eVIS — A digital support for physical activity in patients with chronic pain

VERONICA SJÖBERG

Care Sciences
School of Health and Welfare
Dalarna University, Falun, Sweden
2023
Dissertation presented at Dalarna University to be publicly examined in lecture hall Fö 5 campus Falun, Friday, 24 November 2023 at 09:30 for the Degree of Doctor of Philosophy. The examination will be conducted in Swedish. Opponent: Professor Pernilla Äsenlöf (Uppsala University).

Abstract

Background: Chronic pain is a significant contemporary health challenge, exerting enormous impact on both individuals and societies. Although physical activity is the primary treatment, many patients struggle with incorporating it into their lives. In order to facilitate individualised physical activity within Interdisciplinary Pain Rehabilitation Programs (IPRP), the eVISualisation of physical activity and pain intervention was developed. This intervention consists of device-based measured physical activity, jointly visualised with patient-reported pain intensity, pain interference, and pharmaceutical consumption.

Overall aim: To i) develop the eVIS intervention as a digital support for physical activity in IPRP, ii) to evaluate eVIS’s validity, feasibility, and acceptability as a supplementary treatment for patients taking part of IPRP, and iii) to evaluate the feasibility and acceptability of the trial design and conduct of an ongoing Registry-based Randomised Clinical Trial (R-RCT), where the effectiveness of eVIS as an addition to IPRP is evaluated.

Methods: The Medical Research Council’s updated framework for development and evaluation of complex interventions guided study designs and methodologies. This thesis contains four papers: I. Evaluation of the criterion validity of a wrist-worn activity tracker, II. Evaluation of pre-clinical content validity of eVIS, III. A study protocol outlining trial design and trial conduct of an ongoing R-RCT, and IV. Evaluation of the aforementioned trial design and trial conduct.

Results: The wrist-worn activity tracker provided fair to acceptable measurements of SR. In collaboration with relevant stakeholders, eVIS was continuously developed and found to be relevant, simple, and safe for use by patients, clinicians, and researchers. The first real-world test of the clinical feasibility of the intervention motivated further development in the web application and procedures relating to recruitment and data collection. The evaluation of the acceptability and feasibility of the trial design and conduct provided promising results, with mainly satisfactory feasibility. However, minor revisions are required to safeguard the external validity of the ongoing R-RCT.

Conclusions: Through continuous refinement in collaboration with stakeholders and careful consideration of the intervention’s complexity, key uncertainties, and context, indicate that the intervention is relevant, valid, feasible, and well prepared for effectiveness testing.

Keywords: Chronic pain, Criterion validity, Content validity, Complex intervention development, Device-based measurement, Feasibility, Physical activity

Veronica Sjöberg, Care Sciences

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ISBN 978-91-88679-55-0
urn:nbn:se:du-46281 (http://urn.kb.se/resolve?urn=urn:nbn:se:du-46281)
It is not the strongest of the species that survives, nor the most intelligent. It is the one most responsive to change.”

Charles Darwin, 1809
List of Papers

This thesis is based on the following papers, which are referred to in the text using Roman numerals


IV. Sjöberg, V., Monnier, A., Tseli, E., LoMartire, R., Hagströmer, M., Björk, M., Äng, B., Vixner, L. Feasibility and Acceptability of Design and Conduct of a Registry-Based Randomised Clinical Trial Evaluating eVIS as a Digital Support for Physical Activity in Interdisciplinary Pain Rehabilitation Programs: a randomised pilot study. *In manuscript.*

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# Abbreviations

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<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<tr>
<td>CONSORT</td>
<td>Consolidated Standards of Reporting Trials</td>
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<tr>
<td>CVI</td>
<td>Content Validity Index</td>
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<tr>
<td>EE</td>
<td>Energy Expenditure</td>
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<tr>
<td>eVIS</td>
<td>eVISualisation of physical activity and pain intervention</td>
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<tr>
<td>HRQoL</td>
<td>Health-Related Quality of Life</td>
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<tr>
<td>HR</td>
<td>Heart rate, beats per minute</td>
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<td>IASP</td>
<td>The International Association for the Study of Pain</td>
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<td>IMMPACT</td>
<td>The Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials</td>
</tr>
<tr>
<td>IPRP</td>
<td>Interdisciplinary Pain Rehabilitation Program</td>
</tr>
<tr>
<td>I-CVI</td>
<td>Item Level Content Validity Index</td>
</tr>
<tr>
<td>ICC</td>
<td>Intra Class Correlation Coefficient</td>
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<tr>
<td>LOA</td>
<td>Limits of Agreement</td>
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<tr>
<td>MCID</td>
<td>Minimal Clinically Important Difference</td>
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<tr>
<td>METs</td>
<td>Metabolic Equivalents</td>
</tr>
<tr>
<td>MVPA</td>
<td>Moderate to Vigorous Physical Activity</td>
</tr>
<tr>
<td>MRC</td>
<td>Medical Research Council</td>
</tr>
<tr>
<td>OMERACT</td>
<td>Outcome Measures in Rheumatology</td>
</tr>
<tr>
<td>PATRON</td>
<td>PAin and TRaining ONline (web application in eVIS)</td>
</tr>
<tr>
<td>S-CVI/UA</td>
<td>Scale Level Content Validity Index Universal Agreement</td>
</tr>
<tr>
<td>S-CVI/Ave</td>
<td>Scale Level Content Validity Index Average</td>
</tr>
<tr>
<td>SPIRIT</td>
<td>Standard Protocol Items: Recommendations for Interventional Trials</td>
</tr>
<tr>
<td>SR</td>
<td>Step rate, steps per minute</td>
</tr>
<tr>
<td>SQRP</td>
<td>Swedish Quality Registry for Pain Rehabilitation</td>
</tr>
<tr>
<td>VAPAIN</td>
<td>Validation and Application of a patient relevant core outcome set to assess effectiveness of multimodal PAIN therapy</td>
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Definitions of central concepts

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<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>Acceptability</td>
<td>A multi-faceted construct that reflects the extent to which people delivering or receiving a healthcare intervention consider it to be appropriate, based on anticipated or experiential cognitive and emotional responses to the intervention (Sekhon et al, 2017)</td>
</tr>
<tr>
<td>Content validity</td>
<td>The extent an intervention’s component activities are relevant to the underlying construct (Kassam-Adams et al, 2015)</td>
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<tr>
<td>Context</td>
<td>Physical, spatial, organisational, social, cultural, political, or economic features of healthcare, health system, or public health contexts in which an intervention is implemented (Skivington, 2021)</td>
</tr>
<tr>
<td>Complex intervention</td>
<td>A intervention’s complexity is due to its characteristics, or how the intervention generates outcomes in relation to external factors (recipients, context, etc.) (Skivington et al, 2021)</td>
</tr>
<tr>
<td>Criterion validity</td>
<td>An experimental device’s agreement to the corresponding measurement of a recognised gold standard (Shephard &amp; Tudor-Locke, 2016)</td>
</tr>
<tr>
<td>Demand</td>
<td>The likelihood that a new idea, program, process, or measure is likely to be used (Bowen, 2010)</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>The extent to which the intervention produces intended outcomes in a real-world setting (Skivington, 2021)</td>
</tr>
<tr>
<td>Feasibility testing</td>
<td>Testing if specific elements of a future trial can be done (Eldridge et al, 2016)</td>
</tr>
<tr>
<td>Intervention</td>
<td>Action taken to improve or help a situation (Oxford Dictionaries)</td>
</tr>
<tr>
<td>Implementation</td>
<td>The extent to which a new idea, program, process, or measure can be successfully delivered to intended users in some defined, but not fully controlled, context (Bowen, 2010)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Limited efficacy</td>
<td>The extent to which a new idea, program, process, or measure shows promise of being successful with the intended population, even in a highly controlled setting (Bowen, 2010)</td>
</tr>
<tr>
<td>Pilot testing</td>
<td>Evaluation of methodological components, aiming to support a future definitive trial (Eldridge et al. 2016)</td>
</tr>
<tr>
<td>Practicality</td>
<td>The extent to which a new idea, program, process, or measure can be carried out with intended participants using existing means, resources, and circumstances and without outside intervention (Bowen, 2010)</td>
</tr>
<tr>
<td>Validity</td>
<td>An instrument or a measure’s ability to measure exactly what it is supposed to measure and nothing else (Brink &amp; Wood, 1998)</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>Individuals who are targeted by an intervention, involved in its development or delivery, or those whose personal or professional interests are affected (Skivington et al, 2021)</td>
</tr>
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Personal preface

I started my first position as a registered physiotherapist at Falun Hospital in June, 2006. For the following 12 years, I worked in different in-patient healthcare settings, supporting patients with various diagnoses in restoring their physical functionality. Despite quite a wide range of diagnoses, most of my patient encounters shared two central elements: First, I, as the presumed expert, was envisioned by the patient and by the team, to contribute with knowledge of what the patient needed in order to recover. This also included me transferring this knowledge to the patient in an effective way, including enabling patients to self-manage. Secondly, although my task was to support the restoration of physical functions, it was clear that patients' impairments and their ability to rehabilitate were closely interwoven with their own thoughts, beliefs, experiences, and emotions.

The notion that it is the healthcare staff worker that is the expert, is sometimes known as the “doctor (or physiotherapist!) knows best” phenomenon, and has been firmly anchored historically and internationally within healthcare. It stems from a structure where healthcare professionals provide expertise to which the patient is expected to amend, due to their implicitly expected will and capacity to recover. This expertise, within the context of physiotherapy, often involves prescribing a regimen of a “one-fits-all” model of physical activity to a range of individuals. Although these individuals evidently share a diagnosis or disability, they often had profoundly different prerequisites and abilities to adhere to my delivered regimen and advice. This could sometimes feel frustrating. This frustration was not only due to the obviously limited effectiveness of applying a one-fits-all model, but also from recognising my own and in general, healthcare professionals’ under and overestimation of patient interest, willingness, and skills to execute prescribed self-management, including more or less independently identifying and correcting potential issues.

On the other hand, societal resources of healthcare are finite and those in need should be prioritised. I agree with the notion that patients, if possible, should take on the responsibility of self-management or self-care, both in order to increase individual empowerment and to fairly distribute healthcare resources. One of my personal perspectives is that we, as healthcare professionals, generally view changes in behaviour (for example towards healthy eating, more
or less physical activity, quitting smoking) as requiring little effort – at least once the patient has been provided with information on how to make such changes. We often fail to recognise the gap between evidence-based knowledge of what-works-when and how we can successfully equip patients with the necessary prerequisites required to be able to take an active part in their recovery, sometimes in the presence of disease. In order to change physical activity patterns, most of us need tools such as evidence-based knowledge of not only the disease we are dealing with, but also of the body, its responses to physical activity when affected by disease, as well as tailored support and adequate self-regulating strategies to make it possible to adhere to the advice, information, and regimen provided.

The eVISualisation of physical activity and pain (eVIS) project, led by Associate Professor Linda Vixner, was successfully funded in 2017. Shortly after this, I was admitted to the doctoral program in Care Sciences at Dalarna University to conduct my doctoral studies as a part of the eVIS-project. At the time, the project was broadly outlined in terms of proposed methodology and research questions. Over the course of five and half years, the general conceptual idea of eVIS has remained intact. However, the methodologies used in the included papers have been revised, and outlined in detail, in some cases with significant changes being made since their original presentations. One important aspect of the project is the application of theories and frameworks supporting development of the intervention, as well as its suggested mechanisms of action. These have been explored and outlined within my doctoral studies. The overarching eVIS-project is crowned by a registry-based randomised clinical trial (R-RCT), where eVIS’s effectiveness to improve patient’s physical health after completed Intradisciplinary Pain Rehabilitation Programs (IPRP) will be evaluated. Despite such prospect was very tempting to a doctoral student, this effectiveness trial per se, is not a part of this thesis. However, the thesis contains preparatory research aiming to decrease the risks of intervention rejection and misleading effectiveness results. In addition, an overarching framework of the development and evaluation process of eVIS as a supplement to IPRP has also been anchored in the project. The framework (presented below in this thesis) has guided both the development and evaluation processes. Its overarching idea is also consistent with my perception of research within the field of care sciences – a field where various perspectives are considered in addition to the most obvious one (here by tradition: effect, effectiveness). This has been a golden thread in the work behind this thesis. All the work presented here has been produced by individuals from diverse professions and holding a variation of roles (academic and non-academic experts) working together and has including both junior and senior researchers. This has greatly impacted my journey as a doctoral student.
Introduction

This thesis in the realm of Care Sciences

The research presented in this thesis is situated within the research area and undergraduate discipline of Care Sciences. The Swedish Research Council defines the area as problem focused with multi-professional and interdisciplinary research, guided by human health theories and methods. The doctoral program Health and Welfare with focus on evidence-based practice at Dalarna University, and consequently, this thesis, have adopted this definition.

In this thesis, the concept of ‘health’ is operationalised in alignment with the definition provided by the World Health Organisation: ‘Health is a state of complete physical, mental, and societal wellbeing and not merely the absence of disease or infirmity’. The concept of health is closely intertwined with the concept of quality of life, which encompasses a multi-dimensional perception and assessment of the ‘goodness’ in life’s different domains. Quality of life within the context of disease or disability may be conceptualised as health-related quality of life (HRQoL), and its measurement is recommended as an outcome in clinical trials aiming to compare treatments. In this thesis, and in agreement with the existing literature, HRQoL encompasses emotional, physical, and cognitive functions.

Significant time and financial resources are invested into healthcare research, including research aiming to develop and evaluate health promoting interventions. Despite these efforts, it is not uncommon for seemingly promising interventions to be rejected or poorly adopted due to insufficient efforts in the development, trial design, or in trial conduct. In Sweden, healthcare providers are required to adhere to statutory requirements for good practice, which outline that care must be knowledge-based, safe, individually tailored, equitable, accessible, and effective. Since the early 1990s, the development of evidence-based knowledge regarding the effectiveness of new interventions has been assessed according to benchmarks within the evidence-based medicine (EPM) paradigm. In EPM, evidence of the effectiveness of interventions is primarily derived from highly controlled trials (i.e., randomised controlled trials and observational studies), which provide results with strong internal validity. The paradigm entailed that considerations of tra-
ditions and theoretical reasoning was decreased in favor to experimental evidence aiming to support decisions on safe and effective care. Later, the concept of evidence-based practice emerged, emphasising the integration of clinical expertise and patient perspectives as additional core components alongside best available scientific evidence. Despite this, findings in controlled trials do not always break through to real world clinical practice. In the past decade, a third version emerged: translational practice-based research. Here, the problematic gap between basic clinical research in medical and care sciences and real world clinical practice is highlighted. In practice-based research, two translational steps are added to the clinical research process. These translational steps serve as research settings for further exploration of for example readiness to change, adoption of new treatments, and patient preferences. These are all crucial parts of the process to translate basic research (i.e., bench) and human clinical research (i.e., bedside) to improved individual healthcare.

This thesis presents a systematic process for the development of knowledge and methodology for a health-promoting intervention. Research included is preparatory in nature and has the overall objective to pave the way for a subsequent registry-based randomised clinical trial. This trial, in turn, aims to evaluate the effectiveness of the intervention in further improving patients’ physical health. The positioning of the thesis may be illustrated by placing it in the National Institute of Health’s roadmap for practice-based research (see Figure 1).

**Figure 1.** A schematic illustration of the National Institute of Health’s (NIH) roadmap for medical research from bench (basic animal research) to bedside (human clinical research), and the further translation of research to practice-based research. The red arrow indicates the placement of this thesis in the model. The dotted arrow indicates the placement of the R-RCT. This figure is inspired by “Blue Highways” of the NIH Roadmap.
Regardless of which paradigm’s criteria for evidence are applied, the central emphasis on high internal validity remains. This entails that information on indirect evidence (i.e., non-experimental data, clinical experiences, understanding of context) regarding an intervention’s impact is at risk of being overlooked. Critical arguments have been made regarding highly controlled findings and their insensitivity to intervention context, relevance, scalability, transferability, implementation, applicability, and acceptability, as well as individual patient traits. The absence of such knowledge may increase the risk of over-confident planning of trial activities, leading to inconclusive results due to intervention rejection, inadequate statistical power, biased estimates of treatment effectiveness, and low generalisability.

Scientific viewpoints on credible evidence

In order to evaluate the findings presented in this thesis, it is essential to articulate my perspective on what constitutes credible evidence. Primarily situated within the realm of care sciences, this thesis relies on quantitative data as the foundation for its findings, with conclusions primarily derived deductively within logical empiricism, an approach that draws upon numerical data and statistical analyses. In other words, research in this thesis aligns philosophically with the notion that posits that reality is measurable and verifiable. While this thesis predominantly adheres to the deductive logical empiricism view regarding the credibility of its findings, it also acknowledges the importance of inductive constructivism, or rather inductive pragmatism, as a method to evaluate the research subject in a real-world context. This is particularly evident in Papers II and IV. This addition to the evidence concept aligns with Deweyan pragmatism, where reflection is an “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of grounds that support it, and the further conclusions to which it tends”.

The pragmatic study design is supported by the notion that a pragmatic research design is particularly suited to answering clinically oriented real-world research questions.

In addition, a small portion of data, in the form of written free text, was analysed using a more pragmatic hermeneutic approach. The rationale to employing this approach was to capture additional insights that are inherently elusive in numerical data. The narrative data collected from individuals living with chronic pain and clinicians in pain rehabilitation, although limited in quantity, has proven to significantly influence the process of developing and evaluating the intervention.
Overall, this thesis, situated within the field of care science, was conducted at an early check-point on the road towards *practice-based research*. It encompasses primarily philosophical perspectives of logical empiricism and pragmatism, but also includes hermeneutic data interpretation in specific contexts. The utilisation of several approaches has enriched the understanding and applicability of the research findings.
Background

Chronic pain

The experience of pain is crucial to our survival as a species, as it guides our behaviour through the learning of experiences and serves as a warning signal for threats to our existence. The experience of pain is recognised as multidimensional, and the International Association for the Study of Pain (IASP) defines pain as ‘an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage.

To further signify the impact of the subjective experience of pain, IASP provides six clarifying bullet points for the conceptualisation of pain:

1. Pain is always a personal experience that is influenced to varying degrees by biological, psychological, and social factors.
2. Pain and nociception are different phenomena. Pain cannot be inferred solely from activity in sensory neurons.
3. Through their life experiences, individuals learn the concept of pain.
4. A person’s report of an experience as pain should be respected.
5. Although pain usually serves an adaptive role, it may have adverse effects on function, as well as social and psychological wellbeing.
6. Verbal description is only one of several behaviors to express pain; an inability to communicate does not negate the possibility that a human (or nonhuman animal) experiences pain.

Most people experiencing pain also experience pain resolution as mechanical or inflammatory injuries heal and normal homeostasis is restored. Approximately 25-35% of the European population experiences pain classified as ‘chronic,’ implying pain that recurs or persists for longer than three months. Since 2018, chronic pain conditions have had their own classifications in the 11th edition of International Classification of Diseases (ICD-11). The new diagnostic classifications are based on pain’s clinical characteristics and its pathophysiology and are categorised in chronic primary pain syndromes and chronic secondary pain syndromes. Primary pain is subdivided into chronic widespread pain, complex regional pain syndromes, chronic primary headache and orofacial pain, chronic primary visceral pain, and chronic primary musculoskeletal pain. The second category, chronic secondary pain syndromes have corresponding subcategories; chronic cancer-related pain,
chronic postsurgical or posttraumatic pain, chronic neuropathic pain, chronic secondary headache or orofacial pain, chronic secondary visceral pain, and chronic secondary musculoskeletal pain, and chronic primary pain 29.

There are several theories explaining the transition from acute to chronic pain 34,35. One pathophysiological explanation for this transition suggests that persisting nociceptive stimulation in the periphery seems to emanate prolonged inflammatory processes, which in turn initiates changes described as peripheral sensitisation (involving the production of substance P) and decreased pain thresholds 34. Furthermore, repetitive nociceptive stimulation is believed to elicit changes in the dorsal horn neurons of the spinal cord, leading to the ‘wind-up’ phenomenon, where nociceptive stimulus is aggravated resulting in allodynia (where pain is experienced from stimuli that are not normally painful). Radiologically it seems to be evident that changes in the brain’s networks responding to nociceptive stimuli (i.e., the pain matrix) occurs when sensitisation occurs 34.

Risk factors predicting increased risk of developing chronic pain depend on the characteristics and classification of the pain syndrome. However, the strongest predictors seem to be psychological factors such as depression, catastrophising, and avoidant behavior. Other predictors include sex, age, lifestyle, overweight, high pain intensity, inadequate pain management strategies, education level, and work satisfaction 33,34,36,37. Risk factors such as emotional distress and sleep disturbances, aside from their role as predictors of chronic pain development, have been suggested to have a bidirectional relationship to chronic pain 38.

Living with chronic pain

Living with chronic pain often significantly reduces overall quality of life 39,40. It is therefore not surprising that the societal costs of chronic pain are substantial. According to a fairly dated report from 2003, pain accounts for approximately 90 billion Swedish kronor in direct and indirect healthcare related costs in Sweden every year 41. Depending on individual traits, the multi-dimensionality of the chronic pain experience affects emotions, cognition, social life, and physical wellbeing to varying extents. Negative emotional consequences include altered mental states such as depressive disorders, anxiety, psychological deconditioning, and impaired cognitive processes, such as memory and attention deficits 38,42, all of which may, in turn, negatively affect an individual’s ability to maintain relationships and work. Reported negative physical consequences of chronic pain are sleep disturbances, cardiovascular diseases, fatigue, and physical deconditioning, all of which affect everyday life, work, and the ability to perform physical activity 30,43-45.
Treatment

The primary intent of all pain treatments is to reduce suffering. Throughout the history of pain treatment, there has been a paradigm shift from a purely biomedical view, focusing solely on the physical injury, to today’s well-accepted application of the bio-psycho-social model for understanding the multidimensional pain experience. In current clinical pain medicine, the bio-psycho-social model is considered a well-implemented clinical approach. There is no shortage of reports and clinical guidelines outlining how the model should guide assessment and treatment to achieve the best possible effectiveness.

In the early stages of chronic pain, less comprehensive treatments, such as single pharmacological, physiotherapeutic, or psychological treatments are typically offered in primary care. Physical activity is an essential part of short- and long-term pain management and considered a primary choice. Physical activity is considered evident to improve the pain experience, physical functioning, and quality of life.

Several theories describe the physiological mechanisms of benefits of physical activity are to increase general health and to decrease the impact of pain experience and its negative consequences. In theory, the nervous system is neuroplastic, implying reversibility in affected structures. One explanatory theory of the mechanism of action in physical activity as treatment refers to anti-inflammatory effects of physical activity and proposes that these may reduce systemic inflammation and reduce pain. Secondly, the theory of exercise-induced analgesia involves pain relief due to release of endogenous opioids during and after physical activity and exercise. Aside the endogenous opioid release, physical activity may trigger neuroendocrine responses which increases serotonin, dopamine, and norepinephrine – all analgesic neurotransmitters that may induce pain relief.

At last. By educate and safely expose patients of the accurate response to pain (no true danger), and to movements that causes sympathetic arousal and leads to a defensive behavior (e.g., pain neuroscience education), it may lead to cortical changes and systematic desensitisation, which in turn may facilitate a cognitive process of decreased fear avoidance.
Nevertheless, for approximately 10% of patients with chronic pain, the pain experience significantly impacts activities of daily life, and unimodal treatments may be insufficiently effective. For these individuals, a coordinated, team-based approach is usually recommended to target the multidimensionality of the pain condition and to mitigate further negative consequences. Such treatment programs are often referred to as ‘Multimodal rehabilitation’ or ‘Interdisciplinary pain rehabilitation programs’ (IPRP). They involve at least two treatment measures where one targets physical aspects and the other targets psychological factors, typically delivered by at least two different healthcare professions; physiotherapists, psychologists, physicians, trained social workers, occupational therapists. A definition proposed by the IASP is ‘treatment provided by a multidisciplinary team collaborating in assessment and treatment using a shared biopsychosocial model and goals’. This definition aligns well with the overarching construction of IPRPs in Sweden. Intradisciplinary pain rehabilitation programs consist of several treatment components including key components of physical activity, behavioral therapy, activity training, relaxation techniques, and workplace interventions. They are delivered in a synchronised manner, with an emphasis on team assessment, the establishment of a treatment plan, and effective communication.

Conceptually, two overarching perspectives permeate all interventions within IPRPs. Firstly, theories of behavioral medicine are eminent. Behavioral medicine, as defined by Dekker et al., is a multidisciplinary field concerned with the development and integration of biomedical and behavioral knowledge relevant to health and disease, and the application of this knowledge to the fields of prevention, health promotion, diagnosis, treatment, rehabilitation, and care. Additionally, ideas from Pain Neuroscience Education (PNE) have impacted IPRPs. PNE aims to change patients’ conceptualisation of the pain experience, often with the specific goal of perceiving the pain experience as less threatening.

In comparison to unimodal measures (single treatments), such as pharmacological treatments, physical activity, and psychological measures, IPRPs are considered to be evidence-based interventions, particularly when overall assessments of outcomes are used. However, when considering available outcomes independently, such as sickness absence, return to work, pain intensity, and HRQoL, the effectiveness of IPRPs seems to differ. In addition, the effectiveness of IPRPs seem to vary depending on patient subgroups, suggesting that not all patients benefit equally – and in some cases a small portion even experience a deterioration in their health outcomes. Due to the heterogeneity of the patient population in combination with the lack of consensus on factors such as content, duration, and intensity, it is difficult to draw cross-proof conclusions regarding the effectiveness of IPRPs.
Physical activity
Physical activity is commonly defined as ‘any bodily movement produced by skeletal muscles that results in energy expenditure’, as provided by Caspersen and colleagues in 1985. Physical activities are usually quantified based on the amount of energy required to perform them. Common units of measurement are kilocalories or metabolic equivalents (MET/METs), where one MET is equivalent to the energy expended by an individual in seated rest. In order to categorise physical activity, activities may be designated with one of the following physical intensity levels; Inactivity: energy expenditure below 1.5 METs, Light intensity physical activity – energy expenditure ranging from 1.5 to 3 METs, Moderate physical activity – energy expenditure ranging from 3 to 6 METs, or Vigorous physical intensity – energy expenditure exceeding 6 METs. Subgroups of physical activity include ‘exercise’, which occurs when physical activity is repetitive, structured, and planned with a goal of improving or maintaining fitness, and ‘inactivity’ or ‘sedentary behaviour,’ which refers to waking activities requiring an energy expenditure of below 1.5 METs.

Physical activity is not just about energy expenditure; the construct contains dimensions of duration (time spent in physical activity), frequency (how often an activity is performed within a specific time frame), mode (the kind of activity), type (aerobic or anaerobic), and domain (occupational, domestic, transportation, or leisure).

Physical activity and inactivity constitute multidimensional behaviours and are complex constructs to measure. The main objective of measuring physical activity, exercise, and inactive behaviour is at a societal level, primarily to provide a basis for public health recommendations regarding physical activity and sedentary behaviour. Such recommendations, often based on self-reported data, offer specific guidelines for the recommended duration and intensity of physical activity individuals need to be able to gain from physiological benefits. Although the cumulative amount of how much physical activity an individual is performing is dependent on the individual’s behaviour, the measurement method used is considered to be an important factor.

There are two main categories for measuring physical activity: self-reports (including self-report by proxy) and device-based measurement (objective measurement) methods. In both research and clinical practice, the most preferred method used is self-reporting in the form of surveys, questionnaires, diaries, or logbooks. A self-report can provide information on not only time spent in different physical activity intensities, but also qualitative information on which dimensions and domains physical activity occurred. Self-reports are also low cost. However, despite the method’s flexibility and simplicity to administrate, it is associated with measurement biases, such as observer bias.
social desirability bias, and recall bias. In addition, the method usually imposes a high burden on respondents and requires respondents to be literate.

Device-based methods include accelerometry, heart rate monitoring, direct observation, the doubly labelled water technique, and direct and indirect calorimetry. Accelerometer-based methods are increasingly used in research as they minimise the risk of measurement biases associated with subjective methods. However, it is worth noting that many objective methods are resource intensive in terms of both monetary costs and the high burden they put on researchers.

In the general population, wearable devices designed to keep track of physical activity have become increasingly common. These devices, used for both commercial and research purposes, often utilise accelerometry to make estimations of physical activity levels and are often low-cost and user friendly. The main critical argument against these commercial devices is their unknown validity when used in disease-specific populations. Therefore, it is strongly recommended that any device being used to measure physical activity undergo validation in a population that is representative of the population of interest.

Physical activity in the context of chronic pain

Current international and national guidelines outline recommended levels of physical activity for both disease prevention and treatment. Individuals living with chronic conditions, including chronic pain, are advised to engage in moderate to vigorous physical activity for at least 150 minutes every week, as well as to perform muscle-strengthening activities are recommended for at least two days per week. Despite such straightforward guidelines, many individuals living with chronic pain struggle to reach and maintain these recommended levels of physical activity. Studies show that up to 80% of individuals living with chronic pain do not meet recommended levels of physical activity, regardless of the measurement method used. This may be compared to reports stating that approximately 30% in the general international population struggles to meet the guidelines.

There may be several factors that explain why individuals with chronic pain often have low or inadequate physical activity levels. A bio-psycho-social explanatory model is the Fear-Avoidance model, which suggests pain may cause fear if the individual interprets it as threatening. Such a response can increase sympathetic arousal and defensive or avoidant behaviour, which in turn, may lead to additional limitations in physical function. Brawley and colleagues highlight the importance of specific skills for adhering to long-term physical activity recommendations. Skills include behaviour change techniques (i.e., self-monitoring, goal-setting, self-reinforcement, evaluation, feedback, and
corrective behaviour) and self-management skills (i.e., problem solving, planning, interpersonal skills, coping with lapses, and the ability to reframe problems), both of which are crucial for individuals to maintain and adhere to new behaviours 85.

A number of studies have attempted to identify concrete hindrances and facilitators to physical activity in patients living with non-specific chronic low back pain 86–89. Biological barriers, such as pain and comorbidities, have been identified. Psychological hindrances, such as low motivation, lack of desire to be physically active, kinesiophobia, anticipatory anxiety, a lack of knowledge, and low beliefs in the benefits of physical activity are frequently reported. In addition, socio-environmental barriers, such as lack of time, insufficient social support, and receiving incorrect advice from healthcare staff, are also highlighted as factors that play a crucial role in individuals engaging in physical activity 86. In a secondary analysis of a randomised controlled trial by Schaller et al. 87, barriers to physical activity while partaking in rehabilitation programs for chronic low back pain were evaluated 87. Their findings reported fatigue, pain, and stress as strong barriers to physical activity. Similar barriers have been identified in other studies involving other populations with chronic pain conditions, such as patients living with rheumatoid arthritis 90. A study by Kaleth et al. 88 shifted focus by investigating facilitators for achieving a sufficient amount of time in moderate to vigorous-intensity physical activity among patients living with fibromyalgia. Their results were concurrent with previous findings, showing that the constructs of self-efficacy for intentional physical activity and a reduction of perceived barriers were associated with higher levels of physical activity 88.

**Technologically facilitated interventions to support health behavior**

Technologically facilitated tools aiming to support communication and changes in health behaviors, are commonly referred to as electronic health (eHealth), mobile health (mHealth) or telemedicine. Such technologies provide healthcare services through information and communication technologies. In the last decade, the concept of mobile health (mHealth) has expanded the number of available technologies used to provide healthcare remotely. In the literature, there are two primary motives for providing eHealth and mHealth interventions. The first refers to the sustainability of healthcare systems as a transition towards self-management of diseases or symptoms and may be resource efficient and contribute towards improved chronic care management 91. The second is that many electronically facilitated interventions include features of self-monitoring and the self-evaluation of symptoms, which serve as additional tools that can be used to facilitate self-management and improve patient empowerment 91. A systematic review on the use of technology for chronic pain in self-management interventions identified three...
main technology modalities for delivering self-management interventions; telephone-based, interactive voice response-based, and internet-based, all of which were all found to be beneficial

Technologically facilitated health-promoting interventions usually consist of several components, targeting more than one group in different healthcare settings. Such interventions often integrate elements such as physical activity components, eHealth or mHealth components (smartphone applications, web applications) and apply features of behavior-change strategies, such as education, feedback, communication, recording patient-reported outcome measures, or documenting physical activity. In this thesis, behavior-change strategies are defined in alignment with the well-known and widely accepted definition used by Michie et al.: “an observable, replicable, and reducible component of an intervention designed to alter or redirect causal processes that regulate behavior...” The inclusion of behavior change strategies aims to target patient outcomes, such as pain intensity, disability, HRQoL, self-efficacy, or levels of care-seeking, by enabling the individual mechanisms necessary for self-management and behavior change.

The potential for technologically facilitated interventions to support management and treatment of disease, have been widely reported. This is due to their potential to enhance accessibility of health care and improve physical activity, physical function, self-efficacy, emotional well-being, and functional abilities as well as to reduce sedentary behavior and decrease the frequency of care-seeking among patients living with chronic pain and other chronic diseases. Despite the popularity and scientific support of eHealth interventions for supporting physical activity behavior, improved knowledge, social support, self-efficacy, and health behaviors for patients living with chronic diseases, there is no consensus on which specific components of these interventions are the most effective.

However, the extent of user and deliverer acceptability, motivation, and adherence to treatment are considered important factors both in effectiveness testing as well as in implementation. Stoppok and colleagues describe the use of smartphones as a well-established medium for delivering eHealth interventions to patients with chronic pain. Interestingly, the inclusion of a pain scale and features designed to improve patients’ pain management skills and motivation have been described as important. This finding has been confirmed by other studies. Sorensen et al. highlight the importance of users’ ability and willingness to correctly use interventions as crucial for their effectiveness. The authors suggest that several competencies are required for individuals to successfully use an eHealth resource: the ability to access, understand, and apply them correctly.
Framework for development and evaluation of intervention

Digital interventions targeting physical activity behavior are more often than not complex by nature. This complexity arises from the interventions’ often multiple characteristics and how they generate outcomes in relation to deliverers, users, and the context they are within \(^{18}\). If the complexity is not adequately considered in the development, evaluation, and implementation of these interventions, there is a risk of poor intervention uptake or misleading results \(^{9,18,107}\). In order to successfully develop, evaluate, and potentially implement novel health-promoting interventions, these processes must be performed with careful consideration given to core elements. These include the intervention’s context, the stakeholders involved, program theory, key uncertainties, and economic factors. Taking these into account is advised as crucial to decrease the risk of research waste caused by weaknesses in study design, conduct, and implementation \(^{8,22,23}\).

Initially, a *guidance* of the evaluation process was described by the Medical Research Council (MRC) in 2006 \(^{108}\), based on an earlier framework assisting in the development and evaluation of randomised clinical trials for health improvement \(^{109}\). Since then, this guidance has undergone considerable development and was released by Skivington et al. in 2021 \(^{24}\) as a framework of rules, ideas, and beliefs that are used to plan or decide something \(^{110}\). The main objective of this framework is to aid researchers in their collaboration with stakeholders, and to use the core elements (outlined above) to plan and conduct research in an intervention’s development phase, feasibility phase, evaluation phase, and implementation phase \(^{18}\).

The Updated framework for development and evaluation of complex interventions (the MRC framework) to systematise the development and evaluation processes conducted within this thesis \(^{18,24}\). The MRC framework’s pluralistic nature and emphasis on intervention context, program theory, stakeholders, key uncertainties, economic factors, and continuous refinement (schematically illustrated in Figure 2), has guided our decisions in study designs and data collection processes \(^{8,18,24}\).
Figure 2. Illustration of the Medical Research Council’s updated framework for the development and evaluation of complex interventions. The four small circles illustrate recommended phases in the work process. Six key elements in the centre circle outline important considerations recommended for all phases. The phases applied in this thesis are: Development/identification of the intervention and Assessment of feasibility, acceptability, and study design.

In this thesis, these elements have been instrumental in guiding the overall work process, including the choice of study designs and methodologies. The framework suggests that the development and evaluation of complex interventions can be performed in four, not necessarily consecutive, phases: intervention development or identification, assessment of feasibility, acceptability and study design, evaluation of the intervention, and implementation phase. In this thesis, two of the framework’s four phases were applied: intervention development and assessment of feasibility, acceptability, and study design. In this thesis, assessment of validity is considered a part of the intervention’s development or identification phase, which is hereafter referred to as the “development and assessment of validity phase”.

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Approximately one fourth of the global general population lives with chronic pain. The bio-psycho-social consequences of chronic pain can be relentless for the individual and the costs for society as a whole are far reaching and profound. For individuals whose daily lives are severely impacted by chronic pain, assessment and rehabilitation may be provided in the form of interdisciplinary pain rehabilitation programs (IPRP), which are often considered more effective than unimodal treatments. However, as the knowledge-based evidence of IPRP’s effect on patient outcomes increases, it seems that there is room for improvement. Whether patients’ improve, remain the same, or even deteriorate after completing IPRP seems to be dependent on the specific outcome being measured and the characteristics of individuals at baseline. The notion that more individualised IPRP is required on order to improve outcomes is scientifically supported.

Overwhelming scientific evidence supports physical activity being a key element, not only in single-measure treatments but also in resource-intensive treatment programs such as IPRP. However, despite this, a large portion of patients do not reach the recommended levels of physical activity due to physical, psychological, and/or social barriers. They thereby run the risk of missing out on the general and pain-related effects appurtenant to physical activity. Simultaneously, information on physical activity levels is limited due to imprecise measurement methods. Despite the increased commercial and scientific use of device-based measurement of physical activity, clinically accessible methods for the measurement of physical activity are still mainly subjective. Regardless of the advantages of such methods, the subjective measurement method carries clear limitations in measurement accuracy, which in turn affects physical activity regimens based on measurements.

Therefore, an urgency to develop evidence-based interventions that facilitate the individualisation of physical activity treatments in IPRP has been identified. Such interventions require a clinically available, valid measurement method for assessing physical activity, something that is not available today. Finally, it is essential to take into consideration the known risks associated with intervention rejection and overly optimistic planning of resource-inten-
sive effectiveness trials \(^8,^9,^{22,23,107}\), when systematically developing and evaluating such interventions. Following established scientific recommendations for the development and evaluation of complex health-promoting interventions within the field of care sciences, it is obvious that this process must be conducted in a systematic, step-by-step manner. It must be performed in close collaboration with relevant stakeholders, and with attentive consideration to economic factors, and an understanding of how the intervention interacts within its specific context. In addition, in order to describe key components of the intervention and hypothesise the intervention’s proposed mechanisms of action, a need to develop and continuously refine a program theory was identified and highlighted. Furthermore, a stipulation to continuously strive to identify fundamental uncertainties in the intervention was made, so that necessary and adequate refinements could be carried out \(^{18,24}\).
Aim

The overarching aim of this thesis was to develop the eVIsualisation of physical activity and pain intervention (eVIS) as a digital support for individualised physical activity within Interdisciplinary Pain Rehabilitation Programs (IPRP). In addition, the aim was to evaluate the validity, feasibility, and acceptability of eVIS. Furthermore, the aim was also to evaluate the feasibility and acceptability of the trial design and conduct for a Registry-based Randomised Clinical Trial (R-RCT) that is evaluating the effectiveness of eVIS.

The specific aims for each paper in the thesis were as follows:

**Paper I**
To evaluate the criterion validity of wrist-worn activity tracking devices for estimations of energy expenditure, heart rate, and step count in a controlled laboratory setting and in a free-living setting, for patients living with chronic pain.

**Paper II**
To evaluate the content validity (relevance, simplicity, safety) of eVIS in a pre-clinical context and to evaluate the content validity and feasibility (practicality, acceptability, implementation, limited efficacy testing, demand) in a clinical pain management context.

**Paper III**
To transparently clarify and report on trial designs, aims, outcome assessments, and procedures for a planned multisite, pragmatic R-RCT initiated as a pilot study.

**Paper IV**
To evaluate the feasibility and acceptability of the trial design and conduct of an R-RCT where the effectiveness of eVIS as an addition to IPRP is evaluated.
Methods

The original conceptual idea of eVIS
The intervention in focus is referred to as the eVISualisation of physical activity and pain intervention (eVIS). The initial conceptual idea behind eVIS was to develop and evaluate a supportive treatment tool aimed at enhancing individualised physical activity treatment within IPRP 114. The primary goal of the intervention was to provide additional features known to facilitate self-management skills and behavior change.

Initially, the three key components of eVIS were i) device-based measurement of physical activity, ii) accessible behavior-change strategies for monitoring, evaluation, goal setting, and support, and iii) eVIS was envisioned to help improve self-management skills by facilitating communication between patients and physiotherapists. It was intended to be a tool that could aid identification of trends, hindrances, and facilitators of physical activity despite pain. Three domains formed the core of eVIS. The first is the data collection domain that included tools for monitoring physical activity, a device-based physical activity measurement tool, and daily patient-reported outcome measures of pain intensity and pain self-efficacy. The second is the visualisation domain that was sought to support the evaluation of trends and variations by visualising collected data. The third domain, the communication feature of the intervention, was only theoretically outlined, as eVIS was hypothesised to be used as a collaborative tool that facilitated communication and support between patients and physiotherapists.

Over the course of this thesis, the conceptual idea of eVIS and its features have undergone development and evaluation. As this process has unfolded, the eVIS intervention itself has been developed. Descriptions of the development and evaluation of eVIS as a complex intervention, as well as descriptions of the finalised intervention eVIS, are presented within the applied phases of the updated MRC framework.
Study designs and settings
This thesis includes four papers.

**Paper I**
Paper I was designed as a laboratory and field validation study to evaluate the criterion validity of one wrist-worn commercial activity tracker for its measurement of METs, HR, and SR.

**Paper II**
Paper II had a two-step observational study design. The first step involved a pre-clinical evaluation of content validity, where subject experts assessed the intervention for relevance, safety, and simplicity by rating its domains for data collection, visualisation, and communication. The second step involved the evaluation of content validity and feasibility in a clinical context.

**Paper III**
Paper III was a study protocol that aimed to transparently outline and report core features of the intervention and the details of two subsequent evaluations; 1. A two-armed multisite pragmatic randomised controlled internal pilot study, constituting the initial phase of 2. A two-armed multisite pragmatic registry-based randomised controlled clinical trial (R-RCT).

**Paper IV**
Paper IV constituted a two-armed multisite pragmatic randomised pilot study evaluating the feasibility and acceptability of trial design and conduct of the R-RCT.

In addition to framing the thesis within the updated MRC framework, it is guided by several initiatives and recommendations regarding method selection and outcomes, including the Initiative on Methods, Measurement, and Pain Assessment in Clinical Trials (IMMPACT), the Outcome Measurements of Rheumatology (OMERACT), and the Validation and Application of a patient-relevant core outcome set to assess the effectiveness of multimodal pain therapy. To ensure transparent and high-quality reporting, the Consolidated Standards of Reporting Trials (CONSORT) and the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines have been used. An overview of aims, designs, participants, settings, outcomes, and analyses in each paper can be found below in Table 1.
Table 1. Overview of aims, designs, participants, settings, outcomes, and analyses in each paper included in the thesis, organised by the two applied phases of the updated MRC framework.

<table>
<thead>
<tr>
<th>Aims</th>
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<tr>
<td><strong>Paper I</strong></td>
<td>Evaluate criterion validity of wrist-worn activity tracker</td>
<td>Laboratory and field criterion validity study</td>
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<td>Observational content validity study</td>
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**Assessment of feasibility, acceptability, study design phase in the updated MRC framework**

**Paper II, step 2**

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<th>Evaluate content validity and clinical feasibility of PATRON and eVIS</th>
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**Paper III**

<table>
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<th>Transparently report on planned study designs and conduct within IPRP</th>
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**Paper IV**

| Evaluate the feasibility and acceptability of trial design and trial conduct of an ongoing R-RCT where the effectiveness of eVIS as an addition to IPRP is evaluated | Two-armed pragmatic multisite randomised internal pilot study | Physiotherapists in IPRP (n=7) Patients in IPRP (n=39) | Swedish IPRP | Feasibility and acceptability of: 1. Recruitment- and data collection procedures, 2. Outcome data’s characteristics and completeness, 3. Occurrence of adverse events, 4. Physiotherapist’s ratings on trial design and trial conduct | Descriptive statistics Assessment of pre-defined feasibility criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Descriptive statistics (frequencies, range of ratings per item) Manifest examination of free-text comments, diaries, e-mails.
Participants and recruitment

Paper I

Participants
Participants in this study were adults (aged 18-67 years) living with chronic musculoskeletal pain in the neck or lower back or widespread pain. They were either undergoing treatment for their chronic pain or having it assessed at a healthcare unit in Region Dalarna, Sweden. In addition to meet the criteria of chronic musculoskeletal or generally widespread neck and/or back pain, participants were required to have a good ability to understand verbal and written information provided in Swedish. Potential participants who had given birth within the last three months, were pregnant in the second or third trimester, or were currently undergoing heart assessment or investigation was not eligible to participate due to the jointly performed recruitment and data collection procedures with an adjacent study including electromyography. In addition, participants who needed walking aids indoors were not eligible.

Recruitment
The recruitment process involved the participation of eight primary and specialised healthcare units in Region Dalarna. They performed the first recruitment step by distributing written and oral information about the study to all their patients that matched the study’s criteria in terms of age, characteristics of pain, and language ability. They performed a brief eligibility screening and asked for potential participants’ permission to forward their contact information to study representatives. Thereafter, potential participants were contacted by telephone and more detailed information about the study was provided. If potential participants still expressed interest to participating, a full eligibility screening was performed. If potential participants met the study criteria, a time for data collection was booked. The final step took place at the testing site (the Health and Sports Laboratory at Dalarna University), where eligibility screening was repeated, and participants provided written consent prior to any data collection.

Paper II, step 1: Pre-clinical evaluation of content validity
Paper II was designed to be conducted in two study steps. The first step consisted of the pre-clinical evaluation of content validity, while the second step involved the evaluation of feasibility within a clinical context. From now on, these steps will be presented separately as they are independent of each other, with separate methodological characteristics.
Participants
A total of ten subject experts were recruited to form a criterion measure for the assessment of content validity. These experts had to be one of the following: a patient, clinician, or researcher with expertise in chronic pain, IPRP, physical activity research, eHealth interventions, or patient-reported outcome measures. The group included four patients living with chronic pain and six clinicians, which comprised physiotherapists, occupational therapists, and psychologists. Four of the clinicians also identified themselves as researchers. In addition, a consensus panel consisting of five researchers highly involved in the study provided data for the iterative evaluation process of eVIS validity. Due to the results stipulating an extended data collection on the pharmacological report function, three additional participants, clinicians with expertise in clinical pharmacological pain management, were included in the process.

Recruitment
The recruitment of subject experts was carried out strategically and involved individuals from within researchers’ professional networks, through patient organisations and through the Swedish Quality Registry for Pain Rehabilitation (SQRP), a quality registry working to collect patient-reported data in order to assess the effects of IPRP on function, activity, quality of life, and participation in work and leisure activities. Experts represented the interventions stakeholders and its target population, and possessed clinical expertise in IPRP or research expertise in the field of IPRP, eHealth, physical activity, behavior change, or patient-reported outcome measures.

Paper II, step 2: Evaluation of feasibility in a clinical setting

Participants
The eligibility criteria for subject experts in step 2 stipulated that they had to be either patients or physiotherapists with knowledge and experience of chronic pain and IPRP. Three physiotherapists and seven patients (internal allocation 1:1, 1:3, 1:3) at three separate IPRP units tested the intervention over a period of 2-3 weeks.

Recruitment
One physiotherapist from three separate IPRP units was recruited through communications with colleagues and professional networks. Patients were recruited by these physiotherapists based on the following criteria: individuals were accepted for IPRP due to musculoskeletal or widespread (non-malignant) pain, aged 18-67 years, able to comprehend information provided in Swedish, and had daily access to a web browser via a smartphone, computer, or tablet. Patients requiring walking aids were not included.
Participating units and patients

Approximately 40 specialised healthcare units and approximately 20 primary care units offer IPRP in Sweden. Collectively, these units provided IPRP to approximately 2600 patients in 2022. Ninety percent of Swedish IPRP units systematically report comprehensive patient-reported outcome measures to SQRP. Despite IPRP in Sweden being guided by national recommendations, there are no explicit guidelines for the composition of professions within IPRP teams, time frames, treatment intensity, or program duration. According to recent reports, the treatment duration in Swedish IRPR varies widely – from 1 to 18 weeks \(^{60,69}\). Treatment intensity also varies from 10 to 150 hours per program \(^{37,60}\). Currently, there is no reported evidence favoring any specific composition of professionals, time frames, or program intensity as more effective than others.

According to current ethical approval, a maximum of 15 IPRP-units, split between primary care and specialist care, may be included in the R-RCT. Data collection for Paper IV (i.e., the initial phase of the R-RCT) took place between November 2021 and January 2023. The inclusion criteria for IPRP was based on patient-related, care process-related, and caregiver-related factors \(^{131}\). Suffering from non-malignant chronic musculoskeletal and/or generalised pain was one of the trial’s inclusion criteria. In addition to this, the following inclusion criteria were applied: aged 18-67, ability to comprehend written and verbal instructions provided in Swedish, and daily access to an internet browser. Patients in need of walking aids indoors were excluded from the trial.

Recruitment of IPRP units

Recruitment of units involved the distribution of general study information within the SQRP network through email and regular mail, including invitations to attend open digital information meetings. Approximately 50 of the existing 60 IPRP-units in Sweden were contacted. Units were selected based on the following criteria:

- Affiliated with the SQRP
- Patient throughput \(\geq 20\) per year
- Following the national criteria for IPRP \(^{131}\)

Contact was established with units that participated in the information meetings and a two-hour education module was scheduled. The module covered detailed information about the intervention, its suggested mechanisms of action, delivery, and study design including study activities. Prior to study start,
written approval for participation was collected from unit management, and study material was provided.

**Recruitment of participating patients**
Healthcare staff at the units were provided with printed patient information in the form of an easily accessible flyer and comprehensive written patient information outlining the study design. In addition, forms for written consent and eligibility screening were provided. Staff at the units were encouraged to give the flyer to patients who had been accepted for IPRP due to chronic musculoskeletal or generalised pain, prior to program start. When patients visit the unit, staff members presented the study to them and asked for permission to check their eligibility according to the inclusion and exclusion criteria. If patients agreed to this and met the study criteria, healthcare staff would then ask if they were willing to participate in the study. If a patient expressed willingness, they were given instructions on how to give written informed consent. After this, the allocation procedure was carried out by the healthcare staff member (a physiotherapist).

**Randomisation and allocation**
In order to maintain internal validity of the study, participants were randomly allocated to one of two matching groups. The randomisation schedule was computer-generated (performed by the technical company assigned to develop the web application), included random block sizes (4/6), and had a ratio of 1:1. Physiotherapists at the IPRP units oversaw the allocation process that used sequentially numbered sealed envelopes in intact blocks.

**Intervention group**
Participation in the intervention group involved taking part in the unit’s IPRP, with the addition of the eVIS intervention, for a continuous time span of six months, including the IPRP timeframe. During the education module, physiotherapists at the units received general information about eVIS and were strongly encouraged to integrate eVIS into IPRP by prompting a shared review of patient data at each appointment, communication with the patient about their own reflections on their physical activity level, goal achievement, and PROMs regarding pain intensity, pain interference, and pharmaceutical consumption. Physiotherapists received examples of discussions that guided reflections and prompted questions in order to facilitate initiation of the communication in eVIS. Example questions included: Can you show me your visualisation interfaces in eVIS? What do think about your daily activity goal, does it require revision? How does the collected information – SR, PROMs – vary over time and in relation to each other? Is the collected data evenly distributed or is there any information that needs deeper investigation?
Control group
Participation in the control group involved taking part in the IPRP at the unit and to perform daily registrations of pain intensity, pain interference and pharmaceutical consumption in PATRON during the study period. Participants in the control group did not use the wrist-worn activity tracker or have access to PATRON’s visualisation interface. The study time for the control group was also six months.

Data collection, outcomes, and analyses

Paper I

Data collection
Data collection for Paper I was carried out between March 2019 and June 2020 at the Health and Sports Laboratory, Dalarna University. Data was collected in two settings; a laboratory setting and a field setting. Prior to the primary outcome measurements, weight and height measurements were performed on site in the laboratory setting. Patient-reported outcome measurements of sociodemographic information (age, sex, work status, education level), personal characteristics (using the Multidimensional Pain Inventory Swedish version), pain-related characteristics (type, persistent/intermittent, intensity, duration, number of pain locations), and patient-reported physical activity levels (based on the National Board of Health and Welfare’s questions on physical activity level), were collected prior to testing but in accordance with testing procedures.

Outcomes
Data on the primary outcomes’ METs (the reference measure for physical activity intensity), heart rate, and step rate were collected concurrently using an experimental measure (wrist-worn accelerometry, Fitbit Versa), a criterion measure (indirect calorimetry, Jaeger Oxycon Pro), and a relative criterion measure (hip-worn accelerometer, ActiGraph GT3X) during the following activities:

- Ten minutes of seated rest
- Eighteen consecutive minutes of treadmill walk in three speeds: 3.0, 4.5, and 6.0 km/h.

At the end of each treadmill speed, participants rated their perceived exertion according to the Borg Rating of Perceived Exertion scale which ranges from 6 to 20 (where 6 represents no exertion at all and 20 represents maximal exertion). After completing the treadmill walk, participants indicated their pain
intensity on a scale of 0 to 10 (where 0 represents no pain at all and 10 represents the worst imaginable pain) using a 10 cm straight line (Visual Analog Scale, 0-10 cm)\textsuperscript{135}. In addition to the data collected within the laboratory context, data on METs and step count were concurrently collected by both the experimental measure and the relative criterion measure during a free-living period of 72 hours. Participants were encouraged to go about their daily lives, wear their device for at least 10 hours each day, and register their wear-time in a logbook. All participants were provided with a prepaid envelope to facilitate the return of the devices.

**Analyses**

Analyses were conducted in order to describe the personal and pain characteristics of participants. Descriptive statistics were calculated and presented as mean, standard deviation, and frequencies. In order to determine Fitbit Versa’s criterion validity for the measurement of METs, HR, and SR, evaluations of agreement, correlation, systematic differences, and accuracy between measurements were performed by the experimental, the criterion, and the relative criterion measurements.

Assessment of agreement was performed using several calculations. First, by intraclass correlation coefficient (ICC) [2-way random, average measures, 95% confidence interval, absolute agreement]\textsuperscript{136,137}. Cut-off values for agreement were set at the following: 0.4 = poor, 0.4 - 0.59 fair, 0.6 - 0.74 = good, >0.75 = excellent\textsuperscript{138}. Secondly, in order to visualise agreement between measurements, Bland-Alman Plots with 95% confidence intervals (limits of agreement [LOA]) were conducted\textsuperscript{138}. Thirdly, as a measure of accuracy, Mean Absolute Percentage Error (MAPE) was calculated. Values of MAPE <1% in the laboratory setting were considered acceptable, as were MAPE <10% in free-living measurements\textsuperscript{139}. Assessment of correlations using Spearman bivariate correlation analysis was performed with the following cut-offs for correlations (ρ): <0.2 was considered poor, 0.2 to <0.6 was considered fair, 0.6 to <0.8 was considered moderate, 0.8 to <0.9 was considered very strong, 0.9 to <1 was considered perfect\textsuperscript{140}. Systematic differences between measurements were assessed using analysis of variance (ANOVA).

**Handling of missing data and sensitivity analysis**

Missing data was documented, which could be due to the value being characterised as an outlier, discontinuation during the treadmill walk, non-wear time, missing logbooks, or device malfunction. Sensitivity analysis was performed as recommended by Fox-Wasylyshyn\textsuperscript{141} in order to detect associations between missing data and patient characteristics\textsuperscript{141}.
Paper II, step 1: Pre-clinical evaluation of content validity

Data collection
In order to evaluate the content validity of eVIS, ratings were collected using a four-point Likert scale to quantify the relevance, simplicity, and safety of eVIS. The following ordinal rating scale was applied: 1: Not relevant/simple/safe, 2: Needs revision, 3: Relevant/Simple/Safe but needs minor alteration, 4: Very relevant/simple/safe. Experts were encouraged to provide free-text comments wherever they needed to clarify their ratings.

Expert ratings were obtained independently from each other and focused on eVIS’s key domains; data collection, visualisation, and communication. Ratings were collected through a web-based questionnaire 116, which was developed and piloted by the research group before it was distributed via email to respondents.

Outcomes
The content validity was evaluated based on inter-rater agreement among subject experts regarding the intervention’s relevance (i.e., the extent the element of measurement reflects the construct of interest), simplicity (i.e., how simple the element of measurement is perceived to be to users), and safety (i.e., the perceived level of safety when using the measurement element). The evaluation focused on the four intervention domains; data collection, visualisation, communication, and eVIS as a whole. After summarising results on proportions of agreement among expert raters for each item, any uncertainties identified by the experts, such as low ratings or concerns provided in the free text comments, were discussed within the consensus group. As a final step, the description of eVIS in the questionnaire was revised. A total of three rounds of expert assessments were performed, with revisions made between each round.

Analyses
An Item-Level Content Validity Index (I-CVI) was calculated for each content validity aspect (relevance, simplicity, safety) of each item, resulting in I-CVI values ranging from 0 to 1. A threshold for excellent I-CVI was set to ≥0.78 in accordance with traditional recommendations 116. In addition, the Scale-Level Validity Index Average (S-CVI/Ave) was calculated by summing all I-CVI values and dividing the total by the number of items. Such calculations provided a measure of inter-rater agreement and the threshold for excellent S-CVI/Ave was set at ≥0.9. The third and final measure assessed was Universal Agreement. This value, the S-CVI/UA, measures the proportion of items rated as excellent (≥0.3) by experts, and was considered to be excellent if it was ≥0.8. Free-text comments were interpreted at a manifest level.
Paper II, step 2: Evaluation of feasibility in a clinical setting

Data collection
In order to test the eVIS intervention in a real clinical setting and answer the overarching question of its suitability within the indented setting (IPRP), the second step of Paper II aimed to assess eVIS’s feasibility\textsuperscript{117}. Data was collected on the clinical feasibility of eVIS from both physiotherapists (n=3) and patients (n=7) using two questionnaires designed to capture their ratings of eVIS across the intervention domains, including data collection, visualisation, and communication. Feedback was given using a four-point Likert scale.

Outcomes
In this phase of the study, five focus areas of feasibility were applied, following the framework proposed by Bowen\textsuperscript{117}. These focus areas were: practicality (to what extent the intervention could be carried out with intended participants using existing means and resources without the need for outside intervention), acceptability (to what extent the intervention was perceived as suitable, satisfying, or attractive by the intervention deliverers and recipients), implementation (to what extent the intervention was successfully delivered to the intended participants in a defined but not fully controlled context), limited efficacy testing (the extent to which the intervention showed promise of being successful within the intended population), and demand (the extent to which the intervention was likely to be used). Feasibility was assessed using a four-point Likert scale ranging from 1 to 4, where 1 indicated ‘Not at all feasible’, 2: ‘To some extent feasible’, 3: ‘To a rather large extent feasible’, and 4: ‘To a large extent feasible’). In addition, data in the form of analogue diary entries were collected from both patients and physiotherapists, which included information on participants’ experiences of the support function.

Five items of content validity, initially used in step 1 of the study, were included in this study step. The items included overall ratings of eVIS’s domains, including data collection, visualisation, and communication, with one item specifically targeting the pharmaceutical report function. As in step 1, a four-point Likert scale was used to assess relevance, simplicity, and safety, where 1 indicated ‘Not relevant/simple/safe’, 2 indicated ‘Needs revision’, 3 indicated ‘Relevant/Simple/Safe but needs minor alteration’, and 4 indicated ‘Very relevant/simple/safe’. Finally, two physiotherapists and three physicians partook in two separate video interviews aimed to gather immersed data in two specific areas (pharmacological report function and recruitment procedures).
Analyses
In this study step, patient, and physiotherapist ratings on five content validity items were analysed, following the same method as described in step 1. For the feasibility ratings from patients and physiotherapists, descriptive analysis was carried out, with the results reported as frequencies and ranges. The feasibility was considered to be satisfactory if ratings were $\geq 3$. Items targeting content validity were calculated in accordance with the procedures previously reported in step 1.

Handling of missing data
Any known reasons for data loss were documented. No specific analyses were performed in regard to missing data.

Paper IV

Data collection
In order to evaluate the feasibility and acceptability of eVIS within the context of IPRP and the study design, data was collected through two sources: responses to questionnaires (providing data on the primary outcome and physiotherapists’ ratings of feasibility and acceptability), and data retrieved from the web application PATRON (providing PROMs on pain intensity, pain interference, and pharmaceutical consumption).

In the pilot study, data on the R-RCT’s primary outcome, PCS, was collected manually using RAND-36 as a web-based questionnaire. This data, according to planned methodology, will be collected from registry data in the main trial. At baseline and at follow-up six months after IPRP, all participants received RAND-36 digitally. Up to four reminders were distributed via email and SMS to minimise data loss. The reasoning behind collecting primary data by questionnaire (instead of registry data as planned for the main trial) was convenience, as the retrieval of registry data was considered to be too time consuming. Secondly, in order to collect data on how physiotherapists within the IPRP units rated the feasibility of the study design and acceptability of eVIS, a web-based questionnaire comprising 31 items was developed, pilot tested within the research group and distributed to the physiotherapists in the participating IPRP units. They received the questionnaire via email through Sunet Survey in November 2022, and were reminded to compete it twice. The questionnaire was distributed after being piloted within parts of the author group.

In the main trial, where we aim to assess the effectiveness of eVIS in improving physical health after IPRP compared to IPRP alone, we will collect primary and secondary outcome data from a number of sources, including six Swedish quality registries, data export from the web application PATRON,
and questionnaire responses. For a detailed overview of time points and outcome assessments, specific instruments, and data sources for the main trial and Paper IV.

Outcomes
In this pilot study, we will assess the characteristics of IPRP units and participating patients in order to evaluate the feasibility of recruitment and data collection procedures in the R-RCT. In addition, the proportion of eligible patients who were randomised to either the intervention group or the control group will be analysed, as well as the proportion of participants who were lost to follow-up. This will provide important information on the data collection procedures.

Characteristics and completeness of outcome data in the R-RCT
When evaluating the effectiveness of health-promoting interventions, the primary outcome is often a subjective measurement of health status \(^3\), which is recommended \(^123,124\). Measurement of physical function is included as one of the eight components of the generic health survey RAND-36, which is the best-known PROM used to measure HRQoL. The RAND-36 survey consists of 36 items that are divided into eight different subscales, namely physical functioning, social functioning, role limitations due to physical problems, role limitations due to emotional problems, mental health, vitality, pain, general health perception. Several of these subscales overlap with the core outcome domains recommended by the authors of the Validation and Application of Patient Relevant Core Outcome Set to Assess the Effectiveness of Multimodal Pain Therapy (VAPAIN) study \(^125\).

The health survey RAND-36 was initially intended to measure two independent domains of health; mental health and physical health \(^142\). These two domains are expressed as composite scores, namely the physical component summary scale (PCS) and the mental component summary scale (MCS), based on the eight subscales \(^142\). The physical health construct derived from RAND-36 (equal to Short Form-36) is a composite outcome, scientifically recommended as outcome in clinical pain management trials \(^143\). This combined outcome or composite outcome is known as the Physical Component Summary Scale (PCS), and provides scores on a scale ranging from 0-100, where lower values indicate poorer physical health and higher values indicate better physical health \(^144\). The argument behind using a composite outcome like PCS is grounded in the notion that such an outcome can provide a global estimate of multiple constructs that are important to the target population \(^143\). The PCS value can be calculated differently according to the researcher’s perspective on whether the two main constructs (mental health and physical health) in RAND-36 are independent of each other or not \(^145\)-147. The measurement properties of PCS have been evaluated for individuals living with chronic pain,
demonstrating acceptable structural validity, test-retest reliability, and responsiveness to changes over time 148-150.

In order to interpret clinically relevant changes in PCS and, by extension, establish the effectiveness of eVIS, a Minimal Clinically Important Difference (MCID) was applied 151. In this thesis, an MCID is defined as the smallest change in a certain PROM that constitutes a beneficial difference for the patient between two measurement points, in the absence of extreme costs or burdensome side effects 152. Several MCID values for PCS have been proposed ranging between 2.06-5.73, however, an MCID of 3 is commonly applied 69,153-155.

Secondary outcomes in the effectiveness trial are daily patient-reported data collected through the web application PATRON. These outcomes consist of; pain intensity measured on an 11-point numeric rating scale, where participants mark the number corresponding to their average pain over the last day, (ranging from 0 = no pain at all to 10 = the worst imaginable pain) 156, pain interference measured on an 11-point numeric rating scale, where participants mark to what extent their daily activities are affected by their pain over the last day, (ranging from 0 = not at all to 10 = to a very large extent), pharmaceutical consumption where participants report the name, form, dose, and strength of any pharmaceuticals consumed related to the pain experience. For participants in the intervention group, additional device-based measured data on daily step rate and physical activity goals were collected. In this pilot study, characteristics and completeness of secondary outcome data will also be collected as an outcome on feasibility.

Also as an outcome assessing the feasibility and acceptability of the trial design and conduct, physiotherapists’ ratings were collected covering the following areas: 1. Willingness/attractiveness to participate as an IPRP unit in the study, 2. Acceptability and ability to perform study activities, 3. Feasibility of current conduct, 4. Implementation process, and 5. Adverse events in relation to eVIS. The survey had a total of 31 items, of which 27 used a 4-point Likert scale with the following grades: 1: Not at all, 2: To some extent, 3: To a rather large extent, 4: To a large extent. One item used a 5-point Likert scale with the following grades: 1. 0%, 2. 1-24%, 3. 25-49%, 4. 50-74%, 5. 75-100%. Of the remaining three items, one provided a free text response, one had a dichotomised response (yes/no), and one used a response scale of 0-10 where 0 represented ‘not at all appropriate’ and 10 represented ‘very appropriate’. Respondents were encouraged to provide free text comments with all their responses.
**Sample size calculations**

For Paper IV, a sample size requirement of at least 30 participants (n=15 + n=15) was considered sufficient based on previous research that suggests that a sample size of at least n=30 is deemed sufficient for pilot studies.\(^{157,158}\). Secondly, given that this pilot study does not aspire to involve any hypothesis testing or sample size calculations *per se*, a smaller sample size was deemed preferable.

In the R-RCT, a preliminary power calculation was performed, based on assumptions from previous research regarding the percentage of patients who report a minimal clinically meaningful difference (MCID) of ≥3 in the PCS scale, which ranges from 0 to 100, 12 months after completing IPRP.\(^69\). The calculation used a method for simple randomisation and independent observations and allowed for a dropout rate of 20%. A total sample size of ñ=400 was required to achieve an 80% statistical power to detect a 15% difference between the intervention and control groups.

**Analyses**

In Paper IV, patient and IPRP unit characteristics, as well as outcomes related to data collection procedures, will be presented descriptively.

Characteristics (mean, SD) of the primary outcome were presented both in total and per group to enable assessment of the sample’s representativeness. In addition, the difference in percentage of patients who showed improvement from baseline to follow-up, defined by MCID ≥3 and by a stricter MCID≥10, was calculated to indicate appropriateness of the interim power calculation, which is presented in detail elsewhere.\(^{159}\). The calculations of the PCS were made according to Taft et al.,\(^{146}\) using norm values from the Swedish population provided by SQRP. In order to assess the completeness of secondary outcome data, the extent and long-term adherence to daily registrations were calculated by counting *valid weeks*. A valid week was defined as a week in which a participant completed at least four of the week’s possible registrations (seven). In this pilot study, the acceptable level for valid weeks was set at ≥70% of the total number of weeks (18 of 26 weeks). Proportions and frequencies of participants with acceptable levels of valid weeks were calculated for each group, per outcome, for the total study period (26 weeks), as well for the study period divided into three equal parts (first period = week 1-8, second period = week 9-17, third period = week 18-26). This division allows an assessment of participants’ adherence over the course of the study period.

Physiotherapist’s ratings of feasibility, measured on a four-point Likert scale, were calculated and presented as percentages (%) of ratings. For items with a
0-10 response scale, the median was presented. The study followed methodological recommendations for assessing the feasibility of the R-RCT – several criteria for satisfactory feasibility and acceptability were defined\(^\text{18,120}\).

Satisfactory recruitment and data collection procedures:
- ≥50% of planned IPRP-units (n=15) were recruited within the first six months.
- Included IPRP units were representative of Swedish IPRP in terms of included professions, program duration, and program intensity.
- Included patients were representative of the target population regarding personal and pain characteristics.
- Inclusion rate of ≥10% of the target population with complete baseline and follow-up data was achieved within the first six months.
- <1 adverse event.

Satisfactory feasibility and acceptability as rated by physiotherapists in IPRP
- Satisfactory feasibility (≥3) of study activities designed to attract IPRP units.
- Satisfactory feasibility (≥3) of physiotherapists’ ability to perform study activities and their willingness to randomly allocate participants.
- Satisfactory acceptability (≥3) of the conduct of study activities.
- Satisfactory feasibility and acceptability (≥3) of the implementation process.

Satisfactory characteristics and completeness of outcome data
- <20% of primary outcome data were missing due to dropout or failed completion of baseline or follow-up data.
- For each secondary outcome, data completeness was considered satisfactory if ≥70% of participants provided valid data (i.e., ≥4 of 7 registrations per week) for at least 18 weeks of the complete study period (26 weeks).
- Acceptable longitudinal adherence to data collection, with ≥70% providing valid data in each study period.
- Satisfactory ratings of data accessibility by involved researchers.

An overall assessment of the above outlined criteria was performed in order to identify potential issues in the design and conduct of the R-RCT. Assessments will be categorised as satisfactory (i.e., no changes in design or conduct are required), moderately satisfactory (i.e., changes in design or conduct may be required), or insufficient (i.e., the feasibility of the design or conduct is not appropriate).\(^\text{120}\)
Handling of missing data

Any known reasons for data loss were documented. No specific analyses were performed in regard to missing data.
Results

Development and assessment of validity phase

Evaluation of criterion validity of the wrist-worn activity tracker (Paper I)

Participant characteristics

<table>
<thead>
<tr>
<th>Participant characteristics</th>
<th>n=41</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>43.8 (11.8)</td>
</tr>
<tr>
<td>Sex, females n (%)</td>
<td>31 (76)</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>29.4 (5.8)</td>
</tr>
<tr>
<td>Education, n (%)</td>
<td></td>
</tr>
<tr>
<td>Elementary</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Secondary</td>
<td>28 (68)</td>
</tr>
<tr>
<td>University</td>
<td>12 (29)</td>
</tr>
<tr>
<td>Employment status, working/studying, n (%)</td>
<td>27 (66)</td>
</tr>
<tr>
<td>Years with pain</td>
<td></td>
</tr>
<tr>
<td>3 months to 5 years</td>
<td>20 (49)</td>
</tr>
<tr>
<td>6 – 10 years</td>
<td>5 (12)</td>
</tr>
<tr>
<td>&gt;10 years</td>
<td>15 (37)</td>
</tr>
<tr>
<td>Physical exertion at treadmill walk according to Borg RPE scale (6-20)</td>
<td></td>
</tr>
<tr>
<td>At 3.0 km/h, mean (SD)</td>
<td>9 (2)</td>
</tr>
<tr>
<td>At 4.5 km/h, mean (SD)</td>
<td>12 (2)</td>
</tr>
<tr>
<td>At 6.0 km/h*, mean (SD)</td>
<td>14 (2)</td>
</tr>
<tr>
<td>Self-reported physical activity level**, minutes per week</td>
<td></td>
</tr>
<tr>
<td>Exercise, n (%)</td>
<td></td>
</tr>
<tr>
<td>0-30</td>
<td>15 (37)</td>
</tr>
<tr>
<td>31-90</td>
<td>11 (27)</td>
</tr>
<tr>
<td>91-120</td>
<td>11 (27)</td>
</tr>
<tr>
<td>&gt;120</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Physical activity, n (%)</td>
<td></td>
</tr>
<tr>
<td>0-60</td>
<td>8 (20)</td>
</tr>
<tr>
<td>61-150</td>
<td>13 (32)</td>
</tr>
<tr>
<td>151-300</td>
<td>7 (17)</td>
</tr>
<tr>
<td>&gt;300</td>
<td>13 (32)</td>
</tr>
</tbody>
</table>

*n=36, **As assessed by the National Board of Health and Welfare’s questions on physical activity levels133.
Out of the 42 participants included in the study, 41 completed all data collection procedures. Their mean age was approximately 44 years (SD 11.8) and 76% were female (see Table 2). Almost 50% of the participants reported being physically active for at least 150 minutes per week, as assessed by the National Board of Health and Welfare’s questions on physical activity levels\textsuperscript{133}. Notably, 36 of the participants managed to complete the treadmill walks at all three speeds. Those who discontinued the treadmill walks did so at the highest speed of 6.0 km/h (n=5) and reported that their reason for this was either physical exertion or increased pain.

**Comparison between the wrist-worn activity tracker versus indirect calorimetry**

Results indicated poor agreement between measurements of METs by Fitbit Versa in the laboratory setting and measurements by indirect calorimetry during overall treadmill walks (ICC -0.03, 95% CI -0.08 to 0.08). Systematic differences were observed between measurements in all three individual treadmill speeds as well as during the overall treadmill walk ($P \leq 0.001$).

Agreement in the measurement of HR was excellent during seated rest (ICC 0.99, 95% CI 0.98 to 0.99) and the correlation between measurements was strong ($p=0.96$, $P \leq 0.001$). However, the level of agreement was lower during the treadmill walks compared to seated rest. The best agreement during the treadmill walks was observed at 6.0 km/h with an ICC of 0.40 (95% CI -0.09 to 0.68).

**Comparison between the wrist-worn activity tracker versus the hip-worn accelerometry**

In the second step of comparisons, METs measured by Fitbit Versa and ActiGraph GT3X in the laboratory setting showed very poor agreements at all treadmill speeds (ICC -0.01, 0.02, -0.14), as well as in the overall treadmill walks (ICC -0.04). However, agreement was slightly higher in free-living activities (ICC 0.46), although with large CI (-0.16 to 0.80).

There was a fair agreement (ICC 0.60, 95% CI 0.03 to 0.82) and a strong significant correlation ($p=0.51$, $P \leq 0.001$) in SR measurements by Fitbit Versa and ActiGraph GT3X during the overall treadmill walk. This result also held for the two first treadmill speeds (ICC 0.71, 95% CI 0.44 to 0.84 and ICC 0.69, 95% CI 0.29 to 0.85), but agreement decreased dramatically at 6 km/h (ICC 0.05, 95% CI -0.51 to 0.35).
Development of eVIS and pre-clinical evaluation of content validity (Paper II, step 1)

**Preparation**

The development of the intervention was initiated in May 2019 with a full day *system play* organised by Nordforce Technology AB, the software company in charge of the intervention’s software. This system play consisted of 24 scripted hypothetical scenes, all depicting possible scenarios that users, deliverers, and developers might experience when using the web application PAin and TRaining ONline (PATRON). In total, 11 stakeholders participated in the play, including three researchers, two software programmers, three patient representatives, one clinician (physiotherapist), and two management representatives from Nordforce. Each scene was acted out with a focus on user interfaces, information requirements in the application, data security, data visualisation, etc. Points of views from all stakeholders were carefully documented.

Based on this input, a Beta version of the web application was created, which enabled further development and evaluation of its content validity (relevance, simplicity, safety) with focus on eVIS’s domains (data collection, visualisation, communication). Domains and functions of this initial version of the intervention was described in writing and by figures or pictures, framed as a questionnaire.

**Participant characteristics**

The group of subject experts consisted of four patient representatives and four researchers who also identified themselves as clinicians (including two occupational therapists, one psychologist, and one physiotherapist). The remaining two participants identified themselves as clinicians, both being physiotherapists.

**Pre-clinical content validity**

The pre-clinical evaluation of content validity produced primarily favorable results, with high ratings for content validity aspects (relevance, simplicity, safety) across all evaluated domains of eVIS (data collection, visualisation, communication, and eVIS as an entity). The majority of items were rated as highly relevant, simple to use, and safe, with the lowest S-SCI/Ave of 0.94 for relevance in the first round, and 0.96 for simplicity in the final round.

Despite the overall positive results, a few particularly important findings require attention. Firstly, within the data collection domain, two items regarding the initially proposed daily PROM for pain self-efficacy (the 2-item Short
Form Self Efficacy Questionnaire, PSEQ-2) rendered low safety ratings during the first round of assessment (I-CVI 0.70). Secondly, the proposed translation of the introductory text for the PSEQ-2 also received a low I-CVI in the first round (I-CVI 0.60). The introductory text was revised throughout the assessment rounds and received a rating of 1.0 indicating excellent relevance in the final round. However, free-text comments from experts and discussions within the consensus group led to the conclusion being made that the item was not appropriate for daily PROMs. Instead, the item was replaced by one from the MPI Swedish version. To enable concurrent visualisation, the original response scale of 0-6 was replaced by a response scale of 0-11.

Further crucial information emerged during Step 2 of the evaluation process where the safety aspect of the data collection domain was given a very low ranking by physiotherapists (I-CVI 0.33). It was discovered that an unintentional linking of one user’s Fitbit profile was made to the general Fitbit community. This linkage allowed for unwanted contact attempts from other Fitbit users and resulted in stricter guidance being provided on how to alter the default settings in the Fitbit application to “private”, which prevented unwanted contact from other Fitbit users.

In the visualisation domain, the graphical interfaces displaying collected data rendered ratings above cutoffs, yet subject experts still assessed them to be problematic. Both the 1-day view and the 28-day view were perceived as having issues. To address this, all graphical interfaces were revised in terms of the color choice, additions were made to the guiding text, and adjustments were made to the graphical interfaces.

In the visualisation domain, the ratings for relevance and safety achieved good content validity, but ratings for simplicity did not reach the level of excellent content validity (I-CVI 0.75 after final round). In addition, throughout the clinical test period physiotherapists rated the pharmaceutical report function in eVIS as low (I-CVI 0.33), but patients’ concurrent ratings of the same item were high (I-CVI 1.00). This was explained in the free-text comments, which showed that physiotherapists had not fully explored the pharmacological report function and therefore could not provide an accurate assessment. Based on this, it was decided to include this feature in step 2 of the evaluation.
Assessment of feasibility, acceptability, and study design phase

Assessment of feasibility in a clinical context (Paper II, step 2)

Concurrently with step 1 of Paper II, the web application PATRON underwent further development in collaboration with Nordforce Technology AB. Based on the findings in step 1, the web application was continuously refined and the launch of the 1.0 version was in the spring of 2021. The revisions and subsequent release of the web application provided the possibility to clinically test the intervention in a real-world setting, i.e., within a context of pain rehabilitation.

Participant characteristics

In the study, three physiotherapists from three separate IPRP units participated as subject experts and provided ratings on eVIS’s feasibility in a clinical context. Two of the physiotherapists also participated in the video interview. Five of the seven patient participants provided feasibility ratings from a patient perspective through a questionnaire and also provided diary notes. All the physiotherapists and two patients provided data on the intervention’s support function. Due to the results invoking additional data collection regarding the pharmaceutical report function, video interviews were conducted with three physicians, one of whom also identified as a researcher.

Feasibility in a clinical context

After the test period, both physiotherapists and patients were asked to provide feedback on their experience with the feasibility of eVIS through a web questionnaire. Results were categorised according to five of Bowen’s eight focus areas of feasibility: practicality, acceptability, implementation, limited efficacy testing, and demand. In summary, the results indicated that the acceptability of eVIS was high among patients and physiotherapists who all rated it as acceptable (≥3). However, for the outcome practicality, the pharmacological function of eVIS was highlighted as problematic. All physiotherapists and one of the five patients rated this as low. This finding resulted in interviews being conducted with three experts in clinical pharmacological pain management. Based on their insights, the list of pharmaceuticals in PATRON was considerably extended to include medications for prevalent comorbidities associated with chronic pain.

Both physiotherapists and patients identified a clinical demand for eVIS in pain management. Physiotherapists expressed high ratings on willingness to use eVIS in their work. They also rated the possibilities of integrating eVIS into the clinical context without any changes (implementation) as moderately high, with two of the three physiotherapists rating it as ≥3. Implementation was also rated through items on how the eligibility criteria were perceived and
the perceived ease of assisting patients with the study start-up procedure. Overall, implementation was rated as high. Adjacent to implementation, the concept of limited efficacy testing was assessed through items aiming to determine to what extent eVIS could be implemented without adaption.

The finalised intervention eVIS

After the completion of development and validity assessment phases, the intervention was defined with five key features (see Figure 3):

1. Daily device-based monitoring of physical activity levels quantified as steps per day, using a wrist-worn activity tracker (Fitbit Versa 2)
2. Daily data collection of the following patient-reported outcomes (PROMs): pain intensity (0-10), pain’s interference with daily activities (0-10), and pharmaceutical consumption (name, dose, strength, quantity) in a developed web application named PAin And TRaining ONline (PATRON).
3. Collaborative activity goal setting: If desired, patients could choose to formulate and continuously evaluate a daily activity goal (steps per day) in collaboration with the IPRP team.
4. Graphical visualisation of data: Data collected from the above features are graphically visualised in time frames of 1 day, 7 days, and 28 days in the web application PATRON.
5. Interactive interface for clinical decision making: Patients, together with the IPRP team if desired, can repeatedly and mutually review eVIS’s interfaces (graphical visualisation), enabling improved and detailed clinical decision making to support individualised physical activity levels.

Figure 3. Schematic illustration of eVIS and its key features after finalised development and validation phase. Features of the web application PATRON are indicated by grey rectangle.
In addition, following the recommendations of the updated MRC framework, researchers are advised to develop and continuously revise a robust program theory outlining the intervention’s theoretical foundation and how it is proposed to work.\textsuperscript{8,160,161}

The eVIS intervention rests on two broad foundation pillars, both of which are applied to enable behavior change and self-management skills. The first pillar is Bandura’s Social Cognitive Theory (2001, 2004)\textsuperscript{162,163}. Bandura outlines several constructs important to behavior change:

- The interaction between the individual, environment, and behavior.
- The individual’s ability to conduct behaviors is linked to their knowledge and skills related to the behaviors, and their individual will to learn from the consequences of behaviors.
- A behavior may be successfully modeled by other individuals.
- With internal or external reinforcements, you can increase or decrease the likelihood of a behavior continuing.
- Anticipated consequences of a behavior can influence if the behavior continues or not.
- The individual’s own confidence in their ability to perform the behavior (self-efficacy) is crucial.\textsuperscript{162,163}

The second pillar of the intervention draws from the thoughts of Pain Neuroscience and aims to relieve psychosocial pain triggers and pain beliefs such as catastrophising and avoidant behavior through education, explanations of pain, safe exposure to pain, and the facilitation of action planning.\textsuperscript{59,64}

The intervention is envisioned to provide behavior-change strategies of monitoring, feedback, reinforcement, goal setting, information, prompts, and support. These strategies are hypothesized to evoke mechanisms of action, including motivation, learning, self-regulation, outcome expectations, knowledge, and practice. A complete program theory is presented in Figure 4.
Figure 4: Identified problems, input from the IPRP, and the facilitating behavior change strategies inherent to eVIS. The proposed mechanisms of action (MoAs) in eVIS are described in terms of proximal and distal outcomes.
Assessment of feasibility, acceptability, and study design (Paper IV)

Recruitment and data collection procedures
In the process of recruiting Swedish IPTP units, 50 of Sweden’s approximately 60 IPRP units were sent an e-mail with a brief overview of the study and an invitation to attend an open digital meeting where the study would be described in more detail. Twenty-three IPRP units participated in one of 17 digital meetings. Of these, seven units, with a total of ten physiotherapists, accepted participation, however, one discontinued participation almost immediately. The participating IPRP units varied in their yearly throughput of patients, program duration, and program intensity. They had a range of 40-300 patients per year (see Table 3), program durations of 4-20 weeks, and an intensity ranging from two hours per day up to eight hours per day. The frequency per week also varied from offering a completely tailored frequency based on each individual patient’s needs, up to four days per week.

Table 3. Characteristics of participating IPRP units in Paper IV.

<table>
<thead>
<tr>
<th>Units (1-6)</th>
<th>Patient throughput (n)</th>
<th>Professions represented in team (n)</th>
<th>Main treatment form</th>
<th>Program duration</th>
<th>Program intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~120</td>
<td>Physiotherapist, physician, occupational therapist, access to behavioral scientist and psychologist (3/5)</td>
<td>Group based (only)</td>
<td>4 weeks</td>
<td>6-8 hours/day</td>
</tr>
<tr>
<td>2</td>
<td>~100</td>
<td>Physiotherapist, physician, psychologist, social worker, rehabilitation coordinate (5)</td>
<td>Group based (mostly)</td>
<td>8-12 weeks</td>
<td>2-3 days/week for 8 weeks, 1 day per week for 4 weeks</td>
</tr>
<tr>
<td>3</td>
<td>~300</td>
<td>Physiotherapist, physician, psychologist, nurse with psychotherapist competence, access to occupational therapist (4/5)</td>
<td>Individual (only)</td>
<td>12-20 weeks</td>
<td>3-4 days/week, 1.5 h/day</td>
</tr>
<tr>
<td>4</td>
<td>~80</td>
<td>Physiotherapist, physician, occupational therapist, psychologist, nurse (5)</td>
<td>Individual (only)</td>
<td>Tailored to patient’s needs</td>
<td>Maximum 2 hours/day</td>
</tr>
<tr>
<td>5</td>
<td>~40</td>
<td>Physiotherapist, physician, occupational therapist, psychologist, social worker, nurse (6)</td>
<td>Individual and group based</td>
<td>13/15 weeks</td>
<td>3 days/week, 4 hours/day</td>
</tr>
<tr>
<td>6</td>
<td>~80</td>
<td>Physiotherapist, physician, occupational therapist, psychologist (4)</td>
<td>Group based (mostly)</td>
<td>5 weeks</td>
<td>3 days/week, 7 hours/day</td>
</tr>
</tbody>
</table>

During the recruitment period, approximately 180 patients were assessed for study eligibility, and 65 were randomised to either the intervention or the control group. Of the 115 patients who were not allocated, the majority declined participation (n=77), eleven did not meet eligibility criteria, and the remaining (n=27) were excluded for unknown reasons. A CONSORT chart detailing the study design including recruitment details may be found in Figure 5. By the time of the data collection for this pilot study was completed, a total of 17
participants were lost. Six were lost to drop-out and eleven failed to complete either baseline or follow-up data (n=11).

The inclusion of participating patients continued until at least 15 patients in each group had provided complete baseline and follow-up data. The mean age of participants was approximately 44 years (SD 11.4), with 74% of the total participants being female (across both groups) (see Table 4). When looking at the characteristics of the groups separately, the distribution of females was almost 90% in the intervention group, compared to 60% in the control group. Participants in the intervention group had a median SR of approximately 8000 steps, and they rated their pain intensity on a scale of 0-10 with a median of 5.5 (range 2-10). The control group had a median rating of 6.5 (range 3-9). The corresponding ratings for pain interference (0-10), were 6.0 (range 1-10) in the intervention group and 6.5 (range 1-10) in the control group. All participants reported pharmaceutical consumption related to chronic pain.

Figure 5. CONSORT 2010 flow chart illustrating the study design and enrolment procedure in Paper IV.
**Table 4. Overview of personal and pain characteristics for patients in total and in either group.**

<table>
<thead>
<tr>
<th>Personal and pain characteristics</th>
<th>Total (n=39)</th>
<th>Intervention group (n=19)</th>
<th>Control group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age years, mean (SD)</td>
<td>43.5 (11.4)</td>
<td>45.3 (12.4)</td>
<td>41.8 (10.3)</td>
</tr>
<tr>
<td>Sex, % female</td>
<td>74.4</td>
<td>89.5</td>
<td>60.0</td>
</tr>
<tr>
<td>PROM pain intensity (0-10), median [range]</td>
<td>6.0 [2-10]</td>
<td>5.5 [2-10]</td>
<td>6.5 [3-9]</td>
</tr>
<tr>
<td>PROM pain interference (0-10), median [range]</td>
<td>6.0 [1-10]</td>
<td>6.0 [1-10]</td>
<td>6.5 [1-10]</td>
</tr>
<tr>
<td>Pharmaceutical consumption, % (n)</td>
<td>100 (39)</td>
<td>100 (19)</td>
<td>100 (20)</td>
</tr>
<tr>
<td>Step rate, median [range]</td>
<td>N/A</td>
<td>7894 [816-27408]</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Abbreviations: PROM = Patient-reported outcome measure, N/A = Not applicable

**Characteristics and completeness of outcome data**

*Primary outcome in the R-RCT*

In the intervention group, participants rated their physical health at baseline to be an average of 30.40 (SD 8.05) and 38.39 (SD 11.96) at the six-month follow-up. In the control group participants rated their physical health at baseline to be an average of 31.90 (SD 6.20) and 35.13 (SD 9.36) at the six-month follow-up. A detailed breakdown of means and SDs is outlined in Table 5.

**Table 5. Characteristics of the primary outcome PCS at baseline and at follow-up, presented in total and per group.**

<table>
<thead>
<tr>
<th></th>
<th>Total (n=39)</th>
<th>Intervention group (n=19)</th>
<th>Control group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCS (0-100), mean (SD)</td>
<td>30.66 (7.07)</td>
<td>30.40 (8.04)</td>
<td>30.90 (6.20)</td>
</tr>
<tr>
<td></td>
<td>36.72 (10.69)</td>
<td>38.39 (11.96)</td>
<td>35.13 (9.36)</td>
</tr>
</tbody>
</table>

Abbreviations: PCS: Physical Component Summary Scale.

In order to assess the feasibility of the primary outcome and to evaluate the appropriateness of the interim power calculation, the proportions and 95% confidence intervals (95% CI) of participants who improved, remained unchanged, or deteriorated from baseline to follow-up were calculated for each group (Table 6). Two different cut-offs were used for improved, unchanged, and deteriorated: MCID≥3 and MCID≥10. Calculations showed a difference between proportions of improved in the intervention and the control group of...
19.5% (95% CI 68.6% to 97.1%) with cut-off MCID≥3 and 22.6% (95% CI 31.7% to 72.7%) with cut-off MCID≥10.

Table 6. Proportions and frequencies with 95% confidence intervals (95% CI) of patients per group that were improved, unchanged, or deteriorated from baseline to follow-up in the primary outcome PCS.

<table>
<thead>
<tr>
<th></th>
<th>MCID≥3</th>
<th></th>
<th></th>
<th>MCID≥10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention (n=19)</td>
<td>Control (n=20)</td>
<td>Intervention (n=19)</td>
<td>Control (n=20)</td>
</tr>
<tr>
<td></td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
<td>95% CI</td>
</tr>
<tr>
<td>Improved, %</td>
<td>89.5 (17)</td>
<td>68.6 to 97.1</td>
<td>70.0 (14)</td>
<td>48.1 to 85.5</td>
</tr>
<tr>
<td>% (n)</td>
<td>5.3 (1)</td>
<td>0.9 to 24.6</td>
<td>15.0 (3)</td>
<td>5.2 to 36.0</td>
</tr>
<tr>
<td>Unchanged, %</td>
<td>5.3 (1)</td>
<td>0.9 to 24.6</td>
<td>15.0 (3)</td>
<td>5.2 to 36.0</td>
</tr>
<tr>
<td>% (n)</td>
<td>5.3 (1)</td>
<td>0.9 to 24.6</td>
<td>15.0 (3)</td>
<td>5.2 to 36.0</td>
</tr>
</tbody>
</table>

Abbreviations: MCID: Minimal Clinically Important Difference,

Secondary outcomes in the R-RCT

PROMs of pain intensity and pain interference
One participant in the intervention group avoided reporting pain intensity and pain interference throughout the entire study period. Among the remaining participants in the intervention group, 95% (n=18) completed at least 70% valid weeks (i.e., completing at least 4 of 7 registrations for each week) throughout the study period. In the control group, 70% (n=14) of participants achieved 70% valid weeks. When looking at adherence to reporting pain intensity and pain interference across different study periods (week 1-8, week 9-17, and week 18-26) the adherence remained stable over time. However, participants in the control group showed the lowest adherence to reporting pain intensity and pain interference in the final study period with 70% of participants completing ≥70% valid weeks.

PROMs of pharmaceutical consumption
In the intervention group, 95% of participants achieved ≥70% valid weeks of registrations for pharmaceutical consumption throughout the whole study period, compared to 70% in the control group. This trend was maintained throughout the study with at least 95% of participants in the intervention completing ≥70% valid weeks in all three study periods. However, the proportion of participants in the control group achieving ≥70% valid weeks was only 65%, indicating less satisfactory feasibility for this group.
Device-based measurement of physical activity
Ninety percent (n=17) of participants provided data on their physical activity levels for at least 70% of valid weeks during the entire study. This level of adherence was sustained throughout all three study periods, with the lowest proportion of ≥70% valid weeks identified in study period 3 (90%).

**Feasibility rated by physiotherapists in IPRP**
Seven physiotherapists from five IPRP units provided ratings through the web-based questionnaire. The vast majority of ratings indicated satisfactory feasibility with the procedures and (by information material, education module) assumed prerequisites for correctly performing study activities such as digital information meetings, procedures of providing study information, conducting eligibility screenings, and collecting consent (see Table 8). Despite this, some areas were highlighted as problematic. Firstly, the website designated as the primary support for partaking physiotherapists received low feasibility ratings with only one physiotherapist providing a rating of ≥3. In addition, time resources and support from management were pointed out as possible barriers to participating in the study and performing study activities.
Table 7. Frequencies and proportions of ratings ≥3 per feasibility- and acceptability item.

<table>
<thead>
<tr>
<th>Items of feasibility and acceptability rated by physiotherapists (n=7)</th>
<th>Ratings ≥3, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feasibility of study activities designed to attract IPRP-units</strong></td>
<td></td>
</tr>
<tr>
<td>Digital information meeting</td>
<td>5 (71)</td>
</tr>
<tr>
<td>Designated web site</td>
<td>1 (14)</td>
</tr>
<tr>
<td><strong>Acceptability of study activities</strong></td>
<td></td>
</tr>
<tr>
<td>Provide relevant information to patient</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Assess eligibility</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Collect informed consent</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Perform randomisation</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Questions related to patient’s allocation</td>
<td>6 (86)</td>
</tr>
<tr>
<td>Assist patient in intervention group</td>
<td>4 (57)</td>
</tr>
<tr>
<td>Assist patient in control group</td>
<td>5 (71)</td>
</tr>
<tr>
<td><strong>Perceived feasibility of conduct of study activities</strong></td>
<td></td>
</tr>
<tr>
<td>Safely storage study material</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Procedures of providing study information</td>
<td>4 (57)</td>
</tr>
<tr>
<td>Procedures of eligibility screening</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Procedure of collecting consent</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Procedure of randomisation</td>
<td>7 (100)</td>
</tr>
<tr>
<td>Procedure of handling patient after group allocation</td>
<td>5 (71)</td>
</tr>
<tr>
<td>Procedure of start-up in intervention group</td>
<td>4 (57)</td>
</tr>
<tr>
<td>Procedure of start-up in control group</td>
<td>5 (71)</td>
</tr>
<tr>
<td><strong>Perceived feasibility of implementation process</strong></td>
<td></td>
</tr>
<tr>
<td>Use web application as support to physical activity</td>
<td>3 (43)</td>
</tr>
<tr>
<td>Procedure of incorporating eVIS in treatment</td>
<td>3 (43)</td>
</tr>
<tr>
<td>Time resources</td>
<td>1 (14)</td>
</tr>
<tr>
<td>Technical experience</td>
<td>5 (71)</td>
</tr>
<tr>
<td>Support from management</td>
<td>1 (14)</td>
</tr>
<tr>
<td>Support from colleagues not participating</td>
<td>3 (43)</td>
</tr>
<tr>
<td>Support from colleagues participating</td>
<td>5 (71)</td>
</tr>
<tr>
<td>Perceived potential of eVIS</td>
<td>2 (29)</td>
</tr>
<tr>
<td>Perceived patient interest to participate</td>
<td>1 (14)</td>
</tr>
<tr>
<td>&gt;25% of application of eVIS in total no. of appointments</td>
<td>1 (14)</td>
</tr>
<tr>
<td>Perceived appropriateness of eVIS (0-10)*, median [range]</td>
<td>5 [2-8]</td>
</tr>
<tr>
<td>Occurrence of adverse events, n</td>
<td>0</td>
</tr>
</tbody>
</table>


Adverse events
No adverse events were reported by the participating patients or physiotherapists.

Overall assessment of pre-defined indicators of acceptability and feasibility
The design and conduct of the R-RCT within the IPRP setting was generally deemed feasible. Despite the overall positive results in the areas of recruitment and data collection procedures, physiotherapists’ perceptions on acceptability and feasibility, characteristics and completeness of outcome data, a few areas were identified to have issues that require consideration before moving forward. In the area of recruitment and data collection procedures, the recruitment rate of IPRP units would benefit from acceleration (Figure 6).

Secondly, the information on recruitment at the units and the documentation of this required revision due to some issues emerging. Attention should also be directed towards the retention rate in the control group and the obvious mismatch in sex distribution between the groups, which requires consideration. Within the area of ratings on acceptability and feasibility, results revealed that physiotherapists found that the use of eVIS to support physical activity was a bit unclear. There were concerns about insufficient time resources, and that patient interest in participation was low. Finally, there was considerable decline in the long-term adherence among patient participants in performing daily PROMs of pain intensity, pain interference and pharmaceutical consumption, particularly in the last of the three study periods.
Ethical considerations

Ethical approval was granted prospectively from the Ethics Review Authority for Paper I (registration number 2018-307), Paper II (registration number 2020-02033), and Paper IV, including the subsequent R-RCT described in Paper III (registration number 2021-02109).

Throughout the project, all actions have and will adhere to the central guidelines in The Declaration of Helsinki \(^{164}\) and the Ethical Guidelines for Pain Research in Humans \(^{165}\). Any unwanted and/or unexpected events related to data collection or the use of eVIS have been discussed within the research group and if deemed relevant, reported to the Ethical Review Authority. The most significant risks associated with participation have been identified and will be addressed as follows:

**Risk of involuntary participation**
To minimise the risk of potential participants feeling forced to participate, verbal and written information about the study was provided on several occasions. This information clearly conveyed that participation was voluntary and the decision to participate or not would not affect any other aspects of healthcare. In addition, the undeniable right to withdraw from participation at any time without needing to provide a reason was highlighted alongside practical guidance on how to discontinue the study. Informed consent was obtained from all participants before they were included in the studies.

**Risk of compromised privacy**
To mitigate the risk of compromised privacy when collecting, handling, and storing personal and sensitive data (Paper I, II, IV), measures have been taken. It was also recognised that risks exist when participants register personal, sensitive data (name, email, weight, length, sex, date of birth) in the wrist-worn activity tracker’s appurtenant application.

Several actions have been taken to ensure the pseudonymisation of sensitive participant data. All data was coded, and a translation key was stored separately from the data to ensure that no one could connect it to a specific person. Access to the data was restricted to the principal investigator. In addition, par-
Participants received written and verbal information about the commercial company Fitbit and how they exercise their right to share data from their devices with other countries. In Paper I, only the weight, height, sex, and date of birth of participants were registered by study representatives. In subsequent papers, participants completed the registration with his/her own name and email address, which may increase the risk of comprised privacy. That said, this process (registration of name, email, weight, height, sex, date of birth) does not differ from the commercial use of the Fitbit product. Furthermore, three comprehensive Data Management Plans (DMPs) were finalised (one for each empirical study) providing details on how data was managed and stored, including references to relevant laws and directive guidelines \(^{166}\). In addition, the DMPs outlined local routines for continuous server backups.

**Risk of causing harm**

Several steps were taken to reduce the risk of increased (transiently) pain during or after data collection occasions in papers I, II, and IV. To minimise this risk in Paper I, participants provided consent before proceeding through the test phases and were frequently awaited, and if necessary additional rest was offered. In addition, participants’ pain intensity was continuously assessed during test phases so test leaders could carefully monitor participants’ pain levels. Also, a text message was sent to all participants one day after testing with a standardised question inquiring how they were feeling. Any information that emerged from these text messages was discussed within the research group and if necessary, revisions to the laboratory protocol were made. In papers II and IV, a risk of increased pain due to increased physical activity was identified. Participants in papers II and IV were concurrently participating in IPRP. Changes in individual physical activity behavior is a likely outcome in both studies, and temporary increases in pain is expected as a result of increased physical activity. An increased awareness of how physical activity levels, pain intensity, pain interference, and pharmaceutical consumption vary over time and in relation to each other, may lead to increased functional capacity and health-related quality of life, as shown in extensive research.
Discussion

Main results summarised
This thesis was guided by the updated MRC framework for the development and evaluation of complex interventions, which has resulted in collaboration with stakeholders, including patients, clinicians, researchers, and software developers, and close consideration to intervention’s context, its program theory, as well as continuous refinement of study designs and the intervention’s features, application, and delivery. The first phase’s results showed that the wrist-worn activity tracker overestimated METs systematically, which led to the decision being made to use SR as a quantification of physical activity in the intervention (rather than the initial choice of METs/EE). The intervention’s domains of data collection, visualisation, and communication were simultaneously developed and validated for relevance, simplicity, and safety. Several alterations were made to the intervention during this process, including replacing the initial pain self-efficacy item with a single item of PROM pain interference (0-10), making multiple interface changes in layout, colors, and functions. Linguistic improvements were also made to achieve satisfactory content validity. In the second phase, feasibility, acceptability, and study design were evaluated in two empirical studies. The intervention’s first real-world testing was a small test period in IPRP, where patients and physiotherapists rated acceptability, practicality, demand, implementation, and limited efficacy. Finally, the finalised intervention eVIS was established, and its feasibility, acceptability, and study design were assessed as mainly satisfactory in an internal pilot study, which constituted the initial phase of the subsequent effectiveness trial. However, certain problematic areas were identified, and these need consideration when moving forward in the main trial (R-RCT).

Methodological considerations
Methodological considerations must be performed when interpreting any research findings. In clinical research, various factors such as decisions made during recruitment and participant recruitment, allocation processes, attrition, and the interpretation of results are common sources of bias and can affect the external validity of the study. Here, the primary limitations of the thesis are
addressed and discussed along with reflections on how they potentially affect the findings.

Development and assessment of validity phase

We have followed best practice recommendations for device-based measurement validation both regarding goal population characteristics, choice of outcomes, and choice of criterion measurement. However, a few important limitations should be considered. Firstly, eligible participants in Paper I were patients undergoing assessment or treatment for musculoskeletal or widespread non-malignant chronic pain at any health care unit in the Region of Dalarna. Despite this initially broad sampling criteria, the generalisability of findings to a broader population are further restricted by the additional requirement for participants to understand verbal and written information in Swedish. This language criterion further restricts the generalisation of results. In addition, patients who had given birth within three months or who were pregnant in the second or third trimester were excluded, which could decrease generalisability. Secondly, measurements were limited to seated rest, treadmill walk at three different speeds, and 72 hours of free-living activities. Although these measurements taken in two settings constitute a relatively high ecological validity, additional activities with intensity levels ranging from sedentary to vigorous could have been included to improve both trustworthiness and the generalisability of findings.

In Paper II (step 1, pre-clinical evaluation of content validity), we included a wide range of subject experts. The recruitment aimed to include individuals working in various fields relating to chronic pain rehabilitation, physical activity, patient-reported outcome measures, and intervention development. Nevertheless, a potential source of bias is whether or not the included subject experts possessed the appropriate subject expertise and if a sufficient number of experts were included. The results showed that the initial group of subject experts did not have adequate expertise on the pharmaceutical report function. This was remediated through video interviews with specifically recruited subject experts, which resulted in a deepened evaluation and the possibility to further develop the pharmaceutical report function.

Following recommendations, response options from subject experts were collapsed into two categories (from the original four) for our CVI calculation. It has been argued that collapsing renders less detailed information on the interrater estimate, however, in this study, expert ratings were to a large degree coherent. Moreover, the valuable addition of rich free-text comments provided enough detail to guide the iterative development and evaluation process.
Assessment of feasibility, acceptability, and study design phase

The second step of Paper II (clinical feasibility) included a brief period where physiotherapists in IPRP tested the clinical use of the intervention, as well as the information material intended to inform potential patient participants. This test period constituted the intervention’s first contact with a real-world setting. Despite the short duration (2-3 weeks), a significant amount of important information emerged that made intervention refinement possible. However, the brevity of the test period may have contributed to the low use of the pharmaceutical report function. As a result – there was no input on this feature. This limitation was considered to be major and led to the decision being made to complement the data collection with video interviews involving subject experts in clinical pain management pharmacology.

The main objective of this initial real-world test was to collect data on how physiotherapists and patients rated the clinical practicality, acceptability, implementation, demand, and limited efficacy testing of eVIS – as suggested by Bowen (2009)\textsuperscript{117}. The data on user and deliverer ratings of feasibility was rather small (3 physiotherapists, 7 patients), which clearly affected the generalisability of the findings. However, this evaluation was based on diverse data sources (questionnaires, diaries, interviews, and support errands), which provided broad input on eVIS’s clinical feasibility. All items were categorised according to Bowen’s focus areas by two independent researchers. Although consensus was reached through discussion, the categorisations can be interpreted differently depending on whose perspective (patient or physiotherapist) they represent.

In paper IV, a full-scale evaluation of the acceptability and feasibility of the trial design and conduct was carried out as part of the initial phase of the R-RCT, which aimed to evaluate the effectiveness of eVIS. Despite efforts to achieve high internal validity, including blinding the physiotherapists prior to randomisation, there are some limitations. One was the rather small sample size of participating patients. Although the size is scientifically supported, it is on the smaller side of the recommended sample size for pilot studies.\textsuperscript{157} The drawback of a smaller sample size is that it risks decreasing the variation in data. In addition, unlike the study design in the R-RCT that had a follow-up time of 12 months, the follow-up time of the pilot study was six months. The rationale for this difference was the intention to collect data in a timely manner to facilitate the revision of the study protocol.
The choice and application of framework

The choice and application of the MRC framework has strongly guided study design and data collection in this thesis. The framework is internationally recognized and scientifically established in the fields of medical and nursing research, as well as research into care sciences. The framework’s pluralistic and pragmatic nature makes it particularly suitable in the field of care sciences. In this thesis, the MRC framework, and in particular two of its phases, has strongly supported the systematical work process and decision making regarding study designs and data collection. However, despite a recent update based on an ambitious gap analysis²⁴ of the use of previous guidance, the framework may have a few limitations. Considering the application of the framework in this thesis, the framework does not include clear guidance on the assessment of the validity of intervention features or content. Knowledge of an intervention’s validity is crucial as this impacts user and deliverer acceptability and adoption, which in turn impacts any evaluations of the intervention’s effectiveness in changing patient outcomes. However, in this thesis the phases related to the validation of the intervention and its features were added to address this lack of knowledge of validity, which is considered to be one of the key uncertainties.

Discussion of results

Development and assessment of validity phase

The sample of participants in Paper I shared several personal and pain-related characteristics, such as age, proportion of females, and education level with the goal population in Sweden¹⁶⁹. However, the sample seems to have a lower proportion of patients in work/education (66%) compared to a national sample (85%). The results from criterion validity assessments showed that Fitbit Versa systematically overestimated METs across the entire testing protocol, regardless of the criterion measurement used (indirect calorimetry, hip-worn accelerometry). This result is confirmed in other studies with Fitbit devices used by the general population¹⁷⁰,¹⁷¹ and populations with physical impairments such as obesity, chronic cardiac conditions, and progressive muscle diseases¹⁷²,¹⁷³. The accuracy of METs measurements seems to vary depending on which activity was being performed. Further potential explanations for the overestimations in measurement include firstly the proprietary algorithms applied by the company for calculating METs (metrics of body composition and HR measurement), which is not tailored to specific populations. Secondly, device placement on the wrist seems to be a contributing factor to the overesti-
mation of METs. On the other hand, the results indicated acceptable criterion validity for the Fitbit Versa’s measurement of SR, which is consistent with results from several systematic reviews.

In the evaluation of pre-clinical content validity of eVIS’s domains of data collection, visualisation, and communication, the initial ratings showed acceptable relevance, simplicity, and safety. However, a few areas were identified as problematic. Aside from the immediate change of daily PROMs of self-efficacy, the results identified uncertainties in the simplicity aspect of validity. Subject experts identified unintentional signaling with interface colors, and the need for additional prompts within the web application. The use of eVIS’s content validity as a “checkpoint” prior to effectiveness evaluation, corresponds well with methods described by Kassam-Adams.
Assessment of feasibility, acceptability, and study design phase

The assessment of the intervention’s feasibility and acceptability was carried out on two occasions. Both users’ and deliverers’ perceptions of how the intervention “works” in a specific clinical setting is important to consider in order to increase intervention adherence and sustainability. The results from eVIS’s first real-world contact (Paper II, step 2) indicated that both users and deliverers identified a present demand for eVIS within IPRP, and that an intervention such as eVIS would be possible to implement in its intended setting without significant changes needing to be made. This result is consistent with findings from a study performed by Ledel-Solem et al., where the idea of an eHealth self-management intervention was indicated to be favorable for patients with chronic pain, to increase knowledge of pain, pain physiology, and health promoting behaviors. These results are in line with the a priori assumptions about the mechanisms of action in eVIS, supporting the notion that eVIS may be a tool to increase knowledge, and improve self-management skills. However, these initial results from eVIS provided crucial information on not only required changes to increase feasibility, and they also provided important information on which prerequisites are required if the intervention was to be implemented in IPRP; clarifying information material, outlining recruitment and data collection procedures, and expanding the pharmaceutical consumption report function in PATRON. These insights helped develop a blueprint for design and concept of the effectiveness study.

The second evaluation of eVIS’s feasibility was performed in Paper IV and involved descriptions of unit characteristics, including number and type of professions in the team, types of interventions offered, and the dose, frequency, and intensity of the programs offered by participating IPRP units. They were found to be representative of corresponding characteristics reported elsewhere. In this pilot study, however, results of the recruitment and data collection procedures show an obvious difference in the distribution of sexes between the two groups. This finding has, to my knowledge, no apparent explanation, although it does suggest possible issues in the randomisation process. In addition, a minor attrition issue could be identified as the loss of participants was asymmetrical with less attrition in the intervention group than the control group. The most likely explanation of this could be that participants in the control group did not receive the same incentives as those in the intervention group. This observation constituted an important experience moving forward to planning for the effectiveness trial.

Here, the outcomes of feasibility and acceptability included both study design-related outcomes, including efficiency of data collection procedures, randomisation procedures, characteristics, and completeness of primary and second-
ary outcome data etc., and study conduct-related outcomes (including implementation), such as physiotherapist’s ratings on received support and education, application of eVIS in pain management to support physical activity. This approach is recommended by and recognised in other pilot studies preparing for a larger (and more expensive) study \(^{118,121,177}\). Results of characteristics and completeness of outcome data in the R-RCT showed a generally high level of adherence among participants in both groups not only for performing daily PROMs but for the intervention group also for wearing the wrist-worn activity tracker. This finding supports the hypothesis that self-monitoring may be an important strategy in individualised physical activity levels.

Some results from both Paper II step 2 and Paper IV aligned. In both studies, physiotherapists seemed to acknowledge a need for the intervention within IPRP. This is an important aspect moving forward as perceived demand, or potential benefit of an intervention, are key parts of intervention acceptability and affect how well the intervention is delivered to the user (patient) \(^{21}\). A satisfactory rating of the infrastructure, including written information material and recorded video instructions, was given by participating physiotherapists in Paper IV. This may be due to the quite extensive changes that were made to the web application, information material, and recruitment strategies in Paper II.

The results in Paper IV indicate that the design and conduct of the study were acceptable and feasible. This overall assessment was based on the definition of several feasibility criteria (progression criteria), which were developed by a combination of current research in the field \(^{117,118,120,121,177}\) and the cumulative experiences from the entire research process. Despite this, the updated MRC framework recommends collaboration with relevant stakeholders when defining feasibility criteria. This is because they serve to guide decision-making regarding whether to proceed to the next phase of the research.
Conclusions

- The results in this thesis indicate support for the suggested program theory of the intervention.
- The results show that Fitbit Versa provides a valid measurement of step rate for patients living with chronic pain. This implies its potential for clinical use, and its use in device-based measurement of physical activity may be considered for inclusion in future clinical guidelines for this patient group.
- The content of eVIS was continuously developed and refined in collaboration with patient representatives, clinicians (physiotherapists, occupational therapists, psychologists, physicians), researchers, and software developers, which resulted in acceptable levels of content validity, ensuring the intervention was relevant, simple, and safe for use.
- The results from eVIS’s first real-world contact showed that both physiotherapists and patients in IPRP found eVIS to be a feasible intervention with acceptable ratings for practicality, acceptability, implementation, demand, and limited efficacy testing. However, findings indicated the need for further development of the pharmaceutical report function.
- Comprehensive and satisfactory recruitment and data collection procedures, along with the overall robust primary and secondary outcome data, imply that the trial design and conduct of the R-RCT are feasible. This result indicates that the R-RCT has the necessary prerequisites for successful execution. However, a few areas such as attrition and the sex distribution between the groups need careful consideration moving forward.
- Pilot results show that the characteristics of the primary outcome in the R-RCT, which is the physical component summary score measured using RAND-36, measured at IPRP baseline and at six months follow-up, provided indications that the initial power calculation is appropriate with a scientifically supported MCID of ≥3 as well as with a stricter MCID of ≥10.
- The ratings provided by physiotherapists working in IPRP showed overall satisfactory feasibility and acceptability with the trial design and conduct. Nevertheless, a few areas were identified as requiring additional attention.
The updated MRC framework provided systematic guidance and facilitated decisions on study design and outcomes. However, although the framework has clearly been proven to be supportive in the development and evaluation of a complex intervention such as eVIS, greater clarity within the framework appears to still be needed regarding the assessment of intervention validity.
Clinical implications

• By adopting a systematic approach provided by the Medical Research Council’s updated framework for the development and evaluation of complex interventions, this thesis underscores how thorough preparatory studies, encompassing critical uncertainties, consideration of the intervention’s context, program theory, engagement with stakeholders, and economic elements, have the potential to increase the likelihood of a successful intervention implementation.

• This thesis provides scientific support for the clinical use of Fitbit Versa as a valid device-based measurement of step rate for patients with chronic pain. However, it is important to exercise caution when using Fitbit Versa to measure energy expenditure, as the device tends to overestimate this.

• The intervention eVIS has evolved from a conceptual idea to a finalized digital intervention through close collaboration with important stakeholders. Insights from stakeholders have enriched the intervention regarding its clinical relevance, validation of research questions, and the incorporation of valuable user- and deliverer-centric insights for complex health interventions.

• Despite potential challenges relating to adherence, this thesis demonstrates the overall successful data collection of daily PROMs, including assessments of pain intensity, pain interference, and pharmaceutical consumption, throughout a six-month study period for both the intervention and control group. This shows that monitoring these outcomes in this patient group for an extended time period is possible.

• The trustworthiness of the subsequent effectiveness evaluation of eVIS has increased through preparatory evaluations, including assessments of validity, acceptability, and feasibility. This decreases the risk of intervention rejection and misleading results.

• The thesis provides a valuable resource for clinicians considering the integration of health-promoting interventions like eVIS into clinical practice. It offers unique insights into the systematic process and essential considerations within the context of IPRP.
Suggestions for future research

- Evaluate criterion validity of Fitbit Versa for the measurement of METs, HR, and SR in the general population. Extending this evaluation to a healthy population would provide valuable insights into the device's performance across diverse groups.
- Continue to develop and evaluate eVIS. Further development of eVIS is recommended, including the incorporation of additional patient-reported outcomes (PROMs). In addition, extended feasibility assessments for other patient groups as well as sub-group analyses to explore possibilities to further individually tailor the intervention. Moreover, consider the possibility of jointly visualizing patients' complete or partial pharmaceutical consumption within eVIS interfaces. Furthermore, an exploration of optimal time intervals for PROM registrations and the potential integration of artificial intelligence for individualised treatment are important avenues to explore for eVIS enhancement.
- Explore and describe users’ and deliverers’ concurrent and retrospective experiences and acceptability of eVIS. Despite the so far close stakeholder collaboration, it still remains unknown how the user (patient) and the deliverer (physiotherapist/staff in IPRP) experience eVIS. Such information is essential for comprehensive evaluations and successful implementation. A more narrative approach to complement numerical data could enrich understanding. The theoretical framework of acceptability focusing on affective attitudes, burden, ethicality, intervention coherence, opportunity costs, perceived effectiveness, and self-efficacy, could preferably frame this investigation.
- Assess the feasibility of including objective physical activity measurements in IPRP and SQRP. The results from this thesis support the use of commercially available, cost-effective devices for device-based measurement of activity levels, suggesting potential benefits for their inclusion in these programs. However, further evaluations of such incorporation are required prior to implementation.
- Finalize the evaluation of eVIS’s effectiveness to further improve patient outcomes in accordance with the updated MRC framework. Although this thesis contributes to the development and evaluation of eVIS in terms of validity, acceptability, and feasibility – a resumed
evaluation in alignment with the updated MRC framework will continuously pave the way to practice-based research that will benefit patients with chronic pain. As part of this evaluation, it is suggested to evaluate outcomes informing \textit{time needed to treat} (i.e., required time to apply eVIS to IPRP), which is an important factor to consider and will help facilitate the implementation of eVIS into clinical practice.

- Based on the experiences gained in this thesis, it is recommended to consider additional and enhanced guidance for assessing intervention validity in the updated MRC framework. Such clarification of the framework would enhance its comprehensiveness, and guide researchers in conducting a more robust evaluation of intervention effectiveness.
Bakgrund
I Europa lever upp mot 40% med långvarig smärta, en smärta som kvarstår i minst tre månader. Förutom att upplevelsen är sensoriskt och emotionellt obehaglig, innebär långvarig smärta ofta ytterligare biologiska, psykologiska eller sociala funktionsnedsättningar. För en del kan enskilda vårdinsatser vara tillräckliga för återhämtning, men för många finns behov av multimodala behandlingsprogram där flera yrkesprofSSIONER samverkar i målsättning och behandling. Fysisk aktivitet är en central del av sådana behandlingsprogram. Trots starkt vetenskapligt stöd för fysisk aktivitet som behandling för såväl smärtupplevelse som för många av de biopsychosociala funktionsnedsättningarna, upplever många patienter hinder för att vara tillräckligt fysiskt aktiva.

Det övergripande syftet med avhandlingen var att i en sammanhängande och systematisk process, utveckla interventionen eVISualisering av fysisk aktivitet och smärta (eVIS) som ett komplement till multimodal smärtrehabilitering, att utvärdera eVIS validitet, samt utvärdera genomförande och lämplighet av en register-baserad randomiserad studie som syftar till att utvärdera eVIS effektivitet.

Metod
Interventionen eVIS består av följande fem funktioner:
1. Daglig insamling av fysisk aktivitet uttryckt som steg per dag
2. Daglig insamling av patientens skattnings av smärtintensitet (0-10), smärtans påverkan på dagliga aktiviteter (0-10), läkemedelskonsumtion (namn, dos, styrka, antal)
3. Ett formulerat dagligt aktivitetsmål
4. Grafisk visualisering av data (1-3) i tidsramarna, 1 dag, 7 dagar och 28 dagar.
5. Om patienten väljer, gemensam och upprepade genomgångar av patientens visualiserade data tillsammans med fysioterapeut i syfte att underlätta kommunikation och beslutsfattande gällande individuellt anpassad fysisk aktivitetsnivå.

Avhandlingen innehåller fyra delstudier som genomförts med stöd av Medical Research Councils uppdaterade ramverk för utveckling och utvärdering av
komplexa interventioner. I linje med ramverkets rekommendationer, har interventionens intressenter (patienter, kliniker, patientorganisationer, mjukvareutvecklare) deltagit i utvecklingen och utvärderingen. Dessutom har interventionens tänkta kontext noggrant övervägds då det påverkar hur väl interventionen kan implementeras och hur väl forskningsresultaten kan generaliseras till andra sammanhang.

Delstudie I syftade till att utvärdera en del av interventionen, den handledsburna aktivitetsmätaren för dess mätegenskaper för att mäta energiförbrukning (METs), hjärtfrekvens och stegfrekvens hos personer med långvarig smärta. Mätningarna gjordes i kontrollerad laboratoriemiljö och under vardagsaktiviteter. Simultana mätningar av utfallsmått gjordes av en handledsburen aktivitetsmätare (Fitbit Versa), en så kallad golden standard-mätare (Jaeger Oxycon Pro) och en relativ golden standard-mätning (ActiGraph GT3X).

Delstudie II genomfördes i två steg. Under steg 1 (pre-klinisk innehållsvalidering) utvecklades interventionens delar (datainsamling, visualisering, kommunikation, interventionen som helhet) samtidigt som delarnas relevans, enkelhet och säkerhet utvärderades med hjälp av 10 ämnesexperter och en konsensusgrupp. Utvecklingen och utvärderingen gjordes under tre runder där experterna fick via ett webbformulär, information om interventionens delar och därmed uppmuntrades att självständigt skatta dess relevans, enkelhet och säkerhet på en fyrsiffrig Likert-skala (1=ej relevant/enkelt/säkert, 2= behöver revideras, 3= relevant/enkelt/säkert men behöver revideras, 4=Mycket relevant/enkelt/säkert). Under steg 2 (klinisk genomförbarhet) testades interventionen i liten skala inom klinisk smärtrehabilitering. Tre fysioterapeuter och sju patienter använde interventionen under två-tre veckor och skattade interventionens acceptans, praktisk användning, implementering, efterfrågan och visad potential genom en fyra-gradig skala (1= inte alls, 2= i viss utsträckning, 3= i ganska stor utsträckning, 4= i stor utsträckning).

Delstudie III utgörs av ett studieprotokoll där design och genomförande av en register-baserad randomiserad kontrollerad studie (R-RCT) med syfte att utvärdera eVIS effektivitet som tillägg till MMR presenteras.

För att optimera studiedesign, underlätta implementering av interventionen i tänkt kontext samt förbättra generaliserbarheten av effektivitetsstudiens resultat, har en randomiserad pilotstudie (delstudie IV) genomförts. Studien syftade till att undersöka genomförbarheten av effektivitetsstudiens studiedesign och genomförande inom svensk MMR. Genom sex MMR-enheter rekryterades de första 10 % av effektivitetsstudiens målpopulation (n=400). Fullständighet och egenskaper av det primära utfallsmåttet, fysioterapeuters skattringar av
Resultat

Diskussion och konklusion
Avhandlingen bidrar med ny information om en handledsburen aktivitetsmätarens kriterievaliditet, om interventionens innehållsvaliditet, om hur väl interventionen fungerar i svensk MMR samt om hur en pragmatisch och kontrollerad studiedesign för att utvärdera interventionens effektivitet fungerar i svensk MMR. Hela avhandlingen bidrar till ökad generaliserbarhet/extern validitet av resultaten från den kommande effektivitetsstudien. Resultaten bör granskas i ljuset av de relativt små stickprover och resultaten i delstudierna baseras på, vilket sannolikt påverkat resultaten i viss mån. Studiedesign i de separata studierna har präglats av vetenskapliga rekommendationer i MRC ramverket samt i best practice-rekommendationer. Detta har möjliggjort kontinuerlig revidering av interventionen i takt med att behov av detta har identifierats. Vidare har interventionen teoretiskt förankrats och en programteori har utvecklats. Sammanslaget kan avhandlingen anses bidra med ny och viktig kunskap om interventionens validitet och genomförande i svensk MMR – förutsättningar för fortsatt utvärdering av interventionens effektivitet och framtida implementering.
Erkännanden (Acknowledgements)

Denna bok är resultatet av fem och ett halvt års studier och arbete. Innehållet har uppdraget att både presentera ”mitt” bidrag till detta smala forskningsfälts kunskapsmassa, och samtidigt indikera vad jag fått med mig i form av vetenskapliga kunskaper, färdigheter och förhållningssätt.

Oavsett hur väl texten lyckas med sitt uppdrag, är jag mycket stolt och tacksam över alla erfarenheter jag fått med mig. Forskarutbildningen kulminerar med ett självständigt försvar av avhandlingen, men det är många som på avgörande sätt bidragit till såväl forskningen som till min forskarutbildning. Ni förtjänar att lyftas fram i ljuset nu när avhandlingen uppmärksammas.

Oändliga tack vill jag rikta till alla som valt att delta i någon av studierna, framför allt tack till de med erfarenheter av att leva med långvarig smärta. Ni som generöst delat med er av sådant vi frågat om och velat testa – tack! Tack också för att ni delat med er av långt mycket mer i form av personliga berättelser, råd och hejrapor. Jag hoppas att vi kunnat förvalta era värdefulla bidrag när vi planerat och genomfört studierna.

Tack till alla fysioterapeuter och sjukgymnaster vid de vårdenheter som hjälpt oss med att rekrytera forskningspersoner till de olika delstudierna, som fungerat som experter, och som integrerat eVIS som ett tillägg i det kliniska arbetet i svensk multimodal smärtrehabilitering. Jag har inte tillräckligt många tacksamma ord för att uttrycka min genuina tacksamhet.

Tack till Högskolan Dalarna och till Institutionen för hälsa och välfärd, och framför allt till forskarutbildningen i vårdvetenskap, hälsa och välfärd med inriktning mot evidensbaserad praktik. Så många aktiviteter i forskarutbildningen har varit betydelsefulla för mig i min utveckling; alla seminarier, kick-offer, doktorandträffar, föredrag, forskarutbildningskurser med mera, allt inramat av en fantastiskt kompetent och tillåtande akademisk miljö. Ett särskilt varmt tack till Renée Flacking, Högskolan Dalarnas mest kunniga och bästa studierektor som alltid stöttar, hjälper och ordnar så att allt flyter på. Tack också till Anna Ehrenberg, ämnesföreträdare för mitt forskarutbild-
ningsämne vårdvetenskap, samt till Märet Brunnstedt, vår extremt kompetenta och trevliga forskarutbildnings-samordnare – ni tre är HDs vårdvetenskapliga forskarutbildning.


Björn Äng, biträdande handledare - tack för ditt stöd, för ditt oproblematiska sätt och för att du alltid har nära till hands till uppmuntrande ord. Jag har inspirerats av ditt visionära sätt att se på forskning! Maria Hagströmer, biträdande handledare - vilken dröm att få handledning av dig! Om du visste hur jag har uppskattat dina snabba kloka svar och din uppmuntran. Det är fler gånger än en, när ett meddelande från dig verkligligen gjort skillnad. Mathilda Björk, biträdande handledare – tack för ditt stöd och din kunniga hjälp! Alltid har du tid när jag hört av mig och alltid har jag fått kloka och initierade svar!

Förutom handledarna, har min med-doktorand i forskargruppen DU/Pain, Jens Westergren, gått jämte mig under forskarutbildningen. Tack för alla telefonsamtal och Zoom-möten, och för all tid i Högskolan Dalarnas idrottslaboratorium. Där tog vi tillsammans de första (men väldigt ambitiösa) stegen i våra forskarutbildningar. Våra diskussioner om nuvarande och framtida forskning har inspirerat mig. Snart är det din tur!


Tack till alla juniora och seniora forskare som vid institutionens seminarier lätit mig få delta i kritiska diskussioner om tvärdisciplinär forskning och inte minst, hjälpt mig att se hur mina egna manuselab om kappan (!) kunnat bli bättre. Särskilt tack till Tony Bohman, Fatumo Osman och Marcus Falk Johansson för insiktsfulla och värdefulla diskussioner om kappan.


Jeff. Tack för att jag fått ingå i din familj och starta ”Falu-dagarna” till fantastiskt kaffe och till diskussioner om allt från samhällets maktstrukturer, till politik och föräldraskap. Det har kanske något oväntat, blivit en viktig och trygg del av mitt doktorandliv. För det är jag oändligt tacksam!


Eskil och Vidar – mina fina, smarta, roliga, omtäktamma, ungar. Ni är oavsett allt, sann kärlek och källa till så mycket glädje och stolthet för mig. Jag älskar er mer än vad som kan uttryckas i ord!


I slutet av forskarutbildningen med stor tacksamhet 😊
Veronica Sjöberg
References


