Emerging Technologies for Improving Musculoskeletal Health:
An Evidence Gap Map

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Contents

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Foreword from NIHR Innovation Observatory

The National Institute for Health and Care Research (NIHR) Innovation Observatory is a national health and care horizon scanning research centre. We have developed specialised methods that uniquely position us to conduct comprehensive scans of emerging healthcare technologies, aiding decision-making within the innovation ecosystem. Horizon scanning and foresight methods are invaluable in this context, as they enable the early identification of trends, opportunities, and potential challenges. By leveraging these methods, we can identify current gaps and potential future needs, ensuring that innovation efforts are aligned with the evolving healthcare landscape and that wasteful innovation is avoided.

The value of accurate and timely information cannot be overstated. Our methods ensure that groups, like Orthopaedic Research UK (ORUK), who play a vital role in innovation have access to the most relevant and up-to-date information, empowering them to make informed decisions. Working in collaboration with ORUK has allowed us to play a small, but important, part in supporting them in their efforts to empower entrepreneurial innovation in areas of need within MSK health. In partnership with ORUK, we undertook a horizon scan to identify technologies in development for preventing, managing and treating musculoskeletal (MSK) conditions. Given MSK conditions are a leading cause of disability in the UK and disproportionately affect people from socio-economically disadvantaged backgrounds, with wide social and economic consequences we hope that our report shines a light on where new research and innovation could benefit the system and provide the most transformative change.

Ultimately, we hope that our collaborative work will contribute to ensuring that the right innovations reach patients promptly, improving healthcare outcomes and fostering a more responsive and adaptive health innovation ecosystem.

Professor Dawn Craig
Director, NIHR Innovation Observatory

Foreword from Orthopaedic Research UK

Technological innovation is widely regarded as the saviour of a health system under pressure. This is particularly the case within musculoskeletal (MSK) health which is the third largest area of expenditure for the NHS and linked to rising levels of obesity, anxiety, isolation and depression. Demand for MSK health services will only grow in an ageing society.

The good news is that the use of new technology is already transforming the prevention, diagnosis, treatment and management of people with poor MSK health. The use of artificial intelligence (AI) is improving the accuracy of radiographical image analysis. Clinicians armed with AI-enabled data, including images sourced from motion capture, are making better decisions about the scheduling and planning of procedures and identifying patients likely to require higher levels of post-operative care. Virtual reality is being deployed as an alternative to traditional pain relief. Data from wearable technology is being used to monitor rehabilitation and empower patients to improve their MSK fitness.

This all sounds very exciting, but in reality, we are simply at the beginning of a technological revolution within MSK health. To even come close to addressing the demand for MSK health services we need an even wider pipeline of innovation. We need our smartest clinicians, engineers and computer scientists to put their brilliant minds together to solving MSK health challenges, especially those associated with ageing. How can we use technology to improve the MSK health of an increasingly sedentary nation? How can we prevent or mitigate some of the most common MSK conditions? How can we use technology to deliver better patient outcomes and enhance both the performance and effectiveness of clinical teams?

In the spirit of our charity's founder Ronald Furlong, who combined a highly successful career as an orthopaedic surgeon with an equally successful career as an entrepreneur, we are the first MSK charity to actively support start-ups and entrepreneurs. However, as a small charity we can only make a real difference by partnering with other organisations. This is why we are delighted to be working with the NIHR's Innovation Observatory on this report to identify emerging MSK medical and digital health and care technologies. Technological development is an iterative process – taking inspiration from and building on the ideas of others. We hope that the technologies, as well as the gaps identified in the NIHR's Horizon Scan will inspire a new generation of MSK health innovators.

Dr Arash, Angadji
Chief Executive, Orthopaedic Research UK

Introduction

The focus of this report is on identifying emerging (innovative, in-development) medical and digital health and care technologies[1], including medical devices, with the potential to reduce the occurrence of musculoskeletal (MSK) conditions, improve health outcomes and provide efficiencies within delivery of health and care services for people with poor MSK conditions. It is anticipated that the research findings will be used to highlight early-stage technological innovations to prevent and manage MSK conditions and identify areas of unmet need.

The report uses evidence gathered from a horizon scan undertaken by the NIHR's Innovation Observatory, based at Newcastle University, during February/March 2024. This involves searches of a variety of information sources, such as bibliographic databases, clinical trial records and company websites. This methodology enables the systematic identification of emerging innovations, such as health technologies and medical devices, including those using artificial intelligence (AI) which can inform strategic planning and decision-making in healthcare. An evidence gap map (EGM) was devised to illustrate the volume, breadth and nature of the information on emerging medical devices and digital health and care technologies, especially those which have the potential or ability to reduce referrals to secondary care, and associated hospital inpatient stays.[2]

MSK conditions affect bones, joints and connective tissues, causing symptoms such as pain, limited mobility and fatigue.[3] They are a leading cause of disability in the UK, affecting around one third of the population,[4] triggering significant healthcare costs and impacting productivity. Factors such as older age, obesity and physical inactivity are associated with the occurrence of MSK conditions.[5] Although there are no curative treatments for the most common MSK conditions (osteoarthritis, osteoporosis and rheumatoid arthritis), symptoms can be well managed by maintaining good general physical and mental health.[6] Given that MSK conditions are highly prevalent (common) in the UK and internationally, and can be associated with a myriad of negative health and social outcomes, it is important to identify new technologies for preventing, diagnosing, managing and treating MSK conditions, particularly at earlier stages of the treatment pathway, before surgery is required.

The World Health Organization (WHO) defines innovation in health and care to be any invention or adoption of new or improved health policies, practices, systems, products and technologies, services and delivery methods that result in improved healthcare efficiency, effectiveness, quality, sustainability, safety or affordability.[7] Innovations in medical devices and digital technologies for MSK conditions could reduce their presence, improve outcomes, and enhance healthcare delivery efficiency.

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1   By "digital health and care technologies," we mean computing platforms, connectivity, software, and/or sensors for healthcare and related uses.(8) These technologies span a wide range of uses, from applications in general wellness to applications as a medical device. Such devices intended to diagnose, treat, prevent or cure a disease or condition are regulated and must undergo a conformity assessment to demonstrate they meet legal requirements to ensure they are safe and perform as intended. In the UK, the legal requirements are set out in the Medical Devices Regulations (MDR/2002), which are implemented by the competent authority, the Medicines and Healthcare products Regulatory Agency (MHRA).

2   The methods used to identify technologies for this project and to generate the EGM are reported in Appendix 1.

3   National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Board on Health Care Services; Committee on Identifying Disabling Medical Conditions Likely to Improve with Treatment. Selected Health Conditions and Likelihood of Improvement with Treatment. Washington (DC): National Academies Press (US); 2020 Apr 21. Available from: https://www.ncbi.nlm.nih.gov/books/NBK559511/ doi: 10.17226/25662 [Accessed 3rd April 2024].

4   NHS England. Elective Care Transformation Programme. Available from: https://www.england.nhs.uk/elective-care-transformation/best-practice-solutions/musculoskeletal/#:~:text=They%20can%20range%20from%20minor,quality%20of%20life%20and%20independence [Accessed 3rd April 2024].

5   GOV.UK. Guidance: Musculoskeletal health: applying All Our Health. Available from: https://www.gov.uk/government/publications/musculoskeletal-health-applying-all-our-health/musculoskeletal-health-applying-all-our-health#:~:text=There%20are%20multiple%20risk%20factors,predisposition%20to%20some%20MSK%20conditions [Accessed 3rd April 2024].

6   NHS. Treatment and support – Osteoarthritis. Available from: https://www.nhs.uk/conditions/osteoarthritis/treatment/#:~:text=There's%20no%20cure%20for%20osteoarthritis,healthy%20weight%20and%20exercising%20regularly [Accessed 3rd April 2024].

7   World Health Organisation. Health innovation for impact. Available from: https://www.who.int/teams/digital-health-and-innovation/health-innovation-for-impact [Accessed 3rd April 2024].

Executive Summary

Key Findings

The horizon scan indicated a relatively low level of technological innovation within MSK health compared to other health conditions. 109 innovative technologies (either regulated medical devices or digital interventions, for preventing or treating MSK conditions) were identified within records in specialist biomedical, health literature and clinical trial databases, as well as from information shared publicly by companies that are likely to seek market access within the UK.

The largest proportion of innovative technologies identified were being developed within the USA, followed by the UK. Few technologies were being developed within the EU.

Technologies identified were evenly split between use for multiple and single MSK conditions.

Approximately half of the innovative technologies were digital (such as applications for mobile devices), a third were devices (such as an innovative brace to support mobility) and the rest were devices with a digital component (such as a digital pain-reduction kit). A comprehensive list of digital technologies and devices identified in this project are available in the appendices.

The majority of the innovative technologies did not incorporate the use of artificial intelligence (AI).

The modes of intervention delivery and settings of use indicate a shift from face-to-face intervention delivery by a health care practitioner to remotely monitored self-care.

The majority of the technologies identified were for use within a patient's home.

The most commonly assessed outcomes to measure a technology's impact were pain reduction and improved mobility.

Results

A total of 4,766 records describing technologies of potential relevance to this project were identified from the horizon scan. Of these, 109 were within scope and included in this report[8]. The number of records describing technologies that were identified from information sources and either included or excluded from this report is shown in the PRISMA flow diagram in Appendix 2. The characteristics of included technologies are illustrated in the EGM in Appendix 1.

Care setting for delivery of the interventions

Fifty-four technologies (49.5%) were developed for use at home, while 15 (13.8%) were for use in hospital outpatient departments, and two technologies (1.8%) each were intended for use community settings (such as leisure centres) or primary care (such as GP practices). Sixteen technologies (14.7%) were suitable for use in multiple settings. For the remaining technologies, the setting of intended use was either not reported or were applicable to a different setting to those in the coding framework (e.g., workplace interventions for reducing the risk of back injuries).

MSK conditions addressed by the technologies

Fifty-three (48.6%) of the technologies aimed to address multiple MSK conditions; fifty-two (47.7%) were for single conditions and four studies (3.7%) did not report this information.

Types of technology in development

Most (n=98; 89.9%) of the technologies did not involve an AI component; AI was a component in 11 (10.1%) of the technologies.

Fifty-five (50.5%) of the technologies used digital software (e.g. mobile or web apps), which were not delivered through specific devices; 33 (30.3%) were devices with no digital components and 21 (19.3%) involved a combination of digital and device components.

Forty-three (67.9%) technologies were multi-domain interventions (e.g. they involved both education or advice and psychological components); 28 (25.7%) were 'physical' technologies (e.g. internet-based physical activity programmes); 20 (18.4%) interventions were specifically educational or aimed at providing advice; five were psychological (4.6%) and 13 (11.9%) were classed as another type of intervention.

Forty-five (41.3%) of the technologies were intended for use by the person with an MSK condition (patient) with or without supervision; 24 (22%) involved delivery by the patient and a health professional; 21 (19.3%) were for delivery by the health professional alone. The provider was not reported for 16 (14.7%) technologies and the intervention was delivered by a person other than the patient or a health professional (e.g. an employer) for three (2.8%) technologies.

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8. The majority of records identified during information searches were excluded, as they reported on interventions already in common practice which were out of scope for this project which aimed to identify innovative interventions. Other technologies for preventing, managing and treating MSK conditions considered out of scope of this research project were technologies whose evaluation is reported within specialist (difficult to search) biomedical, health literature and clinical trial databases and unregulated technologies – i.e., those which have not been approved for safety and functionality by an appropriate authority such as the Medicines and Healthcare products Regulatory Agency (MHRA). Treatments such diathermy, acupuncture, acupressure and nerve stimulation which we chose not to define as innovative MSK treatments.

The type of technology as a proportion of all technologies included in this report are summarised graphically in figures 1 and 2a-c, below.

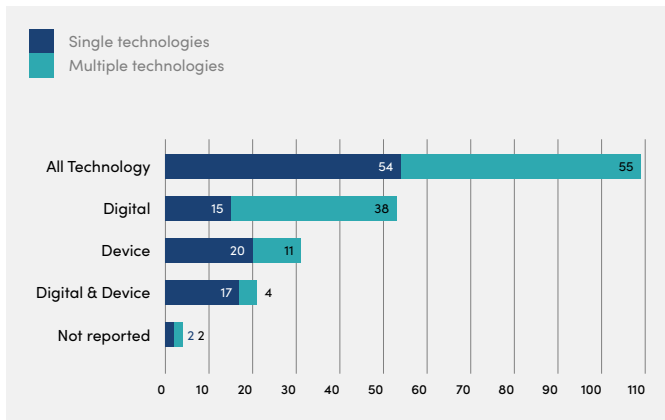Figure 1: number (single of multiple) of MSKs addressed by type of technology (digital, device, both or not reported).

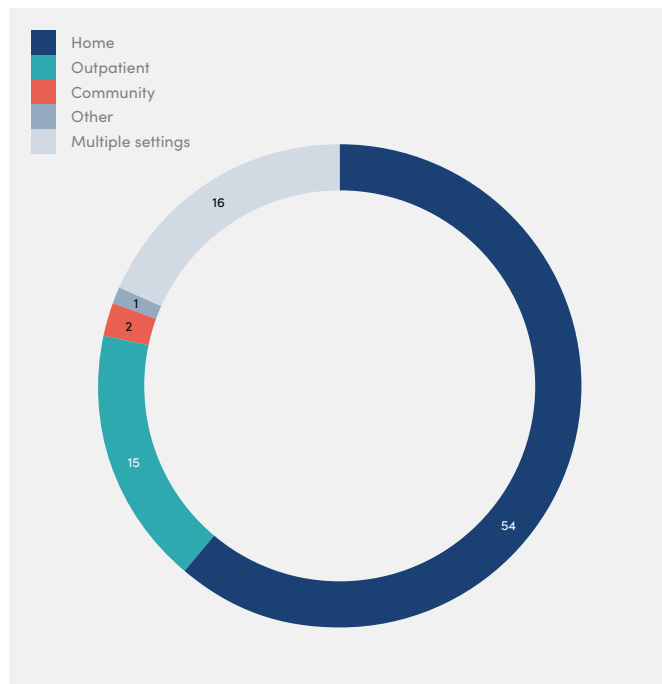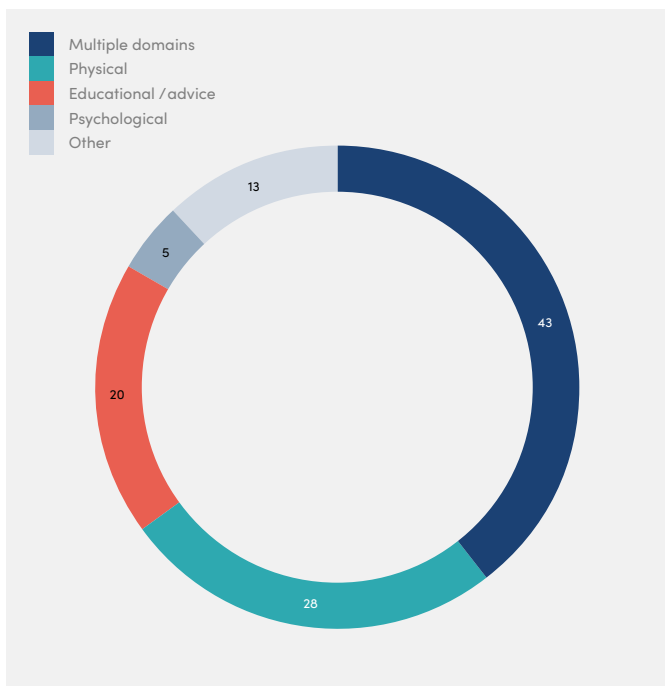Figure 2a. Type of technology by domain of action as a proportion of all technologies

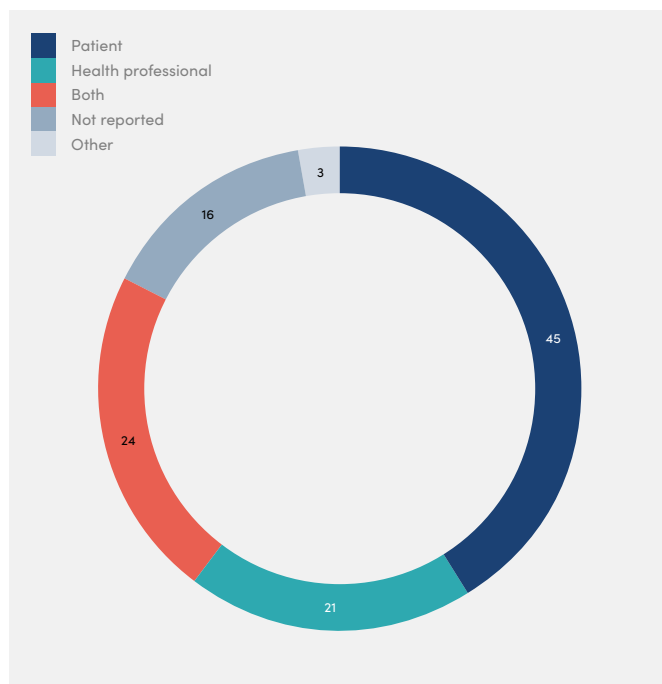Figure 2b. Type of technologies by delivery setting as a proportion of all technologies

Figure 2c. Type of technology by person delivering the intervention as a proportion of all technologies

Impacts of the interventions on health and social outcomes

For the majority of records (n=66; 60.6%), the technology was aimed at improving multiple health and social outcomes. The remaining technologies aimed to improve a single outcome, including: movement for 15 (13.8%) technologies; pain for 14 (12.8%); sleep in two (1.8%); and one study (0.9%) each aimed to improve activities of daily living, quality of life, medication consumption, and healthcare usage. Outcomes were not reported in eight (7.3%) records. The outcomes targeted as a proportion of all of the technologies included in this report, broken down according to the type of intervention (digital, device or both), are summarised graphically in Figure 3.
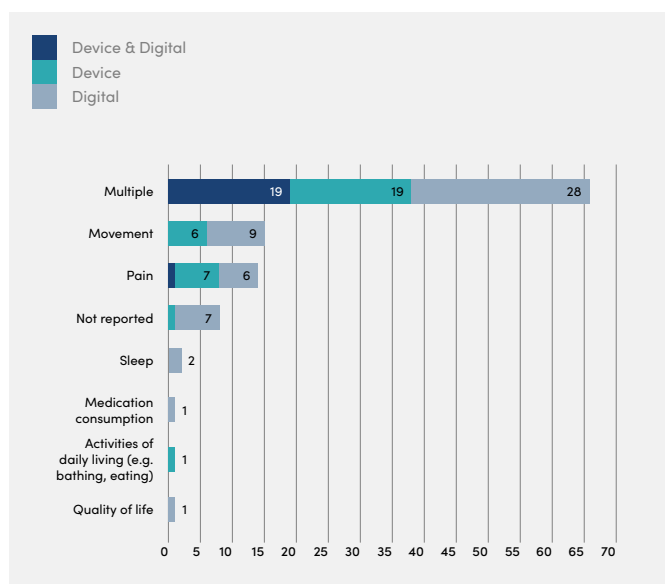

Figure 3. Type of impact (health and social outcomes) which the technologies were assessed in relation to, as a proportion of all technologies and broken down by type of intervention (device, digital or both device and digital).

Geographic setting of development

Only technologies from settings deemed likely to seek market access within the UK were included (i.e. technologies from the UK, EU member states and the USA). The largest proportion of technologies identified were being funded or developed by institutions within the USA (n=52, 47.8%), followed by the UK (n=26, 23.9%); France (n=6, 5.5%); Italy (n=4, 3.7%); Spain and the Netherlands (n= 3, 2.8% each); Croatia, Denmark, Germany, Norway, Sweden and multiple countries (n=2, 1.8% each) and Belgium, Romania and Turkey (n=1, 0.9% each).

Strengths and weaknesses of the research presented in this report

Assessment of the eligibility of included records (screening) and coding of data on technologies described in these records were undertaken by a single reviewer per record. In order to mitigate the risk of bias in screening and coding decisions, we developed eligibility criteria (see Appendix 1) and a framework for coding data to make the process as objective as possible. Furthermore, we undertook piloting of the screening and data coding to maximise consistency in screening and coding between reviewers. This is in line with the Cochrane Rapid Reviews Guidance.[9]

The inclusion of a range of information sources in the horizon scan, comprising bibliographic databases, clinical trial records and websites/ press releases maximised the scope of this research for identifying relevant technologies.

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9   Garritty C, Gartlehner G, Nussbaumer-Streit B, King VJ, Hamel C, Kamel C, Affengruber L, Stevens A. Cochrane Rapid Reviews Methods Group offers evidence-informed guidance to conduct rapid reviews. Journal of clinical epidemiology. 2021 Feb 1;130:13–22.

Examples of Emerging Technologies

A full list technologies identified by the horizon scan is included in Appendix 1. These technologies include:

App using camera on smartphones or tablets to track the body's movements, with tips on posture and form. Link.

Wearable sensor that tracks adherence to exercise programs and offers feedback on form in real-time. Link

Device delivering electrical stimulation treatment that relaxes the muscles and calms the nerves, controlled via an **app** on smartphone. Link

'Digital therapist' allowing physicians to track patient's progress in real time using **wearable motion sensors** linked to AI-powered therapeutic exercise program on a tablet. Link

Micro-processor controlled knee-ankle-foot orthosis. Link

Virtual reality (VR) headset for pain management. Link

Augmented reality illusion therapy for participants with chronic hand joint pain. Link

Ultrasound-responsive **nanobubbles** to deliver treatment for osteoporosis. Link

Wearable technology using 'smart textiles' and sensors embedded in clothing to help older women stay active and keep playing sport. Link

Computer game incorporating a back muscle training device. Link

Wearable sensor designed to detect and monitor muscle atrophy. Link

Use of a wearable to operate **robotic** exoskeletons. Link

3D printed, custom-made orthopaedic foot orthoses. Link

Video game therapy for knee rehabilitation exercises at home. Link

Use of **electromyography sensors and cameras** to evaluate posture and provide feedback for office desk users. Link

Use of **robotic-assisted** passive movement treatment for neurodynamic mobilization of the median, radial, and ulnar nerves. Link

Auricular point acupressure treatment for chronic MSK pain administered by patient using phone **app**. Link

Robotic assisted rehabilitation for balance and gait in orthopaedic patients. Link

Use of **noise-isolating** headphones for pain relief. Link

Laser therapy on neck and shoulder pain. Link

Pressure detecting insoles to reduce knee loading. Link

Note, the selection of these examples is entirely subjective and does not reflect their relative effectiveness or value.

Conclusions

There is an opportunity to make more use of AI technology in future innovations for MSK prevention and treatment. For further information on the potential application of AI to MSK health, we recommend ORUK's AI in Orthopaedics Policy Paper.

The volume of innovative technologies for use at home shows an emerging pipeline with the potential to reduce referral rates into secondary care.

The most common types of technology identified were digital interventions, aimed for use at home by the person with an MSK condition, and involved the use of advice or education to increase movement and decrease pain. This indicates a shift in the setting of therapy provision, from interventions that are delivered face-to-face by healthcare professionals to those which are delivered remotely.

Many of the identified records did not take into account wider social and economic impacts of technologies for treating MSK conditions. As there are a myriad of health, social and economic consequences of MSK conditions, consideration of outcomes beyond measures of pain and mobility would illuminate the wider impacts of these interventions.

The market leaders in developing these technologies were companies based in the USA. As many large US companies have subsidiaries in the UK, this means these technologies could potentially be easily adopted.

Appendices

Appendix 1. Tabulated Technology Characteristics

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
ATLAS Medical Device	Exoskeleton device that applies force to the torso to decompress the spine and relieve pain.	Not reported	Single condition Trunk low back pain	No	Pain	Device	Other Not reported	Not reported
SelfBACK app	App intended to support tailored self-management of lower back pain.	At home	Multiple conditions	Yes	Pain Activities of daily living (e.g. bathing, eating) Condition-specific outcomes (e.g. bone density) Quality of life Healthcare usage (e.g. number of GP visits) Economic outcomes (e.g. work attendance) Movement (e.g. gait, muscle strength and function) Anxiety or depression	Digital	Education/advice	Not reported
Be Me (Bupa)	App providing personalised guidance and support to improve health including increased mobility and flexibility	At home	Not reported	No	Movement (e.g. gait, muscle strength and function) Anxiety or depression	Digital	Education/advice Psychological	Healthcare professional
BRIDGE-intervention	Program aimed at bridging gaps in rehabilitation across levels of care and/or prolong the effect of rehabilitation	Hospital outpatient departments At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Quality of life	Digital	Education/advice Psychological	Healthcare professional Patient (with or without supervision)
At-home work virtual app	Mobile app providing tailored cardiovascular and muscular workouts	At home	Multiple conditions	Yes	Pain Anxiety or depression	Digital	Education/advice	Not reported
Virtual clinic	Virtual care platform, enabling remote physician guided care. Includes AI technology to track/ analyse the patients' motion.	At home Hospital outpatient departments Primary care (e.g. GP surgery)	Multiple conditions	Yes	Not reported	Digital	Education/advice Other Doctors can manage appointments and prescribing, access patient lab readings; patients can access virtual consultant appointments and behavioural advice	Healthcare professional Patient (with or without supervision)
Dario Move	Virtual physical therapy program intended to help users manage their non-acute MSK pain. Users wear a single sensor that tracks their adherence to exercise programs and offers feedback.	At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice	Not reported
Virtual MSK Care	Virtual exercise therapy programme.	At home	Multiple conditions	No	Pain Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice Other Neurological	Not reported

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Motion Coach	App that uses machine learning (ML) to offer individualized care to support self-management of people with conditions including back pain and osteoarthritis.	At home	Multiple conditions	Yes	Movement (e.g. gait, muscle strength and function)	Digital	Physical	Patient (with or without supervision)
Hinge Health Enso	Non-invasive device that delivers electrical stimulation treatment that relaxes the muscles and calms the nerves and is controlled via an app on smartphones.	At home	Multiple conditions	No	Pain	Device	Physical	Patient (with or without supervision)
Digital Therapist	Motion sensors linked to AI-powered exercise programme and digital therapist via a tablet.	At home	Multiple conditions	Yes	Pain Movement (e.g. gait, muscle strength and function)	Both device and digital	Physical Education/advice	Healthcare professional Patient (with or without supervision)
MSK-OS	Cloud-based digital platform involving tracking technology with clinical intelligence and tools for virtual MSK care delivery.	At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice Other Virtual care plan delivery by clinicians	Healthcare professional Patient (with or without supervision)
OneStep's upper extremity measurement app	Smartphone app. Enabling physical therapists to assess range of motion to inform post-surgical recovery and treatment of functionality of joints.	At home	Multiple conditions Upper limb conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Physical	Healthcare professional Patient (with or without supervision)
Big Health's Sleepio	Biometric data from digital health apps are linked with existing pharmacy, medical and lab data to provide a comprehensive view of the members' health.	Primary care (e.g. GP surgery) Hospital outpatient departments	Multiple conditions	No	Medication consumption	Digital	Other Digital formulary to assist healthcare providers identify new technologies to support patient care	Healthcare professional
1) Luna Complete 2) Luna Surgical Readiness 3) Luna Postoperative Success 4) Luna Fall Safeguard 5) Luna Mobility Empowerment	In-home, tech enabled musculoskeletal (MSK) care provider.	Hospital outpatient departments Primary care (e.g. GP surgery)	Multiple conditions	No	Movement (e.g. gait, muscle strength and function) Secondary care referrals Classifies MSK patients according to high, medium or low-risk of surgery	Digital	Physical Other Clinical decision-making	Healthcare professional
Virtual exercise programme	App that delivers personalized, evidence-based exercise programs.	At home	Multiple conditions MSK, chronic pain, risk of falls	No	Pain Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice	Patient (with or without supervision)
Virtual care app	Virtual healthcare, at-home exams and one-on-one appointments with orthopaedic doctors and surgeons.	At home	Multiple conditions	No	Not reported	Digital	Other At home exams and one to one appointments with orthopaedic doctors and surgeons.	Healthcare professional
Luna-Powerback app	App that can be used to provide virtual communication between patients and therapist.	At home	Multiple conditions	No	Not reported	Digital	Physical Education/advice	Healthcare professional Patient (with or without supervision)
Memorial Physical Therapy at Home	Online portal that enables access to a network of therapists.	At home "At patient's preferred time and location".	Multiple conditions	No	Not reported	Digital	Physical Education/advice	Healthcare professional Patient (with or without supervision)
C-brace	Computer-controlled knee-ankle-foot orthosis that uses sensor technology	At home Hospital outpatient departments	Multiple conditions	No	Movement (e.g. gait, muscle strength and function) Quality of life	Device	Physical	Healthcare professional Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Couch to 5k app	NHS-approved app that supports people to start running	Community (e.g. leisure centres, gym, community hubs, community rehabilitation services) At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Physical	Patient (with or without supervision)
High Intensity Physio Light Therapy	Light therapy customized for patient characteristics (e.g., height)	Primary care (e.g. GP surgery)	Single condition	No	Pain Movement (e.g. gait, muscle strength and function)	Device	Physical "The HIPL Therapy™ group will receive phototherapy in addition to the education and exercise intervention twice weekly for four weeks." Education/advice Other 'High Intensity Physio Light (HIPL) Therapy™, a phototherapy method that utilizes an emission wavelength spectrum that has been identified for treatment of musculoskeletal disorders (MSD) such as OA"	Healthcare professional
1) iTBS to the left dlPFC 2) cTBS to the mPFC	Brain stimulation	Hospital outpatient departments	Multiple conditions	No	Pain	Device	Physical	Healthcare professional
Computerized Chemosensory-Based Orbitofrontal Cortex Training (CBOT)	Brain stimulation	At home	Single condition	No	Condition-specific outcomes (e.g. bone density) Anxiety or depression Quality of life Sleep	Both device and digital	Education/advice	Patient (with or without supervision)
Digital-My Arm Pain Programme (D-MAPP)	Digital rehabilitation (exercise and education)	At home	Multiple conditions Distal upper limb disorders (including hand, wrist and thumb osteoarthritis (OA), carpal tunnel syndrome, tendinitis and epicondylitis	No	Pain Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice	Patient (with or without supervision)
Digital Pain Reduction Kit	Virtual reality (VR) headset, therapeutic VR visualization software, and a low-cost wearable transcutaneous electrical nerve stimulation (TENS) unit	At home	Multiple conditions Musculoskeletal injuries	No	Pain Movement (e.g. gait, muscle strength and function) Medication consumption Economic outcomes (e.g. work attendance)	Both device and digital	Education/advice Psychological	Patient (with or without supervision)
SWORD Health digital programme	8-week program composed of therapeutic exercise, education and cognitive behavioural therapy (CBT) program	At home	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Anxiety or depression Medication consumption Economic outcomes (e.g. work attendance)	Both device and digital	Physical Education/advice Psychological	Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Online mindset intervention	Four modules, each with a series of videos and reflective questions.	Not reported	Single condition Knee Osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function) Condition-specific outcomes (e.g. bone density) "The short-version of the Western Ontario and McMaster Universities Osteoarthritis Index (ShortMAC) is a disease-specific 12-item measure of knee pain, stiffness, and function. Anxiety or depression "The PROMIS v.1.1 Global Health Short Form is a 10-item survey that measures overall physical function, fatigue, pain, emotional distress, and social health in healthy and clinical adult populations. Surgical intent "Perceived need for surgery will be assessed by the single question,"	Digital	Psychological	Not reported
SWORD Phoenix®	Digital exercise programme	At home	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Anxiety or depression Surgical intent Economic outcomes (e.g. work attendance)	Digital	Physical Education/advice Psychological	Healthcare professional Patient (with or without supervision)
Digital app for physical exercise	Digital App. Providing instructions for exercises to improve strength and mobility	Hospital outpatient departments	Single condition Hip osteoarthritis	No	Movement (e.g. gait, muscle strength and function) Movement quality, exercise-specific self-efficacy and control competence	Digital	Physical Education/advice	Patient (with or without supervision)
EaseVRx headset	Immersive eight-week virtual reality experience that helps patients adjust their cognitive, emotional and physical responses to chronic pain	At home	Multiple conditions	No	Medication consumption Pain	Both device and digital	Psychological	Patient (with or without supervision)
EaseVRx	Immersive virtual reality (VR) system that uses cognitive behavioural therapy and other methods to help with pain reduction in adults	At home	Single condition	No	Anxiety or depression Pain Movement (e.g. gait, muscle strength and function) Sleep	Digital	Physical	Patient (with or without supervision)
Digital therapeutics, virtual reality, psychological intervention for pain (DTxP)	Digital therapeutic software involving a virtual environment to encourage repeated movement.	Hospital outpatient departments This option was stopped for the intervention group early in the process due to covid-19, and subsequently VR headsets were delivered to participant homes. At home	Single condition Chronic non specific low back pain	No	Pain Movement (e.g. gait, muscle strength and function)	Both device and digital	Psychological	Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Peer-led walking programme	Peer-led walking programme	Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)	Not reported	No	Movement (e.g. gait, muscle strength and function)	Device	Physical	Patient (with or without supervision) Other Patient uses wearable tracker outside of peer-led walking group attendance
Training protocol with the device cervical for treatment (CDAT)	Cervical flexors and muscle training	Not reported	Single condition	No	Pain Movement (e.g. gait, muscle strength and function)	Device	Education/advice	Not reported
Internet based exercises	Internet-based exercise programme	Not reported	Single condition Knee Osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) MSK-HQ assessed independence Condition-specific outcomes (e.g. bone density) On musculoskeletal ultrasound" "Western Ontario and McMaster Universities Osteoarthritis Index " Anxiety or depression Quality of life Sleep	Digital "Internet based exercises"	Physical The intervention "consist of a 6-week internet-based physical therapy program." Other "Interventional group will be given actigraphy device (a device to monitor sleeping pattern) which is CE marked"	Not reported
Nottingham AR smartphone app	Augmented reality illusion therapy delivered via smart phone app.	At home	Multiple conditions	Yes	Pain Medication consumption	Digital	Physical	Patient (with or without supervision)
Telemedicine digital therapeutic	Digital therapeutics intervention for chronic pain utilizing coaching and virtual reality application	At home	Single condition Shoulder pain	No	Pain Movement (e.g. gait, muscle strength and function) Quality of life	Both device and digital	Physical Education/advice	Healthcare professional Patient (with or without supervision)
ESCAPE-pain app	Digital app that guides people to exercise safely in their own homes, provides advice on managing condition and tracks progress	At home Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)	Multiple conditions Knee/hip or back pain	No	Pain	Digital Digital intervention following in-person sessions in the community	Physical Education/advice	Healthcare professional Patient (with or without supervision)
Exo-LiFFT	An ergonomics assessment tool to estimate the effect of back-assist exoskeletons and exosuits on low back disorder (LBD) risk during occupational lifting tasks, without the need for EMG testing.	Other (give details in Info box) Workplaces	Single condition Low back pain	No	Pain	Digital	Other Online calculator to identify where exoskeletons can bring most benefit in reducing back pain.	Other Workplace managers/ occupational health employees
Virtual exercise programme	Exercises delivered virtually via zoom during the pandemic	At home	Single condition Osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function) Quality of life "Social connectedness"	Digital Exercise classes delivered over Zoom	Physical Other Social	Healthcare professional Patient (with or without supervision)
Joint Academy's digital treatment for osteoarthritis	A treatment program based on clinical evidence and connects patients with licensed physical therapists for a chronic joint pain treatment online	At home	Multiple conditions	No	Pain Movement (e.g. gait, muscle strength and function)	Digital	Physical Education/advice Other Social/group working	Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Ultrasound-responsive nanobubbles	A novel ultrasound-mediated nanodroplet-based gene delivery system for osteoporosis treatment	Not reported Can assume primary or secondary care as uses ultrasound guided nanobubbles to deliver targeted treatment	Single condition Osteoporosis	No	Not reported	Device	Other Ultrasound guided nanobubbles facilitate bone development and gene delivery	Healthcare professional
Conity	A wearable motion-sensing system to evaluate low-back function in lumbar fusion surgery patients	Not reported	Single condition post-lumbar fusion surgery	No	Pain Movement (e.g. gait, muscle strength and function) Quality of life	Digital Device	Physical	Healthcare professional
Maximising Inclusiveness in Sports through Female-centric Innovation and Technology (MISFIT)	Wearable technology (footwear) to support women to remain active as they age	At home Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)	Multiple conditions Supporting women to remain active as they age	No	Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating)	Device Smart textiles such as movement tracking leggings and sensors in footwear	Other Smart clothing for assessment of activity	Patient (with or without supervision)
A wearable ultrasound monitor	A wearable ultrasound system that can produce clinically relevant information about muscle function during dynamic physical activity	Primary care (e.g. GP surgery) Hospital outpatient departments	Multiple conditions MSK injuries	No	Movement (e.g. gait, muscle strength and function)	Device Wearable ultrasound to identify correct muscle activation during rehabilitation exercises	Physical	Healthcare professional Patient (with or without supervision)
GyroTrainer	A back muscle training device that can be adapted to the abilities of individual users.	Not reported	Single condition Back pain	No	Movement (e.g. gait, muscle strength and function)	Device	Physical	Healthcare professional Patient (with or without supervision)
Neuromusculoskeletal Modeling (NMSM) Pipeline	An open-source software that constructs and uses personalized computer models of how individual patients move to optimize treatments for neurologic and orthopaedic mobility impairments.	Other (give details in Info box) Lab based testing	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Other Computer aided assessment of neuromuscular system to develop tailored care plans	Healthcare professional
Wearable health sensor	Wearable sensor designed to detect and monitor muscle atrophy.	Not reported	Multiple conditions Muscle atrophy of any cause	No	Movement (e.g. gait, muscle strength and function)	Device Wearable sensor	Other Assessment of muscle change to reduce need for regular MRI	Healthcare professional Patient (with or without supervision)
Stretchable microneedle adhesive patch (SNAP)	A stretchable microneedle adhesive patch (SNAP) device to help people control robotic exoskeletons	Not reported	Not reported	No	Movement (e.g. gait, muscle strength and function)	Device	Physical Wearable patch which could be used to control exoskeleton to support restoration of mobility	Patient (with or without supervision)
Blueback®	A wireless device for indicating, for a given patient, the relative level of contraction of the transversus abdominal muscle.	Hospital outpatient departments	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Quality of life	Both device and digital	Other The device monitors the activation level of the transversus abdominis muscle	Healthcare professional
Software Generated Customized Foot	A custom-made foot orthotic	At home	Single condition	No	Pain	Device	Physical	Patient (with or without supervision)
Immersive Virtual Reality	An immersive virtual reality tool in the treatment of chronic lower back pain	Hospital outpatient departments	Single condition	No	Pain	Both device and digital	Physical Psychological	Healthcare professional Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Telehealth physical therapy	An evidence-based physical therapy (PT) program for persons with chronic low back pain (LBP) originally designed for in-person delivery, adapted for telehealth using videoconferencing.	At home	Single condition Chronic non-specific low back pain	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Anxiety or depression Sleep Economic outcomes (e.g. work attendance)	Digital	Physical Education/advice	Healthcare professional
getUBetter	An evidence-based, CE marked digital self-management support platform for all common musculoskeletal (MSK) injuries and conditions and women's pelvic health	At home	Multiple conditions	No	Healthcare usage (e.g. number of GP visits) Secondary care referrals	Digital	Physical Education/advice	Patient (with or without supervision)
Kinesimeter	A novel proprioceptive rehabilitation device for shoulder joint	Hospital outpatient departments	Multiple conditions Rotator cuff injury, Subacromial impingement syndrome, or Superior labrum anterior and posterior tear	No	Pain Movement (e.g. gait, muscle strength and function) Economic outcomes (e.g. work attendance)	Device	Physical	Healthcare professional
Flowly (TMC-CP01)	A program that uses a combination of virtual reality, biofeedback, and psychological exercises to manage pain associated with Chronic Low Back Pain	Hospital outpatient departments Not reported	Single condition	No	Pain Medication consumption Activities of daily living (e.g. bathing, eating) Anxiety or depression Quality of life Sleep	Both device and digital	Physical Psychological	Healthcare professional Patient (with or without supervision)
Remedee One	Innovative Device for Pain Management by Millimeter Band Radiation	Not reported	Single condition	No	Pain Anxiety or depression Quality of life Medication consumption Sleep	Device	Physical	Not reported
Device-performed-traction-and-vibration-therapy (TVT)	A medical device for performing hip – traction and vibration therapy	Hospital outpatient departments	Single condition Hip osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function)	Device	Physical	Healthcare professional
KneeBright Group	Knee Biofeedback Rehabilitation Interface for Game-based Home Therapy	At home	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Quality of life	Both device and digital	Physical	Patient (with or without supervision)
Internet-based intervention		At home	Single condition Temporomandibular joint disorder	No	Pain Movement (e.g. gait, muscle strength and function) Anxiety or depression Quality of life	Digital	Education/advice	Healthcare professional Not reported
Cloud-enabled intervention technology	A low-cost measurement system which tracks exercise compliance and enables remote health coaching for patients with low back pain	At home	Single condition	No	Pain Activities of daily living (e.g. bathing, eating) Movement (e.g. gait, muscle strength and function)	Both device and digital	Education/advice Psychological	Healthcare professional Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Alpha-phase synchrony EEG training	Alpha-phase synchrony EEG training for multi-resistant chronic low back pain patients	Hospital outpatient departments	Single condition	No	Pain Anxiety or depression Quality of life	Both device and digital	Education/advice Other "The intervention consists of 20 sessions of highly controlled electro-encephalography (EEG) APS operant conditioning (neurofeedback) paradigm delivered in the form of visual feedback."	Not reported
Vitality members app	A health and rewards app supporting healthy living	At home	Multiple conditions	No	Not reported	Digital	Education/advice	Patient (with or without supervision)
Workstation Modification	Artificial intelligence tool for monitoring and maintaining of posture in office workstations	Other Office/ Workplace	Single condition	Yes	Pain Movement (e.g. gait, muscle strength and function)	Device	Education/advice	Not reported
Mobile device remote therapy	A multimodal intervention program that measures associated variables such as catastrophising, pain acceptance, and quality of life using a mobile device in people with chronic pain in an outpatient setting	At home	Multiple conditions	Yes	Pain	Digital	Physical Education/advice Psychological	Patient (with or without supervision)
MSK Self-care app (Service)	Digital app for patient education and self-care for musculoskeletal conditions.	At home	Multiple conditions	No	Not reported	Digital	Education/advice	Patient (with or without supervision)
Multi-domain self management	Individualised osteoarthritis self-management support intervention for promoting health related quality of life and reducing healthcare costs	At home Hospital outpatient departments Primary care (e.g. GP surgery)	Multiple conditions Osteoarthritis and at least one co-morbid condition	No	Pain Movement (e.g. gait, muscle strength and function) Condition-specific outcomes (e.g. bone density) Anxiety or depression Quality of life Healthcare usage (e.g. number of GP visits)	Digital Video call coaching sessions (or in person at home or clinic) + information	Education/advice	Healthcare professional
My Wellbeing (Nuffield)	An at home workout and wellbeing partner	At home	Multiple conditions	No	Quality of life	Digital	Education/advice	Patient (with or without supervision)
NHS MSK Help (MyTherappy)	App providing information on muscle, bone and joint self-management (decommisioned)	At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Digital	Education/advice	Patient (with or without supervision)
Pain Sense Pain Management (MyTherappy)	A CBT-based app that helps users develop self-management skills for pain.	At home	Multiple conditions	No	Pain	Digital	Psychological CBT based intervention delivered by app	Patient (with or without supervision)
Pathway through Pain app	Drug-free Pain Management Programme (PMP) for chronic musculoskeletal pain	At home	Multiple conditions	No	Pain	Digital	Physical Education/advice Psychological	Patient (with or without supervision)
Neurodynamic Mobilizations	Neurodynamic mobilization techniques in patients with hand osteoarthritis	Not reported	Single condition Hand Osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function)	Device	Physical "Nerve slider technique targeted to the median, radial, and ulnar nerves of the symptomatic extremity for 12 sessions over a 4-week timeframe"	Healthcare professional

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Dr. Bart app	An app that guides user to administer auricular point acupressure (APA) treatment on themselves	Not reported	Multiple conditions "knee and/or hip osteoarthritis"	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Anxiety or depression Quality of life Secondary care referrals Economic outcomes (e.g. work attendance)	Digital	Education/advice	Other Researchers "The app is only accessible for users after the researcher has provided access for the app. Throughout the study, participants are able to call and send emails to the researcher when they have questions regarding the dr. Bart app or the study."
Virtual Auricular Point Acupressure (APA)	The device provides acupuncture-like stimulations on ear points using small pellets instead of needles to self-manage pain.	At home	Multiple conditions	No	Pain Quality of life	Device	Education/advice	Patient (with or without supervision)
Serious Game	Designed to provide therapeutic benefits beyond entertainment. These games are often used as part of a treatment plan and targeted implicit attitudes toward medication.	Hospital outpatient departments "The GAMER trial was conducted in the outpatient rheumatology clinics of six hospitals."	Single condition Rheumatoid arthritis	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Condition-specific outcomes (e.g. bone density) Medication consumption	Digital	Other "The 'game' part contained four puzzle types: crossword, sudoku, word search and tangram. The 'serious' part consisted of behavioural tasks that players had to perform to open the game or a puzzle."	Not reported
Ramsey Services Healthcare app	The app is designed to support patients at every step of their treatment journey, offering a range of services including symptom assessment, consultation booking, medication delivery, etc.	At home	Multiple conditions	No	Not reported	Digital	Education/advice	Patient (with or without supervision)
REMCare automated triage	Remcare digitises the end-to-end pathway for elective care. It captures information from patients that enables the validation of waiting lists, the correct and timely triaging of at-risk patients and the pre-optimisation of surgery.	Primary care (e.g. GP surgery) Hospital outpatient departments At home	Multiple conditions	No	Healthcare usage (e.g. number of GP visits)	Digital	Education/advice Other Remote data collection from patients.Remote monitoring of patients 'On app' advice and education to patients. Clinician alerts. Two way messaging between clinician and patient. Customisable platform for any MSK service. Digital self-management for patients with MSK conditions	Healthcare professional Patient (with or without supervision)
Rehabilitation program with Poppy robot	Involves using the humanoid robot as a coach for physical exercises during rehabilitation	Not reported	Single condition	Yes	Activities of daily living (e.g. bathing, eating) Movement (e.g. gait, muscle strength and function)	Both device and digital	Physical	Patient (with or without supervision)
Robotic platform (Hunova®)	A robotic device for rehabilitation and the sensorimotor assessment of the lower limbs and trunk	Not reported Large machine so assuming outside of home	Single condition	Yes	Movement (e.g. gait, muscle strength and function) Quality of life Activities of daily living (e.g. bathing, eating)	Both device and digital	Physical Education/advice	Healthcare professional

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
VR meditation program	An application designed to provide a virtual reality experience aimed at promoting relaxation and mindfulness	Hospital outpatient departments "Additional inclusion criteria included…..to visit the BWH Hospital Pain Management Center (PMC) campus to participate in the study"	Single condition "chronic knee OA"	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Anxiety or depression Quality of life Sleep	Digital	Psychological	Other "Prior to the participant's arrival for their in-person study visit, the researcher set up the VR Oculus Rift S equipment and disinfected the VR headset, hand controllers, and laptop computer."
SitFit (MyTherappy)	Seated exercise programme with 3 different levels. Gentle overall exercise, fitness and stretching	At home	Not reported	No	Movement (e.g. gait, muscle strength and function)	Digital	Physical App delivering seating exercise programs at 3 different levels	Patient (with or without supervision)
BackFit App	The Backfit app offers indications for back pain self-management through strength, motor control, relaxation, flexibility, and self-massage exercise.	Other "If participants were in the face-to-face intervention group, they met with the supervisor twice a week (in a room equipped for physical exercise)." At home "If participants were in the self-managed intervention group, they received the material for use when performing the exercises at home"	Single condition "Nonspecific Chronic Low Back Pain"	No	Pain Movement (e.g. gait, muscle strength and function) Anxiety or depression	Digital	Physical Education/advice	Patient (with or without supervision)
SleepIO (MyTherappy)	A six-week sleep improvement program to help a person fall asleep faster, stay asleep through the night and feel better during the day	At home	Multiple conditions	No	Sleep	Digital	Education/advice	Patient (with or without supervision)
Remotely Monitored Home-based Preferred Music	Listening to preferred music at home to relieve pain	At home	Single condition "Low Back Pain"	No	Pain	Digital	Other "MUSIC CARE® app"	Patient (with or without supervision) Not reported
Spinal Cord Stimulation	Made up of an implanted battery which is attached to a small lead. The leads are programmed to create a small electrical field. The leads are put next to a nerve, and the electrical field can result in a reduction of a specific type of pain	Hospital outpatient departments	Single condition	No	Pain	Device	Physical	Healthcare professional
Back Skills Training (BeST) programme	BeST programme focuses on 'undoing' beliefs about low back pain, and provides skills to become more active, despite pain. The programme uses a cognitive behavioural approach developed by experts in psychology, physiotherapy, cognitive-behavioural therapy,	Hospital outpatient departments	Single condition	No	Pain Activities of daily living (e.g. bathing, eating)	Digital	Education/advice Psychological	Healthcare professional

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
The SENS motion® sensor	The sensor is a wearable physical tracker giving investigators feedback about daily activity. It consists of a wireless activity sensor that automatically transfers data to a secure cloud	Other Patients use this wearable devise in their daily activities which can be outside or at home.	Single condition	No	Activities of daily living (e.g. bathing, eating)	Both device and digital	Other The device is an initial activity tracker with feedback	Patient (with or without supervision)
Erchonia GVL	When both the green and violet diodes are activated simultaneously, in providing temporary relief of minor chronic neck and shoulder pain of musculoskeletal origin	Not reported	Multiple conditions	No	Pain	Device	Physical	Healthcare professional
Virtual Reality based Rehabilitation Program	A system that evaluates the range of motion of the joints, analyses the sensation of joint position, provides biofeedback support to increase joint control and the same time allows exercises to be controlled.	Not reported	Single condition	Yes	Pain Movement (e.g. gait, muscle strength and function)	Device	Education/advice	Patient (with or without supervision)
MLS LASER Therapy	MLS is a patented technology that utilises a combination of wavelengths that are synchronized to work together.	Hospital outpatient departments	Single condition	No	Pain Activities of daily living (e.g. bathing, eating)	Device	Physical	Healthcare professional
Kaia hip and knee pain application	An app software loaded onto a smartphone, recommends specific exercises for the lower extremity. Using the camera on a smartphone, the software then tracks the participant's movements as the participant performs the exercises, analyses those movements usi	At home	Multiple conditions knee and hip osteoarthritis	No	Pain Movement (e.g. gait, muscle strength and function) Healthcare usage (e.g. number of GP visits) Medication consumption Economic outcomes (e.g. work attendance)	Digital	Education/advice	Patient (with or without supervision)
Vorso PROTECT System	Designed to deliver targeted, imperceptible, non-invasive stimulation to the ear to treat the signs and symptoms (e.g., tender and swollen joints, pain, synovitis) of patients with rheumatoid arthritis	At home	Single condition	No	Pain Activities of daily living (e.g. bathing, eating) Condition-specific outcomes (e.g. bone density) Quality of life	Device	Physical "The Vorso PROTECT System is designed to deliver targeted, imperceptible, non-invasive stimulation to the ear to treat the signs and symptoms (e.g., tender and swollen joints, pain, synovitis) of patients with rheumatoid arthritis."	Patient (with or without supervision)
Motivational Counseling and Text Message Reminders	Motivational counselling sessions and tailored text messages aimed at increasing light-intensity physical activity through reduction of sedentary behaviour	At home The motivational counselling was likely to have been delivered in an outpatient clinic, but the technological aspect of the intervention delivered at home. Hospital outpatient departments Motivational counselling component	Single condition	No	Movement (e.g. gait, muscle strength and function) Pain Activities of daily living (e.g. bathing, eating) Quality of life	Digital	Physical Education/advice Psychological	Patient (with or without supervision) Healthcare professional Motivational counselling component

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Immersive Virtual Reality (HIVR)	It is a subset of Virtual Reality technology designed to offer users a heightened sense of presence and immersion in a digital environment	Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)	Single condition	No	Movement (e.g. gait, muscle strength and function) Condition-specific outcomes (e.g. bone density)	Both device and digital	Physical Psychological	Not reported
PMA-zeolite device	A technology of Panaceo Active Mineral Production GmbH (mainly minerals). It is a mechanical treatment which increase particles properties and ion exchange capability	At home	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Condition-specific outcomes (e.g. bone density)	Device	Physical	Patient (with or without supervision)
NMES and exercise supplemented with high BFR	Neuromuscular Electrical Stimulation (NMES) is a technique used to elicit muscle contraction using electrical impulses. BFR include restricting the blood flow to muscles using a cuff or band while exercising	Other "In the clinic"	Single condition	No	Movement (e.g. gait, muscle strength and function) Pain Quality of life	Device	Physical	Healthcare professional
Sustainable WorkEr digital support for Persons with chronic Pain and their Employers (SWEPPE)	An eHealth intervention designed to assist individuals with chronic pain and their employers. It aims to improve work participation and self-management of chronic pain through a digital platform	At home	Multiple conditions	No	Economic outcomes (e.g. work attendance) Pain Anxiety or depression Quality of life	Digital	Education/advice	Patient (with or without supervision)
Upright Go Device	The Upright system is a device which helps provide a sensory reminder to alert users when their posture is poor	Not reported	Single condition	No	Pain Movement (e.g. gait, muscle strength and function)	Device	Education/advice	Not reported
Orthoglide device	The Orthoglide device is designed to aid the patient in performing this movement by reducing the friction/ resistance caused by the heel sliding against the bed	Hospital outpatient departments At home	Single condition	No	Pain Condition-specific outcomes (e.g. bone density)	Device	Physical Education/advice	Healthcare professional Patient (with or without supervision)
Active Moticon OpenGO insole	A high-tech sensor insole designed for capturing and analysing foot dynamics. It can be placed into any pair of shoes to measure weightbearing, balance, acceleration, and foot temperature	At home	Single condition	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Condition-specific outcomes (e.g. bone density) Quality of life	Device	Physical Education/advice	Not reported
PopSole™ Offloading Device	An innovative foot offloading device designed to alleviate foot pain and improve function. Particularly beneficial for individuals with chronic foot conditions, such as plantar fasciitis or heel pain syndrome	At home	Multiple conditions	No	Pain	Device	Physical	Patient (with or without supervision)
Virtual reality device for rehabilitation	A 10-20 minute guided meditation through the virtual reality. The meditation program may include simulated movement, relaxing music, and the voice of a meditation guide	Hospital outpatient departments	Single condition	No	Pain Anxiety or depression	Device	Physical Psychological	Patient (with or without supervision)

Technology	Brief description + link	Setting	Conditions	Uses AI?	Outcomes assessed	Technology type	Technology domain	Who is delivering the intervention?
Virtual reality device for rehabilitation	A rehabilitation program based either on exercises or on a program integrating virtual reality	Other Laboratory of Human Motion Analysis of the University of Liege for pre- and post-evaluation Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)	Multiple conditions	No	Pain Movement (e.g. gait, muscle strength and function)	Both device and digital	Education/advice Psychological	Not reported
EaseVRx	A virtual reality (VR) treatment program designed for patients with chronic lower back pain (CLBP). Non-pharmacologic, in-home treatment that uses established pain management techniques	At home	Single condition	No	Pain Activities of daily living (e.g. bathing, eating) Quality of life Medication consumption	Both device and digital	Physical Psychological	Patient (with or without supervision)
The TENS/EMS electrode wearable garment	An electrotherapy product, based on a wearable garment, to relieve knee OA pain through transcutaneous electrical nerve stimulation (TENS), and exercise muscles through electrical muscle stimulation (EMS).	At home	Multiple conditions	No	Movement (e.g. gait, muscle strength and function)	Device	Other Smart textile delivering wearable electrotherapy and function monitoring sensors	Patient (with or without supervision)
SmArt-E programme	Smartphone-assisted physical training with education for patients with hip and/or knee osteoarthritis	At home Hospital outpatient departments	Multiple conditions	No	Pain Movement (e.g. gait, muscle strength and function) Activities of daily living (e.g. bathing, eating) Quality of life	Digital	Physical Education/advice	Healthcare professional Patient (with or without supervision)
Aviva Wellbeing App	A desktop and mobile application designed to help individuals improve their physical and mental wellbeing	At home Other Workplace	Multiple conditions	No	Sleep	Digital	Education/advice	Patient (with or without supervision)

Appendix 2. Methods

A horizon scan was conducted to systematically identify emerging medical devices and digital health and care technologies.

Search Strategy

The search strategy was designed to identify both evidence and intelligence relevant to two key concepts, health technology and MSK.

(health technology)

AND

(MSK diseases OR MSK disorders OR Orthopaedics OR MSK pain)

Search strings were designed to return evidence and intelligence of relevance to both concepts from each of the following: databases, research funding portals, websites, and industry newsfeeds. The search strings developed were more or less sophisticated according to the search capabilities of the interface through which searching was conducted.

We limited the database searches to identify publications from January 2019 to February 2024 and the searches of research funding portals and industry news sites from January 2021 to February 2024.

An example Medline search can be seen in Appendix 4.

Data Sources

A range of sources were searched to identify both evidence and intelligence of medical devices and digital health and care technologies (which are less likely to have been trialled or reported in academic journals).

Databases

ClinicalTrials.gov, a comprehensive international database of ongoing and completed clinical trials, and Medline (Ovid), a bibliographic database of medical and nursing publications were systematically searched.

Research funding portals

The following sources of information on the receipt of funding for research and innovation were systematically searched: Cordis, Europe PMC, NIHR Funding and Awards, National Science Foundation, and the UK Research and Innovation Grant Finder.

Industry news sites and websites

The following industry news sites and websites were systematically searched for intelligence pertaining to research and innovation: Eureka Alerts, Fierce Biotech, Fierce Healthcare, MedTech News, the NHS mytherappy.co.uk portal, UK Government websites, NHS England website, and UK private healthcare organisations/insurers websites.

Eligibility criteria

- **Actor:**

The intervention could be delivered by any healthcare professional, adult patient or carer.

- **Action:**

Device: any instrument, apparatus, implement, machine, appliance, implant, reagent for in vitro use, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination for a medical purpose.

OR

Digital: use computing platforms, connectivity, software, and/or sensors for healthcare and related uses. These technologies span a wide range of uses, from applications in general wellness to applications as a medical device.

Aimed at maintaining or recovering positive MSK health in adults; this could manifest by impacting on any of the following outcomes of interest: Pain, Movement (e.g. gait; muscle strength and function), ADLs (e.g. bathing, walking, climbing stairs), Condition-specific (e.g. bone density), Anxiety or depression, Quality of life, Healthcare usage (e.g number of GP visits), Secondary care referrals, Surgical intent, Medication consumption, Sleep, Economic (e.g. work attendance).

Must be innovative

- **Target:**

Adults (aged 18 years+) with diagnosed or suspected musculoskeletal condition (Diseases of the musculoskeletal system and connective tissue ICD-10-CM Code range M00–M99: https://icd.who.int/browse10/2019/en#/XIII) (except fibromyalgia – see exclusions)

- **Setting:**

Home, primary care, outpatient or community

- **Context:**

Available, or likely to be made available in the UK, including EU Member states and the USA

Study published / clinical trial completed 2019 onwards

- **Language:**

English language articles only.

- **Exclusions:**
  - Interventions delivered in hospital inpatient including surgical settings
  - Diagnostics
  - Medicines (including injections and infusions)
  - Standard treatments (e.g., TENS, acupuncture) unless there is an innovative component to the treatment.
  - Studies where the participants are exclusively participants with Fibromyalgia, as this is now considered as a disorder of the nervous system.
  - Study published/ CT completed pre-2019

Record Selection, Coding, Visualisation And Strategy For Synthesis

Screening

Reviewers (MS, LT, SG and AS) all screened 20 records from ClinicalTrials.gov and Medline to check for consistency in decision making before records were then single screened within the Screenatron web application. Following this, full-texts of each included record were obtained where possible and single screened in the Rayyan web application (by LT, SG, AS, BH, CU, SH and RP).[10]

Records from research funding portals, industry news sites and websites were screened in-situ, again by a single reviewer (SG, AS, BH, CU, SH, AA or RP) with decisions made recorded in a Microsoft Excel spreadsheet.

Where a screening decision could not be reached by the first reviewer, a second reviewer was consulted. Any disagreements in screening decisions were resolved by discussion and, if needed, by a third reviewer. If we could not assess eligibility (e.g. an abstract contained too few details or we were unable to obtain the full-text), we classed these records as 'awaiting assessment'.

Where more than one report of the same technology existed, we included the report with the most information or most recently published in order to avoid double-counting.

Data coding

Included records were coded for visual representation within an EGM framework constructed a-priori through consultation with Orthopaedic Research UK. The framework was designed to show available evidence and areas of potential unmet need in MSK health that could be fulfilled through medical devices or digital health and care technologies. See Appendix 4 for the full coding tool.

Data coding was piloted by LT then undertaken in full by a single reviewer (from one of MS, LT, SG, AS, BH, CU, SH, and RP) in EPPI-Reviewer.

Data on the following additional features were extracted in to an Excel spreadsheet by a single individual (AS) with a 10% sample checked for quality assurance purposes (by LT): company/sponsor, geographic setting of development, and underpinning intervention type (physical, psychological, educational or other).
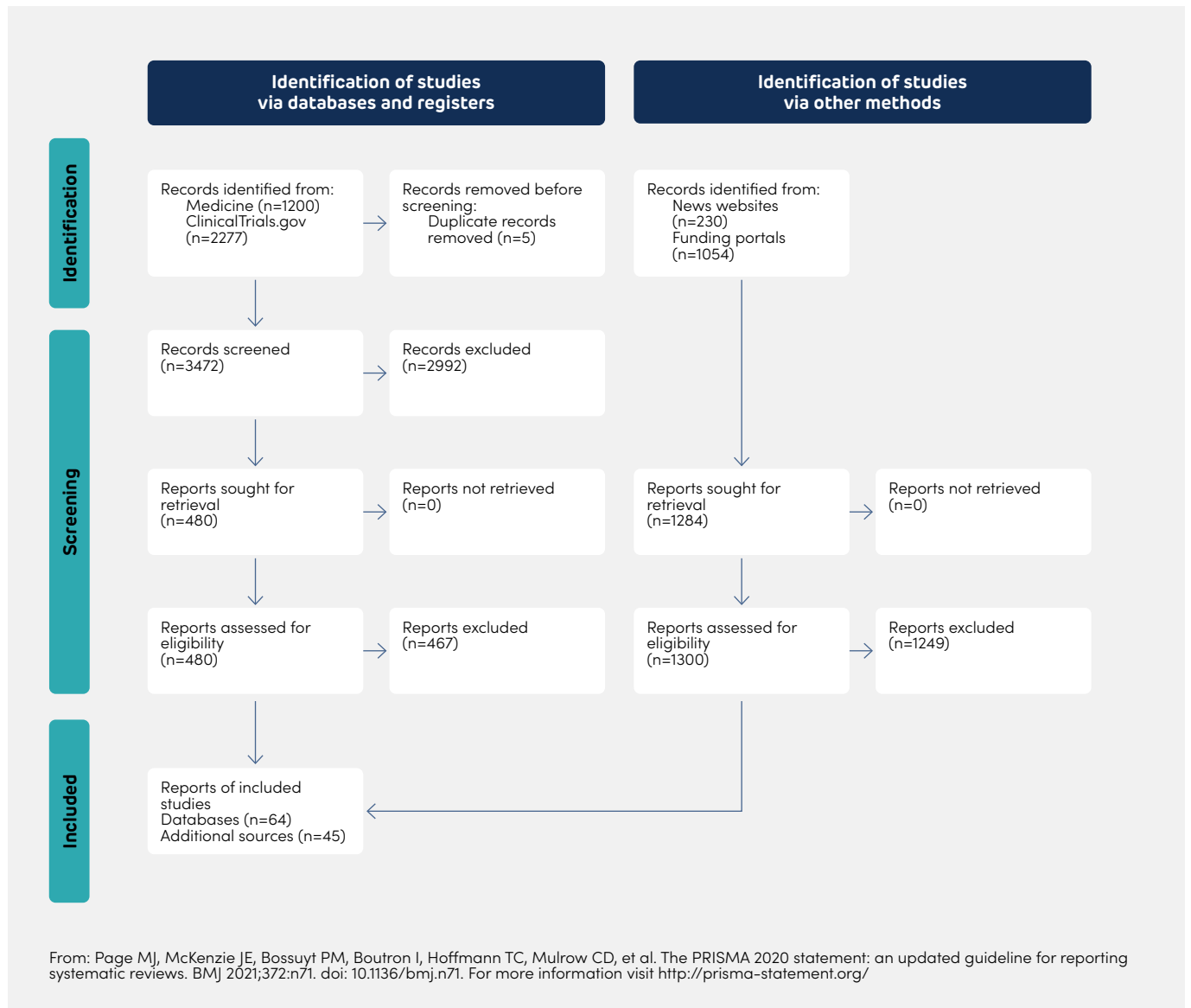
Strategy for synthesis

The Eppi-Mapper wizard was used to create the EGM. The rows show targeted outcomes for improvement and the columns show care setting, while the segmenting variables show the type of technology (medical device, digital health technology, both). Where possible, remaining codes were used as filters within the EGM (e.g. whether or not there was an AI component).

Alongside the EGM, a high-level narrative summary of included technologies was produced. This was structured according to the coding categories used within the EGM to contextualise and highlight key findings. Additional graphs and charts were created using the data visualisation software Flourish.[11]

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10 Mourad Ouzzani, Hossam Hammady, Zbys Fedorowicz, and Ahmed Elmagarmid. Rayyan — a web and mobile app for systematic reviews. Systematic Reviews (2016) 5:210, DOI: 10.1186/s13643-016-0384-4

11 Flourish. Beautiful and easy data visualization and storytelling. Available from: https://flourish.studio/ [Accessed 8th April 2024].

Appendix 3. PRISMA diagram

Identification of studies via databases and registers

Identification of studies via other methods

Identification

Records identified from:
Medicine (n=1200)
ClinicalTrials.gov
(n=2277)

Records removed before screening:
    Duplicate records removed (n=5)

Records identified from:
News websites
(n=230)
Funding portals
(n=1054)

Screening

Records screened
(n=3472)

Records excluded
(n=2992)

Reports sought for retrieval
(n=480)

Reports not retrieved
(n=0)

Reports sought for retrieval
(n=1284)

Reports not retrieved
(n=0)

Reports assessed for eligibility
(n=480)

Reports excluded
(n=467)

Reports assessed for eligibility
(n=1300)

Reports excluded
(n=1249)

Included

Reports of included studies
Databases (n=64)
Additional sources (n=45)

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information visit http://prisma-statement.org/

Appendix 4. Search strategy (Medline)

1. Artificial intelligence.mp. or exp Artificial Intelligence/
2. Computational neural network.mp. or Neural Networks, Computer/
3. Deep Learning/
4. Natural Language Processing/
5. (Computational intelligence or machine intelligence or deep learning).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
6. Algorithms/
7. 1 or 2 or 3 or 4 or 5 or 6
8. Medical technology.mp. or Biomedical Technology/
9. (device or digital or diagnostic).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]
10. 8 or 9
11. Low Back Pain/
12. Musculoskeletal System/ or Musculoskeletal Diseases/
13. 11 or 12
14. 7 and 10 and 13
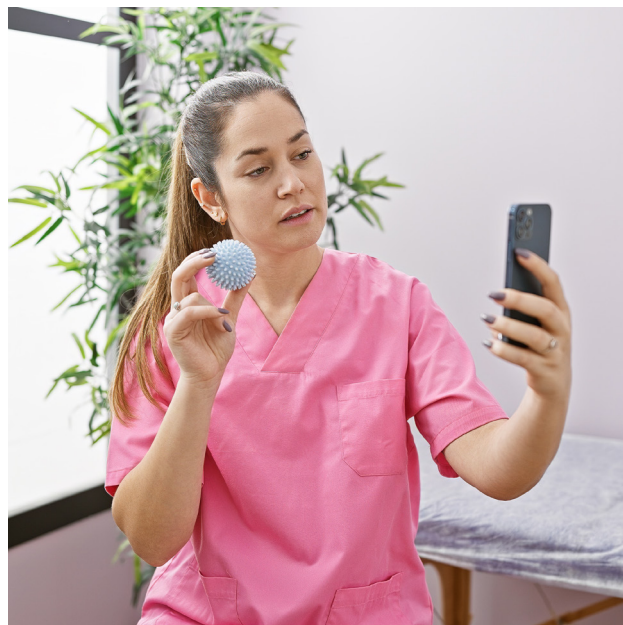
Appendix 5. MSK data coding framework

- **Record Source**
  - Database searches
  - Grey literature (e.g. websites, news articles)
- **Care setting**
  - At home
  - Community (e.g. leisure centres, gym, community hubs, community rehabilitation services)
  - Primary care (e.g. GP surgery)
  - Hospital outpatient departments
  - Other (give details in Info box)
  - Not reported
- **Conditions**
  - Single condition
  - Multiple conditions
  - Not reported
- **Is there an AI component reported?**
  - Yes
  - No
- **Outcome measures**
  - Pain
  - Movement (e.g. gait, muscle strength and function)
  - Activities of daily living (e.g. bathing, eating)
  - Condition-specific outcomes (e.g. bone density)
  - Anxiety or depression
  - Quality of life
  - Healthcare usage (e.g. number of GP visits)
  - Secondary care referrals
  - Surgical intent
  - Medication consumption
  - Sleep
  - Economic outcomes (e.g. work attendance)

- **Type of technology**
  - Digital
  - Device
  - Both device and digital
- **Type of intervention**
  - Physical
  - Education/ advice
  - Psychological
  - Other
- **Who is delivering the intervention?**
  - Healthcare professional
  - Patient (with or without supervision)
  - Carer
  - Other (give details in Info box)
  - Not reported
- **Developer/study sponsor**
- **Geographic setting of development**

Acknowledgements and Disclaimers

In partnership with