemination The study has been approved by the Human Research Ethics Committee of the Central Adelaide Local Health Network, South Australia (SA) Health, Government of South Australia and the University of Adelaide Human Research Ethics Committee. Findings from the study will be published in suitable peer-reviewed journals and disseminated through workshops or conferences.

Strengths and limitations of this study

- ► The proposed study will use a mixed-methods approach, which would provide a unique perspective around patient educational and information needs during the hip fracture care pathway, through a combination of the distinct strengths of each methodology.
- ► The study intends to provide enriched data through interpretation of results, using different theoretical frameworks, including the best practice clinical guidelines, contemporary models of implementation science and behavioural change to guide the design and analysis of study findings.
- ► Involvement of patients and carers is a key feature in the design of this study.
- ► A quantitative survey considering only two hospital settings could be a limitation of the study as the study findings may not be generalisable to the wider Australian context or internationally.

INTRODUCTION

Management of hip fracture in older adults poses significant challenges to delivering quality healthcare due to multiple medical, social and isolation issues, including frailty.[1 2] Worldwide, hip fractures are projected to increase from 1.7 million in 1990 to 6.3 million in 2050 due to significant increases in ageing and life expectancy.[3–5] In 2000, an estimated 9 million osteoporotic fractures occurred worldwide and the annual costs for treatment have been assessed to be around US$20 billion in the USA and €30 billion in the European Union,[6] with 72% of this cost incurred for the management of hip fractures. Following a hip fracture, the use of health services extends beyond the initial hospitalisation for at least 1 year, with much of the healthcare costs attributable to subsequent long-term care.[7–10] Such patients are at high risk of complications with devastating outcomes, loss of independence, decreased mobility and reduced quality of life.[11] Postdischarge, most of these patients attend orthopaedic outpatient departments, which are located in hospitals where access can be difficult, as patients rely on family or ambulance services to attend. For falls prevention, they need to access services generally located in the community, and general practitioners for management of existing comorbidities. This often leads to disconnected pathways of care contributing to discontinuation of appropriate care due to lack of integration between different services. The difficulty related to continuing care could also be due to low empowerment among older people with hip fractures or consumers of health services, in general.[12] Patients and their carers may lack the skills to understand complex instructions related to medication, self-monitoring and self-management, follow-up schedules and prevention behaviours. Adequate health literacy skills are important for understanding surgical procedures, informed consent and adhering to postsurgical instructions. Health literacy is a patient factor that can be influenced by both patient skill level, as well as by the information, communication and education provided to them.[13] Therefore, a single integrated care plan management system is needed that empowers the patient and their carers for both home and community management.[14 15] To be successful, the plan must adopt a systematic approach to ensure that individuals with one or more long-term conditions, and their health and care providers, have more productive and equal conversations, focused on what matters most to the individual.[16] With the advancement of modern information technology, it should be possible to seamlessly integrate different services for older people with hip fracture from acute hospital (tertiary) care to community rehabilitation and management through provision of quality health information. There is an imperative to reorient services to the community so that they can be delivered closer to the patients and in partnership with the consumers and primary/aged care services.

The proposed research aims to develop a 'model of care' by using a digital health solution that will allow delivery of high-quality and patient-centred information, integrated into the existing process, delivered within the community setting. The research will be conducted in different phases, incorporating a cocreation approach involving patients and their carers, primary/aged care clinicians, physiotherapists, dieticians and hospital-based clinicians through an iterative process. This first phase of the study would inform the development of a prototype, a digital health platform (phase 2). This will be further pilot tested for usability in the next stage (phase 3). Thus, this study protocol paper exclusively deals with the detailed methods for the first phase (figure 1). The objectives of this phase of the study are first, to understand the e-literacy level of patients with hip fractures in terms of their current use of technology in accessing health information and their likelihood of using such systems through their computers or mobile and other digital applications (context). Second, to explore specific health information requirements (content) for people with hip fractures, particularly after their discharge from the acute hospital

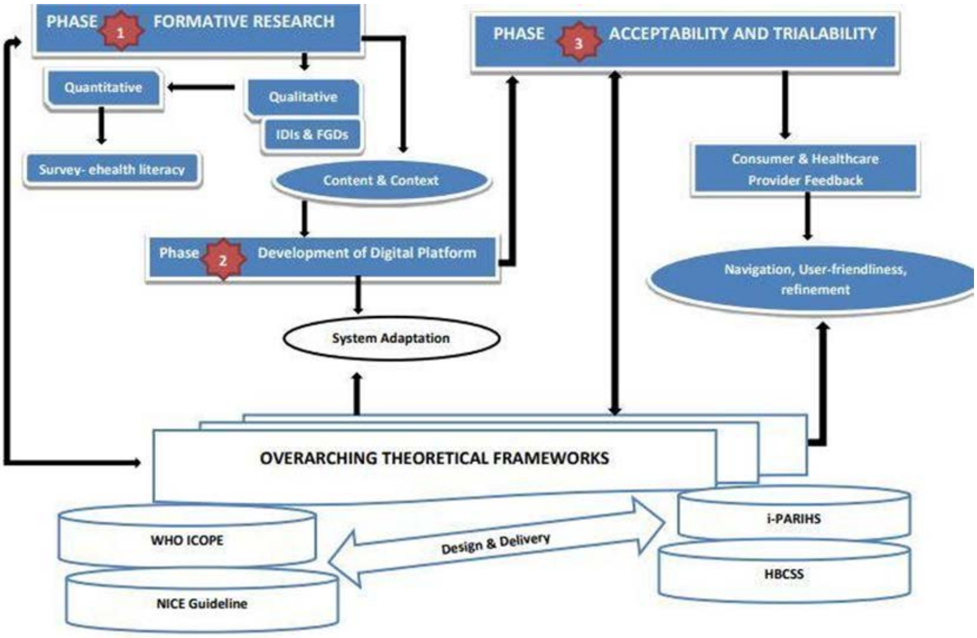

Figure 1 Conceptual Framework-Digital Health Patient Education Platform. FGD, focus group discussion; HBCSS, Health Behaviour Change Support Systems; IDI, in-depth interview; i-PARIHS, integrated-Promoting Action on Research Implementation in Health Services; NICE, National Institute for Health and Care Excellence; WHO-ICOPE, WHO integrated care for older people.

setting, from the perspective of patients and their carers; clinicians and residential care providers. Third, to determine important factors that need to be considered at the time of designing digital health educational platform for the patients with hip fractures (system) including potential barriers and facilitators around future use of such technologies.

METHODS

Study design

The proposed study will be using pragmatic design including mixed-methods research and a participatory approach through engagement of patients, their carers and healthcare providers.[17] Previous research clearly states that the ultimate success of health-related technologies depends on whether the intended users (eg, patients) find the developed applications useful.[18] The process of cocreation allows end users to directly influence how the technologies take shape in order to increase ultimate usability. Evidence indicates that involving end users throughout the technology development process, substantially reduces development time and allows easy translation of technologies to practice, as usability problems are identified and resolved before the systems are launched.[19 20] The study will be conducted at two hospital sites in Adelaide; the Royal Adelaide Hospital (RAH) and the Queen Elizabeth Hospital (TQEH).

Theoretical framework

This study will be using theoretical frameworks to guide the process of design, development and conduct of the study in real-world setting. These are the National Institute for Health and Care Excellence (NICE) guideline on hip fracture management; WHO's guideline on community-level interventions to manage declines in intrinsic capacity through an integrated care approach for older people (WHO-ICOPE); Health Behaviour Change Support Systems (HBCSS) and integrated- Promoting Action on Research Implementation in Health Services (i-PARIHS).[21–24]

According to the recently available NICE guideline on hip fracture management, good quality advice, reassurance, information and education were highlighted by patients as important factors in the recovery process.[22] Examining older people from the perspective of their intrinsic capacity and the outside environment in which they live helps to understand why health services should be oriented towards the most relevant outcomes that affect older people on a day-to-day basis. Further, this approach could eliminate unnecessary treatments, reduce polypharmacy and associated side effects and hopefully improve the overall quality of life for older people. The WHO-ICOPE guideline recommends evidence-based interventions to manage common declines in capacity among older people. These conditions were recommended because they express reductions in physical and mental capacities, as outlined in a WHO framework on healthy ageing and are strong independent predictors of mortality and care dependency in older age.[21] The WHO-ICOPE framework will guide this proposed research study in terms of developing more comprehensive and holistic educational content for the posthospital discharge setting and not just restricted to the specifics of a hip fracture injury.

The study further intends to use concepts from a contemporary theoretical framework around computer mediated communication and persuasive roles. This research domain is termed as HBCSS.[23] HBCSS has been defined as a sociotechnical information system that forms, alters or reinforces attitudes, behaviours or acts of complying, without using deception or coercion.[23 25] The three intertwined components of HBCSS are content, system and context. Content within HBCSS is often referred to as text or video; system is the technological mode and features used to deliver the content; and context is related to the specific organisational context or setting in which the proposed technological solution is desired to be implemented.[23] Due to the complex nature of HBCSS and as it is still evolving as a research discipline, there is a need to combine established theoretical frameworks such as i-PARIHS to further understand the implementation context and guide the design and development of the proposed research study.[24 26]

According to i-PARIHS, successful implementation involves facilitation of innovation, recipients and context, taking account of them together and how they interrelate with each other. The construct of 'innovation' includes explicit knowledge available through evidence and tacit, practice-based knowledge, which is considered to be influencing when it comes to implementation. The construct of 'recipient' includes those people who are affected by and influence implementation process and outcomes at both individual and collective team levels. 'Context' exists as different layers at micro, meso and macro, and is further defined in terms of resources, culture and leadership. It goes beyond local context to wider organisational, health system or external policy influences.[24]

While there are some overlapping constructs or concepts with certain limitations in each of the frameworks, a combination approach to guide different stages of the research process and exploring these constructs or concepts from different perspectives will provide robust understanding around study results.

Quantitative method

Inclusion and exclusion criteria

Consecutive patients aged 65 years and above with a hip fracture injury admitted to either of the two public tertiary care centres in South Australia (RAH and TQEH), and who could carry out their activities of daily living, independently prior to hospital admission, will be invited to participate in the study. Activities of daily living will be extracted from the case records as this is examined by an orthogeriatric nurse as part of the existing practice. Those patients giving written informed consent will be recruited in the study irrespective to their levels of (e) health literacy skills. Those patients highly dependent on medical care who may be unable to give consent, according to the treating clinician's discretion, will be excluded from the study.

Sample size and questionnaire

Approximately, 100 participants will be recruited from the two hospital sites over a period of 6 months. This sample size is based on realistic consideration around recruitment of participants in the given setting and time frame, and can be presented as a representative snapshot of the people admitted with hip fracture in these two hospitals. A published study on health literacy among elderly patients with a heart failure was also considered to justify our sample size, as a surrogate.[27] A structured survey questionnaire has been developed primarily to assess health literacy and e-health literacy using a validated 14-item health literacy scale[28] and electronic health literacy scale.[29] Frailty status of the participants will be assessed through a validated Modified Fried Frailty Phenotype. According to this phenotype, frailty is present when three or more of the following criteria are met: unintentional weight loss, weak grip strength, self-reported exhaustion, slowness and low physical activity level. On the other hand, when one or two of these criteria are met, respondents are classified as prefrail. However, for the purpose of this study, we will be using a dichotomous Frailty Phenotype; non-frail (0–2 deficits, combining non-frail and prefrail categories) and frail (3+deficits).[30] The last section of the questionnaire consists of information around hospital hip fracture care and management. The variables in the dataset have been recommended as part of the Australia and New Zealand Hip Fracture Registry and the Global Fragility Fracture Network.[11] The required information can be extracted from the patient hospital records and admission data. Approximately 20–30 min will be required to complete the survey questionnaire (see online supplementary appendix 1).

Statistical analysis plan

The quantitative data will be analysed to address the first objective of the study related to general health literacy and e-health literacy among older people with hip fracture. Apart from frequencies of basic demographic information, current use of information technology for accessing health information and the likelihood of using the future technological solutions will also be analysed. This will help determine the likely scenario of usability of potential digital health educational platform. The participants will be classified into two groups, non-frail and frail and the differences in the data between the two groups will be analysed using Student's t-test or X^2 test and also separately for each sex. In addition, multivariable logistic regression analysis will be undertaken, adjusted for relevant covariates (age, sex, body mass index and education).

Qualitative method

The qualitative component of this phase of the study will consists of in-depth interviews (IDIs) and focus group discussions (FGD) conducted with healthcare providers from different disciplines, patients, their carers and aged care providers. Orthopaedic and geriatric consultants, residents and nursing staff, physiotherapist, dietician and fracture liaison nurse will be included. Approximately, 15 IDIs and 4 FGDs will be conducted. An interview schedule has been prepared separately for patients, their carers and healthcare providers (see online supplementary appendices 2–4) and separate FGD guides for healthcare providers and patients along with their carers (see online supplementary appendices 5 and 6). Views of patients, along with their carers, will be explored around specific health information requirements (content) for people with hip fractures, particularly after discharge from the acute hospital setting. This component will help to determine important factors that need to be considered at the time of designing a digital health educational platform including potential barriers and facilitators around future use of such technologies. Thus, addressing the second and third objectives of this phase of study.

The audio recording will be transcribed verbatim and analysed according to themes. The researcher will analyse the data simultaneously with data collection until data saturation is reached. Different themes which emerge from the data will then be compared and interpreted according to the constructs of HBCSS theoretical framework.[20]

Data management, ethics and dissemination

A participant information sheet will be provided to potential participant prior to recruitment. This will incorporate the study description including participation requirements, benefits, confidentiality and data protection, the written informed consent process and the opportunity to withdraw from the study at any stage in the project. Findings from the study will be published in suitable peer-reviewed journals and disseminated through workshops or conferences.

Confidentiality and data security

Any information obtained in connection with this research project that can identify study participants will remain confidential. The collected information will only be used for the purpose of this research project and it will only be disclosed with participant's permission, except as required by the law. The IDIs and FGDs recording will be transferred from the audio recording device onto a secure server, soon after the data collection is completed. The data will be deleted from the recording device after ensuring all of the data have been successfully transferred to the secured server drive. The transferred recording on the server will be de-identified and only accessible to the researchers, working on this study project.

Patient and public involvement

Older people including former patients with hip fractures, their family members and representatives from residential aged care providers were involved in the early conceptualisation phase through a consumer research showcase event. This event was hosted by Multicultural Aged Care South Australia and National Health and Medical Research Council (NHMRC) Centre for Research Excellence in Frailty and Healthy Ageing, Adelaide Medical School, the University of Adelaide. One of the authors (LY) led the discussion with the event participants to understand the direction of this research process and informed the study design. Further, the study steering group will also include representation from patients, consumers group and residential aged care providers to guide the conduct of the study at each phase and will be closely monitored.

DISCUSSION

Hip fractures in older age require multidisciplinary integrated care and are often regarded as a surrogate marker of how the health system deals with frail, older patients.[31] A study relating to consumers' perspective conducted in Sweden demonstrated that following an event of hip fracture, patients not only have restricted mobility but also lose their confidence and self-efficacy due to the complex recovery process consisting of both physical and psychological strain. The study further concluded that even after 4 months postsurgery, the previously healthy and independently living felt hip fractures affected their day-to-day life.[32] Another study revealed that due to exposure to the ward culture at the time of acute hospital admission, patients become passive and insecure about their future life situation. This suggest patients believe in recovery but lack psychological support to regain prefracture status[33] or have inadequate empowerment.[34]

The aim of our proposed research is to develop a 'model of care' by using a digital health patient education platform. The development of this digital health educational platform will go through an iterative process, across the three phases. In each phase, patients, their carers including their family members and relevant healthcare providers will be engaged through a cocreation process.

Patients and their carers are interested in being involved in the decision-making process about the management of their condition. Increasingly, emphasis has been given to provide solutions, which assist patients with more information and enable them to actively participate in their care process, including management of their expectations about the recovery process prior to hospital discharge.[35 36] Management of conditions like osteoporosis, which often lead to hip fractures, require complex interventions; of which patient education appears to be the most important component.[37] Educating patients requires provision of good-quality health information to encourage patient participation in healthcare and ensuring that patients have greater power, protection and choice in key aspects of their care.[38] Also, patient information is a key component around effective self-management.[39]

Patient education centres around the assumption that patients who are better informed about their condition and management will be more likely to adopt positive health behaviours[40] and will therefore improve, maintain or slow deterioration of their health status. However, this view of patient education does not acknowledge the role of patient opinions and choices, and implies that health professionals set the education agenda and define optimal health behaviours.[41] Attitudes, beliefs and behaviours are considered to be important factors in influencing information needs of the patients, in addition to contextual factors and the format of educational resources.[42] Our study design is based on using sound theoretical frameworks including clinical guidelines. Each framework contributes in a different manner to the process; the NICE and WHO-ICOPE guidelines will help to guide the best practice around the development of information 'content' for the potential digital health solution. HBCSS will guide the development of digital health 'system' and i-PARIHS focuses on the 'process of implementation' from a health system perspective. There are some overlapping constructs between these frameworks alongside certain limitations. However, simultaneously, the study will also use existing knowledge around the best practices from local healthcare providers' perspective in South Australia.

In a recent study by Brookes, over 228 000 comments posted to the National Health Service (NHS) choice website were evaluated both quantitatively and qualitatively through a computer-assisted programme. The study suggested patients' perceptions for possible areas of improvement within various aspects of NHS service provision. High priority was given to the interpersonal aspects of healthcare provider interaction as well as system or organisational issues in coordinating services.[43] Similarly, by involving the user in a participatory design ensures consumers' requested functionalities can be incorporated to optimise the usability of the potential solution and simultaneously empower healthcare providers.[44]

A recent study demonstrates that older people with hip fractures can respond well to modern technological solutions used for health knowledge in spite of their limited use.[45] Technological advancement should consolidate relevant information in a broad-reaching manner, with real-time support to patients and their carers in their journey from diagnosis to follow-up.[35] Technology can potentially empower and build the capacity of primary healthcare providers to provide integrated care that channels appropriate expertise to the patient and brings specialty consultations closer to the community. Furthermore, technology helps to engage patients through improved communication and fostering self-management skills for their chronic conditions.[46] For success, it must adopt a systematic approach to engage people with chronic disease conditions and complex care needs, along with their care providers, and ensure they have an equal say in the matters about the management of their disease condition.[16] With the advancement of modern information technology, it should be possible to integrate seamlessly the provision of desired educational information for older people with hip fracture from acute hospital (tertiary) care to community rehabilitation and management.

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Contributors LY, TKG, RV, AT and MJC contributed in the study conceptualisation, following iterative process of discussion. LY in routine discussion with TKG conducted the background literature search around theoretical framework and methodology to guide the conduct of the pragmatic study approach. LY write the initial first draft under the guidance of MJC, RV and TKG. The draft was reviewed and critical inputs were provided by TKG, AT, UJ, JDY, RV and MJC. This final version of the manuscript incorporates comments and edits from the authors and approved by all.

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Competing interests None declared.

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CHAPTER 4

PATIENTS AND CARERS AS NETWORKED UNITS

(MIXED METHODS EXPLORATORY STUDY)

Identifying opportunities, and motivation to enhance capabilities, influencing development of a personalised digital health hub model of care for hip fractures: mixed methods exploratory study is a paper published in the *Journal of Medical Internet Research* in 2021.
The paper will follow summary and statement of authorship.

Summary

This paper addresses the third objective of the thesis work by understanding the perspective of the older people with hip fractures, their family members, and residential aged carers, to inform the development of a personalised digital health hub and factors impacting the likelihood of usage.

Contemporary evidence suggests digital technology has the potential to optimise health care including self-management, patient-healthcare provider communication and rehabilitation. This study emphasised on involvement of patients, their family members and residential aged carer together for creating a personalised digital health hub model of care to improve consumer health literacy and integration of health services.

This mixed methods study was conducted at a public tertiary care hospital in South Australia involving patients aged 50 years and above along with their family members and residential aged carers. Overall, 100 people were recruited in the study, representing 55 patients, 13 family members and 32 residential aged carers. Further, findings also contributed to understanding barriers and facilitators influencing the likelihood of using a personalised digital health hub.

Statement of Authorship

Title of Paper	**Identifying opportunities, and motivation to enhance capabilities, influencing the development of a personalized digital health hub model of care for hip fractures: mixed methods exploratory study**
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Overall percentage (%)	80%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper	
Signature		Date: 15 July 2021

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate to include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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Original Paper

Identifying Opportunities, and Motivation to Enhance Capabilities, Influencing the Development of a Personalized Digital Health Hub Model of Care for Hip Fractures: Mixed Methods Exploratory Study

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Abstract

Background: Most older people after a hip fracture injury never return to their prefracture status, and some are admitted to residential aged care facilities. Advancement of digital technology has helped in optimizing health care including self-management and telerehabilitation.

Objective: This study aims to understand the perspectives of older patients with hip fracture and their family members and residential aged caregivers on the feasibility of developing a model of care using a personalized digital health hub.

Methods: We conducted a mixed methods study in South Australia involving patients aged 50 years and older, their family members, and residential aged caregivers. Quantitative data analysis included basic demographic characteristics, and access to digital devices was analyzed using descriptive statistics. Spearman rank-order correlation was used to examine correlations between the perceived role of a personalized digital health hub in improving health and the likelihood of subsequent use. Findings from qualitative analysis were interpreted using constructs of capability, opportunity, and motivation to help understand the factors influencing the likelihood of potential personalized digital health hub use.

Results: This study recruited 100 participants—55 patients, 13 family members, and 32 residential aged caregivers. The mean age of the patients was 76.4 (SD 8.4, range 54-88) years, and 60% (33/55) of the patients were female. Approximately 50% (34/68) of the patients and their family members had access to digital devices, despite less than one-third using computers as part of their occupation. Approximately 72% (72/100) of the respondents thought that personalized digital health hub could improve health outcomes in patients. However, a moderate negative correlation existed with increasing age and likelihood of personalized digital health hub use (Spearman $\rho=-0.50$; $P<.001$), and the perceived role of the personalized digital health hub in improving health had a strong positive correlation with the likelihood of personalized digital health hub use by self (Spearman $\rho=0.71$; $P<.001$) and by society, including friends and family members (Spearman $\rho=0.75$; $P<.001$). Most patients (54/55, 98%) believed they had a family member, friend, or caregiver who would be able to help them use a personalized digital health hub. Qualitative analysis explored capability by understanding aspects of existing knowledge, including willingness to advance digital navigation skills. Access could be improved through supporting opportunities, and factors influencing intrinsic motivation were considered crucial for designing a personalized digital health hub–enabled model of care.

Conclusions: This study emphasized the complex relationship between capabilities, motivation, and opportunities for patients, their family members, and formal caregivers as a *patient networked unit*. The next stage of research will continue to involve a cocreation approach followed by iterative processes and understand the factors influencing the development and successful integration of complex digital health care interventions in real-world scenarios.

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KEYWORDS

digital health; mixed-methods; hip fractures; behavior change; patient education; model of care; mobile phone; patient networked units

Introduction

Background

The population of South Australia is older than that of all the mainland states and territories in Australia, except Tasmania. According to the Australian Bureau of Statistics, the current population of South Australia is approximately 1.7 million [1]. It is expected to increase to 1.85 million by 2026 and to 2 million by 2038 using current population projections. This increase was reflected by a significant increase in the older population. The number of retirees in the 65-79 years age group is projected to increase by 40% by 2041, using 2016 as the baseline. Moreover, the population aged 80 years and older is projected to increase by 117% over the same period [1], which will require an increased need for appropriate health and social care [2]. Although there has been greater realization that the skills, knowledge, and experience of older people could be better used with regard to their health care, there remains a view that they are a drain on society given their health problems and service needs [3,4]. The United Nations Economic Commission for Europe has suggested that altering this view is a key strategy to improve the integration and participation of older people in society [5].

Hip Fractures and Multimorbidity

Fragility fractures mostly occur in older people owing to low-trauma falls, which often result from multimorbidity [6,7]. Multimorbidity is the presence of more than one chronic disease in an individual and is influenced not only by health-related characteristics but also by socioeconomic, cultural, and environmental factors, as well as patient behavior [8]. Hip fractures are among the most devastating fragility fractures, and their management becomes challenging because of the required involvement of several disciplines within health and social care. This cohort not only represents healthy older people at one end of the spectrum but also comprises people with frailty, sarcopenia, osteoporosis, and dementia at the other end of the spectrum. This makes management of an acute event such as a hip fracture complex, with wide-ranging outcomes within the health care systems involving multiple disciplines and service providers [9-11]. It is made even more complex with the crossover between different levels of care, ranging from acute tertiary to primary and residential aged care [12,13]. Most patients who are admitted to acute hospital care are unable to return to their prefracture level of independence [14-16]. Although some patients return to independent living in their own homes, a significant number are either newly admitted or return to residential aged care [17]. Thus, we believe that individual patient outcomes can only be improved by envisaging a model of care that ensures a holistic and integrated approach to health service delivery while empowering patients and their caregivers.

Digital Health–Enabled Models of Care

Models of care (MoCs) are frameworks mutually agreed by key stakeholders accountable for delivering evidence-informed quality health care. Such frameworks must be functional, outlining the optimal manner in which condition-specific care should be made available and delivered to consumers while addressing issues related to specific aspects of service provision [18]. They go beyond clinical practice guidelines to incorporate practical delivery issues of who, when, where, and how care is best delivered and evaluated [18]. Thus, MoCs become complex due to their multidisciplinary workforce links to secondary and tertiary care services, the biopsychosocial needs of the patients, and frequently changing organizational structures. Although the mandate of primary care is to offer a generalist approach for dealing with older adults with multimorbidity, the coordination of community services is difficult. It is often left to the patients and their caregivers to coordinate and navigate through a range of services into which their individual social circumstances and priorities also need to be factored [18]. Provision of accurate, timely, and adequate information by educating patients plays a vital role in improving engagement and participation in the recovery and rehabilitation processes within the MoC. Health professionals often overlook patients' health literacy during routine practice, incorrectly assuming that the health information and instructions provided to patients and their family members have been understood [19,20]. Patient education, which also involves family members and residential aged care staff, is crucial for empowerment and improving health literacy [7,21-23].

Technological advancements have led to the evolution of clinical decision support systems and a myriad of consumer mobile apps to target different stakeholders, with the intention of optimizing health care and self-management of chronic disease conditions and maintaining a healthy lifestyle [12,13,24]. Nevertheless, there remains a need to build on the knowledge exchange process between health care providers and patients, along with their family members and caregivers, acting as facilitators [13]. By targeting different multimorbidities, which correspond to the internal capacity of individual older people, care can be personalized. This aligns with the World Health Organization (WHO) guidelines on community-level interventions to manage declines in intrinsic capacity through an integrated care approach for older people (WHO-Integrated Care for Older People) [13,23]. The WHO describes digital health as a broad umbrella term encompassing eHealth, mobile health, and emerging areas, such as the use of advanced computing sciences in big data, genomics, artificial intelligence, and machine learning [25].

Commitment and strategic engagement of stakeholders, including patients and the community, is required to improve health care services across all stages, from inception to operation or implementation [25]. Further advancement of these technological solutions can bypass some of the care disparities imposed by sociodemographic and geographic barriers and support the move toward universal health coverage [26,27].

Objective

The aim of this study is to understand the perspectives of older patients with hip fracture, their family members, and formal caregivers in residential aged care facilities to inform the development of a personalized digital health hub by understanding their current access to digital devices and factors affecting the likelihood of future use [8].

Methods

Setting and Study Design

We examined patients with hip fracture aged 50 years and older. This mixed-methods study [28] was conducted at the Royal Adelaide Hospital, a tertiary trauma care center in Adelaide, South Australia. This is one of the busiest hospitals in Australia for acute hip fractures, with local estimates suggesting approximately 500 to 600 patients treated annually [29].

Digital Health Hub Initial Concept

In this study, a digital health hub scenario, which is currently under development, was described to generate appropriate responses from the study participants. This proposed web-based health information portal, or a website, is intended for patients who can access all relevant information about their hip fractures. It includes details in multimedia formats of diagnosis and treatment options, medications, wound management and rehabilitation exercises, potential problems encountered during the hospital admission and post discharge, information on how to deal with difficulties, as well as how and when to attend follow-up appointments or seek more help from the health care team. It is interactive, enabling patients and their caregivers to provide both targeted and patient-initiated information to their health care provider, which is captured digitally. It also allows users to selectively make information available to family members or other people involved in their care (either formally or informally).

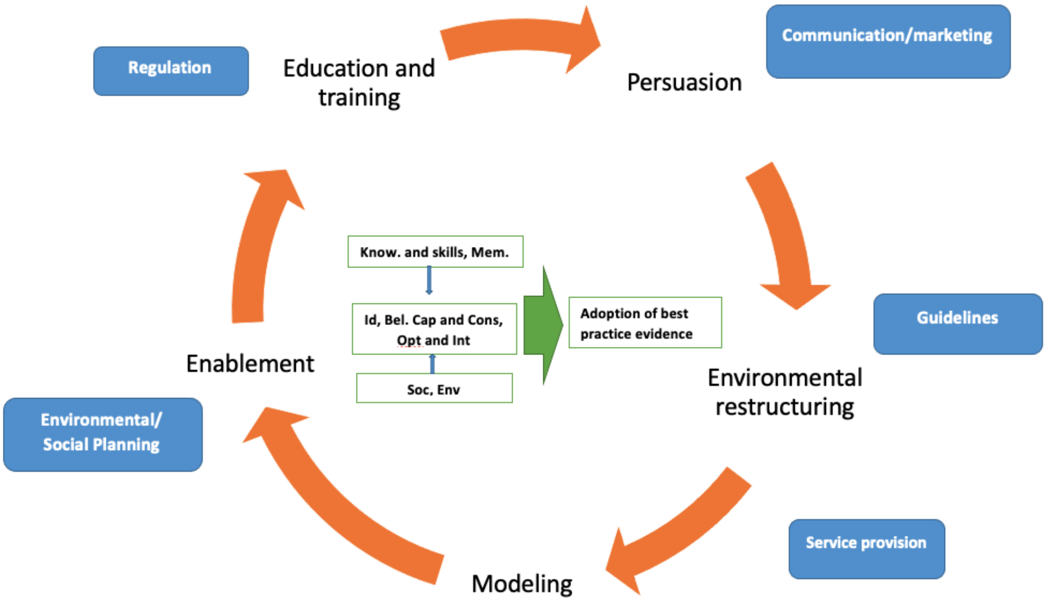
Data Collection and Analysis

Participants in this study were recruited from a previous prospective cohort study that focused on the delivery of fracture liaison service, undertaken between January and December 2016. Patients were contacted consecutively, and those who consented were invited to participate in the study. If participants in the original study had caregivers participating on their behalf, they were approached in a similar manner. Family members were represented as informal caregivers, whereas formal caregivers were caregivers of older people in residential aged care facilities. The data for this study were collected over a period of 6 months, from January 2017 to June 2017, using face-to-face interactions or telephone calls on the basis of individual preferences. A semistructured questionnaire consisting of closed and open-ended questions was developed and administered (Multimedia Appendix 1). Participants' responses to each question were entered into a hard copy Word (Microsoft Corporation) document by the research staff while administering the survey questionnaire. These responses were then compiled on an Excel (Microsoft Corporation) spreadsheet and stored on a password-protected folder on the secured server of SA Health.

Quantitative data analysis included basic demographic characteristics, and access to computers and the internet (digital devices) at home and in the workplace were analyzed using descriptive statistics. Spearman rank-order correlation was used to examine correlations between the perceived role of a personalized digital health hub in improving health and the likelihood of subsequent use of a personalized digital health hub. Fisher exact test and odds ratios were calculated for comparisons across respondent groups with respect to previous access to computers at the workplace, gender differences, and likelihood of potential personalized digital health hub use.

Qualitative data analysis included a series of open-ended questions to identify potential barriers and facilitators for accessing personalized digital health hub. Responses to the open-ended questions were analyzed deductively and aligned with the tenets of capability, opportunity, and motivation [30,31]. These findings interpreted using constructs of capability, opportunity, and motivation embedded within a theoretical Behavior Change Wheel (BCW) framework and helped to understand factors influencing the likelihood of potential personalized digital health hub use. The use of this framework to explore multidisciplinary stakeholder engagement within hip fracture management has been described elsewhere (Figure 1) [31,32].

Figure 1. Constructs of capability, opportunity, and motivation embedded within a Behaviour Change Wheel Framework [27]. Sources of Behaviour box and arrow in green; Intervention functions orange; Policy categories blue. Know: knowledge; Mem.: memory, attention and decision processes (capability); Id: social or professional role and identity; Bel. Cap. and Cons: beliefs about capabilities and consequences; Opt. and Int.: Optimism and intentions (motivation); Soc.: social influences; Env.: environmental context and resources (opportunity).



Ethics

This study was approved by the Human Research Ethics Committee of the Central Adelaide Local Health Network (RAH protocol number R20080704, HREC reference: 080704, ethics approval amendment on 12/12/2016, CALHN reference number: 8977, SSA approval 23/1/2017).

Results

Quantitative Findings

Overall, 100 participants were recruited in the study (Table 1). These included 55 patients, 13 family members as informal caregivers, and 32 residential aged care workers. The age (in years) of patients (mean 76.4, SD 8.4; range 54-88) was similar to that of their family members (mean 77.2, SD 10.0), whereas the residential aged caregivers were younger (mean 45.2, SD 11.6). Females represented 60% (33/55), 54% (7/13), and 86% (28/32) of patients, family members or informal caregivers, and residential aged formal caregivers, respectively. Around a quarter to a third of the participants were from *professional* occupations across all 3 groups. The residential care group included 5 registered nurses and 2 enrolled nurses. Within the patients' group, the common occupations were laborers, clerical and administrative workers, homemakers, machinery operators, and drivers.

With respect to digital access, approximately half of the patients (28/55, 51%) and their families (6/13, 46%) had access to their own computer devices through the internet. A quarter (13/55, 24%) of the patients used a computer as part of their occupation in comparison to 31% (4/13) of family members, whereas more than 91% (29/32) of the residential aged caregivers had computer access.

Patients who reported using a computer as part of their work were 8 times more likely to have access to a computer with internet access at home compared with those who did not use a computer at work (odds ratio [OR] 8.08, 95% CI 1.58-41.18; Fisher exact test=0.0095; *P*=.05). The mean age of those with access to a computer was 4.6 years less than that of those without access (74.2 vs 78.8, *P*=.04).

Approximately 40% (25/68) of the patients and their family members reported using basic operational tools such as email and Google (or other search engines) in comparison to 100% (32/32) of the residential caregivers who used these functions (Table 1). Of these, more than 85% (46/53) of the patients found it *reasonably easy* to *very easy* to operate these basic functionalities through the internet. Skype or other video calling programs were used by only a quarter of patients and their family members, whereas 44% (14/32) of the residential caregivers reported that they used these programs. Among the patient group, men were 3 times more likely to report having used email than women (OR 3.75, 95% CI 1.17-11.9; *P*=.02). However, given the opportunity, 42% (23/55), 38% (5/13), and 56% (18/32) of the patients, their family members, and residential aged caregivers, respectively, expressed their willingness to learn or advance their skills in these areas. While exploring this aspect further, all patients except 1 (54/55, 98%)

also said they had a family member, friend, or caregiver who would be able to help them use a digital health platform.

Approximately 72% (72/100) of the respondents thought that personalized digital health hub could improve the health of patients. Although a moderate negative correlation existed with increasing age and likelihood of personalized digital health hub use (Spearman ρ=–0.50; *P*<.001), the perceived role of the digital health hub in improving health had a strong positive correlation with the likelihood of personalized digital health hub use by self (Spearman ρ=0.71; *P*<.001) and by society, including friends and family members (Spearman ρ=0.75; *P*<.001). Furthermore, those participants who thought that the support content and services provided through personalized digital health hub would improve their health were more likely to use such a platform by themselves (OR 33.80, 95% CI 7.33-155.76; *P*<.001), and their friends and family members (OR 27.23, 95% CI 8.06-91.95; *P*<.001).

In terms of intention to buy a computer, 65% (36/55) of the patients said they would not be willing to purchase a computer or other device to enable them to access a web-based portal. Of the 35% (19/55) who would be willing to purchase a computer or device, 13% (7/55) said they would be willing to spend up to Aus $200 (US $144), 18% (10/55) said they would spend up to Aus $500 (US $360), and 4% (2/55) said they would spend up to Aus $1000 (US $720).

Table 1. Basic demographics and computer access characteristics.

Demographics and access to digital technology	Patients (n=55)	Family members (n=13)	Residential aged caregivers (n=32)
Age (years), mean (SD)	76.4 (8.4)	77.2 (10.0)	45.2 (11.6)
Female, n (%)	33 (60)	7 (54)	28 (86)
Occupation[a], n (%)			
Managers	2 (4)	1 (8)	N/A[b]
Professionals	13 (24)	4 (30)	7 (22)
Technicians and trade workers	6 (11)	2 (14)	N/A
Community and personal service workers	1 (2)	N/A	25 (78)
Clerical and administrative workers	7 (13)	1 (8)	N/A
Sales workers	3 (5)	1 (8)	N/A
Machinery operators and drivers	5 (9)	1 (8)	N/A
Laborers	8 (14)	1 (8)	N/A
Homemaker	5 (9)	1 (8)	N/A
Unemployed	1 (2)	N/A	N/A
Did not respond	4 (7)	1 (8)	N/A
Access to digital technology			
Use of computer	13 (24)	4 (31)	29 (91)
Own computer with internet access	28 (51)	6 (46)	32 (100)
Device access but no internet	4 (7)	0 (0)	0 (0)
Use email	20 (36)[c]	5 (38)	32 (100)
Use Google or other search engines	20 (36)	5 (38)	32 (100)
Use Skype or other video calling programs	13 (24)	3 (23)	14 (44)
Willingness to learn[d]	23 (42)	5 (38)	18 (56)

[a] Occupation groups as defined by the Australian and New Zealand Standard Classification of Occupations.

[b] N/A: not applicable.

[c] Men versus women, odds ratio 3.75 (95% CI 1.17-11.9; *P*=.02).

[d] Willingness to learn how to use email or internet search engines such as Google or a video calling program such as Skype, if the respondents have not used any of them before.

Qualitative Findings

The respondents answered the two open-ended questions within the survey instrument to explore barriers (Q15) and facilitators (Q16) influencing the likelihood of using a personalized digital health hub to educate and empower patients, their family members, and caregivers within residential aged care (Multimedia Appendix 1). These factors were interpreted using constructs of capability, opportunity, and motivation within a BCW framework, and relevant quotes from the study respondents (R) were also provided. Capability in this study was defined as an individual’s psychological and physical capacity to engage with the potential personalized digital health hub, which included having the necessary knowledge and skills. Opportunity considered all the factors lying outside the individual that make the behavior possible or prompt it, such as the likelihood of engaging with the potential personalized digital health hub. Motivation included processes that energize and direct behavior, not just goals but also habitual processes, emotional responses, and analytical decision-making. These constructs influence each other, as they work dynamically, such as access to opportunity can drive motivation, whereas enacting behavior can alter capability, motivation, and opportunity [32]. There were 59 participants who responded to questions corresponding to barriers with further breakdown of 38, 9, and 12 as patients, their family members, and residential aged caregivers, respectively. In contrast, 40 participants responded to questions corresponding to facilitators, representing 24, 3, and 13 patients, their family members, and residential aged caregivers, respectively.

Capability

Some patients recognized that possessing the necessary knowledge and skills while accessing digital devices can help explore relevant web-based health information, which could enable a better understanding of their health condition. Conversely, there were some family members and caregivers who lacked confidence in using digital devices. There was no one available to teach them and also felt inadequate about understanding the patient’s medical condition. The patients’ comments reflect that the information gathered through such a digital health platform would actually help improve their decision-making during the recovery process:

> *Can't use the computer, no one to teach me to use it at the moment.* [R53]
>
> *Would have been very useful (internet), always looking things up anyway.* [R49]
>
> *Keeping up with computers and technology keeps me sharp [informing decisions].* [R38]

Opportunity

Patients and their family members considered their personal environment and the affordability of resources, such as digital devices, as a major limiting factor. Residential aged caregivers saw digital health platforms as an opportunity to provide general health information, including healthy lifestyle, diet, and exercise. Furthermore, it was suggested that a platform such as a personalized digital health hub (or similar) would be more efficient or easier than existing options and would provide a potential solution with resources consisting of videos of exercises such as yoga and tai chi. In addition, several patients were of the opinion that a list of available services (eg, allied health professionals, exercise classes, alternative therapies) along with health management information could be well received by the community:

> *Can't afford computer on aged pension.* [R15]
>
> *Lots of people interested in general information about their health as well ie healthy lifestyle, diet, exercise.* [R72]
>
> *Videos [exercises] would be very helpful, would like information about how long hip replacements last and how to take care of them, any information is good information? Could include tai chi or yoga.* [R24]
>
> *Knowing it’s there [digital platform] to fall back on, list of things/services that are available.* [R47]
>
> *Rehab exercises, suggestions and options, a list of services.* [R67]

Motivation

Being older was identified by both patients and their family members as one of the main hurdles to using the potential personalized digital health hub platform. Residential caregivers, however, identified practical issues such as lack of time in their existing role to use such a solution, which is currently not a part of their job. Participants across all 3 categories identified their existing capabilities as a limiting factor. However, they were also positive about the potential capabilities of a digital solution, such as the availability of information that would reduce the need to visit a physician and access to trustworthy interventions. These interventions include videos and information about health and instructions from reputable sources such as physiotherapists that they can follow in their own time as well as the potential to more easily track their appointments with different health care providers:

> *Hard for other elderly people.* [R8]
>
> *Just not practical, responsible for more than one person at a time so time using this would take away from actually caring for people.* [R83]
>
> *Access to information on demand, not have to visit doctor, not missing phone calls and use on own time.* [R3]
>
> *Reputable sources would be good, videos of exercises helpful, a realistic timeline for recovery would be useful.* [R43]

The residential aged care staff thought that a digital health solution could potentially improve handover processes through a better exchange of information between specialists and caregivers. Most participants were optimistic about the range of functions that a digital health platform could provide; however, some had reservations such as preferring phone conversations or maintaining conventional face-to-face interactions with the physician. Emotionally, some consumers were unhappy with the services provided through technology-based solutions in comparison with face-to-face interactions. One of the patients identified a potential lack of reinforcement in terms of someone who could teach or handhold, which could be a barrier to using a digital solution. Conversely, some patients thought that it could help them achieve more peace of mind and service satisfaction:

> *Would (digital platform) improve handover of information between specialists and carers or the patient, keep everyone on the same page more.* [R88]

> *Prefer phone calls, more personal, know who you're talking to.* [R14]
>
> *Good to be able to see exercises [over the internet], peace of mind.* [R6]

Discussion

Principal Findings

This study was considered as one of its kind due to the involvement of combined perspectives from patients with hip fragility fractures, their family members, and residential aged caregivers. Older people with hip fractures often have low intrinsic capacity, leading to depletion in physical function, mental health impairment, and increased health care costs [33]. Therefore, it is crucial to address hip fractures among older people, particularly those with multimorbidities, as a whole and in an integrated manner, rather than managing individual issues in isolation or silos, including improving health literacy by connecting with family members and formal caregivers as networked units [34]. This study explored the feasibility of a potential personalized digital health hub model of care in educating, empowering, and integrating health services, including self-management, for older patients with hip fractures in South Australia. Quantitative and qualitative methods were used in synergy to maximize the interpretation of findings. The BCW framework was applied through constructs of capability, opportunity, and motivation. These constructs are embedded within the BCW framework, which has been used in many contemporary scenarios for developing complex health interventions, including stroke rehabilitation [35] and multiple lifestyle issues [36,37].

Quantitative findings suggested that patients and their family members were of the same age, and almost half of them had current access to digital devices with the internet, despite only about a quarter of them using computers as part of their occupation (Opportunity). Although significant gaps existed with respect to operating emails, video calling, and exploring search engines (Capability), many of them expressed their willingness (motivation) to advance their skills through the supporting environment. The latter can be strengthened as 98% (54/55) of the patients said they had family members, friends, or caregivers (Opportunity) who would be able to help them use such a resource. Furthermore, the findings from our study suggest that 72% (72/100) of the respondents thought that the personalized digital health hub would be useful for improving their health.

Findings from the qualitative analysis explored deeper meanings of individual capability, opportunity, personal circumstances, and motivational factors varying within each group. Capability mainly focuses on knowledge, skills, and decision-making processes, whereas opportunities could be in the form of availability and access to digital devices and holistic care [10], including healthy lifestyle, diet, and exercise [36]. Some consumers may have better knowledge and skills to understand health information and access web-based resources. These people advocated for the personalized digital health hub being available for communicating high-quality and trustworthy health information resources, tracking appointments, and linking relevant services through a single hub. On the other hand, some preferred traditional face-to-face interactions and considered declining individual capacities due to aging as a possible challenge to cope with learning associated with the new technology. For some, personal circumstances, including affordability and access to computer systems, were important aspects to be considered. Furthermore, the findings suggested that motivation to engage with personalized digital health hub could be adversely affected by increasing patient age and contributing to additional workload for caregivers. However, information available in different formats, such as video or interactive, could improve patient engagement, help navigate different service provisions, and improve workforce handover processes delivered through an agreed model of care [18].

The sharing of information between patients and health care professionals is one of the key pillars of therapeutic relationships [38]. Increasingly, this information is being shared on the web, as digital health platforms through which patients can access education regarding medical conditions, information on self-management, and communication of health information to health professionals [39-41]. Clearly accessing and using some of these platforms will challenge certain groups within populations, such as the older adults. Ulrich and Vaccaro [42] described the benefits to patients receiving health information on the internet. These included improved health outcomes, mainly due to fulfillment of expectations and changes in behavior, which are facilitated by improved availability of information and resources. They note that older people in particular prefer audiovisual or pictorial explanations and information [42]. Furthermore, most patients do not have the capacity to distinguish nonbiased and reputable sources of information from commercially biased promotional materials [42]. The personalized digital health hub research program described here presents an opportunity to standardize and ensure the quality and evidence base of information received by patients and caregivers. A contemporary example of a digital technology used to improve access to first-line care for musculoskeletal conditions is the painHEALTH initiative [43]. This platform was codeveloped with consumers in response to the escalating burden of pain management associated with musculoskeletal conditions. The development of content was aligned to best practice recommendations from musculoskeletal MoC [18,43] and calls to action for improved care highlighted in the Australian National Pain Strategy [44].

Not all people have access to the internet, and this is especially true for people older than 65 years. However, according to the Australian Bureau of Statistics and Household Use of Information Technology survey for 2016-2017, the proportion of users accessing the internet for health-related services or research has more than doubled from 22% in 2014-2015 to 46% in 2016-17. Among older people, 55% of those aged 65 or older accessed the internet in a typical week, a 4% rise from the survey conducted in 2014-2015 [45]. Internet use correlated positively with educational attainment and household income and negatively with rurality. However, the survey is likely to be an overestimate of the proportion of older adults in the population who regularly use the internet as it excluded *people living in nonprivate dwellings such as hotels, university residences,* *students at boarding schools*, *patients in hospitals*, *inmates of prisons*, and *residents of other institutions* (eg, *retirement homes* and *homes for persons with disabilities*) [45]. The survey also noted that 14% of Australian households did not have internet access [45].

Caregivers, spouses, or family members can and should be engaged to assist with the personalized digital health hub platform in consultation with the patient. However, any provision to replace in-person clinical interactions must include a safety net for patients without access. Our study suggests that 46% (46/100) of the participants were willing to learn and develop their skills. Usually, patients accessing public tertiary care facilities are more likely to belong to the lowest socioeconomic status grouping [46]; despite being economically disadvantaged, more than one-third of these patients within our study were willing to buy a computer or other smartphone devices to access the potential personalized digital health hub platform. The majority of them would spend between Aus $200-$500 (US $144-$360), but very few of them could go up to Aus $1000 (US $720). This emerging likelihood of using potential digital health solutions was also supported by another study [47], in which 63% of the participants expressed their intentions as *definitely or probably* to be using a digital health platform as a web-based interface. Such a platform could carry out tasks such as making appointments, asking questions, receiving treatment, information, and providing support for their health and well-being. This study also emphasized the importance of user-friendliness and quickly resolving issues such as bugs in the initial releases [47].

Although digital health care may offer feasible and efficient options for monitoring and securely interacting with patients, an adequate level of engagement with the technology by all stakeholders is critical. In a recent rollout of an Australian opt-out digital health data management system (known as My Health Record), although there was a 90% subscription rate by patients, less than a quarter of health provider organizations were using the system [48]. This was even though 60% ranked clinical integration and improved patient experiences as their top priorities [49]. This mismatch suggests that educating practitioners to use digital systems is as important as patient engagement and compliance [50,51]. Together, this could have an incremental effect on patient outcomes and service delivery.

Limitations

This study has several limitations. One of them was a convenience sample from a single hospital site. However, this site is a major tertiary referral center that receives hip fracture patients across South Australia. Similarly, because of time and resource constraints, we were only able to recruit 100 participants in this study. We recommend that future studies consider a large sample size and further build on the evidence [52,53]. Another limitation is that patients with impaired cognition and high multimorbidity risk were not included. However, we attempted to engage residential aged caregivers who received many of these patients. These caregivers certainly act as facilitators, helping their patients, and are equally important stakeholders in the care process. Our study highlighted, from the perspective of caregivers, that personalized digital health hub could improve the handover process between specialist care and residential age care. [13]. We also acknowledge that these data were collected in 2017; however, we consider the findings from the study to be unique and still relevant, on the basis of the existing literature and development in the area of broader musculoskeletal care and digital health. Nonetheless, studies demonstrate the need to substitute current inefficiencies of siloed health care models with more person-centered and integrated models in which the patients and their caregivers are empowered as a team that works toward a personalized health solution to illness [8,18,51]. We acknowledge that when this study was conducted, the concept of personalized digital health hub was very theoretical; however, with inputs from other study components, we have been able to advance it to the stage of a prototype to be tested in the practice setting in the next stage of our research activity. Another limitation offered by the design of this study was a weak component of qualitative methodology, as the primary data collection tool consisted of only 2 open-ended questions. However, despite this limitation, we attempted to maximize the relevance of findings by applying the analytical behavior change framework. Similarly, in this process, the increased use of digital technologies to support health care is inevitable, particularly in the context of COVID-19, which has not only accelerated the willingness of health care practitioners to adopt telehealth options but also resulted in patients quickly adapting to and embracing these recent changes [54-56].

Conclusions

Recovery from fragility fractures among older people requires input from multiple specialties within medicine and allied health domains depending on the presence of concurrent medical conditions. Rather than approaching patients as isolated individuals, we need to consider them in the context of a network of caregivers and delivery of service as an integrated holistic model of care. Findings from this study contributed to understanding the capabilities, motivation and opportunities of patients, family members and formal caregivers as a *patient networked unit* rather than as siloed groups and provided a proof of concept around a personalized digital health hub [8]. This will provide greater cohesion and opportunities for success while navigating through a complex recovery pathway with multiple caregivers and is critical to the development of a personalized digital health hub–enabled MoC. Future paths will also incorporate perspectives from other relevant stakeholders as part of the *patient networked unit*, evolving through iterative processes and cocreation, to improve our understanding around the successful development of complex health care interventions and its drivers [13,57].

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Authors' Contributions

MJC and TKG conceptualized the initial prospective cohort study, and LY joined in the iterative discussions around the analysis and interpretation of study findings. AT and JDY facilitated data collection for this study. LY wrote the initial draft of this manuscript. The drafts with multiple versions were subsequently reviewed, and constructive inputs were provided by TKG, MJC, AT, and JDY. This final version of the manuscript incorporates comments and edits from the authors and has been approved by all.

Conflicts of Interest

None declared.

Multimedia Appendix 1

In-depth interview schedule (stakeholders).
[DOCX File , 16 KB-Multimedia Appendix 1]

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Abbreviations

BCW: Behavior Change Wheel
MoC: model of care
OR: odds ratio
WHO: World Health Organization

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CHAPTER 5

PERSPECTIVES OF DIVERSE MULTIDISCIPLINARY STAKEHOLDERS

Context, content and system supporting Digital Health Hub (DHH) enabled Models of Care (MoC) for fragility hip fractures: perspectives of diverse multidisciplinary stakeholders in South Australia using qualitative in-depth interviews, is a paper published in the Archives of Osteoporosis in 2021.

The paper will follow summary and statement of authorship.

Summary

This paper addresses the fourth objective of the thesis by understanding the perspective of clinicians from various medical and surgical disciplines, allied health, and other relevant non-health stakeholders to inform the development of a digital health enabled model of care for fragility hip fractures.

Qualitative in-depth interviews were conducted involving thematic analysis of the raw data using inductive coding as the first step. In the second step, the tenets of a theoretical framework (Health behaviour change supporting systems) were deductively applied to the theme constructs generated as part of the first step within the analysis.

In total, 24 in-depth interviews were conducted with stakeholders, identified 18 thematic constructs, regrouped, and presented under the categories of context, content, and systems. Context covers wide range of aspects from frailty, digital literacy, patient/carer participation to structure and culture of existing practice and the need for innovative holistic models of care. Content outlines the active ingredients and approach to developing a digital health hub, alongside highlighting the importance of targeted education and behaviour change. System is a complicated matrix crossing beyond aspects of health care- offering value proposition design through personalisation across modes of content delivery. Further, this must foster trust, ensure adequate financing, and support ownership and utmost privacy by establishing appropriate mechanisms for embedding change. Findings might guide other settings involving comorbid conditions and low and middle-income-countries looking forward to developing innovative digital health solutions.

Statement of Authorship

Title of Paper	**'Context, content and system' supporting digital health hub (DHH) enabled models of care (MoC) for fragility hip fractures: perspective of diverse multidisciplinary stakeholders in South Australia using qualitative in-depth interviews**
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Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper	
Signature		Date: 15 July 2021

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate to include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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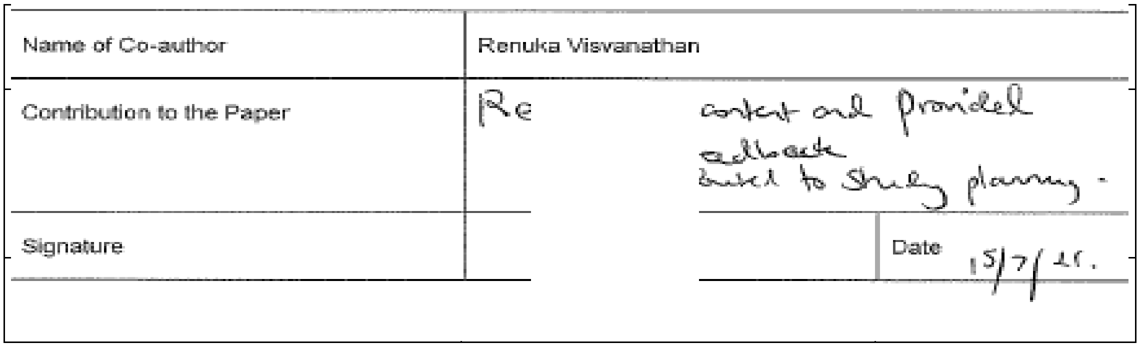

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ORIGINAL ARTICLE

"Context, content, and system" supporting digital health hub (DHH)–enabled models of care (MoCs) for fragility hip fractures: perspectives of diverse multidisciplinary stakeholders in South Australia from qualitative in-depth interviews

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Abstract

Summary Combining thematic analysis and a human–computer persuasive systems framework suggests that hip fracture recovery among older people can be enhanced through person-centered digital health hub models of care focused on behavior change education and integrated care. The findings intend to guide settings involving comorbid conditions and low- and middle-income countries in developing innovative digital health solutions.

Purpose The purpose of this study was to understand stakeholders' perspectives on the development of a digital health-enabled model of care for fragility hip fractures and to map out factors that could influence the design and implementation of such a model.

Methods Qualitative in-depth interviews were conducted with stakeholders from various clinical disciplines, allied health, and computer science. A hybrid process involving thematic analysis of the raw data using inductive coding was the first step. In the second step, the tenets of a theoretical framework (health behavior change supporting systems) were deductively applied to the thematic constructs generated as part of the first step of the analysis.

Results In total, 24 in-depth interviews were conducted with stakeholders. We identified 18 thematic constructs presented under the categories of context, content, and system. Context covered patient characteristics such as frailty, digital literacy, and patient or carer participation, whereas healthcare delivery aspects included the structure and culture of existing practice and the need for innovative holistic models of care. Content outlines the active ingredients and approach in developing a digital health hub, and it highlights the importance of targeted education and behavior change. The system is a complicated matrix crossing different aspects of healthcare and offering a value proposition design through personalization across modes of content delivery. This must foster trust, ensure adequate financing, and support ownership and privacy by establishing appropriate mechanisms for embedding change.

Conclusion The findings from this study provide insights around potential factors related to patients, community support, and healthcare delivery influencing the design and next-stage implementation of a digital health hub model of care for fragility hip fractures.

Keywords Digital health · Models of care · Hip fractures · Qualitative method · Frailty · Multimorbidity

Introduction

Fragility hip fractures among older adults present a significant burden to society in terms of disability, mortality, and economic repercussions for both community and health systems [1–4]. While the rate of fragility fractures in Australia is expected to rise by at least 10% every 5 years, hip fractures are among the most devasting of these fractures, with almost 50% requiring a permanent shift to residential aged

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care within 12 months [2]. The combined health and social care costs in the first year following a hip fracture injury are enormous and unsustainable; the costs are reported to be $43,669 on average, which is higher than equivalent estimates for ischemic stroke and acute coronary syndrome [3]. Hip fracture events are complex, manifested by disequilibrium of normal physiological processes at the individual patient level, and accompanied by inadequate management of multimorbid conditions at the health system level [1–4].

Multimorbidity is the presence of more than one chronic condition in an individual. It is influenced not only by health-related characteristics but also by socioeconomic, cultural, and environmental factors, as well as patient behavior [5]. It is argued that the current health system is predominantly geared toward labeling and addressing chronic disease through siloed care pathways rather than having a wider view of disease etiology and interacting factors [6]. Thus, it is vitally important to acknowledge that the management of older people with fragility hip fractures is a complex, multidimensional issue that extends beyond the acute care facility and immediate discharge care [1, 5, 7].

Recognition of the role that patients, their family members, and other carers play as part of an ecosystem, or "networked units," is becoming critically important for improving outcomes [7–9]. Individuals have unique life circumstances influenced by differing levels of health literacy, which affects their perception of health and wellbeing and their disease outcomes [4, 9–11]. Moreover, with increasing access to information technology through computers and mobile applications, there is a growing recognition that people will become more curious to seek information related to their present health condition. Before undertaking this research, we conducted a comprehensive systematic review to evaluate the effectiveness of targeted patient communication supported through digital health interventions versus the standard provision of health information on the recovery from fragility fractures among older adults [1]. The findings from this review were divided into three categories as defined by the latest World Health Organization (WHO) guidelines on digital health interventions. A meta-analysis suggested that targeted patient communication with primary care physician support using digital health was twice as effective as the standard provision of health information, such as patient information leaflets, in preventing secondary fractures post-hospital discharge. It was further highlighted that providing health information alone does not equate to educating patients. The other two digital intervention categories also improved functional outcomes among older fragility fracture patients. However, significant challenges were involved in using sophisticated forms of interactive digital health technologies, such as personal health tracking and healthcare provider decision support. There is a need to proactively engage different stakeholders, including healthcare providers from multiple disciplines, patients, and their family members, to cocreate a digital health solution that could potentially become an integral part of local service design and delivery [1, 4, 5, 9].

This study is the first phase (formative research) of a research program aimed at informing the development of digital health-enabled models of care (MoCs) to improve patient education, functional outcomes, and quality of life and foster continuity of supported and integrated care among older people with hip fractures [4]. Our previously published protocol paper examined different theoretical frameworks around computer–human persuasive systems (Health Behavior Change Supporting Systems (HBCSS)), implementation science, and best practice guidelines on hip fracture management and the management of older people within the community [4, 12–15]. For this research component, we utilized three constructs of HBCSS (content, context, and system) to guide the design and execution of the study. The "content" essentially refers to the evidence-based information that will be embedded into the digital health solution and the way consumers will be engaged to inform its further evolution and iteration. The "context" includes factors influencing the local setting in which we intend to develop, pilot, and later implement such a digital health solution, while the "system" encompasses the supporting infrastructure requirements, including aspects of operational mechanisms [4, 12].

The objectives of this study were to understand the perspectives of diverse stakeholders on the development of digital health-enabled MoCs for fragility hip fractures and to map out potential factors that could influence design and implementation within the local healthcare setting [4, 12]. Stakeholders in this study are healthcare practitioners from different clinical disciplines, allied health, health education, public health, computer science, and other fields who could influence policy and key decision-making at the local contextual level. The perspectives of patients, their family members, and residential aged carers were covered in another study [7].

Methods

Study design and participants

This study involved a wide range of stakeholders from the Central Adelaide Local Health Network (CALHN), which is responsible for promoting and improving the health of the central metropolitan Adelaide community and provides specialized care for South Australians through integrated healthcare and hospital services. Additionally, a substantial number of people from outside these geographic areas also access services offered by CALHN. Stakeholders in this study were healthcare practitioners from multiple disciplines at different levels, ranging from senior administration to frontline staff. Their disciplines included orthopedics, geriatrics, physiotherapy, occupational therapy, dietetics, public health, and social and computer sciences. These study participants were among the key actors who could influence the micro (local clinical practice), meso (service delivery), and macro (policy and research agenda) levels. An in-depth qualitative interview method was used to enable participants to describe their views and experiences in detail; this method has been previously described [4, 16]. We followed the Consolidated Criteria for Reporting Qualitative Studies (COREQ), a 32-item checklist, throughout this manuscript (Supplementary 2) [17].

Recruitment and setting

A purposive sampling strategy was used, and we identified potential participants through various routes, including clinicians working in the multidisciplinary hip fracture care environment across various settings (primary, secondary, and tertiary care), researchers, and policy or decision-makers. With this sampling strategy, we selected study participants belonging to different but relevant disciplines, with different areas of subject expertise, and with varying years of experience, including some early career participants and some highly experienced participants. This approach ensured the diversity of participants in terms of their roles, professional background, and level of experience.

Participants were approached using multiple strategies, such as email, phone, or in-person invitations. Participants were provided an information sheet with a detailed description of the study and an opportunity to ask questions and written and/or verbal consent was obtained as appropriate. The principal investigator (LY) then identified a suitable time and mode for interviews with interested participants.

Data collection

An interview guide (Supplementary 1) was developed based on the contemporary literature on digital health, social and behavioral change theories, implementation science, and best practice guidelines for the management of hip fractures. This interview guide consisted of open-ended questions divided into three broad categories—content, context, and system—with embedded prompts [4]. This approach provided flexibility during the interview process to allow participants to raise issues that were personally salient to them.

Data analysis

All of the interviews were audio-recorded. LY transcribed the recordings verbatim, checked for inconsistencies, and anonymized the data. Details of individuals, places, or any other identifiable information were removed before sharing transcripts with team members. A hybrid process of inductive and deductive thematic analysis to interpret the raw data was used. This involved thematic analysis of the raw data using inductive coding as a first step and then deductively applying the tenets of HBCSS to the theme constructs generated as part of the first step of the analysis [12, 18]. An initial coding framework was developed while the stakeholder interviews were still being conducted by identifying themes through careful reading and rereading of the first three interview transcripts. This coding framework was further tested and refined as interview transcripts aligned with emerging themes under the broad categories of content, context, and system (HBCSS), and comparisons were made within and across the interviews. The team members (LY, TG, MJC, RV) derived detailed insights and interpretations from the data considering the aims of the analysis and their knowledge of the domain and literature. Data collection ceased when emerging themes were saturated. A range of tools were adopted, using a conventional approach to coding and using modern software technology for data management. An open coding approach helped the researchers understand and search for hidden conceptual meanings, which allowed the freedom to think along different lines and develop new concepts. NVivo 12 [19] was used as a tool for data sorting and management, aiding the further analysis and interpretation of the study findings.

Results

In total, 24 in-depth interviews were conducted with stakeholders representing diverse roles and responsibilities within the CALHN in Adelaide, South Australia. The participants included 11 females and 13 males across a wide age spectrum, from their early 20 s to their late 60 s. Some of them were involved in private clinical practice in addition to their role at the CALHN. Each interview lasted approximately 45 min to an hour on average, ranging from 30 min to an hour and a half. All interviews were conducted in English, and participants provided written informed consent.

The findings from this study are presented in the form of 18 distinct thematic constructs, followed by descriptions and corresponding quotes (Table 1) under three broad categories—context, content, and systems—aligning with the HBCSS framework [4, 12]. The results presented in this

Table 1 Theme constructs

HBCSS category	Theme constructs	Theme description	Quotes
Context Include factors influencing local setting in which we intend to develop, pilot and later implement	Frailty	Frailty in an individual, influenced not only by health-related characteristics but also by socio-economic, cultural and environmental factors, as well as patient behaviour	*"Ageing physiology is a tricky business, So you will have population of people who are very fit, quite ambulant and so the challenge is to restore them back to their function, absolutely to the other end of the spectrum where people are completely bed bound. So I guess we do end up seeing quite a lot of quite frail, pretty much bed bound, and dementia, so medically comorbid patient" [R19].* *"Whereas the medical model is very much the biomedical model, if you don't have any illness or an injury, you are well. We look at the biopsychosocial view of health and it's much more than a lack of illness, it's about well-being" [R13]*
	Digital literacy	Skills needed to live, learn, and work in a society where communication and access to information is increasingly through digital technologies like internet platforms, social media, and mobile devices.	*"Those [Patients]at the one extreme you have a wonderfully intelligent and rich conversation with people that are very savvy, communicating with their smart phones, emails and active even on Facebook and to the other side where they are completely under the reliance of formal carers". [R1]*
	Social support	A network of family, friends, neighbours, and community members that is available in times of need to give psychological, physical, and financial help	*"Although a lot of people would probably have a mobile phone these days. They may not have a smart phone. So, there is that inability there and I think, there is, you know, obviously, proportion who don't have any family support of some kind or friends supports, and don't have access to all those sorts of things. So, there is always going to be a group that don't but again into the future, that proportion is likely to be small because having computers these days is a standard thing, it's not a new thing". [R7].*
	Patient and carer participation	The involvement of the patient and their carers in the decision-making process regarding health issues	*"They [Patients] have to accept the responsibility for large aspect of their care. Their diet, doing exercises, stopping sedentary behaviour, make the distinction between exercise and not being sedentary". [R1].* *"It's a paradigm shift, I think may be some clinicians find it different, like sometimes I get patients, families, children who have done google searches and everything" [R5].* *"I think, telerehab is the one thing that is visual and audio so that's beneficial in that place. But I think a combination of things, even phone calls follow through ……..home visits, depending on the client situation, and providing that education to not only the clients but also to the families and carers involved…… there are the people that are having to reinforce that education daily. So, having those core people involved is really, important ……. depending on their situation, and the client's needs, their family's needs, and , cultural barriers, language barriers, or their levels of motivation, what they are willing to accept,". [R18].*
	Structure & culture of existing practice	Structure represents hierarchy and scope of work whereas culture is the traditional and customary thought process to execute work	*"In the changes over the years, I think there is more multidisciplinary approach to care now than it ever used to be. And there is now since last service redesign in South Australia, there is more focus on allied health service for the patients as well. So it is truly a multi-D (multidisciplinary) team approach to care for the patients. I think we are getting better at that we still have some way to go to include the geriatric component of care. We currently have a five-day service; we need a seven-day service and the anaesthetic component of care. Whilst the patients get anaesthetic input, ideally, I think it could be more pre-operatively than the model currently is". [R3]* *"UK system has really embraced the orthogeriatrician and doing ward rounds lot more and the interns going the ortho [ward], where juniors going on the ward rounds and there has been formal protocol for what needs to be done. And I think that isn't being fully embraced here yet. Certainly having an orthogeriatrician on the weekend doesn't happen here. There is really, if you ask the interns about calcium and vitamin Ds, you know they check their calcium, bone profile of these patients, is often almost advised- no we don't any of these, the orthogeriatrician does that". [R4].* *"So there is also two different mindsets- there is a mindset that says, the quicker we get on operate these patients the better. And delay usually, the risk-benefit of delay usually favours complications rather than getting better. So early surgery tends to favour better outcomes. Whereas the other mindset says, no we think it's better we delay them, medically optimise them before we take them for theatre. And this is a really important issue that we are not on the same page. There is lot of practice variation, here. And that is to do with the anesthetist department and because of the factor that we don't have yet, a really good, coherent shared care model around the anaesthetist-orthogeriatrics- and orthopaedics with very clear practice guidelines that we can work together to reduce that practice variation". [R1]* *"The NoF [hip fracture] patients that I am managing will be sort of looked after by different interns and different RMO and they do change every day. So it will be different doctors that I am, will be liaising with on a daily basis. Mind you because I think … technically sort of I am a bit of senior than them so I would lot of the coordinating, in terms of making sure that the plan for discharge planning is sort of on track and making sure that the interns or the RMOs are following the plans that we suggested. But at the end of the day, I think, the bottom line is that we are still a consulting service, we are not the home team as such. So the main primary responsibility remains in the home team sort of care. I mean, this model is still very different to other hospitals where the orthogeriatric team is actually a shared, a shared service which means that one patient is under a combined bed card; ortho and geriatrics, so then two teams are equally responsible for that particular patient whilst in this case, it's still primarily the orthopaedics, sort of taking the main responsibility, even though we do guide them a lot from medical perspective". [R14].* *"I think it's also we need to change in culture, generally in hospital medicine, because lot of people now being on shift patterns…….. It means even the juniors are doing more changeover and handovers. So really that field of looking after the patients and knowing that patient quite well and in-depth is becoming harder because you are constantly turning handover to the new person every12 hours and it may not be back on the following day. So trying to actually remember all those nuances and know about that patient and not just know about the patient in terms of how they are doing but also subtle things that you know, you see them day before". [R4].*

Table 1 (continued)

HBCSS category	Theme constructs	Theme description	Quotes
	Innovation	As a novel set of behaviours, routines, and ways of working that are discontinuous with previous practice, are directed at improving health outcomes, administrative efficiency, cost-effectiveness, or users' experience and that are implemented by planned and coordinated actions	*"Well one of the things that we do on rehab in the home is we use telerehab, so clients on our program, which is rehab in the home, which is my other role, get an ipad and we can telerehab them through the ipad, we have to one, two..... rehab though..... I think that is great, that's works really great, because you develop that rapport with the clients and you get to see the client and they can show you around the home. So the clients could be linked into the services like that..... with someone where they are given, you know, if they are on, if they are linked into something for saving.... couple of weeks given an ipads, someone can check in on them, review how things are going, that would be a great way of developing that rapport as well as seeing the barriers, seeing how they are coping and they can show you something, they can show you how they are functioning, So, and I find its very, it is very successful, in the rehab in the home". [R18].* *"I think, it can because the world is going digital. And even those, maybe there is generation of older people, maybe not be into eplatform but I think some of them are. But the next generation will be really into it. Because they are using technology, you know, all those people can google. So if you have a platform, a one stop solution to information, where you see, you had a hip fracture, what next I do, you know, go to this website to get all this information you need, you know that will be really helpful or you have had a hip fracture what next should I do? Or there is this app, open it up, read about it even if the families or carers can read and interpret to the patient, so is about, I think it's a good good, you know innovation" [R12]*
	Holistic model of care	Provision of care to patients that are based on a mutual understanding of their physical, psychological, emotional, and spiritual dimensions. In addition, holistic care emphasises the partnership between care provider and patient and the negotiation of healthcare needs that lead to recovery	*"So for me I very much consider the family the unit of care, not just the patient and I guess from my perspective, from a social work perspective, we do tend to stand outside the medical model which obviously is a predominant model. So we do look at the social view of health. We consider that more than just absence of illness or disease which does set us apart a bit. And I think what brings out value to the multiD [multidisciplinary] team, so we do look at the patients in context….. we look at ecosystems, we look at general system series, very much. One of our foundation theories". [R13].* *"We create this....now we will put this health... their hip fracture information which will include stuff about important.... nutrition and around sarcopenia and osteoporosis and about vit D and sunshine and what sort of exercises, probably balance and strength exercises is being there... environmental things, all those sorts of things that you would.... we know... are key around holistic approach, lifestyle approach to hip fractures... medications that they are taking, the risks, the danger zones! But no reason if they concurrently have a problem with their respiration problem from asthma or suffering from COPD or whatever it is... that then down the track, a respiratory physician or somebody would be able to provide them. whomsoever looking after them managing them from that point of view, will also have a portal into this space that allows appropriately integrated, coherent, information that is suitable for that patient in the context that there are multiple... their wellness issues. Some of them would be the generalised lifestyle bit and others would be disease or injury specific" [R2].*

Table 1 (continued)

HBCSS category	Theme constructs	Theme description	Quotes
Content How consumers could be engaged & likely aspects of information becoming part of the potential solution	Digital health hub	Digital health hub built around patients supporting health literacy with integrated care goals and providing a more holistic approach to care	*“We are saying, we are going one step further, it's not just my health record- this is my health space! Which will allow me to not only be able to have this information about my previous health but actually interact through provider prescription form. You know, it's much further than that.... so, it's something that my health record could potentially be expanded into or alternatively you take this, and the patient has the option of linking my health record into as part of this personal hub. So the personal hub is about health information and technology integration. And integrating it with my health record would be just one aspect of it. And that... but this is about patient space, so therefore, completely up to them as to how they wish to use this space and who they wish to engage as their healthcare provider. You know, as people, facilitate their wellness journey in life”. [R2].* *“I see technology as the fourth part of the, aside from the clinical side of it or medical stuff, just put that to one side. I think the four bits for me are the exercise, nutrition, a different mindset around health and this is my view, health and well-being and technology”. [R20].* *“There may we ways to combine all of that into a, an ebook, that could go to nursing home, family, carers, GP, anybody who is involved in that persons care, hospital in the home, rehab, they get a comprehensive guide, now the issues with that is the not all aspects of the guide would apply to every single patient. So then with any guide, you are going to piece together as an eguide, you would need to be able to pull the relevant components and exclude those that are were not relevant. So would need to be almost an editable, you know, booklet. So, I don't know whether it’s possible but just a checkbox of all the content that you would want to provide there so that gives to the patient. And then it essentially creates that document specialised to that patient as opposed to all these different professional”. [R15].* *“And often these people have multiple different care providers or family members involved, and communication between them, can often be like Chinese whispers, so things change throughout the time. So if there's something, you know something they can access, where they can get correct, right information, i think that will help these patients. One of our key things is communicating with these patients, local health providers and their GP's and our communication with them at the moment is generally a discharge summary. And the information in that is so that we have to, with interns, all then type up and write and there can be things that are missed. You know, i think having some other form of record directly links to you know, what's happened to them in the hospital could be useful. Again, that access to the GP immediately is very useful as well”. [R8-].* *“She [Orthogeriatric nurse practitioner] does but this would be specifically to as part of working out what content needs to be on the website to do a follow-up phone call few weeks after discharge. They want the questions, you know, you have and what sorts of things that you would like to know at this point and then based on that you can then work out what sort of content in terms of answering questions, you can then put on the website.” [R9]*
	Patient Education	Process by which health professionals provide specific and detailed educational activities and information to patients, carers and family members so they can actively participate in their healthcare and any treatment they may be receiving	*“Truly educating somebody means that there is going to be change of behaviour. There is also change as a result of what they have got they now have changed in terms of their understanding or their ability and likelihood and actual actions following that process. Having just read and or understood the information without actually making any change or different, is not educating somebody. And those beyond that information provision, they need the processed test to see that their understanding is there and the ability to apply that information, test how they will apply, get feedback on that and then allow them to make it adjustments as required to ultimately reach the goal of applying that information to and achieving the outcomes, the information is designed for or to facilitate”. [R2].* *“I think, often, individual education is challenging. I think actually society education has worked lot better. You know, we seen that with smoking becoming a societal sort of change, doing one-to-one trying someone to stop smoking, didn't really work. Doing a society change of stopping where people could smoke becoming less of a cool thing to do, stop people smoking. We have done with patients getting sore throats and colds, going and saying it's a waste of your time going to GPs and having an antibiotic. Number of times GPs will still get the drugs if they turned up, is still there. And so I think educational changes should probably be considered more as targeting as a societal approach rather than one-on-one approach. You go and see a doctor and he spend lot of time explaining you understand you don't need medicines. You go home and now tells that partner or your mate on the phone, ah, the doctor didn't give me the drugs. They immediately go... ah... why he didn't.... you don't remember half the education what commits you at that point. And so you end up with that bad feeling again because your mates and peer pressure being that you have mistreated or unfairly judged”. [R4].* *“I think definitely there is role for ehealth in patient education and reinforcing sort of their understanding I think we can include things like what is your expected, sort of, care pathway while you are in the hospital, just as a general sort of rule, so you know, before the operation what are you expecting, you will expect to see this doctor, that doctor, that nurse, what are the things that they want to do, the fasting and what are you allowed to do and what you are not allowed to do, and then what will happen after the operation, you know, physio will see you on day one, you will be assessed by different teams, and have that sort of simple outlines on what their expected journey will be and then perhaps at the end, leave it depending upon your progress, these are potential discharge destinations that you may be referred to.... but sort of then leave it as that and they will sort of discuss it according to progress. And I guess maybe another section on, sort of, what to do after you leave hospital, so that the things like hip precaution, clexane for DVT [deep vein thrombosis] prophylaxis and the wound care and that's sort of things. I think if you break it down in separate sections like that and make it so generic that it will apply to everyone but at the same gives them fair idea on what they are going to have, in terms of their journey”. [R14].*

Table 1 (continued)

HBCSS category	Theme constructs	Theme description	Quotes
	Behaviour change	A comprehensive strategy involving behaviour change approach, supportive policy environment and the empowerment of people to gain more control over making informed decisions about their health and well-being	*"Absolutely and that's often with these patients there are multiple losses involved with these patients so they come in, they have have lost their independence, they have lost their health, and they have just lost their function. They face the prospect of loss of their home if they are not going home. So there is multiple layers that we often have to deal with these patients. So, there is quite a bit of almost grief counselling if you like with patients like these. Because if they don't get back home, they gonna be in huge transition, a life transition for them and we all appreciate our independence. So, it is really hard for some patients and for their families too acknowledge and to deal with" [R13].* *"So we always work from a safety first perspective if you like so if we are talking to patients about being as safe as possible at home, that can be, covers a huge range of things, but so, like we do a psychosocial assessment and work from there but it could be anything from talking to a patient about, you know, buying a personal alarm for example and making sure they wear it to talking to families about making sure there aren't mats in the house, that can, you know, could cause them to fall or lots of older persons are very reluctant to use walking aid, even though that would increase their safety so walking stick or walking frame, you know, I can't tell you the number of times they have said, no, that makes me look old, you know, they are in their 90s they won't use the frame. So trying to just educate them around how their use of that frame will increase their safety at home and potentially allow them to remain at home and all of that. And trying to get them open to the idea of accepting home save us...." [R13].* *"If you want to change in activity you then looking more habit creating. Habits as you know, very hard to recreate and remake. The best way to make habits is to actually use habits that people already have. yeah... So one of the greatest ones that say.... habits already have is someone, you know, everyone brushes the teeth, everyone usually hot drinks at some points of the day, everyone gets to the toilet, everyone sits down at some point during the day, to watch TV or read a book, whatever, you know. So if you can link it to the those habits, people already have to prompt them to do something extra on top of that habit, then that's probably not a bad win, easy win to be with". [R4- Orthopaedic consultant].*
System Encompassing aspects of operational mechanisms and supporting infrastructure requirements	Personalisation	A whole-system approach, integrating services around the person including health, social care, public health and wider services	*"For older person, there are different aspect of life, for example, it could be the nutrition, it could be exercise, and different things like that. I think they will, we will, if I am the older person, I would like to have some general information plus it's very important that this information is also personalised to me. Otherwise, it's like me reading the google, right. There are so many stuff which I don't know whether its relevant for me. So personalisation of this factors like exercise routine and nutrition and what else, even sleep, I don't know. And then asking me questions about whether I am doing things whether I am on top of things or whether I am missing certain things, and if something is not going right then if the system could alert me because I am an older person, I can't remember stuff. So that alerting me that you have to do this. So reminders, and tracking the progress and feeding that information to the family and rest as well as. We can't feed all the information to the healthcare providers but we have to filter and then feed in the most critical bits that require their attention". [R16]*
	Mode of content delivery	Aspects of wider digital infrastructure such as access to network connectivity, digital channels making use of multimedia or mobile app-based communications, and offering messages in a variety of formats (such as text, audio and video)	*"So different formats, first of all, at a level of mobile or web, right! different types. So older people may, we have, I think, maybe this, I don't know, how many, how many people have laptops and how many have mobile, I am not too sure whether, I am pretty sure there should be evidence to this. So support, what I am thinking, maybe they are more into web kind of applications rather than mobile, mobile is small, don't know, have to check that out. Anyways so that's one of the choices, first of all we have to make when are going for the prototype. because after that we can always switch, we can have both. But at the start we need to decide, okay, are we going with mobile or are we going with web. First choice and then different formats means different ways of presenting the information, right! So, depends on the information, depends on the type of information". [R16]*
	Value proposition design	A complex design strategy requiring that stakeholders are brutally honest in determining the value of a new digital tool for their everyday work	*"Okay, developing the first bit its easy, from a technological perspective, it's a kind of a knowledge hub. So you need to have this content available and then have roles and permissions who could view this content, and identify which content has to be there. So from technology side, it would be very simple, not a very simple problem but a simple problem. But then the other bit that you are talking about is quite complex. So then because these set of requirements are kind of clear to us, right! But that set of requirements is not very clear, we don't know, specially from a technology side of point, I don't know what exactly is happening and we don't have that knowledge so if we have developer, we have to be very clear on the requirements. So yeah, I think developing the first bit is easy, second bit is going to be hard." [R16]*
	Trust	Strong foundations leading to meaningful engagement with the digital health solution by participants, including management of data	*"I think the big problem now is misinformation and there's a lot. If you look up any symptom online, you can find, you know some horrible things about anything you want. I think that is misinformation and it's a big problem and now that social media……anyone can have a voice about anything. And maybe people who do not specialize in those areas having voice and then saying incorrect things. So i think, that is something that has potential dangers and potential risk to patients. So i think having a hospital based or state or SA health based or whatever it is platform that patients know they can trust, and that is appropriate information by the government or by you know, by doctors that is targeted to them for things that they are, you know, interested in knowing at a level that they can understand, I think that's useful and I think if we can just say direct patient with these questions".[R8].* *"So, it's about getting endorsement may be from professional associations. You know if its... because, I mean, you wouldn't want it to be duplicated, its wasted effort. You know that's why I said, you growing... you done hip fractures, somebody else should do something else like to build on rather than to just keep on build hip fracture, so maybe we went to some organisations or whatever then it will be a collective effort, more likely to have buy-in from more groups that would improve its trustworthiness". [R5].*

Table 1 (continued)

HBCSS category	Theme constructs	Theme description	Quotes
	Financing	Access to capital required to develop, implement and maintain digital health solutions for healthcare including public funding and innovations through private and social enterprise	*"The biggest issues is really for the system is how you pay for it. Not so much the consumers have to pay for their own app, which is fine, but how you pay for the health providers to provide inputs into the app. So if you have a platform, biggest thing for example, with general practices, the ones I know, they can't claim an email consultation. They can claim for teleconsultation, they can't claim a text based conversation, so you can't claim an ongoing relationship that is digitally run. So I think we need to unlock a little bit. There is where I think there is big stumbling pocket. Its fine for, minor GPs, loves new toys, toys for people with, tech people but they had to bring it to the sustainable model post the intervention. You had to find out financial model that underpins it. So that's where we have run into brick wall. Because we can't, there is no financial, medical benefit scheme are here to tackle frailty. Just as an example". [R20].*
	Privacy	Ways in which digital health solutions collect, store and access data to inform best healthcare outcomes for patients, health system without any coercion while maintaining transparency through appropriate governance mechanisms	*"It you gonna make digital solution acceptable to the health system, per say, privacy issues, need to be dealt with, trust needs to be dealt with, usability, I don't use my health records, I don't add anything to it because I don't have time and is not in my flow of work. It's not perceived to be valuable to me at the moment. The moment I get a patient, I do, it will hit me, one moment the patient gets to hospital and they will say, look we access my health record and we saved their lives because we found that on the ward, per say. Then I will opt in. So there is a whole issue of who all are area doctors, the issue of the group that waits and picks up later than ..... so, there is a whole process of digital. So I am waffling. One of the thing is try to get and say that- from a health system service perspective, we have to trust and move their mindsets to technical solutions to health problems. And where I think, if I look at the marketing side of it verses the health side of it, I will have look at the apps I use because they are valuable, they are easy to use, they are easy running app, to download my running app, garmin". [R20].*
	Ownership	Digital health enabled model of care must have ownership determined by relevant stakeholders based on robust assessment and best-practice evidence	*"Who takes who, I guess what I am trying to say is who shoulders that risk, who is modulating, reviewing, accepting changes, and actually seeing patient information and acting on it, appropriately. And who is taking the risk..... and to be able to ask people that you might need to speak to some of us, say for example the community services, for example, the hospital, and the home services. So how does what is the risk management strategy from that point of view. Because if you are going to make it interactive, someone needs to take ownership of that model. So where does that ownership, lie. And is SA health prepared to take that risk". [R19].*
	Mechanisms for embedding change	Broad strategy using systems approach to embed digital health solutions and services harmoniously	*"Well I think as I said, it comes back you can have a big thing and try to tackle the whole world, you never going to anywhere, because it's never going to join up. So at the end of the day, you honed in on hip fracture, then you have to decide next where in hip fracture, so is it going to be a clinician, is that your target group? so who is your target group? then OK, you have decided its the consumer, I actually think even in developing the prototype, you actually honed it down in to one key message, to start with. And you decide what that key message is, you actually try to just deal with that message and use, create a platform that will deliver on that message effectively and then if it can do that then you build on.... like its like building the foundation and then building on top of it and expanding it out right.". [R5]* *"This is a facilitator of person-centred and integrated care.... you are empowering patients and putting a lot more the onus of the care of their own wellness back on the patients in the community. So in it's own right, shift the burden of care away from specialists and in specialists centres and put that responsibility back onto the patient and in their local community because you will empower them with the health literacy they require and in a longer term, you empower them to have a healthier lifestyle that is more achievable because of better understanding and better support through. ……more, and create more liaison type of roles and using technology, we will be able to deliver healthcare..... this is an idea or concept that would fit completely with the direction, need, perceived direction of future of healthcare. So I imagine this should be lot of support by, you know, at a government level, ultimately, for such a system. And that it would also allow at a disease or an injury level or specialist level commercialization of, you know, modules or units or apps that will have specific purposes around specific health challenges that can be created. And so therefore, you allow commercialisation or commercial opportunities to also help grow into the system". [R2].*

section are based on the further grouping of close thematic constructs under the categories of the HBCSS framework.

Context

Frailty and digital literacy

Study participants felt that hip fracture care is complex, reflects heterogeneity in terms of health and digital literacy, and is determined by the patient's intrinsic capacities and social circumstances. On one end of the spectrum, some patients are independent, whereas on the other end, they are frail, have poor nutritional status, and require permanent residential aged care support.

Participants agreed that digital literacy among patients is also variable; patients range from being technologically savvy to finding emerging technologies difficult to comprehend. Additionally, participants expressed the opinion that older people may not have access to smartphones, or the social support required to navigate such devices. However, participants felt that this scenario will change in the future, with older people more likely to have experience using technology.

Patient/carer participation and social support

Participants highlighted the empowerment of patients and their family members to take responsibility for patients' own health, especially in relation to exercise, nutrition, and the avoidance of sedentary behavior. By improving access to credible information and involving patients with their family members and designated carers, self-management and recovery could be optimized.

Participants felt that digital technologies would enable patients to better engage in conversations with their healthcare providers about their care processes. These solutions could range from telephone follow-up to interactive telerehabilitation guided by the expectations of patients and their family members and consider cultural and language preferences.

Structure and culture of existing practice

Study participants responsible for the coordination of multidisciplinary care mentioned that the model of care in the local setting is consistent with best practice evidence. However, there were significant gaps around improving the quality of healthcare and patient satisfaction. Some of the suggestions were process measures, primarily focused on the context outside of in-hospital care, the inclusion of minor fragility fractures, and the extension of multidisciplinary care from 5 to 7 days a week in the acute care setting. Participants also felt that there was a need to improve the coordination of care between different disciplines. An orthopedic consultant suggested that unlike the health system within the UK, the health system in Australia must embrace orthogeriatricians. Geriatric services must be available on weekends, as this may address missed opportunities, such as checking the bone profile of patients.

Another orthopedic consultant felt that there is a difference of opinion regarding delaying or not delaying surgery based on the trade-offs between ensuring better health outcomes versus preventing complications. Furthermore, it was highlighted that the role of the anesthetist must become part of a coherent shared care model aligning with best practice guidelines to reduce variations in the availability of anesthesia care across different practice settings.

The study participants also felt that there is a dilemma around how interns understand the care processes in comparison to the registrar within the orthogeriatric model of care due to their training orientation and experience over time. Although interns are an essential part of the orthogeriatric model of care, communication with patients often lacks the depth required to understand the nuances of coordinated care and patients' expectations due to frequent handovers as interns work in shifts. Participants suggested that patients expect uniform coordinated services across disciplines and are unaware of the subtle differences among healthcare practitioners. Participants also felt that besides hip fractures, there are other priority areas for the orthopedics department requiring more attention from the workforce. They opined that even with a dedicated orthopedic nurse practitioner looking after the multidisciplinary care coordination of hip fractures, staff from different disciplines may struggle to appreciate each other's roles and have conflicting priorities; thus, there is a need to improve mutual agreement over the care of these patients.

Innovation and holistic model of care

A study participant considered the implementation of a telerehab program at home to be innovative. Describing the experience, the participant emphasized rapport building with patients at the beginning of the process, tracking patients' progress over time, and connecting patients with other services. This type of approach was also supported by another participant who suggested that hip fracture needs to be considered beyond local tissue damage (medical model of care) and toward a more holistic biopsychosocial model of care. This involves taking into account the family as a whole unit of care.

Content

Digital health hub (DHH)

When mentioning a patient electronic health record initiative recently rolled out across Australia (My Health Record), a study participant described the potential digital solution as a digital health hub. This hub could provide comprehensive care centered around patients through the provision of quality information and education and integrate different services as per the expectations of patients corresponding to their needs and circumstances. A general practitioner (GP) opined that a model of care supported by digital health would require embracing technological advancements, and such a change in mindset would help focus on overall health and wellbeing, including exercise and nutrition.

Study participants suggested different communication strategies for the hub where multiple care providers, including GP practices or family members, could be engaged through a trustworthy source. There could be an electronic booklet containing comprehensive information on various aspects of care, and relevant components could be pulled out and applied as per the needs of individual patients. An orthopedic registrar suggested that there are different care pathways where patient-centered communication is at the heart of coordinating services, which are often determined by the changing circumstances of the patient. Such a digital health hub could possibly overcome some of the gaps in existing mechanisms, such as with respect to the sharing of one-size-fits-all discharge summaries. A key care coordinator within the hip fracture context, such as an orthogeriatric nurse practitioner, could be engaged and interact with the content of the digital platform based on the follow-up requirements.

Education and behavior change

Patient education must adopt a biopsychosocial view of health rather than merely focusing on the hip fracture injury. Many of the participants argued that education does not equate to the provision of information. Educating patients is a process that involves taking into account their changed circumstances with respect to the injury and likely adjustments they will make on their care pathway. Education must include both patients and their family members, who already may be contemplating several changes and behavioral patterns during the transition process following a hip fracture injury.

A consultant suggested that health promotion and community education, which have worked in contexts such as controlling tobacco use or countering over prescription of antibiotics for the common cold, would yield better results than educating individuals. At times, the latter strategy may not work, as some patients return to the community and follow alternative advice from family members or friends. A clinical social worker had a different perspective around patient education and behavior change, suggesting that it is almost like counseling a patient who is on the brink of losing multiple things, ranging from functional independence to the house in which they spent their life prior to the fracture.

Digital health can be utilized to educate patients and their family members. This education can begin during the hospitalization period, informing them about the details of each care process within the care pathway. Essentially, this will help manage the expectations of patients and their family members. However, caution needs to be taken to avoid overwhelming patients with information that may not be appropriate to their stage of care.

System

Personalization, mode of content delivery, and value proposition design

With respect to the mode of content delivery, the participants believed that digital health solutions need to be personalized at the level of individual patients. The provision of information can be comprehensive, but information must align with the respective stage of care. A computer scientist suggested that developing a digital health knowledge hub may seem easy from the point of view of sourcing content and defining roles around access; however, operationalizing the hub would be complex. Therefore, there is a need to consider establishing effective mechanisms of communication and agreement over requirements and expectations between the software developer and relevant stakeholders responsible for designing and delivering the model of care.

A consultant in orthopedics suggested that information packages, if aligned with the regular habits of the individual, can be more effective than trying to create a new habit or routine. A range of different formats, such as texts (written information in the form of existing handouts or electronic reading), podcasts, and multimedia (videos or interactive solutions to facilitate the active involvement of an individual who can interact and exercise choices), need to be developed for the optimal engagement of patients and their carers on several aspects of care while maintaining general health. Another participant suggested the emerging role of avatars—life-like characters that can digitally interact with patients or become part of virtual reality solutions. The digital health platform could also be a resource center for healthcare practitioners, particularly those at the frontline, including junior doctors.

Trust, financing, privacy, and ownership

There were some areas highlighted by the participants requiring further debate and discussion. These included financing the digital health hub, essentially from the perspective of different healthcare providers. Experiences shared by a GP suggested that intricacies within telemedicine require careful consideration. For instance, compensation is provided for teleconsultation but not for any ongoing digital interactions such as emails or text-based conversations. Furthermore, this participant suggested that when piloting the digital health hub, GPs would be enthusiastic and support the initial implementation phase; however, after the initial pilot, a roadmap should indicate not only how this will be scaled up but also how it will be financed and incentivized.

Participants agreed that internet access is likely to continue to increase in the future, and people may become confused at times due to information overload and misinformation. Thus, there is a need for an authentic digital health solution that could address these issues and guide people in the right direction to access accurate information. A geriatrician suggested that endorsement by professional associations would likely improve information trustworthiness and possibly reduce duplicate efforts by mutual sharing, enabling people to build upon each other's learning. There is also a need to shift the mindset of healthcare providers toward technology-focused solutions wherever possible.

Similarly, another geriatric consultant believed that ownership issues should be addressed once a digital health solution is implemented within the healthcare system. Risks associated with accessing patient information and acting upon it, modulating, reviewing patient education resources, and tracking progress would require careful safeguards.

Mechanisms for embedding change

The study participants believed an appropriate mechanism needs to be in place to allow different stakeholders to interact with the digital platform uniformly and seamlessly according to their role in the hip fracture care pathway. Their engagement also involves assessing patients' health and health literacy and providing them support wherever possible. In participants' opinion, deploying this type of innovative digital health platform would involve intricate processes that would enable positive changes to hip fracture care and improve patient outcomes. It would include communicating with a software developer in a language that can be understood and that is based on mutually agreed-upon priorities. A solution-focused approach, instead of one-way communication or direction, should guide collaboration. It was also suggested by participants that the engagement of experts in education and computer science must be consistent throughout the development, piloting and wider roll-out of a digital health model of care. Furthermore, the participants commented that the digital health content must be easy to understand. It must be assumed that patients and their carers engaging with this platform have a primary education level, and the platform must align with their day-to-day activities.

Another participant suggested that although the intent is to develop a comprehensive digital health solution, it is important to consider the development process in stages, similar to the way a house is built. Study participants reinforced the notion that it is critically important to keep patients at the center of care by empowering them through healthcare practitioners. The platform could also help upskill healthcare practitioners through a mutual learning process. With these embedding mechanisms in place, new liaising roles would be created using technology to deliver new models of care and behavior change.

Discussion

This study involved the perspectives of various stakeholders from multiple disciplines, including clinical, allied health, computer science, education, research, and policy. It contributes to an ongoing program of research focused on a personalized digital health hub (DHH)–enabled model of care facilitating recovery from fragility fractures and potentially other health conditions [1, 4, 5]. We followed a knowledge translation approach to engage people who could influence micro (clinical practice), meso (health setting), and macro levels (thought leaders influencing policy and research agenda). Some of these stakeholders could remain key players during the next stage of implementation, facilitating the integration of the digital health hub and advocating for a person-centered integrated model of healthcare delivery. The findings from this study were classified into 18 thematic constructs embedded within three categories, context, content, and system, which correspond to a theoretical human–computer persuasive systems framework, HBCSS [4, 12]. These thematic constructs covered a range of patient factors, including the role of family members, social support, and the characteristics of existing healthcare delivery, as well as the enabling of computing functionalities and requirements to operate within a multidisciplinary environment.

Stakeholders within our study agreed that new models of care using digital health could strengthen the existing hip fracture care pathway. However, collectively, all of the different healthcare providers associated with the care pathway must take into account patients' needs and outcome expectations, moving beyond the medical model focused on the repair of local tissue damage. Overwhelmingly, contemporary evidence suggests that a significant number of hip fracture patients, once admitted to acute care hospitals, do not return to their pre-fracture residence and are unable to attain optimal health status [2, 20]. Thus, an MoC must go beyond clinical practice guidelines and incorporate practical delivery issues regarding for whom, when, where, and how care is best delivered and re-evaluated [21]. This can become complex due to a multidisciplinary workforce, links with secondary and tertiary care services, the biopsychosocial needs of the patients, and frequently changing organizational structures. However, our study findings take a step further, highlighting that mere change within the organizational structure is not sufficient, and a new mindset embracing technological advancement is crucial for shifting an organizational culture toward envisioning a holistic model of healthcare delivery. There are huge gaps; for instance, primary care offers a generalist approach, and while older adults with multimorbidities represent a large proportion of GP consultations, the required access to other community services is patchy [6, 21]. It is often left to the patients and their carers to coordinate and navigate the range of services, which could be influenced by their social circumstances and priorities [21]. Thus, patient education and the provision of accurate, timely, and adequate information could play a vital role in improving engagement and participation in the recovery or rehabilitation process within a MoC [8]. The DHH-enabled MoC could potentially be a powerful tool empowering patients to take greater control of their health goal(s). Moreover, the processes within a DHH can link patients to a more extensive network of specialists, general practitioners, and community carers [4, 5].

According to the World Health Organization (WHO) Integrated Care for Older People (ICOPE) guidelines, when working toward solutions for older people in the community, we need to acknowledge that older people's health is on a wide spectrum, ranging from perfectly healthy to moribund status based on their "decline in the intrinsic capacities" [15, 22]. Our findings from this study also suggest that future healthcare must focus on an evolving aging physiology, yet the current understanding within the practice environment may be inadequate to fully incorporate this view. The care processes become complex due to different interacting components defined by each patient's unique needs and sets of expectations as well as the health workforce capacity. Our study findings suggest that the coordination and integration of multiple disciplines would require innovation and the effective engagement of patients along with their family members as a whole unit of care. A similar view is supported by some of the contemporary guidelines and recommendations around innovation diffusion and health workforce innovations [23–26].

Musculoskeletal conditions, including fragility fractures, are among the key contributors to the global burden of disease [27] and are predicted to increase, in terms of both their impact and prevalence, due to an aging population and the increased prevalence of noncommunicable diseases [27, 28]. Emerging evidence suggests that digital health interventions improve care outcomes for fragility fractures, osteoarthritis, and chronic low back and neck pain [29–35]. Nevertheless, critical questions need to be raised around what constitutes a digital health "intervention package," and its effectiveness must be tested pragmatically according to the local implementation context [1]. The debate around patients' engagement in their own care has predominantly remained within the confines of narrow pilot research projects or at the level of a philosophical argument without full realization of its practical effectiveness [36]. This may be attributed to a misguided perception of engagement strategies such as cocreation and/or coproduction, which essentially represent "values" and not necessarily intervention strategies [36]. Therefore, while we consider these value-based strategies an important way to empower patients, their family members, and healthcare providers together, understanding other aspects of complexity within an MoC would drive successful implementation [36–38].

Access to technology is a multifaceted factor, as there is likely to be a digital divide due to varied levels of e-literacy or an inability to trust and navigate the plethora of information available online [9]. Existing digital health solutions target healthcare providers and consumers differently. Electronic health records mainly allow communication, data management, and clinical decision support among healthcare providers; these records are not primarily meant to engage patients [39]. The Australian My Health Record (MyHR) is a national, personally controlled electronic health record that can track the journey of patients within the healthcare system through a shareable summary of an individual's health information [39]. MyHR envisages that different healthcare practitioners will eventually move away from the traditional "push" method of accessing patient medical information and towards a "pull" method of information sharing [40]. The latter approach allows healthcare practitioners to access relevant information by pulling information from individual health records rather than pushing a request to other care providers for similar information [40, 41]. A similar change in consumer behavior can be seen in relation to accessing current affairs information. Consumers are rapidly shifting from using conventional media platforms that push current affairs information through television sets to digital platforms such as YouTube or exclusive interactive platforms. The latter multimedia platforms have enabled consumers to pull information according to their choice, thus forcing the content creator to ensure quality, authenticity, and a safe interactive environment [42]. Nevertheless, one must also learn from the recent rollout of MyHR in Australia that despite a 90% subscription rate by patients, less than a quarter of healthcare providers were using the system. The top priorities for this system have been clinical integration and the improvement of patient experiences; however, there could be a significant gap in terms of educating practitioners to use digital systems and facilitate patient engagement. Acknowledging these gaps and working around effective solutions could incrementally improve patient outcomes and service delivery [7]. The findings from our study highlight the complexity of the financing potential digital health hubs, privacy, ownership, and the establishment of trust along with the need to create new business models. Different business models utilizing digital technologies are now emerging in the commerce, entertainment, and media sectors and are demonstrating success with financing, trust, and privacy. This gives us an opportunity to discuss how these business models can be adopted and best translated into health settings [43, 44].

This study involved an in-depth interview methodology with a wide range of stakeholders to map out potential factors that could influence the design and implementation of a DHH-enabled MoC for fragility hip fractures within a local healthcare setting. We did not recruit participants from other local health networks within the region, which could limit the generalizability of our findings, particularly in relation to application across South Australia or Australia. There is a digital divide posed by challenges due to geography, internet availability and uninterrupted internet access, people living with disabilities, and factors related to sociopolitical and economic disparities. However, some of the participants in this study had experience in diverse settings, including other developed countries and emerging economies. We believe this diversity enhanced the richness of the data and provided wider applicability of findings in terms of opening lines for multiple inquiries and future research areas. Our study also attempted to integrate early on the perspectives of frontline healthcare delivery staff and the research context, aligning with the implementation strategies for the next stage of the research program [1, 4, 9].

Conclusion

Our study, which was conducted before the COVID-19 pandemic, highlighted that the organizational structure and existing practice culture across the health system may resist change when introducing digital healthcare. However, as we are living through the current pandemic, the use of digital technologies has not only accelerated the willingness of healthcare practitioners and organizations to adopt telehealth options but also improved the engagement of consumers [7]. Compared to the last decade, there has been a rapid increase in the availability of digital health solutions by a variety of vendors, including health agencies, fitness advocates, and software companies. These applications are primarily designed to support consumers in the domain of general lifestyle and wellness, while some have been developed to support self-management of chronic disease conditions such as diabetes [5, 18, 45]. At the time when this study was conducted, we only had a theoretical concept of a digital health solution to be co-designed with relevant stakeholders. However, with critical insights from this study, including the characterization of DHH and findings from other research components [1, 4, 5, 7, 9], we have been able to advance our concept to the stage of a prototype to be tested in a real-world practice setting in the next stage of our research program. The DHH-enabled MoC will be structured to provide information related to not only hip fractures but also general health and wellbeing, including nutrition, exercise, sleep, and mental health, combined with past medical history [5]. We recommend wider consultations across a range of practice environments or specialty groups so that tailored innovative services can be negotiated, developed, and tested for implementation.

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Author contribution LY, MJC, and TKG contributed to the conceptualization of the study and the design of the interview guide. LY conducted the in-depth interviews, the verbatim transcription, and the analysis, and engaged in routine discussion with TKG and MJC. LY produced the first draft. TKG, MJC, RV, AT, and JY reviewed the draft and provided critical inputs in relation to the thematic constructs and overall flow of the manuscript. Subsequent revisions of the draft followed. This final version of the manuscript incorporates comments and edits from the authors and is approved by all authors.

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Declarations

Ethics Ethics approval for the study was provided by the Human Research Ethics Committee of the Central Adelaide Local Health Network (Ref: R20181005, HREC/18/CALHN/687). Governance review and authorization were granted by the Royal Adelaide Hospital (SSA/19/CALHN/59, Ref: 11183) and The Queen Elizabeth Hospital (SSA/19/CALHN/57, Ref: 11184) and further approved by the Human Research Ethics Secretariat and Legal and Risk Office of the University of Adelaide (Ref: 3338).

Conflicts of interest None.

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CHAPTER 6

INNOVATIONS TO IMPROVE ACCESS TO MUSCULOSKELETAL CARE

Innovations to improve access to musculoskeletal care, was published in *Best Practice and Research Clinical Rheumatology Journal* in 2020.

The published paper will follow summary and statement of authorship.

Summary

This paper addresses the fifth objective of the thesis work by examining innovation, its management and the strategic directions required to improve musculoskeletal health at macro (policy), meso (service delivery), and micro (clinical practice) levels and the discuss the critical role of different stakeholders in driving innovation.

Research and writing for this paper involved collaborators from different academic institutes and disciplines, experts in musculoskeletal care, from Australia and Canada. The focus of the research was to understand contemporary and innovative practice across the globe around management of different musculoskeletal conditions. The paper expands on the idea of innovation and the ways in which contextualisation is crucial to developing a tailored solution for the management of musculoskeletal care at macro (policy), meso (service delivery) and micro (clinical practice) levels. Also, the critical role of consumer agency (patients and their families/carers) is discussed in driving innovation and the need to leverage this through empowerment by education.

Innovations ranged from optimising clinical decision support and workforce development to patient education, including pain management and rehabilitation. Emphasis on technological advances was the central theme and beyond quoting some of the practice examples, the article also discusses evolving technologies, such as big data analytics, blockchain technology and artificial intelligence. The ideas presented in the paper are critical to the future of musculoskeletal care and highlights the value of collaborations moving forward. With emerging evidence, innovations can support systems strengthening and build workforce capacity to support improved access to the ‘right’ musculoskeletal care and explore some of the ways to best manage innovations.

The paper concludes by outlining systematic steps to establish the required leadership, collaboration, research, networking, dissemination, implementation and evaluation of future innovations in musculoskeletal health and care.

The paper has been cited by twelve publications.

Statement of Authorship

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Name of Principal Author	Mellick J Chehade	
Contribution to the Paper	Conceptualisation, review of innovations and best practices, first draft and subsequent revisions	
Overall percentage (%)		
Signature		Date: 16/07/2021

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate to include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

Name of Co-author (Candidate)	Lalit Yadav	
Contribution to the Paper	As a key collaborator I contributed to the conceptualisation, identification of relevant innovations and best practices, subsequent interpretations, producing the first draft and subsequent revision before final publication of the manuscript	
Overall percentage (%)	50%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am one of the key authors of this paper	
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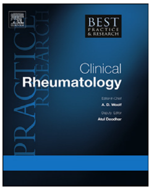

7

Innovations to improve access to musculoskeletal care

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ABSTRACT

Innovation is a form of realising a new way of doing something, often ignoring traditional wisdom, in order to meet new challenges. Globally, particularly in emerging economies, the high burden of musculoskeletal conditions and their contribution to multimorbidity continue to rise, as does the gap for services to deliver essential care. There is a growing need to find solutions to this challenge and deliver person-centred and integrated care, wherein empowering patients with the capacity for self-management is critical. Whilst there is an abundance of information available online to support consumer education, the number of sources for credible medical information is diluted by

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This is part of a series prepared on behalf of the Global Alliance for Musculoskeletal Health to provide the background for developing global and national policies and strategies to address the enormous and growing burden of musculoskeletal conditions and to promote musculoskeletal health for all

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uninformed anecdotal social media solutions. Even with the provision of high-quality information, behavioural change does not necessarily follow, and more robust educational approaches are required.

In this chapter, we examine innovation, its management and the strategic directions required to improve musculoskeletal healthcare at macro (policy), meso (service delivery) and micro (clinical practice) levels. We discuss the critical role of consumer agency (patients and their families/carers) in driving innovation and the need to leverage this through empowerment by education.

We provide a snapshot of real-world examples of innovative practices including capacity building in consumer and interprofessional musculoskeletal education and practice; recommendations to transform the access and delivery of integrated, person-centred care; and initiatives in musculoskeletal care and implementation of models of care, enabled by digital health solutions including telehealth, remote monitoring, artificial intelligence, blockchain technology and big data. We provide emerging evidence for how innovation can support systems' strengthening and build capacity to support improved access to 'right' musculoskeletal care, and explore some of the ways to best manage innovations.

We conclude with recommended systematic steps to establish required leadership, collaboration, research, networking, dissemination, implementation and evaluation of future innovations in musculoskeletal health and care.

Introduction

Musculoskeletal (MSK) conditions are among the key contributors to the Global Burden of Diseases (GBD) [1]. MSK conditions are predicted to rise, both in prevalence and impact, as the global population ages and the risk for noncommunicable diseases increases. This is particularly true in low- and middle-income countries (LMICs) with a greater than 60% increase over the last two decades [2,3]. MSK conditions are also key contributors to multi-morbid conditions, and the risk of multi-morbidity also increases with persistent musculoskeletal pain [4]. However, care is primarily condition-specific, despite policy frameworks re-orienting towards more integrated chronic condition care [3]. More importantly, care disparities remain recalcitrant to change due to complex interacting and context-specific factors evident at the system-level (policy), at the service-level (health workforce gaps, unsustainable models of service delivery) and at the clinical and community-level (inadequate access to care, insufficient consumer voice; inadequate person-centred care) [3,5,6]. Patients and their carers are the end consumers and potentially the most important stakeholders needed to influence key decision-making in policy and markets to innovate. However, empowering them to achieve this outcome requires deliberate and intentional consumer engagement at all levels of healthcare. Therefore, healthcare providers' roles could be defined as partner, nurturer, facilitator of sense-making and enabler within the framework of healthcare education [7,8].

In this chapter, we describe the critical role for innovation to enable improved access to integrated person-centred MSK care. We provide a snapshot of real-world examples of innovative practices including capacity building in consumer and interprofessional musculoskeletal education and practice; recommendations to transform the access and delivery of integrated, person-centred care; and initiatives in MSK care and implementation of Models of Care (MoC), enabled by digital health solutions

Glossary

3D	Three-Dimensional
ADL	Activity of Daily Living
AI	Artificial Intelligence
AIHC	American Interprofessional Health Collaborative
AMSEC	Australian Musculoskeletal Education Collaboration
BJD	Bone and Joint Decade
CIHC	Canadian Interprofessional Health Collaborative
CME	Continuing Medical Education
CORE	Clinically Organized Relevant Exam
DSTs	Decision Support Tools
ECHO	Extension for Community Healthcare Outcomes
ePPOC	Electronic Persistent Pain Outcomes Collaboration
G-MUSC	Global Alliance for Musculoskeletal Health
GBD	Global Burden of Diseases
GHWN	Global Health Workforce Network
GSCI	Global Spine Care Initiative
HCP	Healthcare Practitioner
HWF	Health Workforce
ICOPE	Integrated Care for Older People
IPCHS	Integrated, People-Centred Health Services
IPE	Interprofessional Education
ISAEC	Inter-professional Spine Assessment and Education Clinics
LBP	Low Back Pain
LMICs	Low and Middle-income countries
MAPS	mHealth Assessment and Planning for Scale
MD	Doctor of Medicine
ML	Machine Learning
MoC	Models of Care
MOOCs	Massive Open Online Courses
MRI	Magnetic Resonance Imaging
MSK	Musculoskeletal
NCD	Non-Communicable Diseases
NGOs	Non-Governmental Organisations
OA	Osteoarthritis
OARSI	Osteoarthritis Research Society International
PCEHRs	Personally-Controlled Electronic Health Records
RCT	Randomised Controlled Trials
RGB	Red, Green and Blue
SDGs	Sustainable Development Goals
U of T	University of Toronto
UN	United Nations
WHO	World Health Organisation
WSC	World Spine Care
XAI	Explainable Artificial Intelligence

including telehealth, remote monitoring, artificial intelligence, blockchain technology and big data. We provide emerging evidence for how innovation can support systems' strengthening and build capacity to support improved access to the ‘right’ musculoskeletal care, and explore some of the ways to best manage innovation.

Innovation and application to healthcare

Derived from the Latin word ‘annovare’, meaning renewal, innovation is a popular term often used inappropriately. Innovation involves realising a new way to do something and this may mean starting with a clean slate and ignoring traditional wisdom in order to meet new challenges. Some innovations by design are disruptive, implying that there will be resultant losses as part of the change process, impacting on organisations and individuals that may have profited from the less efficient and/or effective practices that the innovations seek to address. Resistance to the adoption of these innovations is therefore to be expected and needs to be well-managed [9]. In this context, innovation management is critical to the successful development, testing and implementation of innovations. Innovation management can be defined as “the systematic promotion of renewal and innovation in an organisation through planning, organising, management, and monitoring” [10]. There is a whole science dedicated to innovation and innovation management in business, with multiple related areas of innovation including product, process, technology, strategy, organisational and marketing innovation [10]. These areas apply equally to the ‘business of healthcare’.

There are many examples of healthcare innovators globally, including LMICs that have demonstrated new ways to successfully engage with patients whilst both reducing costs and improving quality of care. In partnership with the World Economic Forum, McKinsey published a report looking at productivity in healthcare systems [11]. Based on the analysis of successful and globally acknowledged large scale health innovations, six general strategic directions were suggested:

1. **Get close to the patient and follow their established behaviour patterns** - reduce distribution costs and improve adherence to clinical protocols.
2. **Reinvent the delivery model by using proven technologies disruptively** – ‘repurpose’ existing technologies and infrastructure such as mobile phone systems and call centres to extend access.
3. **Confront professional assumptions and ‘right-skill’ the workforce** – closely align the skills and training to match practice requirements rather than waste over skilled resources.
4. **Standardise operating procedures wherever possible** – minimise waste, facilitate knowledge transfer and optimise resource utilisation.
5. **Borrow someone else's assets** – reduce capital and operating costs by developing partnerships to acquire access to existing infrastructure, networks and logistics capabilities.
6. **Open up new revenue streams across sectors** – generate additional income and/or offset healthcare costs by linking to businesses that are able to sell and/or promote aspects of the health service.

The report also identified that healthcare innovation occurs in four ‘clusters’; Franchising, Product Specialisation, Integrated Care, and Technology-Enabled Networks. These in turn run along a progressive care delivery value chain; monitoring/preventing, diagnosing, preparing/intervening, recovering/rehab, and monitoring/managing. The report concluded that the biggest challenge now was not “inventing” but rather “implementing” the many successful innovations already in place [11].

The critical role of consumer agency in driving innovation in healthcare

“Necessity breeds innovation”, and within healthcare delivery this holds true from historic times, leading to some of the key inventions and present-day entrepreneurships [11]. However, the needs determined by individuals or systems do not always match. Person-centred needs and those perceived by healthcare providers may not reconcile and can be in direct conflict. Consider the example of merging and relocating ambulatory care services into a single more centralised tertiary referral centre that facilitates specialist engagement but results in restricted access to patients and carers because of travel logistics. Aligning needs to support care requires a shared perspective and aligned implementation strategies. Perception of needs is also determined by the knowledge of ‘right’ care options and evidence for their effectiveness [12]. Supply follows demand, but if a patient or carer believes that quality care can only be provided in a tertiary referral setting, they will be less likely to demand community-based services. Patient/consumer agency must be supported and centrally positioned to drive innovation in collaboration with healthcare stakeholders (systems, services, clinicians and researchers, educators and industry). Community education is an important enabler of agency and a mechanism for shaping the goals of innovation [3,8]. The more the consumer becomes educated and empowered with the person-centred and evidence-based notion of 'right' care, the greater will be the forces driving change at both private (commercially driven) and public (politically driven) levels [8].

Service delivery innovations to improve access to MSK care

Innovation in health service delivery and organisation is defined "as a novel set of behaviours, routines, and ways of working that are discontinuous with previous practice, are directed at improving health outcomes, administrative efficiency, cost-effectiveness, or users' experience and that are implemented by planned and coordinated actions" [9]. Service innovation is not dictated by a single event, but rather builds up through a series of processes involving adoption, implementation, sustaining, spreading or diffusion, dissemination or scale up. Further, each of these embedded processes in themselves rarely follow a linear path, and are often considered dynamic and interactive in nature. A wide range of factors have been identified for enabling successful outcomes during each of these processes, including:

- Leadership and management at different levels with a compelling vision committed to change;
- Early stakeholder engagement representing staff and consumers;
- Establishing effective communication strategies relevant to organisational confines;
- Local context adaptations in alignment with existing policies; and
- Continuous feedback mechanism through progress monitoring and determining benefits to health including cost-effectiveness evaluation [5,6,9].

These factors often interact with each other in unpredictable complex ways and vary according to different settings (i.e. factors in various lower-resourced settings will differ from those better resourced). While some innovations might be relatively easy to implement, others require intervention packages designed to fundamentally change the way health services and systems function. Thus, it is important to take account of wider contexts including political, institutional and cultural environments. Given the complexity and scale of manoeuvring to implement change at a system level, it is essential to allow sufficient time and resources for services and organisations to adapt to the new ways of functioning [9].

It has been argued that good healthcare is directly linked to national wealth and that improving healthcare productivity drives national wealth creation [8]. The existing environment of healthcare delivery however is mostly tuned to offer quick and short-term fixes for complex problems, which represents low value care and does not lead to longer term benefits [8]. This approach must be challenged. We must learn to think, work and collaborate in different ways. Workforce productivity can be improved with attention to four major aspects of workforce planning:

1. Reducing absenteeism through improving the well-being and health of the workforce;
2. Developing skills through investing in training, education, and development;
3. Focusing on efficiency through introducing new forms of technology; and
4. Improving effectiveness through innovating with new care and business models.

Promoting these four aspects within the MSK healthcare workforce would bring welfare gains, savings for the health system and gains for the economy [8,13].

Motivated by their own personal health concerns, the more health literate consumers will often attempt to self-educate when they recognise an important gap in their knowledge that relates to their condition [3,8,14]. Whilst there is an abundance of information online, the number of sources for credible medical information is diluted by uninformed anecdotal social media solutions. Although these are mostly unregulated, the landscape of social media continues to mature with time. Another issue relates to the language of healthcare which is so mystifying for many consumers that ‘they don't know what they don't know’. This knowledge gap leaves consumers both disempowered and dependent on the health professional ‘who knows best’ [8,14]. A failure to understand key concepts and principles in ‘medicine and healthcare’ is largely a feature of the unnecessarily complex language often used, the variable levels of health literacy of consumers, and the approach to education – not primarily the capability of consumers to understand and relate to the information [15]. Consumers can be empowered through education and support (including policy frameworks that advocate/recommend self-management) to deliver MSK ‘self-care’. Currently, bodies like painAUSTRALIA work closely and collaboratively with all governments, healthcare agencies and professional associations to support consumer and health professional upskilling as described in the National Action Plan for Pain Management [16] and The National Strategic Action Plan for Arthritis [17]. An extension of this approach is to specifically include the consumer as a defined part of the health workforce (HWF), and therefore surmise that consumer MSK education could be delivered by adapting education programs traditionally designed for healthcare workers [3].

MSK workforce innovations

Aligning MSK health service delivery to global policy and models of care

Globally, the World Health Organisation (WHO) is encouraging governments and health systems to redesign the way healthcare is delivered. This aim is to improve the quality and coordination of care for addressing health disparity; help to mitigate HWF shortage; and to enable the achievement of global Universal Health Coverage (UHC). The WHO Framework for Integrated, People-Centred Health Services (IPCHS) (2016) [18] sets forth a vision in which “all people have equal access to quality health services that are co-produced in a way that meets their life course needs, are coordinated across the continuum of care, are comprehensive, safe, effective, timely, efficient and acceptable; and that all carers are motivated, skilled and operate in a supportive environment” [18]. The IPCHS framework proposes this transformation of healthcare through five interdependent strategies:

1. Empowering and engaging people and communities (focused on individuals, their families and communities and ensuring that reach extends to underserved or marginalised people).
2. Strengthening governance and accountability (through participatory governance and committing to mutual accountability).
3. Reorienting the MoC (needs-based services, shift to public health, prevention, patient-self management and stronger community-based and primary care systems, as well as the utilisation of new technologies).
4. Coordinating services within and across sectors (for individuals, for programs and providers across the health system).
5. Creating an enabling environment (strengthening the HWF, change leadership, improving knowledge translation and striving for quality).

The framework espouses a ‘determinants of health’ focus which is results-oriented, participatory, evidence-informed and ethics/equity-based [18]. Through a co-created web-based platform [19], the WHO offers examples of practices whereby health systems and/or providers have made inroads into one or all of these interdependent strategies. Practice examples are identified as leading, promising, emerging or ‘brilliant failures’ with the intention to share learned experiences and new models of different approaches in efforts towards IPCHS. One such practice example, focused on MSK health (spine care), is provided by World Spine Care (WSC). Haldeman et al. (2015) [20] described a successful attempt to develop a spine care program in Botswana where there was significant burden of disease and minimal healthcare services available to treat individuals suffering from spine pain. In collaboration with the Ministry of Health, the WSC program evolved from a one-site clinical rural program to a three-site program, embedded in a rural community clinic, a mid-level hospital and a large tertiary hospital in the nation's capital.

Over a period of 10 years, the program transitioned from foreign volunteer service providers to home-grown practitioners who were supported in attending academic training programs abroad by the government and by collaborating universities. The WSC program has subsequently evolved into a national spine care program with full government support and the goal of expanding to additional areas of Botswana. WSC's focus was the implementation of an evidence-based spine care model which is person-centred and integrated into local culture. Further, it is supported by policy and funding and coordinated across health settings, thus contributing to local HWF capacity building. Through academic partnerships, accurate data could be collected about the impact and outcomes of the model [20,21]. The WHO identified the WSC program as a ‘promising IPCHS practice’ on the web-based platform. The WSC program has since been scaled up with programs also established in Dominican Republic, India and Ghana. The WSC program serves as an exemplar model to help address the need for spine care services in underserved communities, utilising an evidence-based, person-centred and integrated model of healthcare.

In the follow up to the work of WSC, the Global Spine Care Initiative (GSCI) undertook to develop a new model of spine care proposed for supporting health delivery reform with a focus on LMICs and underserved communities. GSCI published 15 papers in a supplemental issue of the European Spine Journal in 2018 to provide a comprehensive, evidence-based framework to support a new classification of spine disorders and a new model of spine care delivery [22]. Dziedzic et al. (2016) [23] described the implementation of MSK MoC in primary care for high-income economies. A discussion of different programmatic approaches to managing MSK conditions included a comparison of an integrated MoC with a stratified care model and a practitioner-led model. Through this comparison, significant evidence gaps were identified, and research priorities were proposed to help address these gaps:

- Investigating the applicability of MoC across different settings (rural/urban) and for different MSK disorders;
- Increasing research around and support for self-management approaches;
- Understanding the importance of context when choosing a model of care; and
- Describing the implementation of a model of care and evaluating its impact.

Briggs et al. (2018) [24] prioritised the need for integrated care and called for a “renewed and sustained focus on improving musculoskeletal health” at both national and global levels to support the attainment of the 2030 Sustainable Development Goal-3 set out by the WHO. The authors proposed three priorities for action by policy makers to consider. These included:

1. The inclusion of MSK conditions in the WHO Non-Communicable Diseases (NCD) agenda, recognising that MSK conditions impact people across the course of their lives and increase with age, and that mobility limitations and subsequent restrictions on physical activity contribute to the other NCD conditions identified in the agenda (diabetes, cardiovascular disease, obesity and so forth);
2. Setting targets and monitoring systems for functional ability; and
3. That MSK health should be part of national NCD policies implemented in all countries [24].

In examining priorities for driving innovative models of health service delivery from a MSK perspective, it is now acknowledged that MSK conditions are the leading cause of disability worldwide and low back pain (LBP) dominates this disability burden [1]. For decades, efforts have been made to solve the enigma of LBP through extensive research, clinical guideline development, identification of high-value care approaches and a move to encouraging self-directed management by patients [25]. Traegar et al. (2019) [26] identified that a significant amount of treatment delivered for the management of back pain was discordant with clinical guidelines and lacked sufficient evidence to support its use. The authors described health system barriers which impacted efficacious management of back pain and offered potential solutions for policy makers (improved delivery mechanisms, health professional training, access to evidence-based information, incentivising funding to support high value care, and so forth), as well as practical information for health providers and patients for application in clinical practice, calling for the need to change our ideas about back pain [26].

A shared-care spine modelling approach was undertaken in Ontario, Canada, where the Ministry of Health and Long-Term Care undertook a multipronged policy effort to addressing the burgeoning impact of LBP on individuals, their families, communities, the health system and the economy with the goal of enhancing patient-centred, quality care [27]. The iterative policy development included a priority focus on education, as well as pilot testing across multiple steps, summarised in Table 1.

This innovative model addressing low back pain across the province included optimisation of advanced practice physiotherapists and chiropractors to undertake screening and assessment of patients who met the pre-screened criteria for entrance into the Inter-professional Spine Assessment and Education Clinics (ISAEC) program. The model provided streamlined and coordinated assessment of complex low back pain patients with expedited access to advanced imaging and surgical specialists and eliminated unnecessary referrals to these specialists, significantly reducing the bottleneck to access services [27]. Zarrabian et al. (2017) [28] evaluated the data from the early years of the ISAEC pilot project, examining Magnetic Resonance Imaging (MRI) use, surgical assessment wait times and referral appropriateness and efficiency. Referral MRI usage decreased by 31%, and only 10% of all patients were referred for surgical consult, of which 96% were deemed to be appropriate surgical referrals; this, in comparison to the usual data of 75–85% of patients referred to a spine surgeon in Canada not being surgical candidates on examination. The most striking finding from the study was a significant reduction in wait times. These were reduced from a previous average of 6 months, to 2.2 (rural) to 4.3 (urban) and 5.4 weeks in the metropolitan setting. There were also benefits for non-surgical patients such as being assessed faster and receiving evidence-based non-operative treatment more quickly with the primary focus on self-care. Extrapolated cost avoidance related to spine imaging was estimated to be approximately $24 million in terms of previous Ontario practice patterns [28].

The Ontario MoC for LBP reflected many of the strategies recommended within the WHO IPCHS framework. Health services for low back pain were coordinated within and across sectors and tailored to the unique needs of patients. There was mutual accountability and responsibility between providers, programmes and government payers. Reorienting the model of spine care included maximising the scopes and skill sets with patients seeing the appropriate provider for their LBP, shifting management more firmly into ambulatory care and strengthening primary care LBP management through educational initiatives. Patient educational materials were made available through information systems and data collection enabled the evaluation of program efficacy and efficiency. Patients (98%) and providers (92%) had high satisfaction with the program [29]. Wait times were significantly reduced and considerable improvements in efficiency were achieved [27]. As a result, the pilot program was scaled up across the province to facilitate access for more Ontarians with LBP. The scale-up results over the past year are pending and will be published in the near future.

MoC are defined as evidence-informed polices or frameworks that outline the optimal manner in which condition-specific care should be made available and delivered to consumers [30]. Successful implementation of MoC depends on recognition of the complex interplay of health systems across micro (for example, health provider skills, clinical practice, patient capability to participate in care); meso (system infrastructure and delivery design); and macro (health policy and socio-economic factors) levels. MoC utilise the best available evidence, coupled with local contextual factors (patient and community needs as an example) and operational factors in order to provide the "right care for the

Table 1
Shared-care spine modelling approach.

- Amending the Schedule of Benefits (payment schedule for physicians) to eliminate the utilisation of x-rays in low back pain in the absence of diagnostic red flags;
- A province-wide educational program on evidence-based low back pain management with clinical tools [Clinically Organized Relevant Exam (CORE) Back Tool] for primary care practitioners and for empowering patients;
- Mass media education (for both providers and patients) via DocMikeEvans;
- The Inter-professional Spine Assessment and Education Clinics (ISAEC) pilot project (now evolved to numerous Rapid Access Centres across the province);
- Funded Primary Care Low Back Pain Pilot studies across 7 community team-based practices;
- Expansion of Ontario Family Health Team funding for physiotherapists and chiropractors to address spine pain;
- Development of clinical practice guidelines for low back pain and a Quality Based Pathway for Neck and Low Back Pain.

right person, delivered at the right time, by the right team, in the right place and with the right resources" [30].

Briggs, Chan and Slater (2016) [31] recognised that MoC have the potential to be "system-level enablers", translating 'what works' into health policy, health design and, at the micro level, into clinical practice. In further work, Briggs et al. (2019) [32] undertook a comprehensive review of national health policies to address NCD, specifically looking to uncover governmental strategies that integrated the burdensome area of musculoskeletal conditions within policy frameworks. The imperative for MSK inclusion in NCD policies has been extensively discussed, with some nations and regions (e.g. WHO Europe) including MSK conditions in prevention and control planning. In addition, the WHO recently recognised MSK health as a key determinant of healthy ageing and as a key component of their Integrated Care for Older People (ICOPE) framework [33,34]. The contemporary landscape regarding MSK health inclusion was reviewed and the authors concluded that a "significant knowledge gap" remained in the current global policy landscape related to MSK health [34]. These gaps, coupled with a lack of uptake from national and global policy makers to date, have resulted in little global advancement in addressing the enormous health burden of MSK conditions in the 20 years since the inception of the United Nations (UN) Bone and Joint Decade in 2000.

Chehade et al. (2016) [3] also called for the application of an integrated model of MSK care to address the high burden of disease related to MSK conditions, underpinned by educational transformation. The authors opined that to effectively mitigate the escalating prevalence and disability related to MSK disorders and effectively implement evidence-based MoC, health systems need to be redesigned towards integrated, person-centred care with a competent HWF that is collaborative practice-ready [3].

Practice points

- Models of care are important enablers of change, with the potential to impact system health reform, health design and influence clinical practice.
- Models of care incorporating integrated and people-centred approaches enable the "right care for the right person, delivered at the right time, by the right team, in the right place and with the right resources".
- Scalable musculoskeletal models of care are emerging which have demonstrated efficacy and efficiency across community and income settings.

Health professional education and training

For the past decade, increases in global health disparity and inequity have led to escalating shortages in the HWF. The WHO has therefore called for revisioning and reform in health system delivery. Underpinning such healthcare reforms is the importance of ensuring that the current and future HWF is prepared and ready to practice within these newly designed healthcare models. In the Framework for Action on Interprofessional Education and Collaborative Practice (2010) [35], the WHO articulated "interprofessional collaboration (IPE) in education and practice as an innovative strategy that will play an important role in mitigating the global HWF crisis". They defined IPE as occurring "when learners from two or more professions learn about, from and with each other". IPE was noted to be an essential step in preparing the future HWF to be "collaborative practice-ready". The goal of the framework was to provide educational programs with strategies to help them develop and implement IPE within their training programs and to assist health policymakers with ideas to encourage collaboration across professional disciplines in planning for health service delivery within their context [35].

A decade later, there remains nominal evidence regarding the uptake of the framework and the integration of IPE systematically into health professional training curricula. Herath et al. (2017) [36]

undertook a systematic review to determine the level of engagement in IPE across developed and developing countries and to better understand how IPE was embedded in health professional education. They found that while IPE was much more advanced in high income countries and was most prevalently offered at the pre-licensure training level, it was not systematically delivered or evaluated, and its impact on health outcomes was unclear. Further, there was minimal information about IPE in developing countries, showing slow adoption of this innovative educational approach which challenges existing educational paradigms resulting in poor uptake [36]. There are, however, good examples of how universities, where most IPE training occurs, have embedded IPE across health professional programs. Both the Canadian Interprofessional Health Collaborative (CIHC) and the American Interprofessional Health Collaborative (AIHC) share numerous examples of IPE programme models, evaluative instruments and specific curricular content to support the attainment of interprofessional collaboration competencies. One such exemplar is at the University of Toronto (U of T), where IPE became a credit-earning component of 11 health professional faculties in 2009, with learners requiring a mandatory number of IPE credits, obtained during their prelicensure training, to graduate from their programs. The IPE curriculum is competency-based and structured within an educational continuum across three levels of learning: exposure (introduction), immersion (development) and competence (entry-to-practice) [37]. Over the course of their training, learners must participate in a variety of in-person green, yellow and red (levels of learning) educational electives which support them along the learning continuum. Learners are provided with numerous education electives through which to attain these competencies and gain their IPE credits. At St. Michael's Hospital, a U of T-affiliated teaching hospital and an early adopter of IPE within family medicine training, modules were created, delivered and evaluated based on gaps identified in learner needs. One of these gaps was with respect to attaining competency in the management of LBP and other MSK conditions commonly encountered in primary care [38]. Since 2008, the IPE Committee at St. Michael's Hospital has delivered an IPE half-a-day module on the interprofessional approach to managing LBP to over 1500 mixed professional learners across six disciplines. The results from these modules have consistently indicated a high level of knowledge attainment about evidence-based assessment, diagnosis and management of back pain: an improved understanding of the roles different disciplines play in managing back pain and of how they may collaborate together; and improved ability to identify the ‘right team member at the right time for the right person’. Over a longitudinal period of data collection, learners have consistently reported a very high satisfaction with the module and statistically significant differences in improvement with respect to their knowledge and their confidence in their ability to collaborate after the session [39].

Concurrent with the advancement of IPE, there is a push to re-organise health professional training around competency-based education. Frenk et al. (2010) [40] advocated for an overhaul of professional education to address persistent gaps and inequities in health and to transform outdated and inflexible educational approaches. Education was defined as a three-step sequential process:

1. Informative education which involves the acquisition of knowledge;
2. Formative education which occurs when students are socialised around values of their work or profession; and
3. Transformative education which prepares learners to mobilise positive values of knowledge and to step up as leaders [40].

Competency attainment would occur throughout these three stages of education. Competence is defined as “the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values and reflection in daily practice for the benefit of the individual and community being served” [41]. Langins and Borgermans (2015) [42] stressed the importance of the HWF to be able to consolidate competencies and apply them into practice. They noted that competencies:

- Are complex and take time to acquire, ranging from novice to expert;
- Inform recruitment, evaluation and training, and facilitate HWF assessment;
- Are measurable and should focus on improvement;
- Are flexible and evolved based on patient and population needs;

- Include clinical/technical and non-technical or ‘soft’ skills such as communication and collaboration; and
- Distinguish the HWF from other groups of professionals and help to facilitate collaboration within the HWF.

Moreover, for integrated and person-centred health systems to work effectively, competencies are required across the full spectrum of health system participants. This includes educational programs, accrediting bodies, regulators and also patients. For IPCHS to be successful, patients need to make informed decisions, play an active role in their care plan, comply with the agreed treatment, and take an active role in their own health and wellbeing [42].

At the time of writing, the WHO was in the process of developing a Global Competency Framework for Universal Health Coverage. The organisation intends to achieve this by incorporating broad stakeholder engagement through the WHO Global Health Workforce Network (GHWN) Education Hub to develop a framework that identifies the competencies needed for primary healthcare workers at all levels of training and professions. This would enable integrated and person-centred health services to be delivered across the spectrum of care including prevention, diagnosis, treatment, rehabilitation and palliation. Ideologically, this framework will be aligned with population needs and evolving health systems [43]. A focus of the framework is to create a competent HWF that can assist in the mitigation of worker shortfall forecasts (expected to reach over 18 million by 2030), by broadening worker capabilities and skill sets and maximising the scopes of the existing workforce.

In the United Kingdom, an MSK competency framework was created to ensure that primary care health professionals were equipped to deliver person-centred, team-based care and to support the achievement of better health outcomes across the system. Woolf et al. (2018) [44] proposed that rather than creating a new MSK workforce, recognising existing capabilities within current practitioners and health delivery by multi-professional teams would help to enable improved access to quality MSK care. The framework sets out four competency domains which support minimum standards of clinical care at first point of contact: (Person-Centred Approaches; Assessment, Investigation and Diagnosis; Condition Management, Interventions and Prevention; Service and Professional Development) and 14 capabilities within these domains. These are underpinned by described professional values and behaviours (clinical reasoning, critical self-awareness, problem-solving, etc.) expected of all MSK health providers [44]. Similarly, a core capability framework has been developed by Osteoarthritis Research Society International (OARSI) [45] and aligns to HWF knowledge, confidence and skills gaps identified in the current and emerging HWF [46,47].

Perhaps the most comprehensive musculoskeletal competencies framework was developed by Chehade et al. (2011) [48] in Australia in response to a Bone and Joint Decade (BJD) recommendation to define a minimum level of competency for health providers who manage MSK conditions. The BJD released core recommendations for undergraduate medical curriculum which could be adapted to local context, according to patient and population needs [49]. Chehade et al. noticed [48] the broad range of health professionals who cared for patients with MSK disorders and the variable curricula and competencies for MSK care management in Australia. They proposed that, in order to foster interdisciplinary collaboration and consistency of MSK healthcare approaches, there should be a common interprofessional management pathway, and described competencies to underpin this. The Australian Musculoskeletal Education Collaboration (AMSEC) aimed to develop a core set of nationally agreed upon MSK competencies for adoption by all MSK-related health training programs. This created a minimum national baseline reference for MSK education through evidence-informed, principles-based core competencies utilising a stakeholder consensus process [48]. The framework has a foundational body of basic and clinical science knowledge which directly links to clinical competencies with the flexibility to consider individualised patient care and be responsive to population needs. In addition to clinical/technical skills, the framework includes competencies around patient education and self-management, preventative healthcare, evidence appraisal and critical thinking, safety and care quality, professionalism, collaborative practice and patient-focused holistic care [48]. This innovative framework has supported the interprofessional adoption of core MSK competencies across MSK health providers in Australia and has set a benchmark for other countries to consider similar MSK-focused competency-based educational models.

Delivering integrated, person-centred musculoskeletal care

Ultimately, the ability of health systems to successfully redesign themselves depends not only on health policy and funding reform but on the capacity of the HWF to deliver IPCHS. New educational approaches and utilisation of accessible technologies will be critical to achieving health redesign. Currently, however, external barriers pose significant threats to sustaining HWF capacity over the long term. The WHO has estimated that by 2030, there will be an 18 million HWF shortage resulting from a myriad of factors impacting at global, regional and local levels [7]. Langins and Borgermans (2015) and many others [42,43,50] have described the necessity of developing core competencies to deliver IPCHS in the broader context of healthcare. Transformative educational models have been proposed to support competency attainment as described earlier in this chapter. Frameworks and recommendations for competency-based education have also been proposed specifically in the context of the delivery of MSK-related health services such as those included in the AMSEC framework [48]. These are important steps to help support the development of a competent HWF to address the increasing burden that MSK conditions place on individuals and society. However, in the broader context of healthcare design and delivery, these steps are overshadowed by significant challenges faced by the global HWF.

The WHO Global Strategy on Human Resources for Health (2016) [7] is primarily aimed at policy-makers and health system planners, but it is also relevant to all stakeholders in the HWF arena. The vision of the strategy is to assist in the movement towards Universal Health Coverage (UHC) by ensuring “equitable access to health workers within strengthened health systems” and to do this through addressing chronic under-investment in the HWF at national, regional and global levels [7]. The global strategy focuses on all health workers, from community to specialist levels from all health disciplines. Strategies and policy options recommended for local and regional governments include mechanisms to help to attain four broad objectives:

1. Optimisation of the HWF to accelerate progress towards UHC and the SDGs (Sustainable Development Goals);
2. Better understanding and preparation for future health needs, harnessing labour markets to increase job opportunities and sustainability;
3. Building institutional capacity to implement the agenda; and
4. The strengthening of data on human resources for health to better inform local and global strategies [7].

In order to enable an effective, resilient and strengthened health system, health policy and decision makers must take into consideration the complex and dynamic nature of healthcare while planning for a contemporary HWF as conventional approaches are notoriously unreliable. Gorman (2015) [51] noted that this is attributable to the uncertainty of the future health environment but argued that it is possible for HWF planning to accommodate this uncertainty. This led to recommending decision makers to think ‘outside the box’ of simply relying on healthcare data to drive planning, and to instead include ‘healthcare intelligence’ – “looking beyond the numbers to build an understanding of how to achieve desired outcomes.” Gorman (2015) [51] and Rees (2019) [52] pointed to the unique strategy that New Zealand undertook in evolving their HWF planning approaches wherein a reverse approach to HWF planning was utilised. Rather than starting by trying to predict the required future supply of health providers, they instead started with modelling the future needs of the population, then brainstorming ways to meet these needs. This approach also resulted in planners focusing on investing more towards non-Doctor of Medicine (MD) providers [52]. Gorman and Rees recognised, after looking at patient needs, that many of these needs could be met by other healthcare providers.

In the MSK world, providers such as physiotherapists, chiropractors, osteopaths, acupuncturists and other manual therapists could replace physicians for assessing and treating front-line patients attending for care of MSK conditions. This would result in the recalculation of the needs for recruiting and training of more physicians, with a significant reduction in what was originally contemplated. In Ontario, with the move to collaborative care within family health teams, patients are managed by an interprofessional team with the goal of improving access to and quality of care and ensuring that all members of the health team are able to work to full scope and skill sets. This has also resulted in a reduction of physician workload and encouraged more medical learners to opt for a career in family medicine due to a better work-life balance [53]. In addition, allowing health workers to work to their full scope and potential and share care has improved job satisfaction and retention. Maier and Aiken (2016) [54] also proposed strategies to optimise the use of the existing HWF such as nurses (as recommended in the WHO global strategy) rather than training new physicians. They reported that there was sufficient evidence that physician supervision of care had no effect on the quality of care. It did, however, increase the cost of care and created barriers to care provision for vulnerable populations. The authors noted that a critical element towards success in HWF planning was to recognise that other health professions can make a contribution in any setting, and that policy or professional silos, competition and hierarchy can undermine effective team-based health delivery [54].

Critical challenges to HWF stability include workforce mobility and retention which are magnified when health workers are dissatisfied with their job. Improving quality of work life through the full use of skills and the ability to have autonomy and authority around decision-making within a collaborative leadership model have helped to improve health worker retention [50]. In the context of MSK health, HWF planners and policy makers are encouraged to reduce barriers to team-based care and to consider optimising non-physician health workers to initially manage these conditions at the first point of care as espoused by those who have proposed such working models [29,44,48]. This may help to ease the burden on other providers, to mitigate barriers to accessing MSK care, to improve healthcare outcomes and to help reduce inefficiency in MSK health service delivery.

Practice points

- The World Health Organization estimates a health workforce shortage of 18 million workers which is expected to escalate over the coming years.
- Maximising the use of the current musculoskeletal health workforce by utilising full health worker scopes, skills and competencies; eliminating hierarchical structures; and building on broad geographic distribution can help to mitigate workforce shortage.
- Universal musculoskeletal competencies, embedded in interprofessional health education, can help to ensure that new health workers are fully prepared to work effectively in primary care teams.
- Competent, interprofessional musculoskeletal teams are required to enable the provision of person-centred care, improve access to and quality of healthcare, facilitate efficient use of resources and improve retention of team members.

Digital technology innovations to support improved access to musculoskeletal care

The WHO describes digital health as a “broad umbrella term encompassing ehealth, mhealth as well as the emerging areas such as the use of advanced computing sciences in big data, genomics and artificial intelligence or machine learning” [55]. This requires commitment and strategic engagement of stakeholders, including patients and community, across stages of inception to operation or implementation for improving healthcare services [55]. Thus, the WHO positions the application of digital technologies for health-related purposes towards supporting person-centred care. In this context, leveraging digital technologies to improve access in order to support self-management and facilitate better co-care of MSK conditions can act as a system-strengthening tool [56-58]. Further advancement of these technological solutions can bypass some of the care disparities imposed by sociodemographic and geographic barriers and support the move towards UHC [59,60].

Digital health to support implementation of musculoskeletal models of care

We have previously described how digital technologies can be leveraged to support the implementation of accessible, sustainable and holistic MSK MoC [57]. MoC serve as a vehicle to drive evidence into policy and practice through changes at health system (macro), service (meso) and clinician (micro) levels. While the evidence underpinning the use of digital technologies to support better access to musculoskeletal care is nascent, innovation has progressed ahead of the evidence, with many big questions in this rapidly changing field yet to be addressed. Notwithstanding this evidence gap, innovation in digital technology healthcare to improve access to self-management and co-care is appealing and critical given the escalating burden of disease attributed to musculoskeletal conditions. Digital technologies can support capacity-building with significant scaling and sustainability potential [61], and adaptability for lower-resourced settings and for cultural sensitivities [62]. Finding appropriate touch points in current MSK care services and systems where digital innovation is complementary to, and synergistic with, established care models is vital as current MoC will not be sustainable into the future. In this section, rather than a systematic review of the evidence, we provide through examples a snapshot of how digital technology innovation can support improved access to musculoskeletal care.

Leveraging digital technologies to build consumer and health workforce capacity

Digital technologies can support capacity building initiatives, which are aimed at driving improved access to MSK care, by connecting consumer and clinicians to provide better integrated MSK care. Digital enablers to support implementation of MSK MoC ideally aim to complement, rather than replace, established MSK MoC that involve direct consumer interactions with their clinicians [57], and should ideally be interoperable across computer and software systems [63].

One contemporary example to show how digital technologies can be leveraged to support improved access to first line care for MSK conditions is the pain*HEALTH*™ initiative [64]. pain*HEALTH*™ was co-developed with consumers, for consumers, as a response to the escalating burden of musculoskeletal pain conditions. Development of content was aligned to recommendations from musculoskeletal MoC [64] and calls to action for improved care highlighted in the Australian National Pain Strategy [65]. pain*HEALTH*™ promotes an integrated person-centred approach to care, one that advocates active self-management using multimodal approaches to favour recovery and increase self-efficacy through providing credible, readily accessible, meaningful evidence-based information and practical skills. pain*HEALTH*™ connects consumers, clinicians and health services (primary and tertiary) in Australia. Embedding has been achieved through a partnership approach, linking with MSK advocacy Non-Governmental Organisations (NGOs), university clinical training programs, and clinical care standards. pain*HEALTH*™ is widely accessed with the total number of website hits (effective March 1, 2020) >20, 000, 000 from >1,500,000 users in over 150 countries. A recent impact evaluation of pain*HEALTH*™ [66] investigated how the website was currently being used, by whom, what was working well and what could be improved to better support consumers' musculoskeletal pain care. Four hundred and fourteen pain*HEALTH*™ users participated in an online survey, with 26 users contributing to in-depth interviews. A majority of users were overall satisfied/extremely satisfied with pain*HEALTH*™ as a resource to support the self- and co-care of musculoskeletal pain. Consumers and carers perceived pain*HEALTH*™ as filling an important gap in holistic pain care and supporting them to better understand and self-manage/support the co-care of musculoskeletal pain. Health professionals perceived benefits in using pain*HEALTH*™ in supporting person-centred clinical encounters, helping consumers understand the many factors that can interact and influence their pain experience and supporting clinical training of health professionals. pain*HEALTH*™, as a shared resource, is connecting consumers, carers, health services, educational institutions and health systems (policy). Based on the findings from this evaluation, key recommendations to inform policy and practice were derived to ensure that pain*HEALTH*™ remains a credible, engaging and relevant shared resource for consumers/carers and health professionals, services and systems in Australia [66].

Another example of digitally-enabled innovation to support capacity building of health professionals is Bone Health TeleECHO, the Prototype for Technology Enabled Collaborative Learning for

Skeletal Healthcare [67]. TeleECHO is a derivative of Project Extension for Community Healthcare Outcomes (ECHO) and uses state-of-the-art digital communication technologies to connect health professionals and advance their knowledge, so that they are better equipped to manage patients with bone diseases. TeleECHO offers educational upskilling with low disruption to clinical workflows and connects health professionals across care settings. Through replication and innovation in many global locations, Bone Health TeleECHO leverages scarce resources and helps build capacity to support better bone healthcare for more patients closer to their home, at a lower cost than referral to speciality centres [67].

In addition to the advancement of in-person training through IPE programs highlighted earlier in the chapter, the WHO has also called for the use of computer-assisted education to accelerate the upskilling and training of health professionals worldwide to deliver integrated, people-centred care. In GatesNotes, A Big Bet for 2030 (2015) [68], Bill Gates predicted that the rapid advancement and affordability of smartphones and high-speed networks would enable connectivity and significantly improve education around the world. While this represents an important step forward in developed countries, it equates to a revolution in the rest of the world [68]. Advancements in online educational courses have also enabled improvements in accessibility to ongoing professional development for the existing workforce. NextGenU.org [69], an innovative model for transforming web-based learning, began offering globally accessible, free, and accredited health training programs in 2012, and, still uniquely, continues doing so. These award-winning courses are cost-free, advertisement-free, barrier-free and carbon-free [69]. Madhok et al. (2018) [69] identified NextGenU.org's initial priority as building health capacity through online global learning. Courses are offered in a collaborative structure by governments, professional societies, and universities (which provide the course credits on completion), supporting the development and iterative maintenance of the course content and facilitating mentorship for learners [69]. Over a dozen courses (including single courses up to and including a Master of Public Health, the first globally free degree) have been co-created and tested in low-to middle- and high-income countries, with over 8000 registered users in every country, except South Sudan. Student results have included comparable academic outcomes to in-person training (performing "as well as some of the world's most-resourced courses") and good student satisfaction with the modules [70].

Practice points

- A variety of technologies exist with growing evidence to support their role in musculoskeletal care (including internet, online portals, mobile applications, telehealth, social media, sensors, and other remote monitoring devices).
- Digital technologies innovation can support capacity-building initiatives aimed at driving improved access to musculoskeletal care.
- Connecting consumer and clinicians through shared digital musculoskeletal healthcare platforms can help to strengthen health systems.
- Digital platforms can help to accelerate the upskilling and training of health professionals globally to support integrated, person-centred musculoskeletal health and care.

mHealth innovations to support self-management and co-care

Mobile and smartphone technology can support consumer/patient participation in their health. mHealth has the advantage of scaling capacity (across the whole of health) through its portability, acting as a potent lever to support improved access to musculoskeletal healthcare and HWF capacity building, which is very important, especially in lower-resourced settings. The WHO has provided rich resourcing to support the use of mHealth technologies that can be adapted for and embedded within both lower-resourced developing nations and developed countries. In this regard, the WHO mHealth

Assessment and Planning for Scale (MAPS) toolkit provides a self-assessment tool to guide project teams when scaling up their innovations [71], with additional WHO guidance on digital health monitoring and evaluation [9] and the use of digital interventions for health system strengthening [56].

There is growing evidence to show that individuals can actively engage in their self-management using smartphones and mobile applications, especially for chronic conditions [58,72]. Self-management can cover many domains including self-logging progress data about one's condition, connecting remotely to medical records, sourcing health information, receiving regimen adherence support, connecting and contacting other people and engaging in various other self-monitoring activities [73]. A recent systematic review synthesised qualitative evidence for how mobile health (mHealth) technologies can support self-management for young people with chronic non-communicable diseases (NCDs) [58]. Young people with NCDs and implementers (e.g. clinicians, policy makers), shared complementary and unique user perspectives on enablers and barriers to designing, developing, and implementing mHealth technologies to support management of chronic NCDs. In the study, key recommendations were derived with guidance on the associated policy, and practice implications that illustrated how mHealth can support access to self-management tools and drive meaningful change in contemporary health ecosystems. The need to identify and resolve implementation challenges was highlighted as critical to enabling sustainable scaling-up of mHealth solutions [58].

The ‘*iCanCope with Pain*’ integrated smartphone and web-based self-management program highlights the use of mHealth to support improved access to musculoskeletal pain care. Developed in Canada [74], *iCanCope with Pain* aimed to improve access to contemporary tailored pain education; provide young people with practical behavioural strategies to manage their pain, psychological well-being and sleep hygiene; and promote physical activity and provide peer social support [74]. The feasibility and acceptability of *iCanCope with Pain* app have been demonstrated [74]. The app is currently under trial evaluation in Canada to assess implementation effectiveness and health outcomes effectiveness (Clinical Trial Number: NCT02601755). Recently, a mixed-methods study evaluated the acceptability and usability of extant digital technologies, including the ‘*iCanCope with Pain*’ app, for young Australian people (15–25 years) with musculoskeletal pain [75]. With appropriate user-informed cultural adaptations, digital technologies can be tailored to support young people's self-management of musculoskeletal pain and can accelerate access to care while avoiding resource inefficiencies through duplication [76]. In this same study, the use of a real time dynamic data capture and analytics platform [77] further leveraged extant technologies, providing valuable user data, including domains known to be predictors of engagement with digital tools [78].

Notwithstanding some emerging pockets of mHealth innovation informed by best practice recommendations for designing and implementing eHealth interventions [79], the overall quality rating of the pain management app is average at best and highly variable [80,81]. No apps have been evaluated for their effect on health outcomes of people with persistent pain in their habitual real-world settings over extended periods. More flexible, pragmatic trial designs (for example, hybrid implementation trials) may be a critical enabler to support mHealth innovation and may have an impact on and better align with the dynamic and rapidly changing digital health landscape [82].

Practice points

- Mobile and smartphone technologies (mHealth) can empower consumers and patients and improve participation in the self-management of their musculoskeletal health.
- mHealth has scaling capacity, acting as a potent lever to support improved access to musculoskeletal healthcare and health workforce capacity building, which is critical - especially in lower-resourced settings.
- Evidence is lacking for the effectiveness of mHealth interventions used in real-world settings on health outcomes for people with musculoskeletal pain.

Digital innovation in data monitoring, evaluation and decision support

Digitally enabled MoC (including remote monitoring and telemedicine) can support more efficient data collection, monitoring and evaluation, with the aim of informing better clinical decision-making. Greater incorporation of technology into MSK MoC for remote populations, can lead to enhanced patient activation, empowerment, greater adherence, promotion of shared decision-making, and improved patient-reported (health) outcomes [57,83]. Several participatory technologies exist to support patients and clinicians through decision-support, improved data collection, and remote monitoring. Examples of innovations in this space include personally-controlled electronic health records (PCEHRs), mobile applications, telemedicine, and wearable sensors or remote monitoring devices [80,84,85]. The recent advancements in low-power, miniature sensor systems facilitate low-cost, unobtrusive, health monitoring systems. There is also an increased interest in maintenance-free (i.e. battery-less) sensors as opposed to using battery-powered sensing devices for health monitoring [86]. Sensors can now be integrated into textiles [87] creating new opportunities for unobtrusive monitoring of the patient. Researchers are looking into implantable sensors similar to medical implants such as pacemakers, which are made possible by miniaturisation and low-power consumption [88]. Furthermore, linking of devices to one another is possible, making large-scale information readily accessible and potentially enabling more personalised monitoring and tailored care guidance.

Decision support tools (DSTs) can be used to help inform shared decision making between consumers and clinicians on self-management and co-care that are based on best evidence. Improving patient and clinician sharing of knowledge and communication about a condition, often within a broader framework of chronic co- and multi-morbidities, can effectively drive ‘right’ care and shift the balance from low-value care to high value-care [89]. Digitally enabled DSTs can create greater transparency and accuracy around the benefits and risks of care and align with global initiatives such as ‘Choosing Wisely’ [90] that are nudging towards wiser healthcare [91,92]. DSTs also have application at a health system level to monitor performance [9]. Evidence indicates that DSTs can reduce adverse events, reduce the numbers of patients choosing major elective invasive surgery, increase the numbers opting for a more conservative treatment option, and lower treatment costs [91].

Digitally enabled data registries could also facilitate better monitoring and benchmarking of musculoskeletal practice. One example is the development and implementation of the Australian and New Zealand Electronic Persistent Pain Outcomes Collaboration (ePPOC) [93]. The ePPOC programme aims to help improve services and outcomes for individuals experiencing chronic pain through the benchmarking of care and treatment. ePPOC involves the collection of a standard set of data items and assessment tools by specialist pain services throughout Australia and New Zealand to measure outcomes for their patients and develop a national benchmarking system for the pain sector.

Practice points

- Digitally enabled data registries for musculoskeletal conditions could also facilitate better global, national and local monitoring and benchmarking of musculoskeletal practice with the use of standardised minimum data sets, including reporting of outcomes.

Telehealth and telemonitoring to support access and care delivery

There is increased pressure on healthcare systems for optimal utilisation of limited resources, need for greater access to care, alongside managing patients’ expectation for autonomy. The opportunity for digital innovations to support remote treatment and monitoring of patients is widely acknowledged [84,85,94]. Areas relevant to self-management support include remote consultation, rehabilitation tracking, communication, patient education, increasing athletic or activity of daily living (ADL) performance, and falls detection [85,95]. Lee et al. (2018) [96] suggest that telehealth for physiotherapy may help overcome barriers surrounding access to care, improve patient satisfaction and deliver cost benefits for healthcare systems [96]. A recent systematic review with meta-analysis by Cottrell et al. (2017) [94] on the treatment of MSK conditions using remote synchronous video consultation included populations with osteoarthritis (surgical and non-surgical management), low back and neck pain. Telerehabilitation was shown to be an effective form of management in these populations to help improve function and was non-inferior to usual care. Further, a combination of telerehabilitation plus treatment as usual, was shown to be more favourable than usual care on its own [94].

Telemonitoring has also been applied to the sports and exercise field, for example, to remotely quantify posture, power and muscle timing [95]. MSK conditions offer a strong case for telemonitoring, as telemonitoring inherently involves patients in their own care, allowing them to self-quantify their progress, and often involves supplementing patient-reported outcomes with data collected by patients about themselves [97,98]. Remote monitoring also directly engages the patient in data collection in their real-world settings involving habitual patterns. Individuals and treating clinicians can ambiently track physical activity performance metrics via wearables, video-based or pressure sensors or purposefully log data about their condition using mobile applications, thereby providing a quantification of physical performance metrics. This in turn has the benefit for clinicians of being able to guide paced activity levels [84,95].

Digital interventions can also provide feedback to patients remotely, as reported in a recent systematic review of randomised controlled trials (RCTs) with meta-analysis [99]. Interventions provided participants with direct self-performance feedback, such as the user being provided with data about their physical activity or given feedback and comparison about performance. Electronic physical activity feedback was defined as an intervention delivered via digital means (e.g. computer, smartphone/tablet, and wearable device/activity tracker). Interestingly when interventions were compared to minimal or no intervention, the study showed no significant differences between groups for pain or disability at short term and mid-term follow-up. However, only four published studies were included in the analysis, and the overall study quality was deemed low. Findings again highlight the relative infancy of digitally-enabled MSK MoC and the need for further high-quality clinical trials [99].

Practice points

- Telehealth provides an important digital enabler to support better access to, and engagement with, musculoskeletal health and care.
- Emerging evidence supports the use of telehealth (telemonitoring and telerehabilitation) in musculoskeletal care service delivery models.
- Innovation in trial designs is needed to better align with the rapidly emerging iterations of digital technology design and real-world use.

Improving eHealth literacy in HWF and consumers

As digital healthcare has many advantages and the use of technology for monitoring and securely interacting with patients' data could be both feasible and efficient, engagement with such systems by health professionals and patients/consumers is essential. In a recent rollout of an Australian opt-out system for collecting patient data and allowing it to be shared with health providers, the system received a 90% subscription rate, but less than a quarter of health provider organisations were using the system [100]. This was despite the fact that 60% ranked clinical integration and improved patient experiences as their top priorities [101]. This mismatch suggests that educating practitioners on the use of digital systems is as important as patient engagement and compliance.

Part of the process of educating health professionals would be demonstrating the value of using online patient support systems. In this context, outcomes from a recent randomised controlled trial [102] showed that providing patients with online pre-elective surgery education led to statistically significant improvements in health literacy and patient satisfaction with the intervention group reporting a greater improvement in knowledge about their surgery and treatment satisfaction. Ingadottir (2017) [103], through the use of an online simulated avatar game, provided patients with remote education about post-operative pain management. After engaging with the game, improvements were reported as including decreased pain medication usage and increased health literacy.

Further insights on healthcare practitioners (HCPs) perceiving digitally enabled pain care as valuable comes from Fernandez et al. (2017) [104]. This study highlighted that HCPs were more likely to support and recommend patients to engage with online information about their pain when information was perceived to be of good quality. Health professionals perceived this as a catalyst for an improved patient-practitioner relationship [104]. In a qualitative study, perceptions from people with knee osteoarthritis (OA) using an online pain coping skills training program were generally positive [105]. The findings were consistent with online training being broadly acceptable and providing ready access to help people with OA to manage their pain [106]. To optimise user engagement, redesign of some aspects of the program were suggested, as well as the provision of clinical support (potentially also being delivered remotely) [105]. However, outcomes from a previous clinical trial investigating the addition of simultaneous telephone coaching did not augment the pain and function benefits of a physiotherapist-prescribed home-based physical activity program [106].

At HWF level, there are many mechanisms for educating practitioners that can support more rapid upskilling at scale and reach across jurisdictions and borders at a reasonably low to no cost. Online continuing medical education (CME) courses have already been shown to be effective [107] and Massive Open Online Courses (MOOCs) have been suggested as a viable pathway for health professional education, with the main caveat being the development of meaningful training content at low cost. MOOCs are structured online courses supported by infrastructure from many companies including EdX and Coursera. MOOC completion rates are often very low, but they capture tens of thousands of students and in most cases, are free. MOOCs designed to educate HCPs could be cost effective to develop, and one would expect higher completion rates from an invested cohort. Goldberg and Crocombe (2017) [108] propose that MOOCs could be used to support the education of patients as well as clinical practitioners; however, the demographic of the average MOOC user suggests that the typical MOOC student is a graduate tertiary student [109]. Research in this space may therefore not necessarily be applicable to patients/consumers as it can be with some confidence for health practitioners. However, even here, the poor state of evidence to support or refute claims regarding the effectiveness of health profession education highlights the need to adopt a critical and cautious position regarding their adoption [110]. Golberg and Crocombe [108] nevertheless support the use of MOOCs as part of patient—centred care and highlight the convenience, credibility and low cost of MOOCs amongst their useful attributes. Further, as the translational of knowledge ('knowing') into practice ('doing') is challenging, additional educational upskilling may be required to ensure that core competencies are adequate to support effective clinical practice.

Assuming HCPs can be convinced of the value of integrated digital educational systems, what is the likelihood that patients, with a variety of education levels, health literacy and ages, will engage with such systems? We know that there is a broad acceptance of online tools for social means, but the demographics for Facebook show a strong bias towards the younger male demographic with over 60% of users being below 35 and a gender ratio of 40% more males than females [111]. Adult learners in education have often been regarded as independent, self-motivated and mature, yet they are a smaller subset of the community. It is not clear how the general adult population would behave in an online environment where they learn and interact with HCPs. Indeed, it appears that the theoretical basis for adult learners may need to be modified in an online education setting, perhaps to include greater presence of an educator (practitioner), higher fidelity and greater emotional support [112]. The first two are likely to be well-addressed in a clinical setting but the latter may be neglected. We are given some insight into what needs the general community might have with online systems through a study carried out on students learning basic literacy skills [113]. This cohort was made up of people who were unemployed, had been out of education for many years, were receiving government assistance or had special needs. Some required assistive technologies to access the online programs. Eighty percent of this group felt they achieved the goals of their online program, although 90% felt that face-to-face interactions were critical. Thus, it seems that patients could be taught to use simple systems and continue engaging with them to meet the desired outcomes.

Research on adults in online learning has shown that they are more likely to stay engaged if they are intrinsically motivated and satisfied with the experience and remain stimulated. Other aspects such as family support and relevance to the student are also important [114]. It is reasonable to suggest that engaging with online HCP systems will require similar aspects to be addressed. Intrinsic motivation should come from a natural concern about one's health; however, the ability to bring in family support and aspects to stimulate engagement may also be critical. Game-like elements [103] and the ability to discuss concerns online with an HCP or Artificial intelligence (AI), as discussed earlier, may be critical for stimulating engagement, and social media type systems may be effective for support. A recent study on online communities for cancer patients showed that whilst clinical issues were often readily addressed, social support might be ignored [115]. This study defined key aspects such as sharing of information, mechanical aspects (such as filling out paperwork) and emotional support; many of these aspects were also supported by a study of over 2 million contributions to a breast cancer community [116]. Whilst it is not clear whether an online community functionality would lead to greater engagement with clinical activities, it is an aspect worth serious consideration, and the quality of any online interactions is of great importance [117].

Education research has also shown that social support may be of key importance in a patient-centred system. There are digital tools which are likely to be effective in training HCPs and that may also be effective in helping patients use integrated systems. If both patients and providers can be brought on board, we have shown that there are many benefits to be gained with modern technologies to monitor, engage and facilitate meaningful, enhanced care for patients.

Practice points

- Training healthcare practitioners in eHealth is critical for supporting person-centred care.
- Healthcare practitioners are likely to respond well to online learning opportunities to support such training, especially if linked to continuing education requirements.
- A social and supportive online community is likely to be required by patients.

Artificial intelligence to support access to musculoskeletal care

AI is a form of an advanced computing science that uses a suite of technologies to build smart machines capable of performing intricate tasks that typically require an equivalent of human intelligence. Some of the advances in AI include natural language processing; computer vision techniques that allow machines to understand visual images; time series and sensor data analysis; and anomaly detection. Machine learning (ML) algorithms are capable of comprehending semantics of textual and visual information and answering the given question precisely. Park (2018) [118] employed deep learning models to provide multimodal answers (i.e. two modalities provide complementary explanatory strengths with joint textual rationale generation and attention visualisation) for a question asked in natural language. These techniques in combination with advances in conversational AI techniques [119] create opportunities for a patient to have conversations with a virtual doctor. Such innovations could allow patients to manage their own health, thus reducing the burden on healthcare professionals. There are several advances in computer vision which are particularly attractive for self-management in MSK conditions. For example, Mehta et al. (2019) [120] proposed a high precision three-dimensional (3D) pose estimation technique using a single Red, green and blue (RGB) camera. Such techniques combined with expert systems could be used to identify anomalies in the way people exercise for managing pain and musculoskeletal conditions [118,119].

There is also an increased interest in Explainable Artificial Intelligence (XAI) which focus on transparency in ML decisions [121]. Traditional ML approaches are treated as black boxes; the ability for an expert to interrogate the output of such systems is nearly impossible. This could hamper users' trust in the AI systems and lead to the rejection of those systems, especially in the health domain where the consequences are significant. However, with the XAI paradigm, the focus has moved onto improving the visibility into how an AI system makes decisions and executes its actions, and thereby increasing the trust of such systems among end-users.

While AI utilising machine learning or deep learning capabilities has been studied within medical research environments [120-123,124], very little has been effectively translated into improved health outcomes, particularly where there is lack of evidence due to absence of large-scale clinical trials. Future AI research requires acquisition of large datasets for new knowledge generation through development of precise predictive models. These predictive models can streamline clinical practice through standardisation of operating procedures, improving diagnostic/prognostic capabilities, guiding clinical pathways and thus proactively optimising patients' journeys in the recovery process. Future research must focus beyond pre-clinical scenarios of just comparing machine verses human capabilities and examine outcomes from actual application of this technology in differing clinical contexts. Further, clinical trials need ‘consumers’ at the centre of engagement operating alongside an AI literate HWF [124].

Blockchain for security of musculoskeletal health data

Security is a key requirement for all online systems but is especially relevant in healthcare where trust and confidentiality are key. Blockchain technology, originally invented for the cryptocurrency Bitcoin, offers a verifiable, permanent and attack-resistant system for recording data [122]. These characteristics in Blockchain technology create tremendous opportunities to transform healthcare and place the patient at the centre of the healthcare ecosystem by increasing the security and interoperability of health data [123]. Some key benefits of using Blockchain for storing health and medical records of patients are explained below. Firstly, all changes to the Blockchain are visible to all members of the patient network. Therefore, any unauthorised modifications can be easily detected. Secondly, the patients would have control over their data. The encrypted information can only be accessed by the patient's private key. The patients will and could control who sees their encrypted data and what they see through use of their private key. Thirdly, medical history in Blockchain data is complete, consistent, timely, accurate and easily distributed. Fourthly, there is no mediator for storing data and hence performance bottlenecks can be eliminated.

Blockchain technology has a strong potential to be a suitable solution for common problems related to access to healthcare such as interoperability of electronic health records, shared trust between healthcare providers, auditability and ability for patients to control who they want to share their data with. However we believe that additional research, trials, proofs-of-concept and experiments must be carried out before applying it on a larger scale in the healthcare domain.

Digital innovation can act as a system strengthening tool, empowering patients/consumers and clinicians and improving access to MSK care across care settings; it also has a reach including developed and developing nations [89]. Leveraging digital technologies to support implementation of MSK MoC requires a sophisticated understanding of the complex ecosystem and interactions that underpin healthcare, and the many macro-, meso- and micro-level factors that can act as barriers or enablers to effective implementation [58,125]. Applying evidence-based guidelines [11] to support effective implementation is critical to address these challenges. Ideally this should begin from inception of technology development and ensuring coherence between existing evidence-based care and digitally-enabled MSK care models, thereby mitigating potential digital divides. Partnership-based approaches to assist with policy diffusion and innovation in public health may also have value in shedding light on how we can more effectively address challenges [126]. Empirically-derived evaluation frameworks developed specifically for eHealth interventions [127] need to be applied to ensure that digital technologies are doing what they have been purposed to do.

Practice points

- While evidence still remains inconclusive within musculoskeletal health, there is an undeniable emerging role for novel technological advances (such as artificial intelligence and blockchain).
- Blockchain technology has a strong potential for resolving a common tension between data sharing (health) and privacy.
- Artificial intelligence technologies, including machine learning and deep learning, could play a key role in enabling practitioners to deliver more person-centred care with optimal engagement of their patients.

Meeting global challenges with local solutions

People with MSK conditions mostly have coexistence of more than one chronic disease condition, and the impact of an MSK condition is influenced not only by health-related characteristics and patient/consumer behaviours, but also socio-economic, cultural, and environmental factors. Addressing these complex and often interacting ‘biopsychosocial, socio-political and environmental factors’ therefore requires a shift in treatment focus away from a ‘biomedical structural tissue damage’ model towards a holistic integrated care. Here, the patient/consumer is empowered to manage their care with support from their health and social care professionals [3,14,128]. ‘Person-centred and integrated care’ is increasingly viewed as the future for optimising health access and improving health outcomes. Integrated care, however, may require multiple stakeholders that cross boundaries between community and specialist hospital care and include many siloed and poorly connected specialties. This challenge makes integration of services both difficult and inefficient [3].

In this chapter, we have described innovative exemplars reflecting evidence-based patient-centred integrated MSK care, such as the Global Spinal care initiative targeting the MSK burden in some of the LMICs [20-22]. MSK MoC in Ontario, Canada, with a focus on low back pain through shared care involving a multipronged policy approach and optimisation of advanced practice physiotherapists and chiropractors, resulted in reduction of unnecessary diagnostic procedures and surgical consultations. Through these initiatives, patient education has been an essential pedigree for success [27-29]. Similarly, the WHO has facilitated global sharing of emerging best-practice MoC through an open access web platform. This platfrom acts as a learning network, providing an opportunity for innovative ideas to flourish with lessons gained through setbacks or success stories within a given context [19]. Further, an imperative for MSK inclusion in non-communicable diseases (NCD) policies in alignment with the WHO ICOPE framework could help realise more innovative practices [24,31-34]. Setting the stage with the development of a comprehensive MSK competencies framework has already started influencing discussions around improving capabilities of future HWF and fostering confidence in patient-healthcare provider communication exchange. This framework not only provides clinical/technical skills to the HWF but also includes strategies for managing each patient holistically. This allows for the integration of capabilities such as patient education and self-management, preventative healthcare, critical thinking and evidence appraisal, including safety and quality of care [3,48]. Moreover, increasing recognition of MSK workforce comprising not merely of physicians but also physiotherapists, chiropractors, osteopaths, acupuncturists and other manual therapists could be a game changer for improving access to MSK care [50–54]. While on the other hand, digitally enabled innovative solutions for MSK self-care, such as pain*HEALTH* and the ‘*iCanCope with Pain*’ app, show evidence for improved pain management, which is a common feature of all the MSK conditions, and highlights a need for improved active self-management and self-efficacy [62,66,74]. Telerehabilitation now has been possible in the areas of management of osteoarthritis as with low back pain and neck pain due to these advancements in digital technology [94,105]. In addition, capacity building of health professionals through BoneHealth TeleECHO is another promising initiative intended to be replicated at several locations, globally [67]. Similarly, the future potential of digital health in the areas of data monitoring, evaluation, decision support, telemonitoring through wearable devices or trackers and utilising AI and blockchain technology could offer disruptive, positive solutions to support improved MSK care [57,58,73,80,83-85,88,89-92,95,118-123]. Further, the role of open online content for education of the MSK workforce, customisable for local context, can be aligned to develop patient education solutions to empower consumers and communities more broadly [108-110,112-117,14].

Some of the attempts around 'person-centred care' for multimorbidity care have demonstrated improved overall patient experiences, yet without changing quality of life [129]. Therefore, high quality evidence is required to better understand the determinants required to optimise this complex care model and develop tools to support successful implementation. Individual needs must be identified and targeted to empower patients and their carers with the capacity to make positive changes to their health and wellbeing. Timely access to care is essential for reducing morbidity and mortality. When we think of terms such as 'remote' and 'outreach' we are likely to think of distant and isolated rural communities that lack access to healthcare, but the reality is that patients can be living within a block of a major health facility and be prevented from access due to several factors influencing their care seeking. These factors range from simple logistical issues such as the availability of suitable transport to lack of awareness around consequences of MSK conditions and traditional belief systems within Low- and Middle-income countries (LMICs) [130]. Similarly, studies were conducted to understand the care-seeking behaviour of consumers having conditions related to MSK care and the adoption of best practice evidence within an LMIC setting. This involved healthcare providers from multiple disciplines and patients and their carers representing services ranging from one of the best national public healthcare facilities to those of a remote state in India [131,132]. The findings revealed that major stakeholders have the best intent to adopt best practice evidence yet feel helpless or dejected by the enormity of fragmentation in the existing health systems. Further, improvement strategies were co-identified at the individual setting level and policy level, reflecting the need for better coordination of services through effective communication. Overall, this would require implementation of complex interventions with a co-ownership approach of the LMIC healthcare providers, policy makers, patients and others who must operationalise them beyond formal clinical setting [133].

Similarly, in a recent review focusing on initiatives using digital health in fragility fracture recovery, the initiatives came mostly from developed country settings [15]. Thus, it is not just about improving implementation of best practice evidence, but also the development of workforce research capability within LMICs. Further, this should also facilitate larger scale adaptations and adoption as part of continuous improvement cycles. Innovation processes are complex, non-linear and dynamic in nature, and are at times unpredictable [9]. There is a need for strong global advocacy bodies such as the Global Alliance for Musculoskeletal Health (G-MUSC) to provide leadership and support through international and regional fora. Such peak bodies need to represent diverse stakeholders across the globe; have a focus on health policy and evidence; and work with a mandate to develop strategies and set agendas aimed at improving the quality of life for individuals with MSK conditions [134]. At the local/decentralised level, however, the focus must be on 'service design' and involve team members responsible for service execution and patient care. These team members need to be encouraged to interrogate evidence when determining the value of an innovative solution (e.g. a digital tool) in their day-to-day work. Central to the evaluation of a 'value-based proposition' is the contemplation by each team member, based on their real-life experiences, as to how this 'solution' is likely to impact service delivery in the context of their routine workflow. This process is essential in the redesign or improvement of MSK care [135].

Improvements in communication systems have led to great advances in human society in recent times, allowing critical information to be disseminated in a timely fashion, thus better linking and organising communities and individuals. These systems are helping to shape societal and economic behaviour through their core role in transactions and interactions [136]. Advances in modern technologies support the view that a person-centred, integrated MoC can be delivered. Further, resources to optimise pain management, physical activity, nutrition, sleep hygiene and mental functioning could all be integrated into this holistic MSK MoC, are intuitively care components relevant to all NCDs, and assist in the reorientation of services closer to consumers within their own community [15,137].

The WHO workforce 2030 report clearly outlines the challenge to provide UHC with a projected deficit of 18 million healthcare workers. This deficit in HWF capacity may be addressed through training a more ‘fit-for-purpose workforce’, with defined capabilities for scope of practice, aided by technology-assisted service delivery to better ‘engage and empower patients’ and their communities; collect important ‘big data’; and apply emerging artificial intelligence (AI) solutions [3,7,8]. A ‘digital personal health hub’ can be used to provide the information required to support integrated care involving multiple clinical and social services and to organise additional personalised digital data sources, while also acting as a platform to collate and interpret useful health information. This is potentially a very powerful tool to empower consumers to take greater control of their health. The major limiting factor with existing ‘health hubs’ is that they are not linked to mainstream health services and do not connect to primary care practitioners' or specialists' networks. Innovations designed around the consumer are required that can specifically bind them to a more extensive network of specialists, general practitioners and community carers, that is, consumer ‘communities of (virtual) practice’. This is crucial to the development of a strongly integrated team approach that is more responsive to patient's/consumers' and communities' needs in a holistic manner [14].

Clearly, there are many challenges to be addressed and equally many opportunities to explore. Governments would need to invest in this approach through both policy and funding, but the potential gains extend well beyond the health sector to improved national productivity [6]. Instruction and adoption of digital health supported healthcare could be incorporated into school educational policy. Existing practice management software and apps could interface with this platform. Cloud access, information storage and security would need to be addressed, but there are policies and procedures within existing health and governance structures that could be effectively implemented. Rather than waiting to be shaped by the impact of digital technology and machines on the workforce, stakeholders and organisations need to become agile, using learning systems which educate, re-educate and support workers, to gain a productive and competitive advantage and maximise staff well-being. Further, the healthcare industry needs to overhaul its rudimentary approaches to the leadership, development and coaching of individuals and teams, embracing proven techniques which raise motivation and performance [8,14].

We envisage a world where the consumer is an active and health-literate partner; person-centred and integrated MSK care is provided holistically; healthcare workers are competent in the principles of online education and behaviour modification; and people with multimorbidities are managed more efficiently in the community, aided by digital personal health hubs linked to the most contextually relevant best-practice care. A co-created health environment with all parties learning from the same page would help optimise outcomes [3,8,14,137].

Summary and next steps

Globally, there are many examples of successful innovation in MSK care and healthcare which are, in general, leading to improved efficiencies and quality of care around more integrated and person-centred MoC. These innovations, driven by growing needs and the consumer voice, will increase with further advances in technology, communication exchange and healthcare education. It is in the area of innovation management that we must grow to allow the large and often chaotic innovations to be rigorously tested, filtered, adapted and adopted into practice to improve healthcare productivity and outcomes (health and socio-economic). Innovation must incorporate solutions that are equitable in driving improved access to MSK care ‘sans frontiers’ and supporting UHC. While there is an agreement over the list of ‘healthcare needs’ among global healthcare think tanks, prioritising requires alignment with contextual factors. This may seem simplistic, but it comes with complex challenges to agree upon what needs to be prioritised and what gains we can anticipate by doing so. The key steps required will not be realised without strong leadership supported by policy and funding and without the consumers strongly positioned and engaged across systems. We propose a number of recommendations for future innovation to support improved global musculoskeletal health and care, shown in Table 2. These recommendations are guided by evidence-based principles and frameworks for innovation and implementation discussed in this paper and indicate the steps required to systematically establish the infrastructure, resources and data required to create a sustainable network of collaborators to improve productivity. These recommendations can be applied across the life span and the continuum of MSK care from establishing preventative services to rehabilitation and monitoring of recovery processes

Table 2
Recommended steps for future research and innovation in musculoskeletal health and care.

1. Develop and support a global network of current and future leaders through peak bodies such as G-MUSC, OARSI and IASP who can collaboratively champion evidence-based innovations prioritised for adaptations and adoption in musculoskeletal health.
2. Develop a global consensus on suitable platforms and evidence-based frameworks to guide the collection, sharing, organisation and management of MSK research and innovation projects to ensure applicability and equity of access to LMICs.
3. Task a lead global group to direct and drive research innovation to ensure that healthcare gaps (including prevention) and needs in MSK conditions are accurately identified, quantified and prioritised in line with WHO policy, guidelines and strategic directions.
4. Encourage creativity while carefully selecting innovations for potential viability, evidence of efficiency and effectiveness to support improved context-specific and sustainable musculoskeletal care. Use global, regional and local fora to bring together innovators and stakeholders, supported by innovation management skill sets. Potential conflicts of interest must be identified and managed to prevent blockages to high value, disruptive innovations by conflicted persons or organisations potentially threatened by the innovation.
5. Develop a strategy for dissemination of evidence for successful MSK innovations using one of the many useful and reliable tools for developing and sharing content and customise for purpose. This will help to inform and inspire current and emerging leaders, entrepreneurs (business and social) and consumer groups in all areas of health and technology including basic and clinical science, technology and data, health policy and economics, education (workforce and community), health administration and all levels of clinical practice and care giving.
6. Develop guidelines to engage global and regional partnerships to support implementation of innovations. Leverage 'in kind' resources provided by the global network of individual and organisational contributors with funding from governments, research institutions, business/industry partnerships, social entrepreneurs/philanthropists, etc. (eg G-MUSC leading with WHO, and others working with NGOs to help set research agendas).
7. Facilitate the collection of standardised local, regional and national data to monitor outcomes and inform continued innovation research (e.g. establishing and/or linking into data registries with globally consistent data sets).

[11]. In line with these recommendations, there have been significant gains to date. Under the umbrella of G-MUSC and in close alignment with the WHO, there are a growing network of organisations (Global Fragility Fracture Network, Global Spine Care Initiative, International Association for the Study of Pain, etc.) and individuals representing healthcare disciplines, research institutions, governments, industry and consumers who are working together to drive improved MSK care delivery and health and economic outcomes. These are being achieved through the organisation of international, national and local meetings; epidemiology (GBD), clinical outcomes (hip fracture registries) and digital health research (virtual clinicals and digital health hubs, activity monitoring); network communications (internet and social media); and education (competency standards, content frameworks and online resources/training).

While being locally successful, most of these innovations are yet be more broadly adapted and adopted, which is a critical step for sustainable health. This is our collective challenge.

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Declaration of Competing Interest

The authors have declared that no competing interests exist.

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CHAPTER 7

PERSONAL DIGITAL HEALTH HUBS FOR MULTIPLE CONDITIONS

Personal digital health hubs for multiple conditions, was published in the Bulletin of the World Health Organization in 2020.

The published paper will follow summary and statement of authorship.

Summary

This paper addresses the final objective of the thesis by describing a vision for future healthcare to address increasing population multimorbidity through the co-creation of digital health hubs that recognises the importance of patient agency in driving the evolution of health services.

This chapter provides an overall summary of major concepts and ties together lessons, theories and thought processes generated from this clinical and translational research program to date. This was published as a 'Policy and Practice' paper as a proof-of-concept to be tested in various settings. The area for initial intervention will include fragility hip fractures but it can then be extended into other musculoskeletal and multimorbid conditions across diverse settings, ranging from developed countries and regional settings to low- and middle-income country settings.

Contemporary evidence suggests that multimorbidity involves more than one chronic disease but is a whole person condition influenced by complex and often interacting biopsychosocial factors. Thus, there is a need to alter the treatment focus from a 'structural tissue damage' model towards person-centred care. However, this will require a dynamic shift in the conversation between healthcare providers and consumers by contemplating health messages in terms of biopsychosocial factors.

Moreover, consumers need to be empowered to self-and/or co-manage their own health. For this reason, this research program initiated the development of a digital health patient education solution utilising existing learning management systems. This is a collaborative exercise undertaken in a South Australian setting with the intention of improving orthogeriatric care within the community through the engagement of multiple medical disciplines, education, computer science and local government. In addition, the translation of knowledge in other ‘multimorbid scenarios’ could offer better solutions in other country settings.

Informed by collaboration between patient, health and education communities, an early experience in the development of a digital health hub around a cohort of patients with hip fractures has been shared through this paper. The digital health hub could allow important advances and efficiencies to be achieved in workforce practice and education; patient and carer engagement in self-care; and the collection of patient-reported health data required for ongoing research and improvements in health care.

This paper has been cited by seven publications

Statement of Authorship

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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate to include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution

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Overall percentage (%)	50%	
Certification	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreement with a third party that would constrain its inclusion in this thesis. I am one of the key authors of this paper	
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Personal digital health hubs for multiple conditions

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Abstract Multimorbidity is the presence of more than one chronic disease condition in an individual. Health-related, socioeconomic, cultural and environmental factors, as well as patient behaviour, all influence the outcomes of multimorbidity. Addressing these complex and often interacting biopsychosocial factors therefore requires a shift in treatment from a physical damage model towards person-centred integrated care with increased patient agency. Education influences behaviour and can be used to empower patients and their carers with greater agency, thus allowing greater responsibility for and control over the management of patient care. In this paper we reflect on our own learning as a community of health practitioners from different disciplines. Recognizing the increasing importance of patient agency in driving the evolution of health care, we describe the concept of a web-based personal digital health hub for integrated patient care. Informed by collaboration between patient, health and education communities, we share our early experience in the implementation of a health hub around a cohort of patients with hip fractures. We also describe a vision for future health care based on the co-creation of digital health hubs centred on patients' and carers' needs. The health hub could allow important advances and efficiencies to be achieved in workforce practice and education; patient and carer engagement in self-care; and the collection of patient-reported health data required for ongoing research and improvements in health care.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

Multimorbidity is the presence of more than one chronic disease condition in an individual. By viewing multimorbidity as a person-centred concept we acknowledge that the impact of a condition is influenced not only by health-related characteristics but also by socioeconomic, cultural and environmental factors, as well as patient behaviour.[1–3] Addressing these complex and often interacting biopsychosocial factors therefore requires a shift in treatment for multimorbidities from a physical damage model towards person-centred integrated care with increased patient agency. Such a model allows patients to have greater responsibility for and control over the management of their care.

Complex models of care that involve multiple health and social care disciplines are increasingly being developed. A trial of integrated person-centred care for multimorbidity found that patients expressed overall satisfaction with care services although they did not gain significant improvements to their quality of life.[4] Similarly, there is increasing evidence around the value of innovations in digital health applications and in the health workforce to improve efficiencies and quality of care, as driven by the needs of the local context. However, the driving forces for scaling-up these initiatives will be political and economic and involve health-care professionals and patient advocates.[5,6] In this paper we examine our own learning through our combined perspectives as a community of practitioners from different disciplines. Further, we highlight the importance of patient agency in driving the evolution of health services that are empowered by improved, digitally enabled strategies for patient education.

Community-driven progress

As best practice in health care and the learning process within medicine has evolved, so have community attitudes towards health care. Historically, progress in medicine has been shaped primarily by the health workforce driving continuous improvements in health care. However, there is now recognition that greater access to health information has allowed the involvement of patients and their carers (both formal and informal) to be considered as part of a community of practice, which is also influencing ways of delivering health-care services.[5] Moreover, increasing access to digital technology could result in further patient and community empowerment and influence the balance between vertical (institutional) and horizontal (community) governance systems. This synergy between patient desires, digital technology and health-care expertise could provide innovative solutions and change the direction in which health care evolves.[5,7]

Patient education

The World Health Organization (WHO) *Global strategy on human resources for health: workforce 2030* report clearly outlines the challenge to providing universal health coverage with a projected deficit of 18 million health-care workers.[7] A contribution to addressing the deficit could be through training a workforce for a defined scope of practice, supported by technology-assisted service delivery to better engage and empower patients and their communities. The workforce could help facilitate the collection and use of the immense amount of data (so-called big data) that can be captured from patients and could be involved in applying emerging artificial intelligence solutions to health care.[1,6,7] Recently WHO introduced digital health as a broad term to encompass

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health services provided electronically (eHealth), including mobile health technology solutions (mHealth), as well as emerging areas, such as the advanced use of computing sciences to manage big data, genomics and artificial intelligence systems.[8,9] A major challenge now is how to process digitally collected data and interpret it in a meaningful way.[2,9] For health practitioners and patients alike, the amount of health information from sources, such as friends and family, the internet, medical journals, health pamphlets and specialists can be overwhelming and lead to confusion rather than clarity. Differing levels of health literacy already affect patients' ability to understand health information and to make informed decisions about their health. Differences in ability to access and use technology, the so-called digital divide, create further inequities in access to health information.[1]

While electronic health records allow communication and data management among health-care providers, these types of records were not designed with the primary goal of engagement with patients. Some software applications on mobile devices are designed to collect data for use by health professionals, such as patient-reported outcome measures. Yet the information flow usually offers limited, if any, effective ways to involve patients in their own care. Overall, there has been a rapid increase in the availability of mHealth applications,[10] by a variety of vendors including health agencies, fitness advocates and software companies.[11] These health applications are primarily designed to support patients or consumers[12] in the domain of general lifestyle and wellness, such as applications on mobile phones or wearable devices that monitor activity levels or heart rate. However, there are also developments in the use of eHealth services to support the management of specific diseases (such as rheumatoid arthritis, diabetes, anxiety and mood disorders) in conjunction with specialist services.[1,12] For example, there are now applications for patients with diabetes, which can be synced to small monitoring devices inserted subcutaneously to monitor glucose levels continuously. This technique allows controlled insulin delivery in wearable automated pumps while providing critical feedback to both patients and their carers to inform necessary medication, dietary and lifestyle adjustments. Some of these applications have readily become accessible and inexpensive, reducing the need for expensive doctor visits and laboratory-based investigations.[12] However, access to such technologies is not universal for patients or health-care providers. Research can identify the technologies and processes that are most feasible for supporting effective implementation of digital health solutions. Applying evidence-based guidelines is therefore important for mitigating potential digital divides.[5] There is likely to be a strong emphasis on the use of widely used technologies, such as mobile phones where patients and health-care workers are likely to have greater access to the technology.[13] Applying best-practice guidelines at the inception of a new system will ensure coherence between traditionally established care practice and emerging, digitally enabled models of care.[5,9]

The success of some of these software applications in actually changing patients' behaviour[11,14] should come as no surprise if the principles and theories on which they are based are clearly understood.[15,16] Information is provided to users in a format that is easily understood and meaningful in the context of users' goals. The knowledge gained can be applied to solve users' problems and the success of that application is assessed with immediate and specific feedback to the user. Based on this feedback the users are able to make the necessary changes required to further their individual goals and the cycle repeats. The theory is related to fundamental approaches to education, where the process of learning can bring about behavioural change. Most clinicians involved in faculty and student training are well aware of the principles. Yet how often are these principles applied as part of clinical practice? Unfortunately, simply providing information and awareness is not the same as providing education. Awareness and understanding of important information do not automatically improve an individual's capability and translate into positive behavioural change.[1] Patients, particularly those with chronic conditions, often do not adhere to treatment guidelines, such as prescribed medications, lifestyle changes, rehabilitation and exercise programmes. Given the many circumstances where patients mis-hear, misremember or misunderstand information and advice from their health professional, there will often be adherence issues. To translate knowledge into successful health outcomes, a co-designed and integrated approach to patient education is needed, with a consistent and shared understanding among all care providers.[17] The same arguments that have led to increasing the agency of students in education can be applied to patient agency in health care.

Personal digital health hub

A personal digital health hub can specifically collate and interpret useful health information, facilitating the integration of data from different health services and other personalized digital data sources. This personalized hub is potentially a powerful tool, empowering patients to take greater control of their health goals. The major limiting factor, however, is that current applications are not connected to mainstream health services and are not linked to the professional networks of family practitioners or specialists. In contrast, processes that are specifically designed around the individual can link patients into a more extensive network of specialists, general practitioners and community carers. This holistic approach is important for the development of a strongly integrated team approach that is more responsive to the needs of patients and communities. Models of care need to be further redesigned by deploying digital health solutions that will allow delivery of high-quality and patient-centred information to strengthen and integrate care closer to the community setting. There are existing eHealth applications used to enable the implementation of models of care in patients with arthritis[18] and skeletal fragility.[19,20] The applications streamline system-level referrals, build workforce management capacity and support patients in managing pain or performing exercises at home.[21]

Collection of selected data linked to patient-reported outcome measures would contribute to big data repositories, such as outcome registries and could be used for health research. The data might be used for validation of artificial intelligence-based predictive algorithms and decision-support tools and could inform improvements in the design of these tools.[1,5,17] Blockchain technology, which provides a transparent, unalterable record of a transaction, offers a verifiable, permanent and attack-resistant method for recording health data. By increasing the security and patient trust in the quality and use of the data, a personal health hub can create opportunities to transform health care and place the patient at the centre of the health-care network.[5] With these innovations, we envisage role shifts among health-care workers, in which diagnostic and prescriptive roles give way to more supportive, collaborative, nurturing and motivational skills to empower patients. Collectively, these technological innovations are expected to drive major changes in the composition, scope of practice and training (based on required capabilities) of the workforce, allowing more efficient use of resources to deliver the right care, at the right time, in the right place, by the right person with the right resources.[5]

In the absence of a strong sense of need and urgency, and to manage resistance to change in well entrenched care practices, this approach will need to be introduced in stages. Depending on the organizational model used within different health-care settings, implementation could be initiated either through empowered specialty groups or from within primary care. With linkages to the patient and community services established, new systems could be further optimized around a variety of chronic disease models of care. Eventually the systems could transition into a patient-controlled and government-supported system, linked to the mainstream suite of public and private health services. The personal digital health hub could connect with other wellness providers, such as nutritionists, physical therapists, psychologists and social workers; and a myriad of suitable, commercially available mHealth applications. Patients, whether living independently or under a care arrangement, could have their own customized health hub with the ability to share relevant and selected categories of information with health-care providers and community or social support networks. The shared platform could also function as a virtual workplace for vocational training, allowing a mutually transforming process of learning (both cognitive and sociocultural), through participatory practice[22] of patients, carers, health-care practitioners and students alike.

The personal digital health hub would be specifically built around patients. All stakeholders would have a role to play in supporting the individual's health literacy. Care goals could be integrated, providing a more holistic approach to care with improved health outcomes and health-system efficiencies.[1]

Adaptable software solutions to create a digital hub already exist in the form of learning management systems that are widely used in the education sector.[5] Many of these systems are based on open-source software, which would facilitate their future adaptation and implementation in low- and middle-income economies. The roles of course administrators, teachers, students and observers can be substituted by health-care providers, liaison officers, patients and family or carer supporters. These platforms have design features that provide services, such as secure internet access for users; content management; monitoring of the volume and frequency of communication exchanges between participants; progress tracking of assigned tasks; and assessment of users' engagement through data on time spent online and on specific pages or tasks. Patient-reported outcome measures can be readily collected to monitor individual outcomes, as well as contribute de-identified data to large health research databases. Plug-ins allow the data and functionality of existing or new mobile applications to be integrated into the hub software and accessed through both web and application-based interfaces. A community of learners can be created to support the education of health-care workers and patients alike.[1,23]

Clearly, there are many challenges to be addressed. Governments would need to invest in this approach through both policy and funding, but the potential gains extend well beyond the health sector to actual improved national productivity.[6] Cloud access (the ability to access files stored on internet servers), information storage and security using emerging blockchain technology would need to be addressed. However, there are policies and procedures within existing health and governance structures that can address issues, such as patient confidentiality and ownership of data, and could be adapted and implemented effectively. As a contained system the digital health hub could also ensure that the data mined remains fully transparent, patient-controlled and used solely for the purpose of analysing and influencing health behaviour and enhancing health-care outcomes. The system should ideally remain completely separate from control by data brokers with commercial and political interests. The technologies used to secure data would support this to some extent, but the use of open-source software and the local political environment will likely be influential.

Early experiences

Our concept of a digital health hub has evolved since 2012 when we established a telephone-based remote follow-up and virtual clinic service for hip fracture patients. With 500–600 patients annually, the Royal Adelaide Hospital is one of the busiest hip fracture centres in Australia. In this cohort, we considered all patients as remote, even those living locally, due to the logistics of travel and support required to attend a hospital-based clinic.

To address the challenges and insights that emerged from the virtual clinic we designed a digital patient health hub using a transdisciplinary approach in this specialist orthogeriatric setting.[17] Input was provided from clinical disciplines (geriatrics, orthopaedics, emergency medicine, anaesthesiology, rehabilitation medicine, general practice, nursing, allied health and pharmacy); non-clinical disciplines (health economics, computer science, higher education, mathematics, architecture and demography); and patient and consumer groups. We used a collaborative and co-design approach to translate our knowledge and experience into successful health outcomes.

The digital health hub was designed to improve education, service integration, data exchange and engagement of all stakeholders including patients and health-care providers.[17] We structured the web-based platform to provide information related to health issues under four key sections: (i) current concerns (for example, a hip fracture); (ii) essential wellness (nutrition, exercise, sleep and mind); (iii) community health (hygiene, contagious diseases); and (iv) past health. The digital hub was thus designed to support a lifelong approach to healthy ageing through lifestyle approaches, while addressing injuries or illnesses as they arise. Preliminary background research of this elderly patient cohort and their carers confirmed that they had significant capacity to access digital health solutions through the support of networks of carers.[9]

As we develop this new model of care, nurses or other health-care workers with defined competencies in orthogeriatrics, would be further trained to fulfil the additional roles of a fracture liaison coordinator, an online educator and a facilitator of behavioural change. Patients and carers will be engaged from the time of admission and provided with instructions and secure access via the digital hub to resources designed to provide a clearer understanding of the complete course of hip fracture. A liaison officer coordinating the information exchange and engagement through the digital hub will be the first point of digital contact, while the patient or designated carer retains control of access rights for additional carers and observers. The liaison role will be further supported by decision-support protocols with oversight by, and ready access to, orthopaedic and geriatrician specialists.

We expect that a wide range of quality, evidence-based educational resources will be adopted, adapted or developed in partnership with patient and consumer groups and delivered through the online learning platform. The resources will be made available in a variety of suitable digital formats to address individual educational needs around understanding of the injury, management and support options (including surgery, anaesthesia, pain, thromboprophylaxis, discharge medications, nutrition, exercise and post-operative mobilization, sleep, wound care, falls risk assessment, osteoporosis, sarcopenia, frailty, cognition, advance directives and community services). These educational resources are similarly used to inform the associated community health-care professionals and students engaged with the patient in the digital health hub.

A calendar, with functionality for several reminder options, will be used to schedule and manage follow-up tasks, including progress feedback, appointments and community-based investigations. Further communications can be via email, text message, telephone, videoconference or face-to-face appointments, as required. Patient engagement is tracked using multiple metrics, which are monitored and captured, such as time spent in specific areas of the health hub, communication exchanges and tasks completed. Feedback of patient progress will be primarily digital, with telephone follow-up as required, and include information used to both inform immediate clinical management and provide patient-related outcome measures for audit and research purposes.

We believe that important progress towards a more patient-centred and integrated health-care system can be made through the collective wisdom of health-care providers from multiple disciplines in partnership with patients. Nevertheless, this new model of care and the digital health hub, while showing great promise in this challenging cohort of older patients with a hip fracture, are still in a development phase. Further refinements of the digital health hub will be informed by the iterative development process, gained from user feedback and analysis, before wider implementation and evaluation in the specialist setting. This will be followed by application of the model to manage conditions involving other specialty areas and ultimately by adaptation for use in a community-based primary-care setting.

Other settings

For low- and middle-income countries, the use of open-source software and mobile phone technologies may provide the greatest opportunity to support universal health coverage through contextualizing a personal digital health hub. Mobile phone penetration is high in many low- and middle-income countries and mHealth is already recognized as promising to provide patient-centred care in some of these countries.[24] Emerging evidence reflects digital health being used in these settings to strengthen primary health-care systems[25] by targeting service delivery and increasing community health workforce capacity;[26] improving health education and lifestyle behaviours;[27] and supporting self-management of noncommunicable diseases.[28] Some digital health interventions that were focused on capacity-building or training of community health workers were not informed by the theories in education and, ironically, lacked an understanding of what counts as learning.[29] We expect that a system built on best-evidence education principles would be more likely to succeed.

Future directions

We envisage a world where person-centred, integrated health care is provided holistically; the patient is an active and health-literate partner; and health-care workers act as life coaches, competent in the principles of online education and behaviour modification. Multimorbidity will be managed more efficiently in the community, aided by digital personal health hubs linked to best-practice content most relevant to the context. [1,17] ■

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ملخص

مراكز الصحة الرقمية الشخصية للحالات المرضية المتعددة

تعدد الأمراض هو وجود أكثر من حالة مرضية مزمنة واحدة لدى الفرد. تؤثر العوامل الاجتماعية الاقتصادية، والعوامل الثقافية والبيئية، المرتبطة بالصحة، وكذلك سلوك المريض، على نتائج تعدد الأمراض. إن التعامل مع هذه العوامل البيولوجية النفسية الاجتماعية المعقدة، والمتداخلة غالباً، تتطلب تحولاً في العلاج من نموذج الضرر الجسدي إلى الرعاية المتكاملة التي تركز على

الشخص، معتمكين أكبر للمريض للمشاركة وتحمل المسؤولية في العلاج. يؤثر التعليم على السلوك، ويمكن استخدامه لتمكين المرضى ومقدمي الرعاية لهم من خلال ومشاركة أكبر، وبالتالي السماح بمزيد من المسؤولية تجاه إدارة رعاية المرضى، والتحكم فيها. نركز في هذه الورقة على تعلمنا كمجتمع من الممارسين الصحيين من مختلف التخصصات. في ظل إدراك الأهمية المتزايدة لتمكين المريض في دفع تطور الرعاية الصحية، فإننا نصف مركز الصحة الرقمية الشخصي على شبكة الإنترنت للرعاية المتكاملة للمرضى. وبناءً على التعاون بين مجتمعات المرضى والصحة والتعليم، فإننا نشارك تجربتنا المبكرة في تنفيذ مركز صحي حول مجموعة من المرضى الذين يعانون من كسور الورك. كما نصف أيضاً رؤية للرعاية الصحية المستقبلية استنادًا إلى الإنشاء المشترك لمراكز الصحة الرقمية التي تركز على احتياجات المرضى ومقدمي الرعاية. يمكن أن يسمح المركز الصحي بتحقيق تطورات وكفاءات هامة في ممارسة القوى العاملة والتعليم؛ ومشاركة المريض ومقدم الرعاية في الرعاية الذاتية؛ وجمع البيانات الصحية التي قدمها المريض، والمطلوبة للبحث والتحسينات المستمرة في الرعاية الصحية.

摘要

针对多重病症的个人数字医疗中枢

多重病症是指一个人患有一种以上的慢性疾病。与健康有关的因素，社会经济、文化和环境方面的因素以及患者行为都会影响多重病症患者的治疗结果。因此，若要解决这些复杂且经常相互作用的生物心理社会因素，需要将治疗从物理性损伤模式转换为以患者为中心的综合护理，并提高患者在其中所发挥的作用。教育影响行为并且可以用来为患者及其照顾者赋权，让他们发挥更大的作用，从而对患者护理的管理工作承担更大的责任和管控力度。在本文中，作为一支汇聚不同学科从业人员的团队，我们反思了我们总结的经验。我们意识到患者在推动医疗护理改革方面所发挥的作用日益重要，因此我们描述了一个基于网络的个人数字医疗中枢的概念，用于整合患者护理。通过患者、卫生和教育团体之间的合作互通，我们围绕一批髋部骨折患者分享了我们在医疗中枢实施方面的早期体验。我们还基于共建以患者和护理人员需求为中心的数字医疗中枢，表达了对未来医疗卫生事业的美好愿景。医疗中枢可以在人员实践和教育方面实现重要进展和效率提升；可以让患者和照顾者参与自我护理；可以收集患者自述的医疗数据，所收集的数据用于医疗护理事业的长期研究和提升。

Résumé

Centres de santé numériques et personnalisés pour pathologies multiples

La multimorbidité est la présence de plus d'une maladie chronique chez un individu. L'aboutissement de la multimorbidité est influencé par des facteurs sanitaires, socio-économiques, culturels et environnementaux. Aborder ces facteurs biopsychosociaux complexes et souvent interdépendants requiert donc un changement de traitement, qui consiste à s'éloigner d'un modèle axé sur les dommages physiques pour se rapprocher d'un modèle de soins intégré et centré sur la personne, allié à une meilleure implication du patient. L'éducation a un impact sur le comportement et peut être utilisée pour renforcer la capacité d'agir des patients et de leurs soignants, ce qui permettra de conférer plus de responsabilités et un meilleur contrôle de la gestion des soins aux patients. Dans ce document, nous réfléchissons à notre propre apprentissage en tant que communauté de professionnels de la santé issus de différentes disciplines. Nous reconnaissons l'importance croissante de l'implication du patient pour stimuler l'évolution des soins de santé, et imaginons un concept de centre de santé numérique et personnalisé via site Web pour la prise en charge intégrée des patients. Grâce à la collaboration entre patients, professionnels de la santé et structures pédagogiques, nous partageons nos premières expériences en matière de mise en œuvre d'un centre de santé regroupant des patients présentant des fractures de la hanche. Nous dévoilons également notre vision d'avenir pour les soins de santé, qui repose sur la cocréation de centres de santé numériques adaptés aussi bien aux besoins des patients qu'à ceux des soignants. Ce concept pourrait faire progresser l'enseignement et la pratique pour les professionnels du secteur, mais aussi améliorer leur efficacité; favoriser la participation des patients et soignants dans les soins auto-administrés; et enfin, permettre la collecte des données fournies par les patients, et nécessaires à la poursuite des recherches et améliorations dans le domaine des soins de santé.

Резюме

Персональные цифровые центры здоровья в случае нескольких хронических заболеваний

Мультиморбидность это наличие у одного человека нескольких хронических заболеваний. Исход мультиморбидности зависит от факторов, связанных со здоровьем, социально-экономических, культурных и экологических факторов, а также поведения пациента. Таким образом, решение вопросов относительно этих сложных и часто взаимосвязанных биопсихосоциальных факторов, требует перехода в лечении от модели физического повреждения к комплексному медицинскому обслуживанию, ориентированному на человека и предоставляющему большую свободу действий пациенту. Обучение влияет на поведение и может использоваться для расширения возможностей пациентов и ухаживающих за ними лиц, предоставляя им больше ответственности и контроля за процессом лечения и ухода. В этой статье авторы рассматривают процесс собственного обучения как сообщества практикующих специалистов из разных дисциплин. Признавая растущую важность свободы воли пациентов как движущей силы эволюции здравоохранения, авторы описывают концепцию сетевого персонального цифрового центра здоровья для комплексного подхода к лечению пациентов. Опираясь на опыт сотрудничества между пациентами и сообществами здравоохранения и образования, авторы делятся первоначальным опытом в части создания центра здоровья для контингента пациентов с переломами шейки бедра. В статье также описана концепция здравоохранения будущего, основанная на совместном создании цифровых центров здоровья, сосредоточенных вокруг потребностей пациентов и лиц, осуществляющих уход. Центр здоровья может позволить добиться значительных успехов и эффективности в сфере практической деятельности и обучения медицинских работников, вовлечения пациентов и ухаживающих за ними лиц в процесс самопомощи, а также сбора предоставляемых самим пациентом данных о его здоровье, которые необходимы для текущих исследований и совершенствования системы здравоохранения.

Resumen

Centros de salud virtuales personalizados para múltiples afecciones

La multimorbilidad es la presencia de más de una enfermedad crónica en un individuo. Los factores medioambientales, culturales, socioeconómicos y los relacionados con la salud, así como el comportamiento de los pacientes, influyen en los resultados de la multimorbilidad. Por lo tanto, se requiere un cambio en el tratamiento desde el modelo de daño físico hacia una atención integrada y centrada en el individuo con una mayor participación del paciente para abordar estos factores biopsicosociales complejos y a menudo interactivos. La educación influye en el comportamiento y se puede utilizar para que los pacientes y sus cuidadores tengan más capacidad de acción, lo que permite una mayor responsabilidad y control sobre la gestión de la atención al paciente. En este documento reflexionamos sobre nuestro propio aprendizaje como comunidad de profesionales de la salud de diferentes disciplinas. Se describe el concepto de un centro de salud virtual personalizado para la atención integrada del paciente, al reconocer la creciente relevancia de la participación y la acción del paciente en el proceso de evolución de la atención médica. Gracias a la colaboración entre las comunidades de pacientes, de salud y de educación, compartimos nuestra experiencia inicial sobre el establecimiento de un centro de salud en torno a una cohorte de pacientes con fracturas de cadera. Asimismo, describimos una visión de la futura atención médica basada en la creación conjunta de centros de salud virtuales que se centran en las necesidades de los pacientes y de los cuidadores. El centro de salud permitiría alcanzar importantes avances y mejoras en la práctica y la educación de la fuerza de trabajo; en el compromiso de los pacientes y los cuidadores con el autocuidado de la salud; y en la recopilación de los datos sobre la salud que los pacientes comunican y que se requieren para la investigación y las mejoras continuas en la atención médica.

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CHAPTER 8

DISCUSSION, FUTURE DIRECTIONS AND CONCLUSION

The thesis had six stated objectives with different methodological approaches. Although each research activity was distinct, the methods and findings were intertwined and added significantly to the body of knowledge related to cocreation of a digital health model of care, focused on empowering patients and their carers through improving health literacy for fragility hip fractures. Emphasis of this pragmatic research approach is on patient-centred education and integration of multidisciplinary care using digital health innovation. Further, this will impact behaviour change through effective knowledge translation and the implementation science strategies improving rehabilitation practice (1-6).

Hip fracture among older people is a major public health issue (7). Evidence suggests that in Australia, 87% of new fractures occur due to low impact trauma or bone fragility, with an estimated rate of 199 hip fractures per 100,000 population (8). Hip fracture patients represent society's most vulnerable groups in terms of pre-existing physical, mental, psychological, neurological, and social challenges (9-14). For instance, over 25% of hip fractures occur in residential aged care facilities, while 50% never return to their pre-fracture level of mobility and activities of daily living (8).

The first episode of a fragility fracture, irrespective of the injury site, is a vital signal for assessing and commencing osteoporosis treatment. Despite this, a mere 20% of fractured patients are adequately assessed and treated by healthcare providers (15). In some community settings, patients with osteoporosis, at risk of falls, are identified and managed after discharge from acute care. This has led to improvements in communication between different practitioners through interdisciplinary education (16), marginal reduction in re-fracture risk, reduced mortality, increased assessment of bone mineral density, increased treatment initiation and adherence, and cost-effectiveness (17). However, improving functional outcomes requires empowering patients through consistent education to achieve person-centred care (18). Patient education involves improving health literacy, which impacts patients' ability to access and utilise healthcare services, optimise patient-healthcare provider communication, and improve self-care.

The key question underpinning this PhD study was:

How can we conduct a program of research focused on establishing a person-centred and integrated model of care for older people with hip fractures, assisted by digital technology and modern educational approaches?

8.1 Summary of the findings

The six research objectives, corresponding to the activities undertaken (Chapters 2 to Chapter 7) all contributed to addressing the overarching research question. Section 8.1.1 focuses on objectives 1 and 2 with key findings from synthesis of contemporary evidence (Chapter 2) and processes of developing a dynamic conceptual framework (Chapter 3). Section 8.1.2 addresses objectives 3 and 4, by involving patients, their family members, residential aged carers (Chapter 4), and stakeholders from multiple disciplines (Chapter 5) in the primary research studies. Finally, Section 8.1.3 focuses on objectives 5 and 6, exploring innovations in MSK care (Chapter 6) and the wider application of digital health hubs for multimorbidity (Chapter 7).

8.1.1 Synthesis of existing evidence and conceptual framework development

In the process of synthesising evidence, existing digital health interventions were mapped and a comprehensive review of the literature, including a meta-analysis, was undertaken. The study focused on evaluating the effectiveness of digital health supported and targeted patient communication versus the usual provision of health information that aimed to educate patients recovering from fragility fractures. The findings of the systematic review were aligned and classified based on the latest WHO guidelines around digital health (19). This is currently the best synthesis of evidence available examining the role of digital health interventions targeting patient "education" in the recovery of fragility fracture.

With the support of digital health solutions to improve education- there is great opportunity for patients and carers to become more active partners in healthcare and achieve optimal outcomes (20). These opportunities will be enhanced by advances in artificial intelligence and machine learning, virtual and augmented reality, and blockchain technology.

With the use of a dynamic conceptual framework, different phases were outlined for a research program centred around the use of a digital health hub enabled model of care for hip fracture rehabilitation (Chapter 3). The concept of co-creation for developing a digital health solution was used in relation to stakeholder engagement, including patients, their family members, residential aged carers and healthcare providers, from multiple disciplines. The term co-creation has also been used interchangeably with co-design or co-production or co-implementation as described within the wider literature (21). Contemporary evidence suggests that several health, social, and other initiatives, including digital health, focused on improving care outcomes, have used co-creation as part of their intervention solutions (22-27). The collaborative creation of healthcare solutions promises to produce long-lasting outcomes through which inequalities in health or social care can be addressed. Co-creation by necessity is disruptive. Through an open process of participation, exchange and collaboration it would change the relationships, positions, and rules between the involved stakeholders - crossing organisational boundaries and jurisdictions at a fundamental level (21).

8.1.2 Pragmatic mixed methods research

Two primary studies were undertaken in this thesis, each utilised a distinct methodological approach and incorporated behaviour change and implementation science frameworks.

A mixed methods study (Chapter 4) was conducted to inform the development of a personalised digital health hub by understanding the perspectives of patients and carers around both the use of, and access to digital technology.

This study demonstrated that people are interested in empowering themselves and are willing to access health information using digital health solutions given access to adequate support. However, impairment with hearing and vision, insufficient dexterity, commonly associated with older adults are barriers that must be taken into consideration in the design of future solutions (28).

By engaging with the patient as a member of a networked unit (which includes family, friends and formal carers) it is envisaged that better engagement and leverage of available resources (social and digital) would follow.

The second study (Chapter 5) used qualitative in-depth interviews to understand perspectives of clinicians from various medical and surgical disciplines, allied health, and other relevant non-health stakeholders to inform the development of a digital health enabled model of care for fragility fractures. These multidisciplinary stakeholders shared their experience as professionals, experts, thought leaders, and front-line healthcare workers. Findings provided an understanding of different thematic constructs corresponding to the factors likely to influence design and implementation of digital health hubs at the local setting level. This wider engagement of stakeholders was critically important, particularly the post COVID-19 pandemic, there is likely to be increased interest in digital health solutions which optimises access to healthcare institutions, and virtual engagement. Digital health enabled model of care will be a complex healthcare intervention which will require incorporation of behaviour change and implementation science frameworks (29-37) to enhance understanding during future phases of the research program.

8.1.3 Innovations in MSK care and digital health hub for multimorbidity

While the primary research studies engaged a wide set of stakeholders locally, my research also sort to understand the process of innovation and its potential application to improve MSK healthcare at macro (policy), meso (service delivery), and micro (clinical practice) levels. It included a critical examination of the roles played by different stakeholders in driving innovations (4). The concluding paper, published in the Bulletin of World Health Organization as a policy and practice paper, provides a more generalised and global vision in a healthcare system with an aging population and increasing multimorbidity. The importance of patient agency in driving the evolution of health services must be recognised and with the use of combined digital technology and education strategies, personalised digital health hubs can be created to empower patients and their carers to achieve better health outcomes (3).

8.2 Strengths and limitations

The research undertaken for this thesis had several strengths and limitations.

This thesis work includes the most contemporary and comprehensive review of evidence including mapping of digital health interventions to support fragility fracture recovery. The key strength of this review was combining the RCTs and quasi-experimental studies in a unique way with the latest WHO guideline on digital health interventions. Thus, the interpretation of findings from meta-analysis and narrative synthesis were further enriched.

Patients, formal and informal carers, health professionals, software professionals, and educationalists, were all successfully engaged to understand key factors and identify thought leaders who could influence local clinical practice and policy and drive next phases of the research program.

The conceptual framework developed has enabled effective engagement with important stakeholders in each phase of the research activity and provides a clear direction and actionable pathways based on the principles of co-creation for future research. Critical aspects ranging from local context to the macro political environment were covered providing relevance for broad translation. At the intersection of innovation and digital health, cross-cutting issues were identified and applied to outline potential solutions within the wider context of MSK health and growing multimorbid conditions.

The pragmatic use of multiple research methods helped maximise methodological rigor in a holistic fashion by embracing human realities based on the ontological assumption of multiple truths (38). In particular, the behavioural change and implementation science frameworks allowed a more robust interpretation of data to enhance our understanding of potential barriers and facilitators to engage and implement changes at both individual stakeholder and health system levels. Further, the thesis is well aligned to the recommendations of the Global Call to Action on Fragility Fractures (CtA) published in 2018 [39]. The CtA noted that there was an urgent need, globally, to improve:

- Acute multidisciplinary care for the person who suffers a hip, clinical vertebral and other major fragility fractures
- Ongoing post-acute care of people whose ability to function is impaired by hip and major fragility fractures
- Rapid secondary prevention after first occurrence of all fragility fractures, including those in younger people as well as those in older persons, to prevent future fractures

In 2020, the Fragility Fracture Network (FFN) published Clinical and Policy Toolkits to support implementation of the CtA [40-41]. Of the three so-called Clinical Pillars of the CtA, significant progress has been made in many countries regarding the first pillar, through multidisciplinary

Orthogeriatric Services, and the third pillar, with Fracture Liaison Services. As noted in the FFN Clinical Toolkit [40] and the second edition of the textbook on orthogeriatrics [42], the evidence base relating to the second pillar on rehabilitation has developed considerably in recent years. However, in routine clinical practice, much work still needs to be done to improve patient management. This echoed the 2017 Call to Action on Rehabilitation by the World Health Organization which noted the profound unmet need for rehabilitation, and that the role of rehabilitation in health care must be considered an essential component of integrated health services [43].

The major limitation is that the specific findings from primary studies conducted as part of this thesis cannot be generalised across Australia or internationally, however a similar co-creation research methodology can be adopted for different settings and contexts. Although broadly inclusive of patients and carers, the sample size of the primary research study was relatively small for the quantitative analysis component. While sample size was not a methodological issue, the qualitative study was limited to participants from central Adelaide.

The scope of this research did not allow to explore digital divide among older people, who cannot access digital technology. This needs to be addressed as part of this ongoing research program.

8.3 Implications of the study

Overall, the research undertaken as part of this thesis has wider implications for both clinical practice and research methodology. Digital health solutions focused on person-centre care and education could be developed and quickly translated into primary care settings by engaging and supporting GPs, related healthcare workers, and patients/carers to use the cocreation approaches outlined in this thesis.

Although access to current information and communication technology (ICT) for older persons is better than initially assumed, a significant gap still exists. Closing this gap however can be greatly improved by actively identifying suitable family, friends, and other community resources to form networked units to support individual patients. Age should not be considered as an insurmountable barrier to digital health care.

Health care systems need to be reimagined to successfully deliver person-centred and integrated care in our era of advancing technology. Information and communication technology, interprofessional care, behavioural change and education competencies must be integral in curricula to train our future health workforce. New roles, such as telehealth liaison carers (TLCs) need to be developed to support and link patient networks with primary and specialist care in a digital health environment.

8.4 Future research

Input from this thesis (Phase 1 formative research), has contributed to the commencement of development of a digital health hub (DHH), part of Phase 2 of this work (Supplementary items 1). A parallel project has also commenced in which a nurse with orthogeriatric specialty training has been engaged to develop and define the additional competencies and training required for a TLC. This role will support person-centred and integrated care of older persons with hip fractures utilising the DHH and link multidisciplinary, hospital-based specialist care with a network built around the patient and their community-based care (Supplementary item 2).

Future work in Phase 3, study sites will be selected from the Central Adelaide Local Health Network for participant recruitment. The aim of the Phase 3 research will be to test the feasibility, safety, and efficacy of the digital health hub model of care for fragility hip fractures, facilitated through a TLC. Learning from the development and implementation of the digital health hub model of care within CALHN will inform further iterations and scaling-up across South Australia.

Moreover, there is the potential for findings from future research activities to be applied to other healthcare settings in Australia and internationally.

Evaluation of consumer receptiveness and effectiveness to the concept of networked units could be highly valuable. Given that South Australia is a multicultural society, evaluating networked units among different ethnic and cultural groups could provide insights to tailor and personalise the concept further for specific groups in society. Similarly, application of this approach in other Australian states and other countries could yield valuable insights.

In September 2021, Osteoporosis New Zealand published the second edition of Clinical Standards for Fracture Liaison Services in New Zealand [44]. These standards, in combination with the New Zealand arm of a new Australian and New Zealand Fragility Fracture Registry, will enable Fracture Liaison Services in New Zealand to benchmark the care that they provide against the Clinical Standards. The standards were based on the so-called '5IQ' structure:

- Identification: A statement of which individuals should be identified
- Investigation: A description of the types of investigations that will be undertaken
- Information: A description of the types of information that will be provided to the individual
- Intervention: A description of pharmacological interventions and falls prevention
- Integration: A statement on the need for integration between primary and secondary care
- Quality: A description of professional development, audit, and peer-review activities

'People with fragility fracture, their family members and whānau* or carers will be provided with information – in their own language and in plain language – on bone health, lifestyle

measures (including exercise, alcohol and smoking), nutrition (including calcium and vitamin D intake), sun exposure and the relationship between osteoporosis and fracture risk.'
[* Whānau is a Māori-language word for extended family] [44]. The notion of driving greater awareness of bone health among family members of hip fracture patients could be an enabler in the development of networked units.

The Covid-19 pandemic has forced a step-change in virtual delivery of healthcare and receptiveness among patients to engage with online health information sources. The shift in mindset has occurred at a pace that could not possibly have been imagined at the beginning of this period of doctoral study. The pandemic will surely mark a point of inflection in the uptake of digital health innovations. A follow-up study may be undertaken to evaluate shifts in the various stakeholders' perspectives because of the pandemic. Similarly, if the approach was implemented in other countries and/or for other conditions, the project will include from the outset a planned follow-up evaluation of stakeholders' perspectives after implementation of a new Digital Health Hub.

Large scale registries such as the Australian and New Zealand Hip Fracture Registry or the UK National Hip Fracture Database provide an opportunity to conduct 'sprint audits' to explore new approaches to care in a significant number of patients in a short time period. Potentially the Australian and New Zealand Hip Fracture Registry can be used to evaluate the usage and patient experience of the Digital Health Hub in some hospitals across Australia to as a sprint audit. If this work served as a pilot initiative to link use of the Digital Health Hub to a registry-based national quality improvement programme, and proved successful, approaches could be made to the leadership of hip fracture registries in other countries in due course.

8.5 Conclusion

The work undertaken as part of this thesis strongly argues that treating fragility hip fractures among older people requires *patient agency* by adopting more participatory, co-created and empowering approaches- to involve patients, family members, formal carers and healthcare providers in improving healthcare delivery.

Hip fracture is an excellent exemplar of a complex issue involving multimorbidity, requiring person-centred and integrated multidisciplinary care. To improve the patient journey and allow broad translation of clinical research pathways, it is critical to understand and overcome the multilevel constraints inherent in the wider health system organisational contexts and policy frameworks. Ultimately, healthcare delivery needs to shift from decisions based on the system's perception of need to solutions based on outcomes defined and prioritised by patients and consumers. Patient agency is required to make them an integral part of the health system and, through self and co management, an extension of the healthcare workforce.

With increasing access and advancement of digital technology impacting all spheres of life, healthcare systems can move in this direction by designing solutions which could educate their patients and empower them to make positive behaviour changes through adequate facilitation and engagement. It is crucial to encourage development of patient-centred networks which are able to link with healthcare provider networks and various other community and social support groups seamlessly. So that patients and their family members are not left alone navigating and negotiating the complexity of healthcare systems while readjusting to their changing circumstances in life.

Patient education is not just about understanding aspects of managing their present disease condition, but it is about exerting their rights as cocreators of health systems. My thesis argues that patients and their informal carers should be considered as potential active co-participators in the health workforce and as such receive the necessary health education and support to be effective in that role. This new perspective is shared across all interviewed patients and healthcare stakeholder groups.

A digital health assisted model of care is an inevitability with great potential to improve care and outcomes for older people with hip fractures and the population in general if carefully implemented.

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SUPPLEMENTARY MATERIALS

CHAPTER 2

Supplementary item 1: Logic grid and Database search

Fractures	Older adults	Models of care/approach	Education/patient engagement
Fractures, bone[mh] Hip fractures[mh] Spinal fractures[mh] Hip fracture*[tiab] Osteoporotic fractures[mh] Osteoporosis[mh] Fragility fracture*[tiab] Proximal femur fracture*[tiab] Intertrochanteric fracture[tiab] Intracapsular fracture[tiab]	Frail elderly[mh] Elder*[tiab] Older*[tiab] Aged*[tiab] Frail*[tiab] Frailty[mh] Geriatrics[mh] Multimorbidity[mh]	Rehabilitation[mh] Recovery[tiab] Post discharge[tiab] Telemedicine[mh] eHealth[tiab] mHealth[tiab] Orthogeriatric[tiab] Post hospital[tiab] Post acute[tiab] Multidisciplinary[tiab] Integrated care[tiab] Health and social care[tiab] Physiotherapy[tiab] Physical therapy modalities[mh] Patient discharge[mh] Patient-centered care[mh] Extended care[tiab] Health restructuring[tiab] Health systems[tiab] Delivery of health care, integrated[mh] Information and communication technologies[tiab] Patient care[mh] Continuity of care[mh] Patient care management[mh] Models, nursing[mh] Models, education[mh] Artificial intelligence[mh] Health policy[mh]	Education[mh] Patient participation[mh] Empowerment[tiab] Power(psychological)[mh] Patient empowerment[tiab] Community empowerment[tiab] Health literacy[tiab] Self-management[tiab] Self-management[mh] (just indexed as MeSH term in 2018) Learning management system[tiab] eLiteracy[tiab] Transformative education[tiab] Patient education as topic[mh]

Database search

SR NO	Search terms	Articles resulted
PUBMED		
1	Hip fractures[mh]AND frail elderly[mh] AND rehabilitation[mh]	46
2	Hip fracture*[tiab] AND older*[tiab] AND discharge*[tiab] AND rehab*[tiab]	189
3	Education[mh] AND hip fractures[mh] AND rehabilitation[mh]	41
4	Power (psychology)[mh] AND hip fractures[mh] AND rehabilitation[mh] (here power corresponding to empowerment)	1
5	Health literacy[tiab] AND hip fracture*[tiab] AND recovery*[tiab]	1
6	Community*[tiab] AND hip fracture*[tiab] AND recovery*[tiab]	121
7	Self-management [tiab] AND hip fracture*[tiab] AND recovery*[tiab]	1
8	Recovery[tiab] AND hip fractures[tiab]	217
9	Recovery[tiab] AND hip fractures[tiab] AND post discharge[tiab]	2
10	Orthogeriatric[tiab] AND hip fractures [tiab]	76
11	Physiotherapy[tiab] AND hip fractures[tiab]	26
12	Patient discharge[mh] AND integrated care[tiab] AND hip fracture[tiab]	1
13	Patient discharge[mh] AND multidisciplinary[tiab] AND hip fracture[tiab]	14
14	Fragility[tiab] AND fractures[tiab] AND frail elderly[mh]	55
15	Fragility[tiab] AND fractures[tiab] AND frail elderly[mh] AND patient discharge[mh]	3
16	Patient centered care[mh] AND patient discharge[mh] AND fracture*[tiab]	4
17	Healthcare restructuring[tiab]	34
18	Integrated care[tiab] AND ehealth[tiab]	22
19	Ehealth[tiab] AND “health systems”[tiab]	79
20	Delivery of health care, integrated[mh] AND telemedicine[mh]	232
21	Eliteracy[tiab]	1
22	Patient participation[mh] AND Fractures, bone[mh]	41
23	Patient participation[mh] AND fractures, bone[mh] AND frail elderly[mh]	1
24	Fractures, bone[mh] AND frail elderly[mh]	388

25	Fractures, bone[mh] AND frail elderly[mh] AND patient discharge[mh]	9
26	Fractures, bone[mh] AND frail elderly[mh] AND patient discharge[mh] AND Patient-centered care[mh]	2
27	Mellick Chehade[Author]	18
28	Tiffany Gill[Author]	99
29	Lalit Yadav[Author]	7
30	Renuka Visvanathan[Author]	90
31	Morley JE[Author] AND fractures, bone[mh]	16
32	Mohit Bhandari[Author] AND fragility fracture*[tiab]	7
33	Fragility fracture*[tiab] AND integrated care[tiab]	2
34	Fragility fracture*[tiab] AND persanali* care[tiab]	1
35	Fragility fracture*[tiab] AND self management[tiab]	3
36	Fragility fracture*[tiab] AND education*[tiab]	82
37	Osteoporosis[tiab] AND telemedicine[tiab]	11
38	Osteoporosis[mh] AND telemedicine[mh]	8
39	Hip fractures[mh] AND telemedicine[mh]	2
40	Osteoporosis[mh] AND eHealth[tiab]	1
41	Frailty[tiab] AND telemedicine[tiab]	7
42	Transformative* education*[tiab] AND patient care[mh]	27
43	Transformative* education*[tiab] AND continuity of patient care[mh]	10
44	Self-management[mh] AND continuity of patient care[mh]	49
45	Osteoporosis[mh] AND models, nursing[mh]	5
46	Osteoporosis[mh] AND models, nursing[mh] AND continuity of patient care[mh]	1
47	Fractures, bone[mh] AND models, nursing[mh]	14
48	Patient education as topic[mh] AND telemedicine[mh]	727
49	Patient education as topic[mh] AND telemedicine[mh] AND osteoporosis[mh]	2
50	Artificial intelligence[mh] AND osteoporosis[mh]	56
51	Artificial intelligence[mh] AND geriatrics[mh]	28
52	Artificial intelligence[mh] AND frailty[mh]	2
53	Artificial intelligence[mh] AND fragility fractures[tiab]	1
54	Fractures, bone[mh] AND multimorbidity[mh]	3
55	Health policy[mh] AND frailty[mh]	2
CINAHL		
56	Telemedicine or telehealth or telecare [AB] AND osteoporosis [AB] AND patient education [AB}	2
Embase		
57	Telehealth[tiab] AND osteoporosis [tiab] AND patient education [tiab]	1
ProQuest dissertations and thesis global		
58	“fragility fractures” AND “Integrated care”	4

Supplementary item 2: PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5-6
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	7-8
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	9
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix-1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	10-11 & figure 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	9-10
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7-8 & 12

Supplementary item 2: PRISMA Checklist

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	11
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	13
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	13

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	13-14 & Table 2
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10-11
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-11 & Table 1 to 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	11 & Appendix 3
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	12-14
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	13
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	13-14
DISCUSSION			

Supplementary item 2: PRISMA Checklist

Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	14-17
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14-17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	17-18
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	18-19

CHAPTER 3 and 5

Supplementary item 1: In-depth interview schedule (Stakeholders)

Thank you for consenting to be part of this research. Through this interview, I wish to explore your perspective around potential development of an electronic health information education platform for older people with a hip fracture injury.

Name:______________________________Age____/years Sex______

Designation_____________________Department/Hospital______________________

Date of consent__________________________

Context

Question-1: What is your experience, in general, with older people with hip fractures admitted to the hospital or attending clinic/consultation for treatment?

Probe: physical status, gender, education level, empowerment, priority, recovery needs, care pathway, role of carer

Question-2: What is your perspective, particularly around health literacy in this group of population?

Probe: health information needs/areas, existing provision, difficulty in accessing, possible improvement solutions, ehealth

Content

Question-3: In your opinion, what are the important areas of health information for patients recovering from a hip fracture injury after their discharge from the hospital?

Probe: clinical recovery, functional improvement, WHO ICOPE, multiple medical conditions, other issues

Questiona-4: In your opinion, do you think there is a need or scope for improving the quality of health information for this group of patients? Do you have any possible suggestions or solutions in this direction?

Probe: barriers and facilitators, role of carers and community providers (health and social care), different platforms including ehealth or IT solution

System

Question-5: Can you please recollect from your previous experience of coming across any electronic platform used for patient education and/or service delivery? Or any comment in general about the use of IT/ehealth solutions?

Probe: setting, usage and function, challenges, possible learning and suggestive improvements

Question-6: Can you please elaborate factors, in your opinion, needs to be taken into consideration while designing an ehealth platform for such group of patients?

Probe: system functionalities, patient response, existing system integration

CHAPTER 4

Supplementary item 1: Patient, family members and carer survey questionnaire

My name is … and I am conducting a short survey about your use of computers and other technology.

Firstly I would just like to check with you….

Name (patient):

DOB (patient):

URN:

Date:

Person completing form: Patient Family/community carer Nursing home carer

Gender: Male Female

Age: ______

Now I would like to ask some questions about your experience with computers and the internet.

1. What kind of work do/did you do now/in the past? (occupation) ___________________________
2. Did/does any of that work require using a computer? Yes No
3. Do you have your own computer or device with access to the internet? Yes No
4. If not, do you have access to a computer, iPad or similar type of device? Yes No

5. Do you use email? Yes No

6. If yes, on a scale of 1 to 7 where 1 is very difficult and 7 is very easy how difficult or easy do you find using email?
    - ○ 1/ Very difficult
    - ○ 2/ Quite difficult
    - ○ 3/ Slightly difficult
    - ○ 4/ Neither difficult or easy or unsure
    - ○ 5/ Reasonably easy
    - ○ 6/ Quite easy
    - ○ 7/ Very easy

7. Do you use Google or any other Internet search engine? Yes No

8. If yes, on a scale of 1 to 7 where 1 is very difficult and 7 is very easy how difficult or easy do you find using Google or another search engine?
    - 1/ Very difficult
    - 2/ Quite difficult
    - 3/ Slightly difficult
    - 4/ Neither difficult or easy or unsure
    - 5/ Reasonably easy
    - 6/ Quite easy
    - 7/ Very easy

9. Do you use Skype or any other video calling program? Yes
   No

10. If yes, on a scale of 1 to 7 where 1 is very difficult and 7 is very easy how difficult or easy do you find using Skype or another video calling program?
    - 1/ Very difficult
    - 2/ Quite difficult
    - 3/ Slightly difficult
    - 4/ Neither difficult or easy or unsure
    - 5/ Reasonably easy
    - 6/ Quite easy
    - 7/ Very easy

11. If you don't use any/all of the above, would you be willing to learn? Yes
    No

Now I would like to ask you some questions about giving information to you about your hip fracture using an online health information portal. An online health information portal is a website where you could access information about your hip fracture and treatment, common problems people encounter after their operation and how to solve them or when to get more help from your doctor and videos of rehabilitation exercises. It would also be interactive, meaning you would be able to provide information to your doctor, similar to that you already provide over the phone. The online portal can be used for doctors and nurses involved in your care to provide advice to you about what you can try to solve any problems you are experiencing or when you need to come back in and talk to your doctor. You would also have the ability to make this information selectively available to other family members or people involved in your care should you chose to do so. It would be a little like having you own personalised hip fracture care channel.

Now, keeping in mind what I just described, could I please get your thoughts about the following:

12. An online health information portal such as the one described above would be very useful to improve my health
    - 1/ Strongly disagree
    - 2/ Disagree
    - 3/ Somewhat disagree
    - 4/ Neither agree or disagree or unsure

- 5/ Somewhat agree
- 6/ Agree
- 7/ Strongly agree

13. My friends and family would use an online health information tool like the one described above
    - 1/ Strongly disagree
    - 2/ Disagree
    - 3/ Somewhat disagree
    - 4/ Neither agree or disagree or unsure
    - 5/ Somewhat agree
    - 6/ Agree
    - 7/ Strongly agree

14. Overall, how likely would you be to use an online health information portal such as the one described above health
    - 1/ Very unlikely
    - 2/ Unlikely
    - 3/ Somewhat unlikely
    - 4/ Neither likely or unlikely or unsure
    - 5/ Somewhat likely
    - 6/ Likely
    - 7/ Very likely

15. Can you think of any specific things stopping you using the internet, email, google, skype or an online health information tool such as the one described above?

16. Can you think of any specific benefits to using an online health information tool such as the one described above?

17. (For patients only) if you did not want to or could not use an online health information tool such as the one described above, is there anyone who could help you to use it?

18. Would you be willing to invest in a computer device for health management (for either yourself or the ones you are caring for) and how much would you consider spending? (I am going to read out a few options)
    - 1/ No, I wouldn’t be interested
    - 2/ Up to $200
    - 3/ Up to $500
    - 4/ Up to $1000
    - 5/ other amount: ________

CHAPTER 5

Supplementary item 2: Consolidated criteria for reporting qualitative studies (COREQ): 32-item checklist

No. Item	Guide questions/description	Response
Domain 1: Research team and reflexivity		
Personal Characteristics		
1. Interviewer/facilitator	Which author/s conducted the interview or focus group?	LY conducted the in-depth interviews, described in the methods section of the manuscript
2. Credentials	What were the researcher's credentials? E.g., PhD, MD	BDS, MPH [alongside the supervisory panel members TG, MJC & RV all have PhDs and are domain experts in their respective fields of medicine and public health]
3. Occupation	What was their occupation at the time of the study?	*PhD scholar *Senior Research Fellow *Associate Professor and **Orthopaedic Consultant *Professor & ***Director **Orthopaedic Nurse Practitioner *Adelaide Medical School, Faculty of Health & Medical Sciences, University of Adelaide, Australia **Department of Orthopaedics & Trauma, Royal Adelaide Hospital, SA Health, Australia ***Department of Aged & Extended Care, The Queen Elizabeth Hospital, SA Health, Australia
4. Gender	Was the researcher male or female?	Male and Female
5. Experience and training	What experience or training did the researcher have?	LY have an extensive experience in conducting interviews and focus group discussions within different country scenarios and diverse settings. His work involving qualitative research methodologies has been published. Whereas the supervisory panel also have extensive experience in guiding research

		candidates around mixed methods approach
Relationship with participants		
6. Relationship established	Was a relationship established prior to study commencement?	Yes, initial relationship was established with the study participants for rapport building as the study approach demanded participants express their views openly and in greater detail
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	Prior to any data collection, we provided all the potential participants with an overview of the study including personal goals and how they can contribute in expanding the horizon of our understanding through this research study
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	Guided by the appropriate epistemological prism for conducting in-depth interviews in this setting, the principal investigator (LY) introduced himself at the beginning of each interview by name, occupation and the purpose of conducting these interviews
Domain 2: study design		
Theoretical framework		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	A hybrid process of inductive and deductive thematic analysis to interpret the raw data was used. This approach allowed 18 thematic constructs to emerge through the inductive coding which were the applied to the tenets of Human Behaviour Change Supporting Systems (HBCSS) framework deductively
Participant selection		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	Purposive sampling
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	Participants were approached using multiple strategies such as email invitation, phone, or personal approach. A participant information sheet was

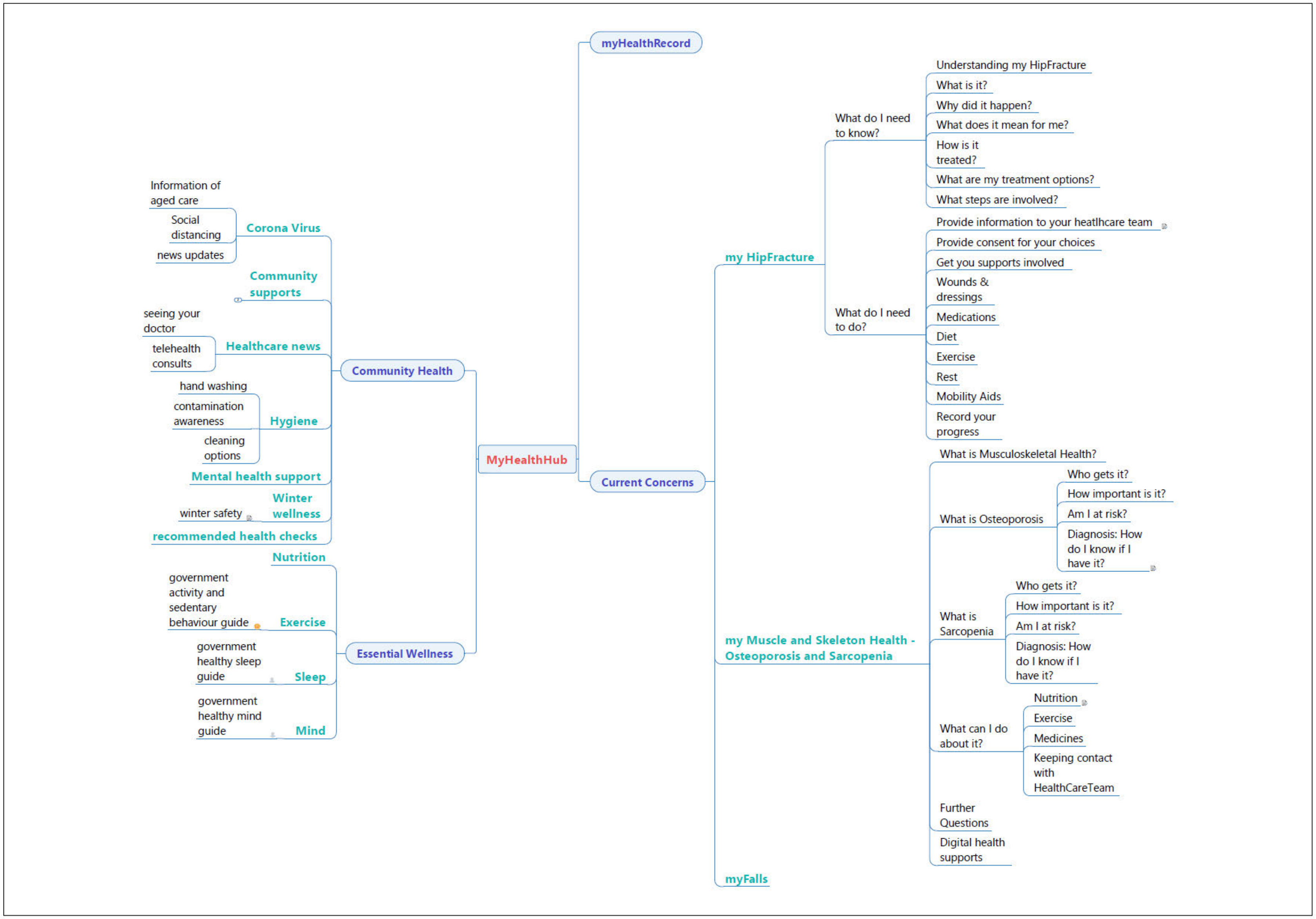
		provided to give a detailed description about the study along with an opportunity to ask questions or clarifications and appropriate written and/or verbal consent were taken. The principal investigator (LY) then identified a suitable time and mode of interview with interested participants. All face-to-face except one which was conducted as a telephonic interview
12. Sample size	How many participants were in the study?	A total of 24 in-depth interviews were conducted
13. Non-participation	How many people refused to participate or dropped out? Reasons?	We had difficulty with reaching out to few participants initially but with persistent follow-ups, all the participants we approached gave the required consent and dedicated time for an interview.
Setting		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	All the interviews were conducted in and around the workplace of study participants in an informal setting environment. Besides one interview was conducted through telephone where the participant was at home
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	Non-participants were not allowed at the time of interviews. Any non-participants were requested to immediately leave in case if they have entered by accident in the space where these interviews took place
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	The study participants were diverse in their roles and responsibilities, age-range, and gender. Importance were given to both their professional and personal life experiences
Data collection		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	Yes, the in-depth interview guide has broad questions along with prompts and flexibility was exercised by the interviewer depending upon the direction of inquiry and depth needed at the time of conducting these interviews. The guide was pilot tested with

		researchers within our extended networks and suggestions were incorporated in the final guide.
18. Repeat interviews	Were repeat inter views carried out? If yes, how many?	N/A
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	Digital audio recordings were made and transcribed verbatim
20. Field notes	Were field notes made during and/or after the inter view or focus group?	Field notes were a crucial part of conducting each of these interviews and detailed notes were taken in case any participant requested certain aspect of their interview to be not recorded
21. Duration	What was the duration of the inter views or focus group?	On an average, each interview lasted 45 minutes to an hour, with a variation where some lasted for 30 minutes while some extended to 1.5 hours
22. Data saturation	Was data saturation discussed?	Yes, the data from the interview transcripts were analyzed simultaneously till the emerging themes got saturated
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	N/A
Domain 3: analysis and findings		
Data analysis		
24. Number of data coders	How many data coders coded the data?	The initial coding framework was developed by LY based on analysis of first three transcripts, these were later revised and refined with subsequent analysis of the transcript. During each of the stages, TG and MJC were involved in detailed discussions and iterations
25. Description of the coding tree	Did authors provide a description of the coding tree?	We have done non-hierarchical coding and the description is provided in the text
26. Derivation of themes	Were themes identified in advance or derived from the data?	A hybrid process of inductive and deductive thematic analysis to interpret the raw data was used. This approach allowed 18 thematic constructs to emerge through the inductive coding

		which were the applied to the tenets of Human Behaviour Change Supporting Systems (HBCSS) framework deductively
27. Software	What software, if applicable, was used to manage the data?	In this study, NVivo 12 was used to as a tool for sorting and data management
28. Participant checking	Did participants provide feedback on the findings?	N/A
Reporting		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	Yes, each thematic construct presented within the Table 1 has a corresponding participant quotation
30. Data and findings consistent	Was there consistency between the data presented and the findings?	Yes, we have attempted to present our findings in this work in a manner that reflects rigor and transparency of the processes involved
31. Clarity of major themes	Were major themes clearly presented in the findings?	All the thematic constructs coming out the analysis were presented in the results section and corresponding Table 1 of the manuscript
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	N/A

CHAPTER 8

Supplementary item 1: Schematic representation of DHH prototype (Phase 2- under development)



CHAPTER 8

Supplementary item 2: Image representing DHH model of care

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