Journal of Bodywork & Movement Therapies 38 (2024) 211–253

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

# Empowering patients with persistent pain: The potential of cognitive functional therapy in interdisciplinary care: A single-case experimental design

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ARTICLE INFO

Handling Editor: Dr Jerrilyn Cambron

*Keywords:*
Musculoskeletal pain
Chronic pain
Rehabilitation
Behavioral change
Biopsychosocial

ABSTRACT

*Introduction and purpose:* Persistent musculoskeletal pain (PMP) is multifactorial and causes both societal and financial burdens. Integration of multifactorial management in patients with PMP remains challenging. A single-case experimental design was performed on three patients suffering from high impact PMP (lumbar spine, shoulder and knee) to i) assess the potential for Cognitive Functional Therapy (CFT) in interdisciplinary care, ii) describe in detail the clinical journey patients experienced during the intervention, and iii) evaluate the changes and associations in relation to the outcome measures of pain, disability, maladaptive movement behavior, subjective overall improvement, health related quality of life and work status. These were monitored over one year, at the end of each of the six intervention modules.
*Results:* After introducing the intervention systematic changes were seen, with medium to large changes (Non-overlap of All Pairs 0.67–1) for all outcome measures. Associations between changes of the outcome measures were large ($r \geq 0.50$) and changes occurred concurrently. Minimally clinically important difference thresholds were exceeded for all outcome measures and two patients achieved relevant improvements related to work reintegration.
*Discussion:* The positive results of this study are comparable with recent CFT studies. However, the difference regarding the number of sessions and duration of the intervention is evident. The length of the intervention in this study seemed to enable continuous significant improvements up until 12 months post onset and follow-up.
*Conclusion:* CFT in interdisciplinary care was effective for all measures. The detailed descriptions of the clinical processes aim to improve clinical care.

## 1. Introduction

Persistent primary musculoskeletal pain (PMP) is defined as "pain experienced in muscles, bones, joints, or tendons that (1) is characterized by significant emotional distress (such as anxiety, anger, frustration, or depressed mood) or functional disability (interference in daily life activities and reduced participation in social roles), and (2) cannot be attributed directly to a known disease or damage process" (Perrot et al., 2019) and which recurs or lasts for more than 12 weeks (Treede et al., 2019). PMP is a leading contributor to years lived with disability (Vos et al., 2017), thereby creating a significant financial burden, with work-related costs accounting for the majority of this (Gustavsson et al., 2012). Hence, improving PMP management is both necessary and crucial. The total costs of PMP are comparable to those of diabetes and cancer treatment combined (Wieser et al., 2018).

PMP is characterized by phenomena such as maladaptive cognition, maladaptive movement behavior and faulty pacing and coping strategies. Cognitive factors (e.g., negative illness beliefs, catastrophizing), emotional factors (e.g., fear, depression, anxiety), lifestyle factors (e.g., sleep deprivation), pathoanatomical factors (e.g., advanced multilevel

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https://doi.org/10.1016/j.jbmt.2023.11.063
Received 7 July 2022; Received in revised form 24 November 2023; Accepted 26 November 2023
Available online 23 December 2023

disk degeneration, vertebral endplate changes), physical factors (e.g., physical deconditioning, provocative movement behavior) and social factors (e.g., work related stress) are known drivers of pain and disability in the context of PMP (O'Sullivan et al., 2018). In addition, PMP "negatively impacts physical and psychosocial health, daily functioning, participation in life roles, healthcare utilization and the health-related quality of life (HRQoL)" (Ernstzen et al., 2017) of patients and those close to them (Duenas et al., 2016). The persistence of pain and disability can cause secondary musculoskeletal problems to arise, further complicating the management of PMP.

The above-mentioned statements indicate the necessity of analyzing and treating PMP beyond the biologic and mechanistic level (Brodal, 2017). This involves adopting a broader approach, such as within the framework of a biopsychosocial model. Cognitive functional therapy (CFT) has been proposed as an approach to address this challenge (O'Sullivan et al., 2016; O'Sullivan et al., 2018; Vibe Fersum et al., 2013). CFT entails a multidimensional clinical reasoning framework involving a biopsychosocial basis for a multifactorial management approach, which reconceptualizes the patient's pain and targets their modifiable key drivers (Mitchell et al., 2018; O'Sullivan et al., 2018). Interdisciplinary care is recommended in clinical guidelines and literature to tackle the various biopsychosocial factors related to PMP (Foster et al., 2018; Gatchel et al., 2014; Kamper et al., 2015; Oliveira et al., 2018). The recent CFT RESTORE trial by Kent et al. (2023) demonstrated the superior effects of CFT in reducing disability, pain, and cost-effectiveness compared to usual care in patients with persistent low back pain.

While some clinicians support biopsychosocial interventions, evidence shows that clinical translation is often inadequate (Synnott et al., 2015). Lack of confidence, knowledge, skills and time constraints are known barriers to successfully adopting a biopsychosocial model in the treatment of PMP and may lead to low-value care (Hartvigsen et al., 2022; Holopainen et al., 2020; Synnott et al., 2015; Young et al., 2019; Zangoni and Thomson, 2017). Misconceptions and negative beliefs about persistent pain continue to exist on the individual, communal and professional levels (Darlow, 2016; Darlow et al., 2013), thereby facilitating the transition to chronicity (Chen et al., 2018). Although previous research has shown that CFT can function as a management framework to successfully adopt a biopsychosocial model whilst at the same time improving clinical effectiveness, it has not been explored if these principles can be applied in a general PMP population and applied in interdisciplinary care. The logic and necessity of defining PMP in a generalized way, in contrast to e.g., region or anatomy specific definitions, is underlined by ICD-11, where "chronic musculoskeletal pain" is defined as a separate entity (Perrot et al., 2019; Treede et al., 2019).

Therefore, the aim of this study is to assess the potential for CFT in an interdisciplinary program in a generalized, high impact (defined as health-related work absenteeism) PMP population. The population aimed for was in accordance with the ICD-11 definition of "chronic musculoskeletal pain". Secondly, facilitation of the translational process was aimed for by presenting a detailed description of the clinical process. A third aim was to improve clinical insight of the course and association of the outcome variables. The key uniqueness of this study, in contrast to previously region-specific (spinal) publications, was that this approach extended CFT principles to the general population with PMP in interdisciplinary care. The hypotheses can be formulated as follows: 1) normalizing movement behavior and improving functional loading capacity are prerequisites for symptom alleviation and 2) CFT in an interdisciplinary program improves pain and disability in a generalized PMP population. See Appendix 5.1 for a detailed description of the hypotheses.

## 2. Method

### 2.1. Design

In order to provide a detailed clinical insight into the different cases, a Single-Case Experimental Design (SCED) was chosen to assess the effects of an interdisciplinary CFT program on PMP (Kazdin, 2011). A SCED provided valuable insights into the individual multifactorial analyses and related treatment, in addition to the course of the treatment and outcome measures (Krasny-Pacini and Evans, 2018; Tate et al., 2016a). To determine the effects of introducing the CFT approach in patients with PMP, a non-concurrent multiple baseline SCED, with *a priori* determined multiple phase change, was used (Kazdin, 2011). The study was written according to the Single-Case Reporting guideline in BE-havioural interventions (SCRIBE) 2016 (Tate et al., 2016a, 2016b). To demonstrate the replication effect of the CFT approach, three patients, with different primary symptomatic regions serving as an "across patient multiple baseline" were selected. The patients were treated according to an *a priori* determined "A-B1-B2-B3-B4-follow-up" sequence. Phase A was a four-week baseline phase with no intervention. This phase contributed to the validation of the historical baseline (based on the chronic nature of the problem) to control for maturation. The B-phases represented the sequential introduction of the different foci of behavioral treatments. They were applied in the following order: illness cognition (B1 = modules 1 and 2), local functional loading capacity (B2 = module 3), supervised work-related loading capacity (B3 = modules 4 and 5) and independent work-related loading capacity (B4 = module 6). No interventions were applied in the subsequent follow-up phase, only evaluations were conducted during this period. Due to the necessity of initiating treatment as soon as possible, treatment onset was determined nonrandomly according to order of application.

### 2.2. Timeline

The program involved six modules applied over a 12-month period. The program was structured as follows: four weeks for the individual modules 1–3, six weeks for modules 4 and 5 and six months for module 6 (see Fig. 1). The historical baseline was established on anamnestic findings and described the duration and trend of symptoms prior to the start of Phase A retrospectively (see Graph 1a-d). At the end of each module, extensive intersubjective evaluations were conducted, and reports written. A module was deemed completed when the following three criteria had been met: 1) implementation of planned therapy weeks, 2) therapy sessions were conducted, and 3) the module goals (see Appendix 5.2) were partially or completely achieved. Based on these criteria, a joint decision whether to continue or not was made with the legal insurance companies' case manager.

The collective modules entailed of one year of regular treatments and evaluation sessions. These treatments and evaluations provided high intensity patient therapy and afforded sufficient time to enable cognitive, psychosocial, structural, and neurophysiological changes to be reversed. Two follow-up evaluations were conducted on each patient.

### 2.3. Patient information and context

The selected patients were treated as part of a collaborative work reintegration program. All of the patients involved in the CFT based work reintegration program were referred by a legal health insurance company due to PMP-related work absenteeism. The referral process aimed to 1) improve the patient's physical health status sufficiently enough that job reintegration was possible, or 2) to document the patient's inability to restore sufficient physical functioning, thereby

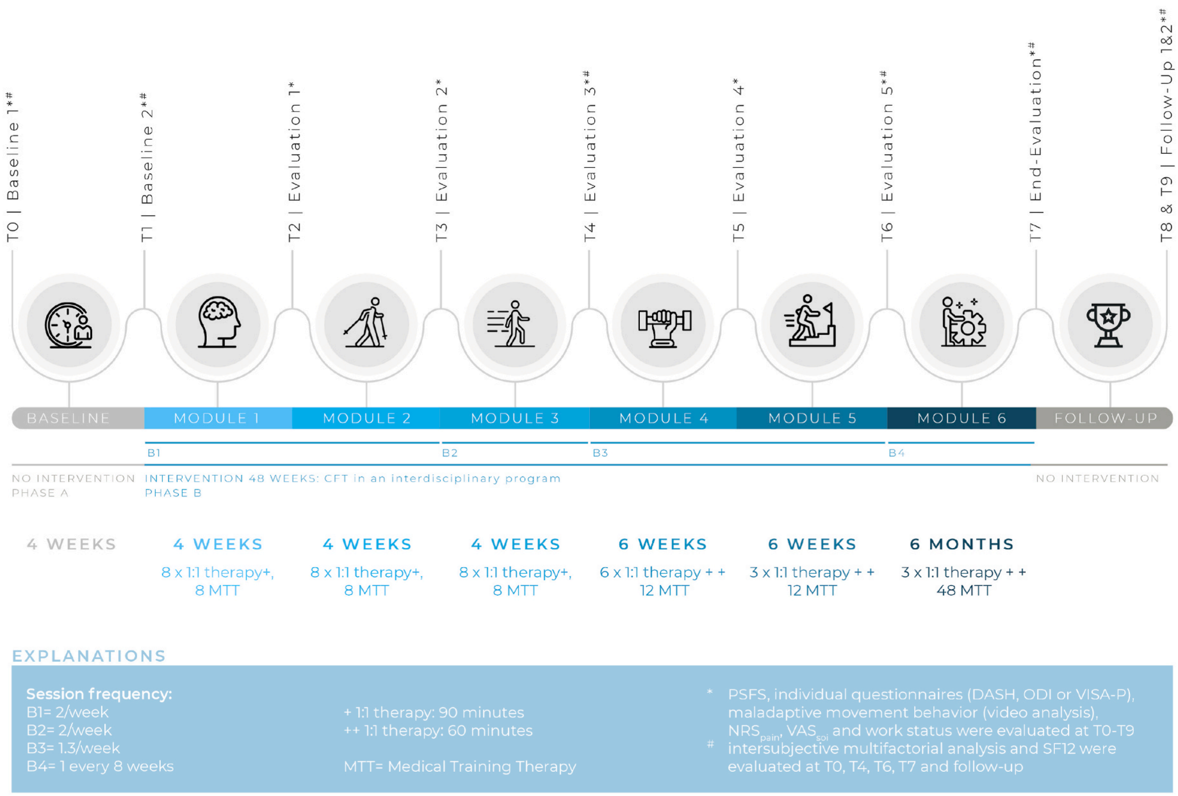



**Fig. 1.** Timeline of the one-year CFT intervention in an interdisciplinary program.

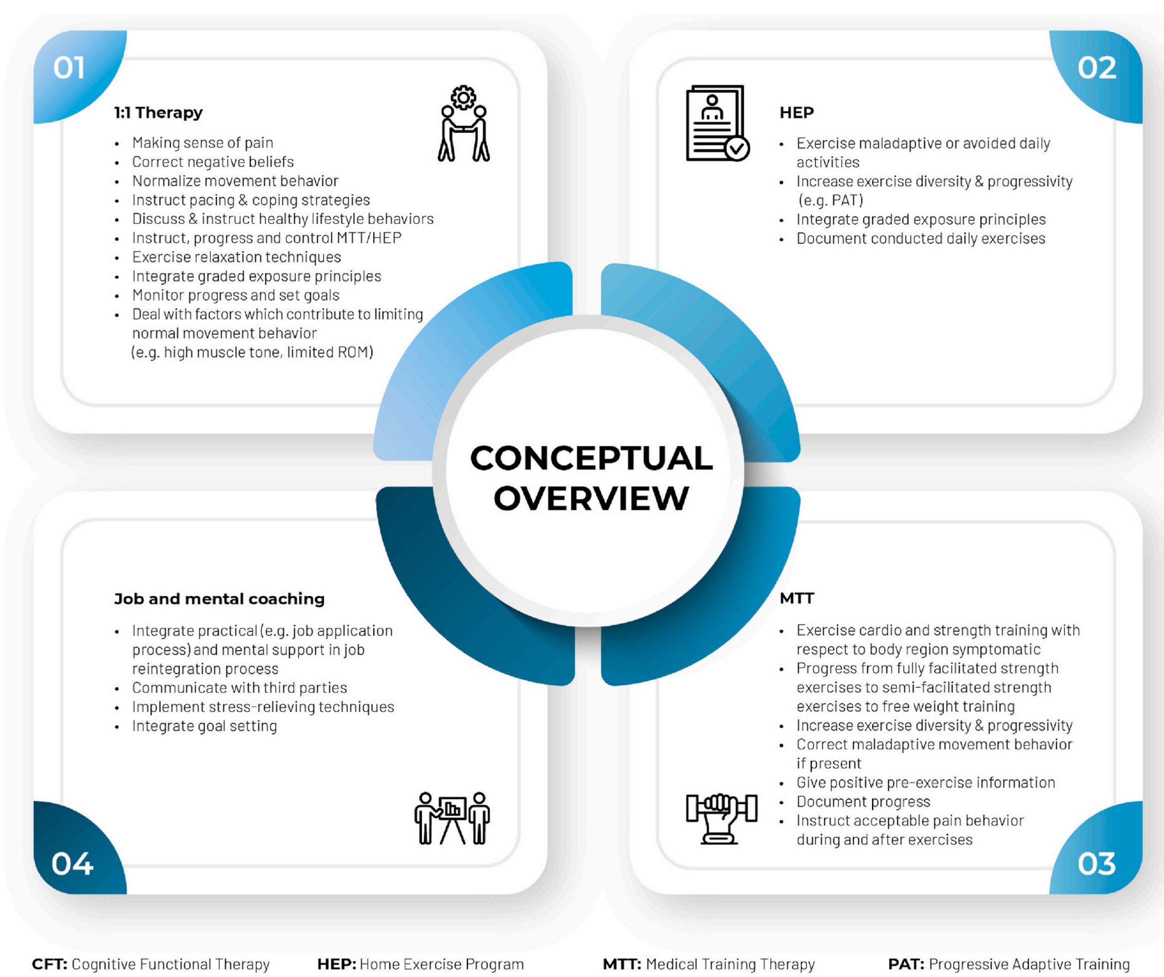



**Fig. 2.** Conceptual overview of CFT in an interdisciplinary program.

providing legal reasoning and support for the subsequent disability pension application. The legal insurance company's advising medical doctor and case manager, were both specialized in physical health related work absenteeism, and referred the patients for an intake session to the interdisciplinary CFT program. Prior to referral, the medical (i.e. red flags, serious underlying pathoanatomical causes and neurological pathology) (Finucane et al., 2020) situation was screened and assessed. An intersubjective decision was made about the patients' inclusion or exclusion from the program based on three factors: 1) the potential for improvement based on identifying key modifiable drivers of the health problems according to the multifactorial analysis (see Results 3.3.2), 2) the willingness of the patient to accept the provided multifactorial analysis of the problem and to be treated accordingly and 3) the willingness to participate in the full intensity and duration of the program.

Two men and one woman with a mean age of 53 years were selected (see Table 1). The primary regions of persistent pain were located in the lower back, the shoulder and the knee (see Table 2 for patient information). The patient names of the patients were replaced as patient 1 = Sam, patient 2 = Dean, patient 3 = Ann. It is important to note that all of them had had unsatisfactory primary care interventions such as surgery, pharmaceutical treatment, and conservative treatment prior to the CFT program. All prior treatments were primarily aimed at pathoanatomical factors, despite the examination (Appendix 5.3) identifying several key drivers of pain in the psychosocial domain. Therapy was provided in a large private physiotherapy clinic equipped with extensive fitness facilities. The practice provides secondary care and is located in a northern rural German speaking Swiss area. Table 2 details an extensive overview of both demographic and clinical patient information including previous treatments.

**Table 1**
Inclusion and exclusion criteria.

| Inclusion criteria | Exclusion criteria |
|---|---|
| - aged ≥18 years<br>- musculoskeletal pain >3 months<br>- health related work absenteeism | - lack of willingness to participate<br>- systemic diseases preventing necessary physical loading<br>- any condition that could require immediate surgery or acute medical care<br>- serious and specific pathology |

## 2.4. Clinical findings

### 2.4.1. Intake session

The intake session consisted of a 1.5-to-2-hour interview and a physical examination and was performed by two PTs who had additional training in CFT treatment principles (CFT training included workshops and patient examinations). The interview focused on acquiring a detailed insight into the history, cause, course and current symptoms the patient presented with, as well as a definition of the factors (see Radar Graph 2a-c in results; blue lines represent intake values) driving the persistence of the symptoms (Cowell et al., 2023; O'Sullivan et al., 2018). For interview prompts and quotes please see O'Sullivan et al. (2018). Special attention was paid to aggravating and/or impaired movements and how these related to the patients' individual goals. The "making sense of pain" process, including e.g., correcting negative illness beliefs by reflective questioning (Vibe Fersum et al., 2013) began during the interview and continued throughout physical assessment. A patient-centered and validating communication approach was integrated to explore beliefs, behavioral and emotional responses to pain, and to build a therapeutic alliance (Holopainen et al., 2021; Nijs et al., 2020).

The interview concluded by presenting the patient with a summary of the multifactorial analysis of the problem as part of the process of "making sense of pain" (Kent et al., 2023; O'Sullivan et al., 2018) (see Clinical reasoning Appendix 5.4). Patient consent, and readiness to accept the analysis of the problem (along with the logical merits of the analysis), the proposed treatment strategy and full participation in the program were essential requirements.

The physical examinations assessed: pain aggravating movements and activities (the specified individual activities as reported in the PSFS), maladaptive movements and potential underlying factors (e.g., faulty illness beliefs), the presence of local or general sensitization, and physical factors that limited normal physical functioning (e.g., joint stiffness, range of motion (ROM), muscle tone, strength deficit). Aggravated movements and maladaptive movement behaviors were analyzed using

**Table 2**
Overview of patient baseline demographics.

| Patients | Sam | Dean | Ann |
|---|---|---|---|
| **Gender/Age/Former profession** | M/56/Carpenter | M/40/Metalworker | F/62/Factory employee |
| **Symptoms** | Persistent low back pain (LBP) (NRS 8/10) with non-dermatomal right leg pain (NRS 5–8/10), intermittent hypoesthesia/paresthesia, reduced force in M. quadriceps femoris and gluteal muscles and loss of control. | Right anterolateral shoulder pain (NRS 9/10) with tension in the neck-shoulder region. | Right anteromedial knee pain (NRS 8.5/10) with concomitant functional impairment and additional left anterior hip pain. |
| **Duration of symptoms/Course** | 96 months/Stationary | 31 months/Progressive | 12 months/Stationary |
| **Onset** | Back pain and left leg pain started after a minor lifting trauma at work. | Occupational accident, pain started after a fall on the right shoulder. | Occupational accident, a fall on the right knee. |
| **Previous Treatments** | Spinal injections eight years ago: left leg pain reduced, but right "non-dermatomal" leg pain occurred. (see Appendix 5.3 "Pathoanatomical Factor"); pharmaceutical treatment: pain treatment (opioids), anti-inflammatory drugs and antidepressants; physiotherapy: 27 sessions consisting of massage, manual therapy, and an attempt of medical training therapy (MTT). Sam reported that MTT was unsuccessful due to the incapability of managing his pain. None of the interventions reduced symptoms. | Surgeries (see Appendix 5.3, "Pathoanatomical Factor"); therapeutic interventions: no physiotherapy prior to first surgery, postoperative treatment after 2nd arthroscopy consisting of mainly passive interventions (e.g., massage, trigger point therapy, manual therapy), attempt of MTT resulted in pain exacerbation; pharmaceutical treatment: pain treatment (NSAIDs) and anti-inflammatory drugs. Neither the surgery nor the interventions reduced symptoms sustainably. | Surgery (see Appendix 5.3, "Pathoanatomical Factor"); postoperative pharmaceutical treatment: pain treatment (NSAIDs) and anti-inflammatory drugs; physiotherapy: mainly passive treatment strategies (e.g., massage; manual therapy); cortisone injection. The interventions did not reduce symptoms. |
| **Current work situation (start treatment)** | Employment termination after health-related work absenteeism. Unemployed for eight years; seeking employment. | Employment termination after health-related work absenteeism. Unemployed for one year; seeking employment without having any professional support. | Employment termination after 12 months of health-related work absenteeism. Until the accident she was employed for 20 years at the same factory. |

inspection and palpation, for example palpating the abdominal wall during lumbar flexion to detect physical reactions such as muscle guarding (i.e., increased local or general muscle tone) (O'Sullivan et al., 2018), signs of holding one's breath or shallow breathing, all of which may indicate underlying cognitive factors such as hypervigilance, negative beliefs, fear, or catastrophizing (Simons et al., 2014). Underlying cognitive factors were analyzed by means of reflective questioning. A typical example of how this would be communicated would be: *"I see that there is a lot of tension being built up during this movement. What do you think your pain could mean?"* If an underlying cognitive factor or emotional response was hypothesized to drive maladaptive movement behavior, guided behavioral experiments were conducted to test the hypothesis (Caneiro et al., 2021). For example, after Dean was enabled to reduce his muscle guarding using relaxation and breathing techniques, the ROM and pain improved immediately. This demonstrated the potential influence of protective muscle guarding on movement performance. If movements were only aggravated after a certain number of repetitions, this was considered a clear sign of a lack of functional loading capacity. In those cases, the chances of successfully exercising functional loading capacity were expected to be higher. Additionally, palpation was performed in the resting position to determine base muscle tone.

The active and passive range of motion (ROM), muscle tone and strength were examined using classical manual physiotherapeutic techniques. Strength testing at a baseline level was not possible in any of the cases due to pain provocation. Local sensitivity was examined by palpation (light touch) and pressure sensitivity (global sensitivity) was quantified using the "Algopeg" device (Cámara et al., 2020; Egloff et al., 2011). A full neurological examination was carried out. The key findings from the physical examination are presented in Appendix 5.3. The multifactorial analysis (see Radar Graph 2a-c) was independently rated by two specialized PTs. In the case of agreement (a difference of $\leq 2$) the mean value was taken. If a factor was scored with a difference of $>2$, a discussion-based consensus was agreed upon.

### 2.4.2. Intervention: CFT in interdisciplinary care

CFT was integrated into an interdisciplinary and holistic approach, which required the cooperation of several participants: the legal insurance company's case manager and counseling medical doctor, PT, job, and mental coach. All parties mentioned above worked together as a "harmonized" group, theoretically covering all the potentially relevant domains of the patient's health. Evaluations within this team were carried out at the end of each module or in the case of any unforeseen, potentially exacerbating events.

The program was financially fully covered by the legal insurance company. In order to enhance the quality of reporting, the intervention description closely followed the TIDieR checklist (Hoffmann et al., 2016; Yamato et al., 2016).

In line with the recommendation of O'Sullivan et al. (2018) and Kent et al. (2023), key aspects of CFT were integrated into this approach, such as: **(1) "Making sense of pain", (2) "Exposure with control"** and **(3) "Lifestyle changes"**. Psychologically informed physiotherapy, which includes CFT, is supported by current literature (Holopainen et al., 2021; Keefe et al., 2018; Wilson et al., 2017). Therefore, motivational interviewing techniques (McGrane et al., 2015; Nijs et al., 2020; O'Halloran et al., 2014) and deliberate word choice (Richter et al., 2010) were applied throughout all interventions.

The authors implemented CFT key aspects into a clinical setting as follows:

**"Making sense of pain":** This was considered an essential first step in the therapeutic process, based on the patient's history, symptoms and presence of pain drivers in the multifactorial domain (Caneiro et al., 2021; O'Sullivan et al., 2018). However, making sense of the situation was an ongoing process throughout the CFT intervention. Therapeutic intervention therefore started during the intake session, when an intersubjectively rated multifactorial analyses and an appropriate treatment plan, including prognosis, were discussed with the patient. Therefore, the aim of the initial session was to create an understanding (cognitive factor) of the patient's condition in context, correcting faulty illness beliefs (cognitive factor) (Bunzli et al., 2017; Caneiro et al., 2021) and thereby improving self-efficacy and possibly already changing behavior (lifestyle and physical factor). All contributing factors that became apparent during the interview were integrated individually into the intervention.

**"Exposure with control":** Exposure with control was executed as described by Caneiro et al. (2021), O'Sullivan et al. (2018) and Kent et al. (2023). The process involved guided behavioral experiments in which the patient's identified provoking and aggravating activities were analyzed through video analysis. This addressed the patient's individual negative illness beliefs, tissue sensitivity, and levels of conditioning. Exposure with control aimed to alleviate fear-avoidance behavior by retraining the movement behavior in a non-threatening way, while also addressing negative illness beliefs and emotional responses to pain through a gradual approach. After normalizing the behavior, the exposure is gradually increased to such an extent that can be functionally integrated into activities of daily life.

**"Lifestyle change":** The need for, and importance of, lifestyle behavioral changes in many patients with persistent pain is supported in the literature (Bjorck-van Dijken et al., 2008; Dean and Söderlund, 2015). During the interview, lifestyle and its impact on the current situation was analyzed and discussed. In this approach, a Polar A360 tracking watch was used to analyze the patient's lifestyle (e.g., current activity level and sleep behavior) and to set target levels, specifically at *level 2* activity. Attempts were made to guide and restore normal activity levels and healthy sleeping behavior. An activity tracker is a cost effective and practical tool that can be used to guide and restore normal activity levels (Laranjo et al., 2020) and healthy sleeping behavior. The patients were then given an individually tailored "activity protocol" (see Walking protocol Appendix 5.5). This protocol was progressed according to the graded activity principles (Fordyce WE, 1976; Garland and Jones, 2019; Lindström et al., 1992) and aimed to reach *normal* (defined as Polar level 2) activity levels. To address the deconditioned state of the patients, a supervised, documented, progressive (according to the PAT principle, Appendix 5.8) exercise regime was implemented in the form of medical training therapy (MTT).

The authors have implemented the different patient-centered intervention aspects along with the proposed foci and principles into four blocks (see Fig. 2): 1) 1:1 Therapy, 2) Progressive, functional and documented Home Exercise Program (HEP), 3) Progressive Medical Training Therapy (see Appendix 5.8), and 4) job and mental coaching (detailed intervention description in Appendix 5.6).

Duration of the 1:1 therapy was 90 min in modules 1–3, and 60 min for modules 4–6 (see Fig. 1). Passive therapy measures, such as desensitization and mobilization techniques, usually took up 15 min. The role of the job and mental coaching is described in detail in Appendix 5.6. The three individual journeys of the applied CFT intervention are described in detail in Appendix 5.7.

## 2.5. Outcome measures

Pain, patient selected functional limitations, functional disability, movement behavior, subjective overall improvement ($VAS_{SOI}$), health related quality of life (HRQoL) and job status were defined as outcome measures using several tools: the "Numeric Rating Scale" ($NRS_{pain}$), the "Patient-Specific Functional Scale" (PSFS: score is the mean value of the evaluated functions) (Horn et al., 2012), questionnaires (these were patient specific, being "Oswestry Disability Index" (ODI) (Mannion et al., 2006), The "Victorian Institute of Sport Assessment – Patellar

Tendinopathy" (VISA-P-G) (Lohrer and Nauck, 2011) and "Disabilities of Arm, Shoulder and Hand" (DASH-G) (Offenbacher et al., 2003), video analysis with quantification, the visual analogue scale ($VAS_{SOI}$) and the "Short Form Survey" (SF-12) (Hayes et al., 2017) with age-related norms (Utah Departement of Health, 2001). The psychometric properties of the outcome measures are presented in Appendix 5.9. Job status was divided into work "status" (ordinal scale) and percentage. Work status was included to capture potential qualitative aspects for improvement and was scored in an ordinal fashion from 1 to 9. The codes 1 to 9 represent: 1) unable to work, 2) seeking work in adjusted field, 3) seeking work in preferred field, 4) able to work with reduced percentage in adjusted field, 5) able to work with reduced percentage in preferred field, 6) 100% with reduced competency in adjusted field, 7) 100% with reduced competency in preferred field, 8) 100% in adjusted field and 9) 100% in preferred field. Due to the clear distinction in each individual score, the authors expected a minimal change of "1" to be subjectively meaningful and to represent a detectable change in the work situation of the participants. Movement behavior was quantified by means of video analysis. Based on the interview and/or physical examination, maladaptive movement behaviors, relevant to functioning in daily life and/or job performance, were selected. The proposed method to quantify and evaluate maladaptive movement behavior using video analysis represented a target behavior according to Tate et al. (2016a) and was defined by the authors as follows: the selected movement behaviors were recorded on video and independently rated by two PTs from 0 (poor or maladaptive) to 100 (excellent or normal movement quality). The criteria used to rate the movement quality were symmetry (if applicable), fluency of movement, controlled execution, apparently effortless, executed in a "natural manner" (e.g., movement speed), and as if not apparently influenced by pain (e.g., facial expression). If the difference of the two independent raters did not exceed 30%, the average was used. If it did exceed this threshold, a third independent PT was asked to rate the movement and an average value was then used. The multifactorial assessment was performed in a similar fashion. Two PTs independently rated all the multifactorial domains (see Results 3.3.2) after the intake from 0 to 10, where "0" indicated that the corresponding factor was not estimated to drive the pain, and "10" indicated the rated factor was a strong driver of the pain (O'Sullivan et al., 2018). Again, a threshold of 30% was used for consensus in line with the method used for video analysis.

Primary outcomes were defined as patient selected functional limitations (PSFS), pain and work status, whereas functional disability (individual questionnaires), movement behavior, subjective overall improvement and HRQoL were defined as secondary outcomes.

#### 2.5.1. Social validation measures

Social validation was integrated within this approach to assess the socially relevant dimensions of the intervention (Kazdin, 1977, 2011). The incorporation of MCID values, SF12 age-related norm values and sustainability during the follow up period served as a social validation measures.

### 2.6. Visual and statistical analysis

In the absence of a consensus on the statistical procedure (Kratochwill et al., 2013), a combination of visual (Kratochwill et al., 2013; Wolfe et al., 2019) and statistical analyses (Manolov et al., 2014) were used to analyze the proposed outcome measures. The "What Works Clearinghouse (WWC) Single-Case Design standards" guideline by Kratochwill et al. (2013) was followed in order to conduct the visual analysis (Kratochwill et al., 2010, 2013). In addition, Conservative Dual-Criterion (CDC) method was used for visual aid (Fisher et al., 2003; Swoboda et al., 2010). For the statistical analysis, the Nonoverlap of All Pairs (NAP) was considered as an effect size measure (Parker and Vannest, 2009; Pustejovsky and Ferron, 2017). Cross-lagged correlation analysis using Simulation Modeling Analysis (SMA) (open access download http://www.clinicalresearcher.org/software.htm) (Borckardt, 2008) was performed to analyze temporal associations, and the strength between two proposed outcome measures during the course of the proposed intervention for the same patient. A complete description of the visual and statistical analysis can be found in Appendix 5.10.

### 2.7. Blinding

Evaluations were performed by two PTs with additional training in CFT, one of which was the treating therapist, whilst the other was not involved in the treatment of the participant and was a blind assessor.

### 2.8. Procedural fidelity

To enhance procedural fidelity (Tate et al., 2016a), as proposed by Krasny-Pacini and Evans (2018), the following strategies were applied: 1) an individual patient management plan was developed and goals were defined for each module prior to the start; 2) the management plan was reviewed and approved by a second PT before the start and after the completion of a module; 3) a session-by-session documentation (therapy log book) of applied interventions was conducted; 4) patients were asked to document their progress of HEP and MTT protocols, to analyze and monitor their loading capacity and adherence. This procedure was evaluated and discussed at every treatment session to enhance internal validity.

### 2.9. Ethics

Informed written consent was given from all three patients and "Clarification of responsibility" from the cantonal ethics committees (swissethics) revealed that no ethical approval was needed.

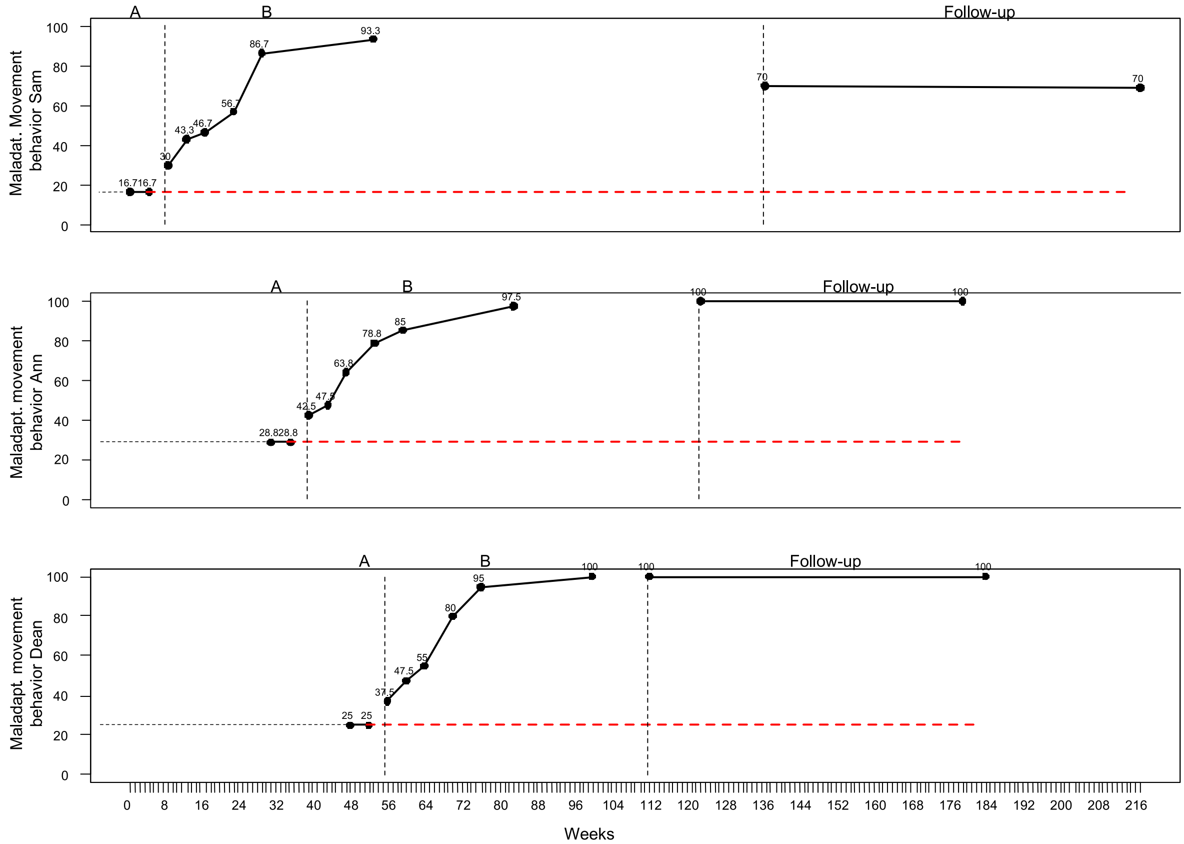
## 3. Results

All three patients underwent the defined interventions, and a total of 36 × 1:1 therapy and 96 x MTT sessions were applied to all three patients (see Fig. 1 Timeline). The number of sessions and interventions could be implemented as planned and no adverse events occurred. The PT documented the progress in a therapy logbook, which was verified by a second PT during the evaluations. The patients also documented their HEPs and MTT sessions as planned.

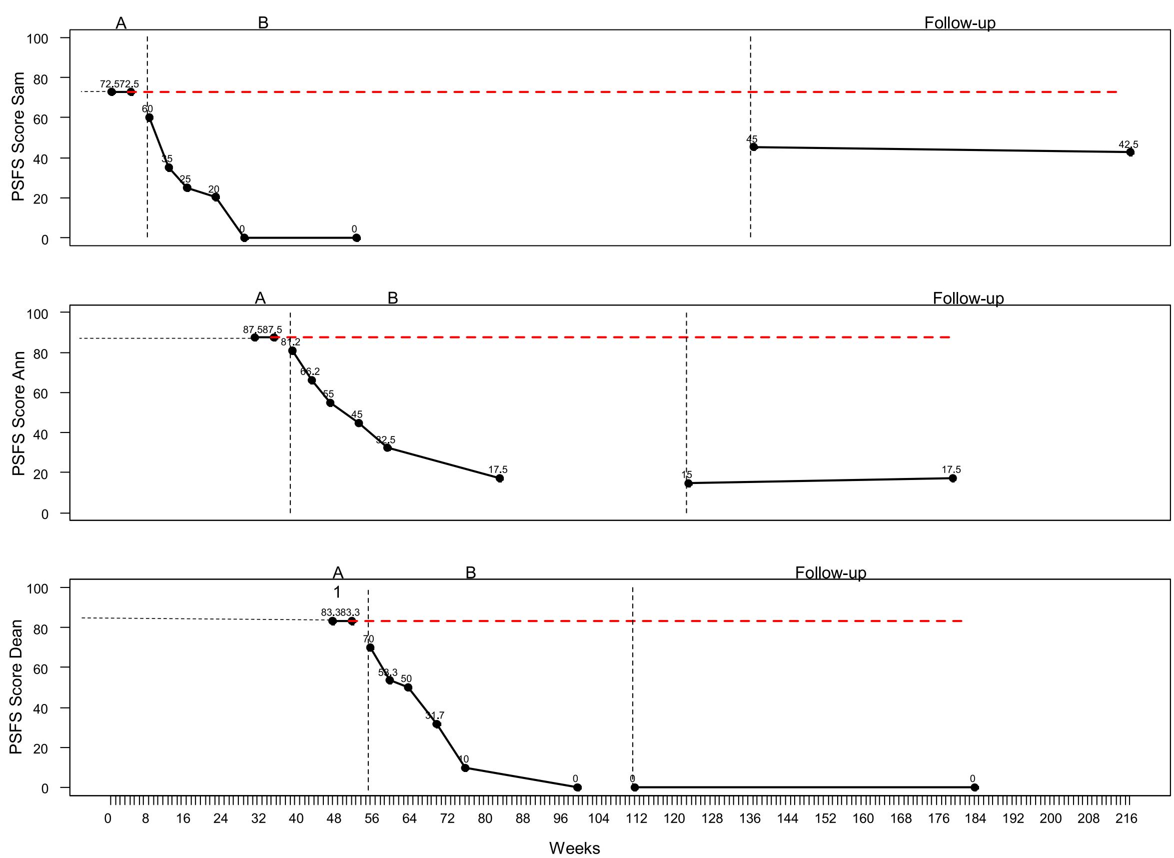
### 3.1. Visual analysis

The three non-concurrent multiple baseline results are shown in real time in Graph 1a-e. Visual analysis showed that 1) a stable baseline (no trend) was present in all three patients; 2) an immediate effect after the start of the intervention was established for all outcome measures, except for pain in the story of Ann, 3) all outcome measures revealed an increase/decrease of the mean in phase B compared to phase A, 4) a strong favorable trend in phase B was detected for all outcome measures (see Appendix 5.11 for trend analysis), 5) no substantial variabilities were observed except for certain fluctuations, within the individual questionnaire scores (Sam and Ann), and pain in Ann's story. Similar patterns in all three patients were observed and visual analysis indicated a treatment effect.

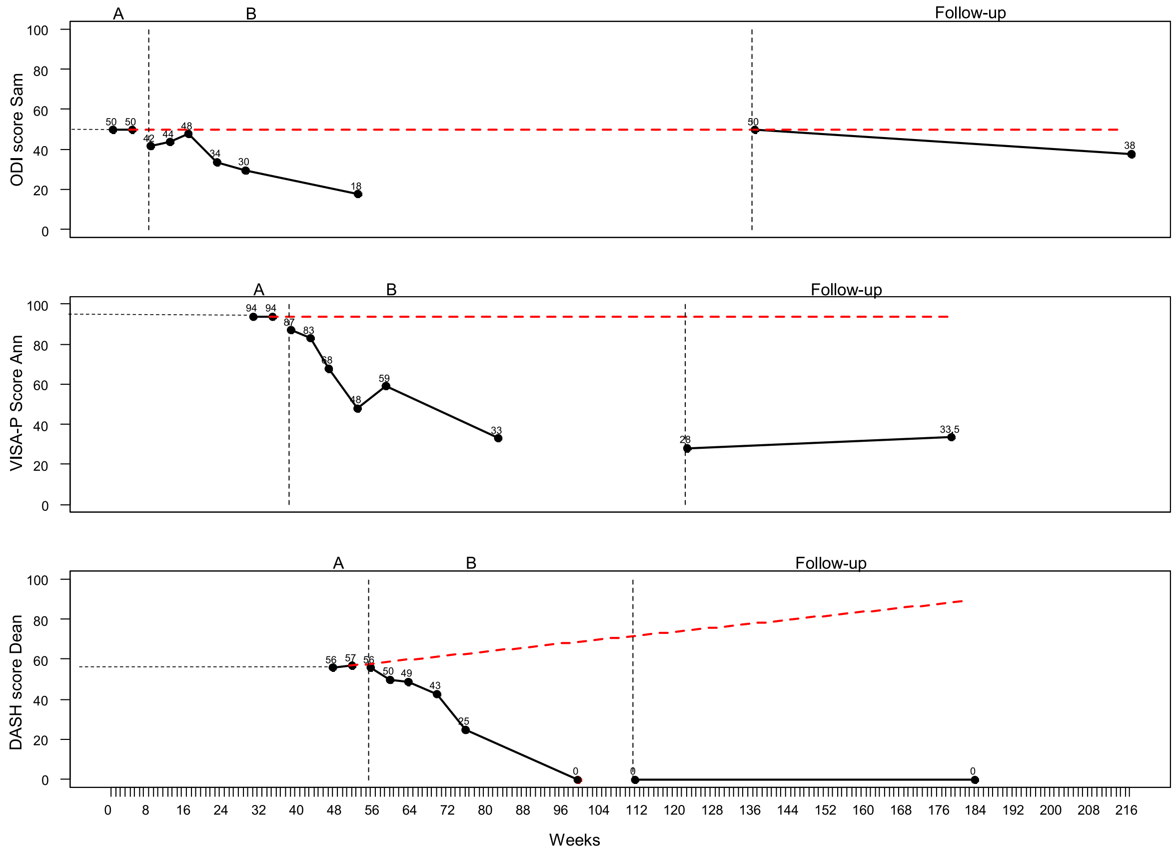
Graph 1a-e: Visual analysis of non-concurrent multiple baseline design in real time.



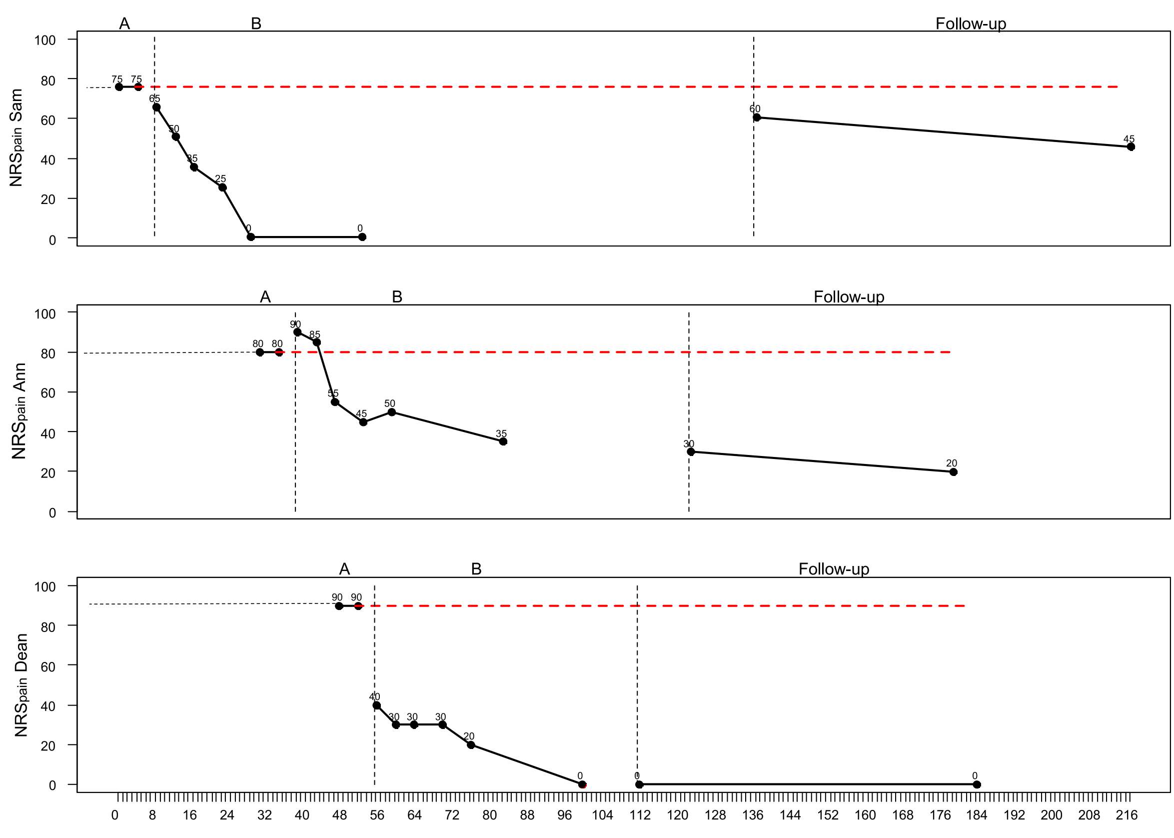

**Graph 1a.** Graphical representation of maladaptive movement behavior data in real time.



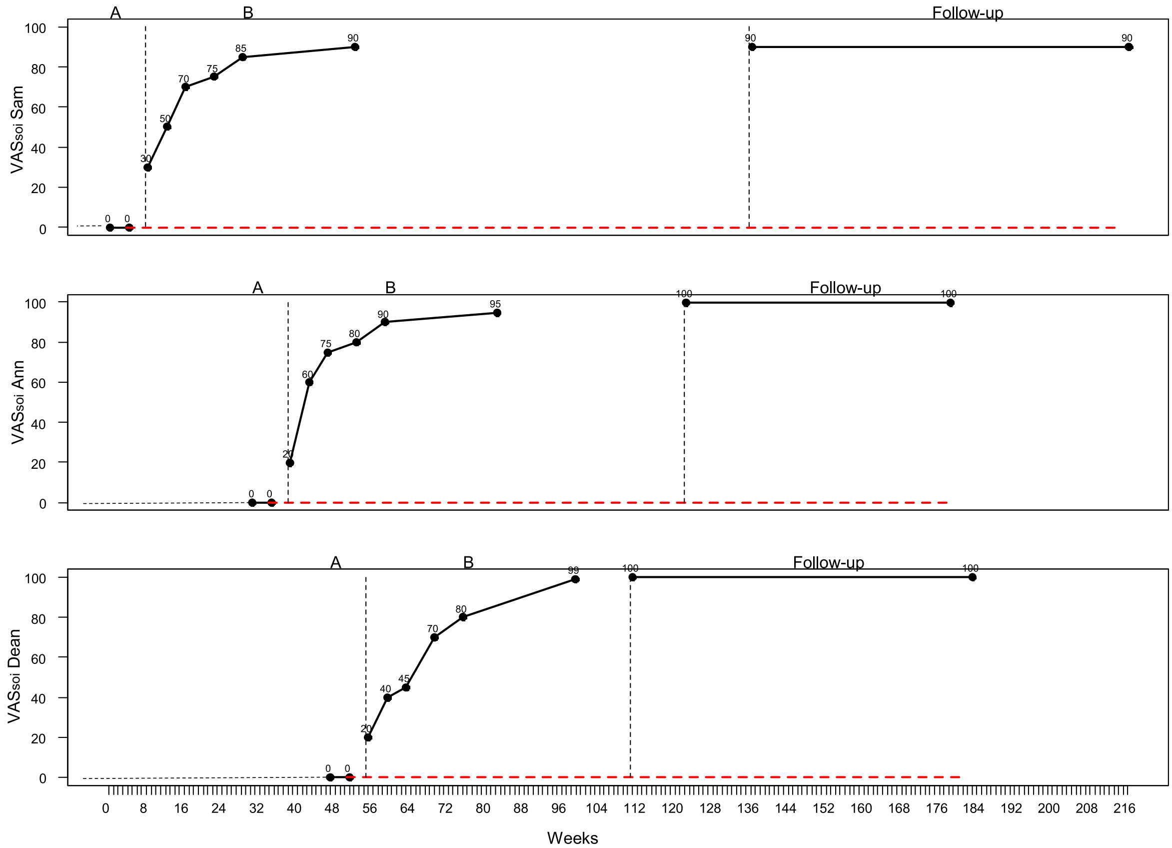

**Graph 1b.** Graphical representation of disability (PSFS) data in real time.




**Graph 1c.** Graphical representation of disability (individual questionnaires) data in real time.




**Graph 1d.** Graphical representation of $NRS_{pain}$ data in real time.




**Graph 1e.** Graphical representation of $VAS_{soi}$ data in real time

Abbreviations: black dashed line = historical baseline, PSFS= Patient-Specific Functional Scale, ODI= Oswestry Disability Index, VISA-P-G= The Victorian Institute of Sport Assessment–Patellar Tendinopathy german version, DASH-G = Disabilities of Arm, Shoulder, and Hand german version, $NRS_{pain}$ = pain, $VAS_{SOI}$= Subjective Overall Improvement

Phase A = no intervention phase, 4 weeks duration; Phase B= CFT intervention phase in an interdisciplinary program, 48 weeks duration, Follow-up evaluations were conducted at different time points: for Sam at 88 and 168 weeks after termination of the intervention, for Ann 40 and 136 weeks after termination of the intervention and for Dean 12 and 84 weeks after termination of the intervention.

#### 3.1.1. *Conservative Dual-Criterion (CDC) method*

For all outcome measures, except for pain in Ann's story, a systematic change (improvement) can be stipulated. The CDC results are presented in Appendix 5.12 and the graphical representations in Appendix 5.13.

### 3.2. *Statistical analysis*

#### 3.2.1. *Treatment effect (NAP) of the intervention on pain, disability, maladaptive movement behavior, subjective overall improvement and HRQoL*

All NAP values revealed a medium to large effect. Significant treatment effect was verified for all outcome measures with the exception of HRQoL (SF12) in the stories of Dean and Sam. In Ann's case, a significant treatment effect can be confirmed for all outcome measures except for pain ($NRS_{Pain}$) and health HRQoL (SF12). A statistical summary for the NAP analysis is presented in Appendix 5.14, and the individual graphical course for the proposed outcome measures in Appendix 5.15.

#### 3.2.2. *Cross-lagged correlation analysis*

Associations using SMA were analyzed for pain, disability, maladaptive movement behavior and subjective overall improvement. All associations between changes in the proposed outcome measures were significant and large (r = ≥0.50). Regarding temporal association, the summary of statistics revealed that all outcome measures (100%) changed concurrently (at a time-lag of zero) for all three patients (see Cross-lagged correlations and temporal associations of proposed outcome measures in Appendix 5.16). A sensitivity analysis along with the most disabling activity showed similar results (see Sensitivity Analysis Appendix 5.17).

### 3.3. *Social validation measure*

#### 3.3.1. *Overview of outcome measures*

Table 3 shows the within-person changes for the proposed outcome measures during person-centered and modular intervention for all three patients suffering from PMP. All three patients surpassed the MCID thresholds for all outcome measures during the intervention. The module at which the MCID threshold was surpassed varied from M1-M5.

**Table 3**
MCID thresholds of proposed outcome measures.

| Pain (NRS) | BL 1 | BL 2 | M1 | M2 | M3 | M4 | M5 | M6 | FU1 | FU2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Sam | 75 | 75 | 65 | 50 | 35 | 25 | 0 | 0 | 60 | 45 |
| Dean | 90 | 90 | 40 | 30 | 30 | 30 | 20 | 0 | 0 | 0 |
| Ann | 80 | 80 | 90 | 85 | 55 | 45 | 50 | 35 | 30 | 20 |
| MCID improvement= 20 points | | | | | | | | | | |
| MCID deterioration= 20 points | | | | | | | | | | |
| **Disability (PSFS)** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 72.5 | 72.5 | 60 | 35 | 25 | 20 | 0 | 0 | 45 | 42.5 |
| Dean | 83.5 | 83.5 | 70 | 53.5 | 50 | 31.5 | 10 | 0 | 0 | 0 |
| Ann | 87.5 | 87.5 | 81.5 | 66.5 | 55 | 45 | 32.5 | 17.5 | 15 | 17.5 |
| MCID improvement= 20 points | | | | | | | | | | |
| MCID deterioration= 20 points | | | | | | | | | | |
| **Disability (Questionnaire)** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam ODI (in % ) | 50 | 50 | 42 | 44 | 48 | 34 | 30 | 18 | 50 | 38 |
| Dean DASH-G Score | 56 | 57 | 56 | 50 | 49 | 43 | 25 | 0 | 0 | 0 |
| Ann VISA-P-G Score | 94 | 94 | 87 | 83 | 68 | 48 | 59 | 33 | 28 | 33.5 |
| MCID improvement: DASH-G=10.8 points; ODI= 8 points, VISA-P >13 points | | | | | | | | | | |
| MCID deterioration: DASH-G=10.8 points; ODI= 8 points, VISA-P >13 points | | | | | | | | | | |
| **Maladaptive movement behavior** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 16.5 | 16.5 | 30 | 43.5 | 46.6 | 56.5 | 86.5 | 93 | 70 | 70 |
| Dean | 25 | 25 | 37.5 | 47.5 | 55 | 80 | 95 | 100 | 100 | 100 |
| Ann | 29 | 29 | 42.5 | 47.5 | 64 | 79 | 85 | 97.5 | 100 | 100 |
| MCID improvement= 30% | | | | | | | | | | |
| MCID deterioration= 30% | | | | | | | | | | |
| **Subjective overall improvement ($VAS_{soi}$)** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 0 | 0 | 30 | 50 | 70 | 75 | 85 | 90 | 90 | 90 |
| Dean | 0 | 0 | 20 | 40 | 45 | 70 | 80 | 99 | 100 | 100 |
| Ann | 0 | 0 | 20 | 60 | 75 | 80 | 90 | 95 | 100 | 100 |
| MCID improvement= 30% | | | | | | | | | | |
| MCID deterioration= 30% | | | | | | | | | | |
| **Work status** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 4* | 4 | 4 |
| Dean | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 8* | 9 | 9 |
| Ann | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 4 | 4 | 4 |
| Clinically important change according to authors: 1 point | | | | | | | | | | |
| **PCS12** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 32.8 | 32.8 | - | - | 38.2 | - | 40 | 47.3 | 32.8 | 37.3 |
| Dean | 22.5 | 22.5 | - | - | 25.1 | - | 35.0 | 56.6 | 56.6 | 56.6 |
| Ann | 32.7 | 32.7 | - | - | 34.0 | - | 36.8 | 54.2 | 35.3 | 47.3 |
| **MCS12** | **BL 1** | **BL 2** | **M1** | **M2** | **M3** | **M4** | **M5** | **M6** | **FU1** | **FU2** |
| Sam | 35.8 | 35.8 | - | - | 30.2 | - | 42.2 | 46 | 32.5 | 35.4 |
| Dean | 60.6 | 60.6 | - | - | 63.8 | - | 61.5 | 60.8 | 60.8 | 60.8 |
| Ann | 19.1 | 19.1 | - | - | 27.1 | - | 32.1 | 43.4 | 34.0 | 59.4 |
| MCID improvement PCS12 >3.29 points; MCS12 >3.77 points | | | | | | | | | | |
| MCID deterioration | | | | | | | | | | |
| Reached age-related norm | | | | | | | | | | |

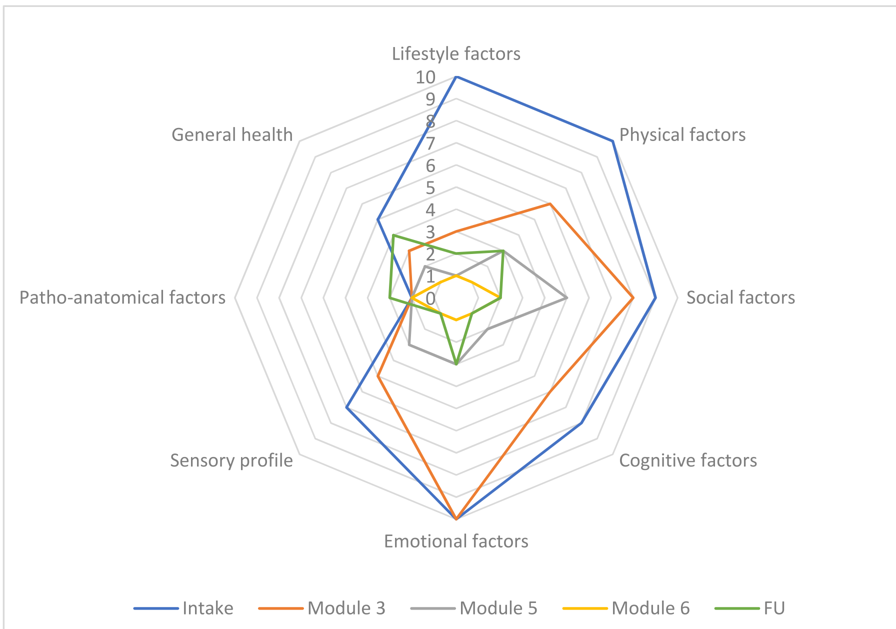
Abbreviations: PCS12= SF12 physical component summary, MCS12= SF12 mental component summary, MCID = Minimal clinically important difference, PSFS= Patient-Specific Functional Scale, $VAS_{SOI}$= Subjective Overall Improvement, $NRS_{pain}$ = pain, ODI= Oswestry Disability Index, VISA-P-G= The Victorian Institute of Sport Assessment–Patellar Tendinopathy, DASH-G = Disabilities of the Arm, Shoulder and Hand, M1-M6 = Module1-6, FU1= Follow-up evaluation 1, FU2= Follow-up evaluation 2.

The reached MCID threshold remained in two patients in FU2. SF12 scores, with the exception of MCS12 Sam, reached age-related norms (from M6 onwards) or were already within the norm (MCS12 Dean).

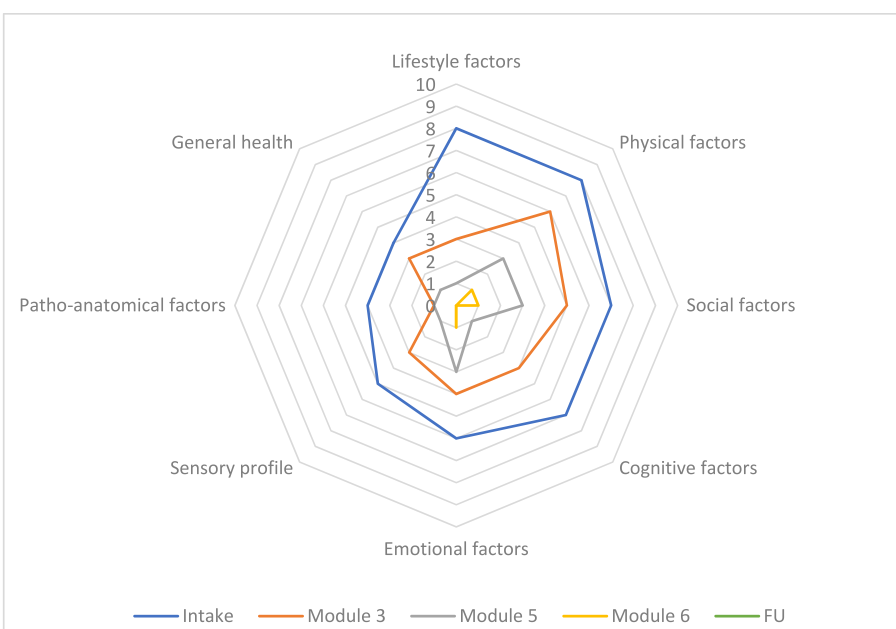
In relation to work status, all patients increased their functional capacity and increased the minimum one point, which was rated as clinically important by the authors. Dean was successfully integrated back into the work process in M6. He found a full-time permanent position with the support of a job coach. Sam was able to start a work trial in M6 with the perspective of a permanent position. Ann had successfully increased her functional capacity through the load management and did not have to claim for disability insurance. As Ann was close to retirement age, she decided not to look for a job and opted for early retirement. However, she did clarify that the outcome was "satisfactory."

### 3.3.2. *Multifactorial analysis*

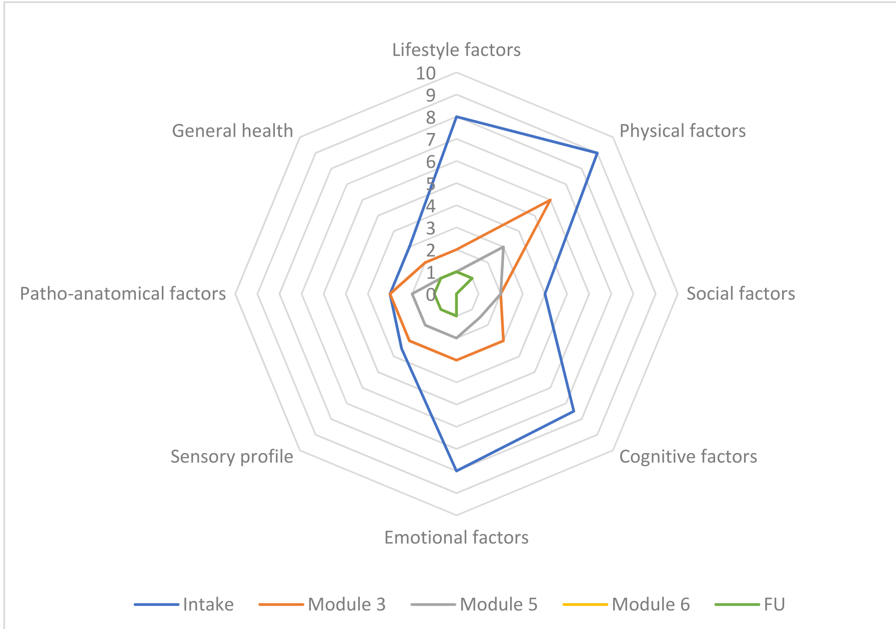
A favorable change of the intersubjectively assessed multifactorial analysis is shown in Radar Graph 2a-c.




**Radar Graph 2a.** Intersubjectively rated multifactorial analysis of Sam.




**Radar Graph 2b.** Intersubjectively rated multifactorial analysis of Dean.




**Radar Graph 2c.** Intersubjectively rated multifactorial analysis of Ann.

### 3.3.3. *Follow-up*

Two out of three patients reported lasting reductions in pain, disability and HRQoL, and all three patients mentioned improvement in maladaptive movement behavior as well as subjective overall improvement. Dean's pain reduction, along with his regained functional capacity remained unchanged post CFT, whereas Ann's pain continued to decrease steadily even after the intervention was completed. Sam reported increased pain intensity and functional limitations in FU1 due to the onset of a new disease unrelated to the initial pathology. The data in FU2 did reveal a downward, decreased trend. Dean showed a stable HRQoL post CFT, Sam's and Ann's HRQoL decreased slightly in FU1 but was rated significantly higher in FU2.

## 4. Discussion

The primary aim of this SCED was to assess the potential for CFT as a framework in an interdisciplinary setting when applied in a generalized PMP population. The secondary aim was to facilitate the translational process by presenting a detailed description of the clinical process. A third objective was to improve clinical insight throughout the course and the association of the proposed outcome measures. Visual analysis showed an immediate positive effect as soon as the intervention was introduced for almost all outcome measures. A medium to large treatment effect of the intervention was verified by statistical analysis for all outcome measures. All outcome measures revealed a strong interconnectivity and changed concurrently. Clinically important changes were achieved in all patients, for all outcomes, and were maintained during follow-up in two patients. The other patient showed detrimental values, however, due to unrelated pathology with onset post-intervention. In one case, successful work reintegration was achieved, while in the other, work reintegration was in progress.

Considering the massive individual and societal burden caused by PMP (Vos et al., 2017), every individual with PMP-related job loss, where relevant clinical improvements, as well as *successful job reintegration* is achieved, is therefore interpreted by the authors as highly relevant on both an individual and a societal level. For HRQoL (all cases) and pain (Ann), the statistical analysis (NAP) and social validation measures provided conflicting results. In the case of Ann, the initial increase of pain affected the average. This explains the significance failing to rise. However, since the course and end-values are decisive for the clinical outcome, the improvement of pain, in the case of Ann, has been interpreted by the authors as significant. The low number of measurements and relatively small changes on the SF-12 could be an explanation for the statistics failing to demonstrate significant outcomes. The achieved MCID or age-related norm values are a reason for the authors to interpret the improvements of HRQoL as relevant.

Furthermore, the clinical merits of the proposed CFT approach, in contrast to solely biomedical approaches, (e.g., exercise therapy, manual therapy or pharmaceuticals) are underlined by the marked speed in which pain intensity, in two cases (Sam and Dean), was reduced. A sole biomedical explanation for such a rapid improvement, after a stable baseline of 96 and 31 months respectively, is highly unlikely (Brodal, 2017). For example, any physiological training effects, such as the improvement of muscle strength within four weeks, after completing behavioral exercises only in Module 1, are not possible. Rapid changes that are theoretically plausible, are a change in mindset, belief (cognitive factor) and a corresponding adaptive behavioral change. The lack of success of previous treatments may be attributed to the fact that they failed to address the biopsychosocial nature included in the multifactorial analyses (see Appendix 5.3). Hence, the authors interpret the rapid onset of pain reduction as underlining the importance of a cognitive functional approach. The initial increase of pain in the story of Ann can be attributed to renewed, normalized loading (Ann showed strong maladaptive loading of the leg pre-intervention) of the involved leg, causing a temporary flare-up.

The applied CFT intervention and acquired results are comparable with the recent SCED studies carried out by Wernli et al. (2020a) and Caneiro et al. (2019). Similar to this study, the studies evaluated the effect of CFT on pain, disability and movement behavior (Caneiro et al., 2019; Wernli et al., 2020a). Caneiro et al. (2019) reported improvements in pain and disability of 57% and 61% respectively after 12 weeks, in comparison to 34% and 30% in this study. Although the effect size was larger after 12 weeks, in the study by Caneiro et al. (2019), the increasing trend is similar to our study result. The percentage of change and disability in the study of Wernli et al. (2020a) are only presented graphically, however the displayed trends seem comparable to our study. A recently published RCT, the RESTORE trial, demonstrated that CFT can produce a large and sustained improvement for people experiencing persistent, disabling lower back pain (Kent et al., 2023). The reported effects on pain, disability and the PSFS at 13 weeks are significant and align with our findings. These positive outcomes persisted for 52 weeks in the RESTORE trial, whereas the results in the present study continued to show improvement within the one-year intervention period. However, a prominent difference between the three reported studies is the applied number of sessions and the duration of the intervention. While both SCEDs offered around 10 sessions during the three-month intervention phase and the RESTORE trial a mean number of 7 in a 13-week intervention period, we integrated thirty six 60-90' sessions into a one-year CFT intervention. The long duration of our intervention can also be attributed to the aim of job reintegration, which is a time-consuming process. Noteworthy is that the long duration of the CFT intervention in our study seemed to enable continuous significant improvement up to 12 months post onset, whereas in the studies by Caneiro et al. (2019) and Kent et al. (2023) the achieved improvements mostly stagnated after 12 weeks. The 6-month work-hardening phase (module 6) aimed at reconditioning could possibly explain the continuous improvement. Although sustaining improvements in PMP is uncommon after treatment cessation, as noted by Ho et al. (2022) our follow-up data from 3 to 5 years revealed not only stability but also partial continuous improvement. The authors consider this to be a marked result.

HRQoL (e.g., SF12) is stated as one of the core outcomes in interdisciplinary multimodal pain management (Kaiser et al., 2018). Evident changes in this study, e.g., the achievement of age-related norms of SF12 in M5 and M6, might not have been achieved if the intervention had been terminated after 12 weeks (M3). It was therefore concluded that it may be clinically valuable to employ a longer intervention duration in the treatment of PMP. Although the treatment adherence and follow-up data in the current study suggest promising results, further studies are needed to address the optimal duration of CFT in interdisciplinary care for patients with PMP.

This study presents clinical details of the described CFT approach within an interdisciplinary setting to facilitate the translational process from a scientific to practical approach. The authors are aware that it is not feasible for most primary care clinicians to duplicate the extensive resources, such as the performing of evaluations with two clinicians, used in this study. However, it is important to note that the CFT principles, applied in the clinical reasoning and therapeutic process, can be adopted by a solo primary care physiotherapist, as demonstrated in the study of Kent et al. (2023). In addition, considering the burden PMP causes, the authors emphasize the significant value of raising awareness about the applicability of CFT in a generalized population.

SMA revealed a simultaneous change in the proposed outcome measures. Therefore, the proposed hypothesis that movement behavior will change prior or simultaneously to pain, does not have to be rejected. Improvements in movement behavior were strongly associated with pain reduction and/or reduced disability (100%). All three patients developed less protective movement behavior and increased their ROM in the present study. These findings correlate with two recently published SCEDs where CFT in LBP patients was applied (Caneiro et al., 2019; Wernli et al., 2020a). Wernli et al. (2020a) reported a relationship between changes in movement behavior and pain as well as disability in patients with LBP (74%). Simultaneous changes were observed in the majority (54% changed at lag zero). It has to be noted that the measurement intervals (4–6 weeks) may have a considerable influence on our results regarding the temporal associations. Kratochwill et al. (2013) proposed weekly measurements to detect optimal change. However, due to practical issues (e.g., time constraints), it was not possible to conduct weekly measures. Although the changes within the time intervals remain unclear in our study, the consistency, between our study and above-mentioned studies, seems to underline the validity of the results.

In contrast to the above-mentioned studies, the recent systematic review by Wernli et al. (2020b) shows varying results regarding the relationship of movement behavior and pain and/or disability. The results showed only a 31% relationship between these variables. The difference in results could be explained by prior studies failing to address the biopsychosocial factors in general, and the cognitive aspects of movement specifically. Psychological factors such as pain-related fear, catastrophizing and depression have a direct effect on spinal motor behavior. Patients with pain-related fear or depression have higher muscle activity and less movement amplitude (Christe et al., 2021). This highlights the importance of including psychosocial factors to achieve a change in movement behavior and/or explain the observed variability.

### *4.1. Strengths and limitations*

A key aspect of the methodology of this study is the heterogenous patient selection. Hence, the methodology inherently strengthens the external validity. The potential patient population where the proposed intervention can be applied is, as depicted in the introduction, substantial. Additionally, considering the growing individual and societal burden caused by PMP, the social relevance of this topic is highly significant as well. Despite clinicians recognizing the merits of adopting psychosocial management principles in treating PMP, they are experiencing difficulties translating this into clinical practice. A strength of this study is that it presents detailed, extensive descriptions of the clinical process integrating subjective, intersubjective, and objective parameters, thereby facilitating the adoption of the proposed treatment principles. The described multifactorial analysis is presented to provide clinicians with a concrete tool to enable practical, feasible assessment of these factors and integrate them into clinical practice, as stated in the TIDieR checklist, providing good reproducibility (Hoffmann et al., 2016). Measuring all aspects of the clinical problem also aims to reduce the risk of bias by preventing reliance on sole parameters (with inherent "chance" measurements). According to Tate et al. (2013), this study has fulfilled the criterion of at least three inter-subjective replications, enhancing internal validity. Causal influence of the applied intervention is likely as this non-concurrent multiple baseline design showed a replicational effect (Horner et al., 2005) among three patients with different symptoms within the ICD-11 code. Finally, according to Kratochwill et al. (2010) the intervention was systematically introduced and manipulated by the researchers as the B-phases represented the sequential introduction of the different foci on behavioral treatments.

Despite all efforts to follow the guidelines of this study design, there are some limitations regarding the research methods that need to be acknowledged. Although the minimum of three patients (Kratochwill et al., 2013) was included, the minimum of three data points during the baseline phase could not be fulfilled due to practical issues such as patients' travel distance. However, it should be stated that the unchanged historical baseline (between 12 and 96 months) in all patients and the conducted comprehensive analysis in every evaluation underpins the objective representation of the patient, and strengthens the two baseline data points. It can therefore be concluded that maturation as a confounding factor is highly unlikely (Kratochwill et al., 2010) and more baseline data points would not significantly influence the results of the treatment effect. Of note, the results are comparable with the findings by Caneiro et al. (2019), who performed more baseline measurements and weekly assessments. Moreover, the present study is limited by the fact that evaluations were conducted at long time intervals and the changes occurring within these intervals remain unclear. It is very likely that the results of our cross-lagged correlation analysis were influenced by the time interval between measuring points. These results should therefore be interpreted with caution. However, the overall study results display such robust results, that the authors do not expect the chosen time-intervals to have a significant effect on the final conclusion. Furthermore, it should be noted that the clinical context described cannot be deemed as "typical care" due to the involvement of "high disability" participants, the extensive time investment, and the financial and interdisciplinary support of the legal insurance company. Although the feasibility of the documented CFT approach in a primary care context has not been studied previously, the applicability of CFT is underlined by Kent et al. (2023) in the RESTORE trial. Kent et al. (2023) describe cost effective, superior long-term effects of CFT compared to usual care in patients with low back pain delivered by solo primary care physiotherapists. Additionally, all therapists that participated in this study received additional training in CFT, which is a prerequisite. The required extensive and comprehensive training for CFT experts is clearly stated by Simpson et al. (2022). The integration of two physiotherapists within the intakes and evaluations is undoubtably a quality enhancement, though challenging to put into practice within a clinical setting. Generalizing the results to therapists lacking additional CFT training should be carried out with care.

### 4.2. Clinical relevance

- Implementing a multifactorial management plan in PMP remains challenging for clinicians. Our study describes the multifactorial analysis, treatment, and evaluation process in detail in a heterogenous group of patients with PMP aiming for job reintegration. This study thereby facilitates the translational process from science to practice, aiming to improve adherence of clinical practice to clinical guidelines.
- CFT in an interdisciplinary program can be implemented when aiming for job reintegration and improving health related quality of life. Although interdisciplinary rehabilitation programs are recommended, the question of funding such sophisticated and holistic approaches needs to be addressed (Oesch and Kesseling, 2017).
- This study provides insight into the course and associations of a variety of outcomes. These insights support the understanding of PMP pathology and may improve clinical reasoning.
- The study design exposes great insight into the monitoring and documentation processes and stipulates clinical implementation. This can encourage clinicians to generate evidence on an individual level. This evidence can provide the necessary motivation for the patient, as well as the clinician, and supports clinical reasoning.

### 4.3. Future research

The importance of replicational research is evident. We therefore suggest a systematic replication of the proposed approach in a heterogeneous group of patients suffering from PMP by multiple researchers in multiple locations within a "normal clinical setting" (Birnbrauer, 1981). To extend this present study and to provide further information on optimal CFT intervention duration, a concurrent multiple baseline SCED with four patients is suggested. CFT intervention duration will differ among the patients as a staggered phase B will be applied. If possible, weekly evaluations should be integrated in future research to detect changes (Kratochwill et al., 2013). To enhance the design's scientific credibility by increasing internal validity, randomization tactics should be incorporated (Kratochwill and Levin, 2010). To increase internal validity, a case randomization could be applied, randomly determining which participant starts intervention phase B first. Additionally, an randomized intervention starting point could be applied to further reduce the researcher's bias (Levin and Kratochwill, 2021). Integration of different effect sizes (e.g., between-case standardized mean difference effect sizes for single-case designs (Valentine et al., 2016) for comparing SCED and group designs should be addressed and the Örebro screening questionnaire, to reflect cognitive aspects, should be implemented.

Finally, the study protocol by Vaegter et al. (2021) aims to determine if CFT+ with psychologist support, potentially supplemented with usual care, is more effective and cost-efficient in reducing disability over 12 months than the usual interdisciplinary pain management pathway in patients with severe low back pain. The results of this trial may serve as an interesting comparison.

### 4.4. Conclusion

The study findings suggest that CFT in an interdisciplinary program is an effective way to reduce pain, improve functional disability and work status in a heterogeneous small sample of patients with PMP. All outcome parameters show a high interconnectedness and simultaneous change. As integration of multifactorial PMP management remains a challenge for most clinicians, the detailed descriptions of the clinical processes could serve as a tool for clinical translation to improve future clinical care.

## Authors' contribution

**SZ:** Conceptualization, literature search/review, methodology, data analysis, data curation, visualization (figures/graphs), writing – original draft, review & editing.

**MdG:** Conceptualization, methodology, writing – original draft, review & editing.

**RH:** Supervision, data analysis, writing – review & editing.

All authors contributed resources, contributed to the review and editing of the manuscript, and approved the final manuscript.

## Data sharing

All data are available in the manuscript and in online appendices. The R code is available from the corresponding author on request.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

During the preparation of this work the author(s) used chatGPT in order to improve language and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

## CRediT authorship contribution statement

**Simone Zingg:** Writing – review & editing, Writing – original draft, Visualization, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maurice de Graaf:** (shared first authorship w. S. Zingg), Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Roger Hilfiker:** Writing – review & editing, Supervision, Formal analysis.

## Declaration of competing interest

All authors reported no conflicts of interest.

## Acknowledgments

A sincere thank you belongs to Ferry Pingitzer for the inspiring collaboration, invaluable contributions in the past years, and the development of the clinical program together with Simone Zingg. A special thanks goes to Thomas R. Kratochwill of the University of Wisconsin-Madison, who assisted us with his tremendous methodological expertise in SCED.

## Appendices

### 5.1. Hypotheses

| Number | Hypotheses | Y/N |
|---|---|---|
| **Treatment effect using the patient centered CFT approach in interdisciplinary care** | | |
| 1 | The NAP analysis shows a large treatment effect on pain ($NRS_{pain}$) in all three patients | No, as only in 2 out of 3 patients |
| 2 | The NAP analysis shows a large treatment effect on disability (PSFS total score) in all three patients. | Yes |
| 3 | The NAP analysis shows a large treatment effect on movement behavior in all three patients. | Yes |
| **Social validation** | | |
| 4 | MCID thresholds of disability (PSFS total score) will be surpassed after M3. | Yes |
| **Temporal association between variables** | | |
| 5 | Maladaptive movement behavior will change prior to or simultaneously to the decrease in pain intensity ($NRS_{pain}$) | Yes |
| 6 | Reduction of disability (PSFS total score) will change prior to the change of pain intensity ($NRS_{pain}$) | No, as concurrent change was stated |
| 7 | Reduction of pain ($NRS_{pain}$) will change concomitantly with subjective overall improvement ($VAS_{SOI}$) | Yes |

### 5.2. Goal setting per module

**Module 1: "Try Out Phase"**
- Motivation and self-initiative to change the current situation and lifestyle is present
- Achieve understanding of the explanation for the vicious circle causing the pain
- Understanding of contributing factors is present, plus willingness to proactively change them
- Mutually agreed individual short and long term goals
- Beginning is evident of a change in maladaptive movement behavior
- Training and change of body awareness has been integrated into daily life
- Start of regular aerobic training
- Active coping strategies and self-management techniques are used: regular performance and documentation of functional and specific home exercises

**Module 2: "Belief phase"**
- Partial or complete change of illness beliefs and their integration into everyday life
- Partial or complete change of negatively influencing lifestyle factors and integration into daily life
- Complete change of maladaptive movement behavior and body perception with successful integration into daily life
- Performance of accompanying basic medical training therapy exercises to progressively increase loading capacity according to progression line (equipment training).
- Active coping/pacing strategies and self-management techniques are used: implementation and documentation of progressive and functional home exercise program on a regular basis.
- Active participation: newly learnt strategies for self-management are integrated into daily life

**Module 3: "Local functional loading capacity phase"**
- Complete change related to negative illness beliefs and anxiety
- Normalized movement behavior can be applied to low-impact daily activities
- Increased loading capacity: supervised progressive adaptive training with functional exercises can be increased and documented according to progression line (equipment training with variations).
- Active coping strategies and self-management techniques are applied: progressive functional home exercise program is gradually increased
- Increase of loading capacity is evident to perform non-loading activities of daily living

**Module 4: "Supervised work-related loading capacity phase 1"**
- Normalized movement behavior is applied during demanding everyday activities
- Regular performance of active training is performed upon agreement
- Progressive adaptive training with functional exercises can be gradually increased according to the progression line (pulling exercises)
- Partial or complete independence in performing active training
- Modified and adapted pacing strategy is applied: adequate planning regarding daily loads and training is applied, resulting in no exacerbation
- Increase in exercise capacity is evident
- Progression and documentation of the progressive home exercise program is evident
- Beginning of the organization of reintegration into occupational life

**Module 5: "Supervised work-related loading capacity phase 2"**
- Completely independent performance of controlled active training.
- Progressive adaptive training with functional exercises can be gradually increased according to the progression line (free weight exercises)
- Significant increase in loading capacity is measurable
- Functional analysis: there are only minor limitations in the demanding activities of daily living.
- There is a significant reduction in symptoms
- Reintegration into the work process (old/new job) has occurred

**Module 6: "Work-hardening phase"**
- Continue to build and maintain functional loading capacity
- Regular implementation of progressive adaptive training to maintain lifestyle changes
- Resumption of former hobbies (e.g., playing football, tennis, pilates, boxing, motocross etc.)

### 5.3. Examination findings at baseline

| Examination findings | Sam | Dean | Ann |
|---|---|---|---|
| **Pathoanatomical factors** | **2/10**<br>MRI one month after trauma revealed normal age-related disk degeneration at L3/4 and L4/5 and disk bulging L3/4 without nerve compression. MRI 3 months prior to intake indicated no further abnormalities. Back and leg pain could not be linked to underlying degenerative findings (Maher et al., 2017). | **4/10**<br>**Three years prior to intake** Arthroscopy with reconstruction of the rotator cuff (suture of M. Supraspinatus with the placement of metal anchors due to partial rupture/thinning of tendon); no symptom reduction.<br>**Two years prior to intake** 2nd arthroscopy (re-reconstruction of rotator cuff: refixation of rotator cuff with horizontal anchorage (“screws”) in the head of the humerus, biceps tendon tenodesis, acromioplasty); again, no symptom reduction.<br>**One year prior to intake** MRI one year prior to intake showed relatively thin but intact infra- and supraspinatus tendon. AC joint arthrosis, slight fluid accumulation subacromially and subdeltoidally. | **3/10**<br>MRI 1 month after fall: a lateral meniscal tear and strain of the lateral collateral ligament grade 1 were visible. 6 months after the onset, a partial lateral meniscectomy was performed. MRI after 10 months: a re-rupture of the lateral meniscal. These structural findings did not correlate with the clinical presentation, as the symptoms were solely anteromedial. |
| **Cognitive factors** | **8/10**<br>**Self-efficacy** Helpful explanations of his current situation and effective treatment strategies to control the pain were not provided by previous healthcare providers and left him insecure: “*Healthcare professionals have given me different explanations for my pain, and they told me I have to live with my herniated disc. Physiotherapy hasn't been helpful so far. Therefore, there must be another reason for my pain. This makes me anxious.*”<br>**Coping** Passive coping strategies: medication intake (opioids), relief by sitting or lying down for 3 h. No awareness of effective active strategies for symptom relief.<br>**Hurt = Harm** “*Doing activities with pain may cause more damage. That's the reason why I stop activities as soon as I feel pain. I don't want to end up in a wheelchair.*”<br>**Beliefs** Loss of positive beliefs in physiotherapy and any medical treatment as previous PTs didn't take his situation seriously and advised him to accept his situation. Biomedical beliefs were present.<br>**Fear** Constantly fearing his pain and the possibility of further damage, he carried a small folding chair in a backpack to sit down and relax.<br>**Pacing strategies** Regular overloads resulted in boom-bust cycle of pain and frustration. E.g., 15″ of gardening resulted in an hour of rest. | **7/10**<br>**Negative Beliefs** The patient presented strong pathoanatomical beliefs and related the cause of his shoulder pain to the metal anchors and screws in his shoulder.<br>*"My pain is triggered by the metallic screws in my shoulder, and they will destroy the bones. Therefore, I must move slowly and gently. Pain means I should stop moving"*.<br>**Catastrophizing** He was afraid that lifting his arm would “break” the screws.<br>**Negative Treatment Experience** Loss of positive belief in physiotherapy and any medical treatment as former physiotherapy management (primarily passive management) didn't relieve his symptoms.<br>**Fear Avoidance** Lifting his arm (>40°G/H elevation) was avoided.<br>**Pacing Strategies** Despite a general pattern of inactivity and avoidance, Dean did attempt to use his arm for daily activities (e.g., ironing) now and then, resulting in overload and creating a boom-bust cycle of pain and frustration.<br>**Coping** Mere passive coping strategies such as taking rest and pharmaceutical symptom reduction were present. | **7.5/10**<br>**Beliefs Regarding Scans** Based on the MRI findings, Ann believed her knee was “broken”.<br>**Hurt = Harm** Ann interpreted the pain as dangerous and harmful, which led to avoidance.<br>**Coping** Mere passive coping strategies such as taking rest and pharmaceutical symptom reduction were present.<br>**Negative Treatment Experience** Surgery and previous physiotherapy (primarily passive treatment strategies) did not provide any symptom relief.<br>**Fear** Ann was constantly afraid of falling due to her weakened knee. This was reflected in her movement behavior as her movements were slow and careful. In addition, Ann used walking sticks to get around. In general, she was afraid that straining herself could cause cardiac arrest. This led to avoidance of all forms of activities. |
| **Emotional factors** | **10/10**<br>**Frustration** Due to failed medical treatment and therapy.<br>**Feeling of Uselessness** Due to unemployment.<br>**Depressed Mood** Due to occupational and financial stress. | **6/10**<br>**Grief** See life stress event; the stillbirth caused strong feelings of grief and depressive feelings.<br>**Frustration** Failed medical treatment and therapy resulted in frustration.<br>**Depressed Mood** See life stress events; in addition, his work situation led to financial and family stress, further affecting his mood negatively.<br>**Fear** pain experience was associated with fear and emotional distress (see catastrophizing).<br>**Loss of Identity** Due to unemployment. | **8/10**<br>**Anxiety** See life stress events. Her cardiac arrest led to significant anxiety, leading to severe sleep disturbances (see Lifestyle factors). |
| **Social factors** | **9/10**<br>**Social isolation** Report of supportive family environment; social isolation due to job loss.<br>**Socio-economic factor** Financial insecurity due to unemployment. The patient identified strongly with his work and had a strong desire to return.<br>**Cultural factors** Could no longer play the role of family provider through unemployment. | **7/10**<br>**Life Stress Events** Stillbirth of first child around onset of symptoms; employment termination.<br>**Social Isolation** Prior to the accident, Dean was a very active, sporty, and resilient individual, who had a good social network. Job loss as well as physical limitations led to social isolation as former hobbies such as football were not possible anymore.<br>**Socio-Economic factor** Financial insecurity due to unemployment. | **4/10**<br>**Life Stress Events** Ann experienced a cardiac arrest during the anesthetic procedure of her first knee operation, which generated massive anxiety and the fear of dying.<br>**Social Isolation** Before the accident Ann was regularly socially active. Her fear led her to become inactive and to not go out of her house anymore, which led to isolation. |

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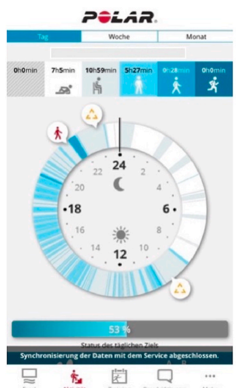
(*continued*)

| Examination findings | Sam | Dean | Ann |
|---|---|---|---|
| **Lifestyle factors** | **10/10**<br>**Sleep Hygiene** Severe sleep-maintenance insomnia (5–6 h awake at night, up to three nights a week) led to constant fatigue. Due to constant fatigue, Sam could not even perform normal daily duties and he was dependent on his wife.<br>**Activity Level** Sam stopped engaging in regular activities eight years ago, resulting in an 15 kg weight gain (BMI = 29 kg/m$^2$) and a significant reduction in functional capacity<br>**Polar Activity Tracker** showed sedentary lifestyle: 17 h/day were in lying or sitting position.<br><br><br>Example of Polar activity output. | **8/10**<br>**Sleep Hygiene** Sleep-maintenance insomnia due to shoulder pain when lying on one's side.<br>**Activity Level** was massively reduced since the pain started; sedentary lifestyle: Dean in general avoided any activity due to fear of exacerbation.<br>**Polar Activity Tracker** Showed sedentary lifestyle and no recovery sleep pattern. | **8/10**<br>**Sleep Hygiene** See Life Stress Events. A distinct sleep disorder was present due to an anxiety related to the cardiac arrest. Ann feared she would not wake up anymore, especial in the dark at night. She therefore always turned on the TV and did not switch off the lights in the bedroom. She reported a maximal sleep of 2–3 h per night. Both sleep-onset insomnia and sleep-maintenance insomnia were present. She reported massive fatigue.<br>**Activity Level** Her activity level was significantly reduced due to fear of pain and symptom exacerbation.<br>**Polar Activity Tracker** Showed sedentary lifestyle and no recovery sleep pattern. |
| **General Health** | **5/10**<br>Co-morbid neck pain and headaches, generally fatigued, obesity, deconditioned | **4/10**<br>Co-morbid neck pain; obesity; smoking, deconditioned | **3/10**<br>No significant co-morbid diseases were present besides deconditioning. |
| **Sensory Profile** | **7/10**<br>**Local Sensitivity** Regional hyperalgesia in lower lumbar spine and gluteal soft tissue right > left, non-dermatomal hypoesthesia in right anterior leg.<br>**General Sensitivity/pressure sensitivity** Significant high Algopeg values: finger 7/10; earlobe 7/10 (hyperalgesia). | **5/10**<br>**Local Sensitivity** Hyperalgesia in anterior and posterior soft tissue structures of the right shoulder were present with palpation.<br>**General Sensitivity/pressure sensitivity** Significant high Algopeg values: finger 6/10; earlobe 8/10 (hyperalgesia). | **3.5/10**<br>**Local Sensitivity** The medial side of her right knee showed strong local sensitivity, as well as the proximal anterior right hip.<br>**General Sensitivity/pressure sensitivity** High Algopeg values: finger 5/10 (hyperalgesia); earlobe 5/10 (within normal range)<br>positive pinprick test NRS 8/10 provocation of medial knee pain with knee extension |
| **Physical Factors** | **10/10**<br>**Strength** Atrophy of upper right leg and gluteal muscles was noticeable upon visual inspection.<br><u>**Maladaptive Movement Behavior**</u><br>**Standing** Active lumbar hyperextension; anterior pelvic tilt; bilateral tension of M. erector spinae and bracing of abdominal wall (co-contraction); right leg loading was avoided.<br>**Sitting** Hyperextended lumbar spine; avoidance of right leg loading; right knee was typically held in 30° knee flexion.<br>**Walking** Limping: loading of the right leg was avoided; right leg was held in excessive external rotation; clenched fist was observed.<br>**Forward Bending** Performed with excessive lumbar extension, anterior pelvic tilt and bracing of abdominal wall; flexion relaxation was absent; NRS 7/10.<br>**Returning to upright from forward bending** Performed with breath holding and use of the hands to support the trunk.<br>**Standing on right leg** Not possible due to lack of balance and fear.<br>**Stair Climbing** Alternated descending was possible (although very insecure) with support of the handrail, ascending only possible step-to-step whilst pulling himself up on the handrail.<br><u>The following activities were integrated in movement behavior analysis:</u> standing, walking and stair climbing.<br><u>**Functional Capacity**</u><br>**Standing** >5 min not possible due to LBP and right leg pain aggravation.<br>**Walking** >10 min not possible due to LBP and right leg pain aggravation.<br>**Ascending stairs** Alternating only possible when using | **8/10**<br>**Strength** Manual strength tests could not be performed due to pain provocation. Atrophy of M. Supraspinatus and M. Infraspinatus was noticeable upon visual inspection.<br><u>**Maladaptive Movement Behavior**</u><br>**Sitting/Standing** Excessive erect thoracic spine posture; excessive active G/H* depression/external rotation; visible tension and overactivity of M. trapezius pars descendens.<br>**Walking** Arm swing was avoided, right arm was pressed against the body.<br>**Combing Hair** Excessive muscle guarding (in neck-shoulder region); rigid spine, i.e., dissociation of cervicothoracic movement; slow and careful movement; holding of breath, grimacing, and sweating.<br>**Lifting a 1.5L bottle to drink** support of left arm needed; excessive muscle guarding.<br>**Turning his head** Dissociation of cervical and thoracic spine was avoided, rotation of full upper body.<br>**Lifting loads overhead** Excessive muscle guarding (in neck-shoulder region); slow and careful movement, along with accompanying behaviors of holding one's breath, grimacing, and sweating.<br>**Put on and take off sweater** non-use of right arm, excessive muscle guarding (neck muscles); slow and careful movement; breath holding.<br><u>The following activities were integrated in movement behavior analysis:</u> Combing of | **9/10**<br>**Strength** Manual strength tests could not be performed due to pain provocation. Atrophy of upper right leg muscles was visible by inspection. Isokinetic muscle strength analysis performed 10 months after the intake, i.e., after 10 months of strength training, displayed a 30% deficit. Therefore, an initial >30% strength deficit is considered evident retrospectively.<br><u>**Maladaptive Movement Behavior**</u><br>**Standing up from sitting** Loading of the right leg was avoided, the right knee was maintained in 30° flexed position.<br>**Standing** Loading of the right leg was avoided.<br>**Sitting** The right knee was typically held in 30° knee flexion, i.e., not as flexed as the left knee.<br>**Walking** Stand-phase of the right leg was prolonged, thereby creating increased loading. Walking pace in general was reduced. Normal, natural flexion during the toe-off phase of the right leg was avoided; the whole leg in general was held stiff in extension. She used a cane for walking.<br>**Stair Climbing** Stepping down with the right leg was avoided completely.<br><u>The following activities were integrated in movement behavior analysis:</u> Walking, getting up from a chair, stair climbing.<br><u>**Functional Capacity**</u><br>**Going for a walk** >30 min was not possible due to symptom aggravation; during 30-min |

(*continued on next page*)

(*continued*)

| Examination findings | Sam | Dean | Ann |
|---|---|---|---|
| | the handrail for support.<br>**Standing up from a chair** Only possible with support of both hands.<br>**Shopping** Only possible with support from his wife.<br>**Bending and lifting tasks** Avoided completely due to pain and fear of falling.<br><u>Included in PSFS:</u> Standing >5 min, Walking >10 min, stair climbing | hair, lifting a 1.5L bottle to drink, lifting loads overhead, putting on and taking off sweater.<br><u>**Functional Capacity**</u><br>**Lifting a 1.5L bottle to drink** Not possible, support from left arm was needed.<br>**Lifting loads overhead** Was avoided completely.<br>**Driving a car** Not possible without pain.<br>**Combing of hair** Not possible without support from left arm.<br>**Put on a pullover** Not possible without support from left arm.<br><u>Included in PSFS:</u> Lifting a 1.5L bottle to drink, lifting loads overhead, combing of hair | walks Ann needed several breaks.<br>**Descending stairs** Was not possible with the right leg.<br>**Picking up a light object from the floor** Was avoided completely while Ann was fearful of falling, she waited for help to have it picked up.<br>**Walking outside** Ann was afraid of falling and of aggravating her knee. In addition, she was afraid straining herself could lead to cardiac arrest. She limited her walks outside and planned them very carefully (timing and route).<br>Prior to the accident, Ann was very active. She went for a 2-h walk every day and rode a bicycle several times a week.<br><u>Included in PSFS:</u> 30 min walking, getting up from a chair, stair climbing, 20–30 min sitting, lifting object off the ground |
| **Guided behavioral experiment** | During **forward bending**, relaxation of the abdomen and back muscles combined with posterior pelvic tilt achieved immediate pain relief.<br>*"Bending in a relaxed way feels good, what does that tell you?"* | **Lifting the arm** with diaphragmatic breathing, positive thoughts about this movement and relaxation of neck and shoulder muscles reduced protective movement behavior and pain from NRS 9/10 to 5/10. This positive movement experience enhanced his compliance significantly. | **Walking** Was not modifiable initially.<br>**Sitting** Diaphragmatic breathing and positive thoughts reduced tension and pain significantly, thereby enabling a significant improvement in normalizing (bending and stretching the knee) sitting behavior. |
| **Range of Motion** | **Lumbar spine**<br>**Active** A 2/3 reduction of lumbar spine flexion, extension, rotation, and lateral flexion due to pain NRS 7/10.<br>**Passive Physiological Motion Palpation** Flexion and left rotation stiff; extension normal but painful (NRS 8/10).<br>**Passive Accessory Motion Palpation** Central and unilateral PA L4/5 normal but painful (NRS 9/10).<br>**Muscle length** Thomas test: positive bilaterally (unable to maintain lower back and sacrum against the table and upper leg −15° to horizontal). | **G/H**<br>**Active Abduction and Flexion** Limited to 40° due to pain NRS 9/10.<br>**Active ER/IR**<br>30°/0°/40° due to pain NRS 8/10 and muscle guarding<br>**Passive Abduction and Flexion** in supine limited at 150° due to pain NRS 5/10; end-feel is empty.<br>Cervical spine ROM testing revealed only tension in active rotation bilateral, otherwise no significant abnormalities. | **Knee**<br>**Active Flexion/Extension** −10/0/95; limited due to pain (NRS 8.5/10)<br>**Passive Flexion/Extension** −10/0/100: end-feel is empty (due to pain (NRS 8.5/10) and muscle guarding) |
| **Palpation** | Increased muscle tone of M. erector spinae, abdominal wall (co-contraction) and gluteal muscles bilaterally; tenderness of L4/5 spinous processes. | Increased muscle tone of M. trapezius pars descendens, Mm. Rhomboideii and M. Supraspinatus. | Increased muscle tone of hip adductors and M. Semitendinosus were present. |
| **Individual goals** | 1) Being able to walk for 30 min without leg pain and LBP<br>2) Regaining better back mobility to improve everyday life<br>3) Pain reduction<br>4) Return to work | 1) Return to work<br>2) Being able to play with his son<br>3) Having knowledge about strategies to manage possible symptoms/flare-ups on his own<br>4) Improvement in general health and quality of life. | 1) To be "fit for work"<br>2) Take walks of 2.5 h<br>3) Be "independent" in daily life, i.e., buy groceries, do household tasks, etc. |

### 5.4. Clinical Reasoning

*Sam*

Negative treatment experiences caused by previous healthcare providers played a crucial role in Sam's story. On one hand, there was a lack of an explanation for the cause of his pain, and on the other hand, previous interventions failed to alleviate his symptoms. Sam's previous treatment strategies primarily involved opioid therapy (Bigal, 2018; Cahill and Taylor, 2017; Colvin et al., 2019; Juurlink, 2017), which potentially maintained his pain condition. Furthermore, Sam did not receive any management plan and physiotherapy to enhance his loading capacity and to improve his quality of life. A low level of pain self-efficacy was evident, which was related to his fear avoidance behavior (de Moraes Vieira et al., 2014). These previous treatment experiences led to negative illness beliefs (hurt vs harm) and fear avoidance behavior, which manifested as maladaptive movement behavior in daily activities such as bending and walking. Sam's persistent pain and disability were also associated with catastrophic thoughts, which were identified with hypervigilance (Sullivan et al., 2001). Considering the experimental learning from guided behavioral experiments it can be concluded that the pain was strongly linked to posture, habits, and negative beliefs. Pain could be modified by reducing tension and promoting relaxation, which enabled him to gain some control over his pain. Other significant factors included Sam's faulty pacing and coping strategies, which led to constant under-and overloading, resulting in a mechanism for tissue strain and ongoing peripheral sensitization (International Association for the study of pain, 2020). As a result, Sam gradually developed sedentary behaviors, further contributing to his deconditioning. It is noteworthy that recent work suggests that low levels of physical activity and sedentary behaviors may be associated with disabling LBP (Heneweer et al., 2011; Heuch et al., 2016). Receiving employment termination contributed to financial concerns (Bunzli et al., 2013) and promoted increasing sleep-maintenance insomnia. This, in turn, caused further deconditioning and emotional distress. It is therefore evident that all these afore mentioned factors maintained Sam's persistent pain state, creating a vicious cycle.

*Dean*

Despite undergoing various surgeries without experiencing any symptom reduction, Dean developed strong pathoanatomical beliefs, which were coupled with fear avoidance behavior. As he strongly believed that pain is causing further damage (hurt = harm) and movements might break his "screws", he developed a counterproductive and maladaptive movement behavior. His guarded movement behavior influenced his persistent state of pain by providing a mechanism for ongoing tissue strain. Faulty pacing and coping strategies also resulted in overload and created a boom-bust cycle of pain and frustration. His increased pain reactions after activity reinforced his negative beliefs (that pain and activity are harmful) and consequently generated a general pattern of inactivity and a sedentary lifestyle, which led to deconditioning and obesity. Sleep disturbances due to financial insecurity increased significantly after employment termination, which in turn had further negative impacts on his emotional state (Ben Simon et al., 2020) and quality of life. This in fact caused further deconditioning and sensitization. These factors represent a maladaptive response to his pain, which in turn became the mechanism that drove the disorder and represented a barrier to recovery (Ravindra et al., 2018).

*Ann*

Her story began with a fall on the knee, after which persistent knee pain led her general practitioner to decide to check for pathoanatomical lesions by means of radiological imaging. The MRI images showed a lateral meniscus tear. This "structural damage" became central to her story as it formed the basis for her strong pathoanatomical beliefs, i.e., that her knee was "broken". This led her to develop a fear of loading her leg and she became inactive. The avoidance behavior in turn led to deconditioning and both local and general sensitization. The cardiac arrest experienced during the second operation added a general fear of straining herself, amplifying her inactivity pattern, and, in addition, generating sleep deficiency due to fear of dying during the night, causing further deconditioning and sensitization.

## 5.5. Walking protocol

Example of progressive and documented walking protocol for Sam.

| For: Sam | Start date: January 3rd 20XY | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | M1 January 3rd | January 4th | January 5th | January 6th | January 7th | M2 January 8th | January 9th | January 10th | January 11th | January 12th | January 13th | January 14th |
| 15‘ Walking, 15‘ increased speed | | | | | | | | | | | | |
| 20‘ Walking, 10‘ increased speed | | | | | | | | | | | | |
| 25‘ Walking, 5‘ increased speed | | | | | | | | | | | | |
| 30‘ Walking | | | | | | | | | | | | |
| 27‘ Walking | | | | | | | | | | | | |
| 25‘ Walking | | | | | | | | | | | | |
| 23‘ Walking | | | | | | | | | | | | |
| 20‘ Walking | | | | | | | | | | | | |
| 18‘ Walking | | | | | | | | | | | | |
| 15‘ Walking | | | | | | | | | | | | |
| 12‘ Walking | | | | | | | | | | | | |
| 12‘ Walking, 1 break | | | | | | | | | | | X | X |
| 10‘ Walking | | | | | | | | X | X | X | | |
| 10‘ Walking, 1 break | | | | | X | X | X | | | | | |
| 7‘ Walking | | | | X | | | | | | | | |
| 7‘ Walking, 1 break | | | X | | | | | | | | | |
| 5‘ Walking | | X | | | | | | | | | | |
| 5‘ Walking, 1 break | X | | | | | | | | | | | |
| Date: | M2 January 15th | January 16$^{6h}$ | January 17th | January 18$^{8h}$ | January 19th | January 20th | January 21st | January 22nd | January 23rd | January 24th | January 25th | January 26th |
| 15‘ Walking, 15‘ increased speed | | | | | | | | | | | | |
| 20‘ Walking, 10‘ increased speed | | | | | | | | | | | | |
| 25‘ Walking, 5‘ increased speed | | | | | | | | | | | | |
| 30‘ Walking | | | | | | | | | | | | |
| 27‘ Walking | | | | | | | | | | | | |
| 25‘ Walking | | | | | | | | | | | | |
| 23‘ Walking | | | | | | | | | | | | |
| 20‘ Walking | | | | | | | | | | | | |
| 18‘ Walking | | | | | | | | | | X | X | X |
| 15‘ Walking | | | | | | | X | X | X | | | |
| 12‘ Walking | | | X | X | X | X | | | | | | |
| 12‘ Walking, 1 break | X | X | | | | | | | | | | |
| 10‘ Walking | | | | | | | | | | | | |
| 10‘ Walking, 1 break | | | | | | | | | | | | |
| 7‘ Walking | | | | | | | | | | | | |
| 7‘ Walking, 1 break | | | | | | | | | | | | |
| 5‘ Walking | | | | | | | | | | | | |
| 5‘ Walking, 1 break | | | | | | | | | | | | |

### 5.6. Intervention: CFT in interdisciplinary care

1:1 Therapy

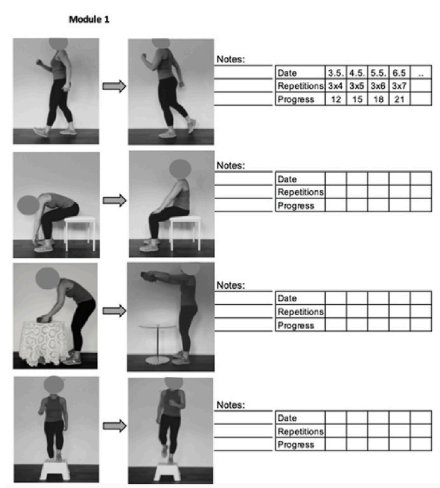
Individual time with the patient was used for
- Making sense of pain
- monitoring progress
- exposure with control
- correcting maladaptive movement behavior and negative illness beliefs
- evaluation of treatment effects (see the “24-h rule”)
- instruction in pacing and coping strategies
- dealing with factors which contribute to limiting normal movement behavior (e.g., high muscle tone, limited ROM)
- MTT: exercise instruction and planning
- instruction in lifestyle change (Dean and Söderlund, 2015)
- determining loading capacity
- instruction and correction HEP
- desensitization measures (e.g., deep friction, extracorporeal shock wave therapy (Ann), foam roller exercises).
- Instruct and exercise diaphragmatic breathing techniques (Busch et al., 2012) and mindfulness exercises in order to calm down central nervous system and reduce apprehensive tension (relaxation).
- Discussing goal setting before and after each module (Gardner et al., 2019)

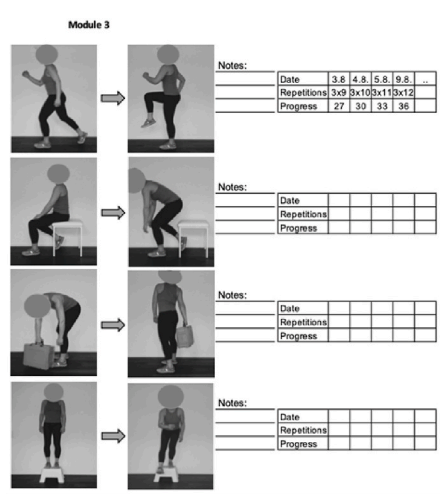
**HEP**

The aim of the HEP was to
- exercise maladaptive or avoided daily activities
- increase exercise diversity and progressivity (e.g., PAT)
- increase functional loading capacity by graded exposure principles (Garland and Jones, 2019)
- strengthen trust in loading the symptomatic region and to motivate patients by demonstrating documented progress.
- optimize pacing strategies

A selection of maladaptive movement behaviors and daily activities such as climbing stairs, getting up from a chair and lifting were selected for the HEP. During the initial sessions, the functional loading capacity baseline was determined by asking the patient to repeat the selected movement until 20 repetitions were achieved or until pain was provoked. To be able to perform a movement 20 times was considered enough for physical functioning in daily life or to start repeating this movement with added resistance to e.g., improve the loading capacity sufficiently for job performance. Pain provocation was defined as a change of 3 on the $NRS_{pain}$ or an increase of 30% if a consistent pain was already present. The aim was to perform the movement 3x20 repetitions with a 30–60 s break in between. If the patient was able to perform a certain movement 3 × 20 times, progress to the next, (functionally) more demanding variation of this movement was “allowed”. If 3x20 was not possible, patients were instructed to start with the current loading capacity (as determined in the initial phase) and increase the number of repetitions slowly (an increment of 1–3 repetitions/day was typical) until 3x20 repetitions were achieved. The patients were asked to document the date and the number of repetitions they performed at home.

**Example of HEP Module 1 and Module 3 with documentation**




Own photographs

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| | |
|---|---|
| **MTT** | MTT was integrated in order to increase a patient's functional loading capacity (Ambrose and Golightly, 2015) and to contribute to pain sensitivity reduction (Belavy et al., 2020). MTT consisted of cardio and strength exercises to improve local and general functional loading capacity, and thereby facilitating improved physiological regenerative capacity and sleep quality (Gong et al., 2020). The selection of strength and cardio exercises was chosen with respect to the symptomatic body region and individual goal setting. During the 1:1 therapy sessions the initial loading capacity baseline was determined. Then, patients were instructed to aim for continuous progression of resistance level according the "progressive adaptive training" rule (PAT) (see Appendix 5.8). Observed maladaptive movement behavior during the exercises was reported back to the patient with an instruction to modify (e.g., correct hyperextended lumbar spine and anterior pelvic tilt in sitting position on the bike ergometer). Direct influence on the pain behavior was then discussed. Moreover, fear reducing explanations about exercising and reassurance regarding the safety of exercises were essential prior to the start of MTT in order to reduce negative beliefs (Nijs et al., 2015).<br>**Documentation**: As loading the symptomatic region is highly linked to patient (and therapist!) cognitive and emotional factors, documenting exercise load and progress was considered an essential tool. Documentation provides evidence on an individual level of improved loading capacity and improves load related clinical reasoning. In addition, demonstrated effectiveness on an individual level can improve patient and therapeutic exercise motivation. To gradually increase the neuromuscular complexity of the exercise training, strength exercises were progressed from fully facilitated strength exercises (machine exercises), to semi-facilitated strength exercises (cable machines) to free weight training in modules 1–2, 3–4 and 5–6, respectively.<br>**Exercise and pain:** explanations regarding pain behavior during and after training were given to safeguard optimal dosage. Reactions to the applied load were evaluated with the "24-h rule", adapted from Thomeé (1997):<br><br>Reactions \| Explanation<br>1 = The situation is "normal", i.e., it did not worsen \| dosage increase was possible<br>2 = Mild symptom exacerbation occurred within 24 h but attenuated within 1–2 days \| dosage was on the border of the loading capacity and therefore the same dosage should be continued until reaction 1 occurred<br>3 = It significantly worsened and/or it did not attenuate within 1–2 days \| was interpreted as overload and exercise loading should be either reduced or stopped<br><br>During exercising, patients were instructed to tolerate light to moderate pain (NRS 3/10) (Smith et al., 2017, 2019). If pain or unpleasant feeling occurred during exercising, patients were asked whether they recognized it as their usual pain (NRS 0–10) or if other feelings, e.g., muscular effort, were experienced. |
| **Job and mental coaching** | Health related work absenteeism is related to psychological, emotional, social, and financial stress. The coaching sessions had the aim to address these factors and provide practical and mental support of the reintegration process. Coaching involved problem analysis, goal setting, motivational interviewing, stress-relieving techniques, job (seeking) support and communicating with third parties (employers, health insurance, doctors, etc.). |

## 5.7. Detailed multifactorial treatment

*Key aspects of each module are provided for every patient*

It is important to note that the process of making sense of pain and reducing the fear of movement was a prerequisite for initiating the loading approach in medical training therapy (MTT). MTT is also part of lifestyle factors as regular training sessions can lead to increased physical activity and a transition to a more active lifestyle.

| Sam | | |
|---|---|---|
| Lifestyle change | Exposure with control | Making sense of pain |
| **Module 1 (M1)**<br>**Pacing Strategies:** Start pacing him to prevent irritation and simultaneously improve functional loading capacity*: activity plan was discussed together. Sam was encouraged to do regular light duties: gradual resumption of his gardening hobby in standing position: start with 3x5'/day in relaxed behavior.<br>**Physical activity:** Sam was encouraged to go out (5 days/week) for a walk, initially protocolized. Start with 5′ walking (with one break) with support of his folding chair in order to make him feel secure.<br>**Sleep quality:** 1) Explanation of 'sleep hygiene rules'. Sleep quality was tracked with the "Polar A360 tracking watch". Video about sleep was provided (Walker Matthew, 2017).<br>2) Instruction of breathing exercises in supine position to reduce emotional stress before sleeping and calm down SNS. | **1:1 Therapy: Graded exposure and functional re-training**$^{*+}$<br>1) sitting$^{*+}$ in relaxed position with Lx flexion and relaxed abdominal muscles; 2) lumbar flexed sitting$^{*+}$ position and rolling down/up in combination with muscle relaxation and breathing awareness (see picture 1); 3) Standing$^{*+}$: posterior pelvic tilt, weight on the right limb was gradually increased, integration of visual feedback (mirror).<br>**1:1 Therapy: Exercise training**$^{*+}$<br>1) exposure to Lx flexion in controlled way: posterior pelvic tilt in supine position (avoid co-contraction of abdominal wall) to reduce tension of M. lumbar erector spinae; unloaded active trunk movement$^{*+}$ in all directions in supine and standing position; start with progressive walking ABC: sideward/backwards walking, lifting knee to get Lx flexion$^{*+}$<br>**1:1 Therapy: Relaxation**<br>Relaxation was integrated with functional exercises whenever tension (physical or mental) was starting to build up.<br>**1:1 Manual Therapy**<br>Massage with mobilization into lumbar spine flexion in a side lying position was performed to reduce tension in the M. errector spinae and to facilitate movement into lumbar flexion.<br>**HEP**$^{*+}$ Determine functional loading capacity of his back. Besides functional progressive loading of his back, loading of his right limb is emphasized$^{*+}$; walking protocol$^{*+}$.<br>**MTT**$^{\#+}$: Begin with strength training on machines, correct unnecessary tension and excessive Lx hyperextension$^{*+}$. | 1) **Making sense of pain**: Sam was provided with the multifactorial analysis of his current situation by implementation of motivational talk: detailed information about provocative factors (see clinical reasoning). "Kieran O'Sullivan test" was integrated: *"how would you explain your consultation findings to your family?"* Explanation of module goals enhanced motivation and provided confidence.<br>2) **De-threatening of radiological imaging**: *"disk degeneration is also common in the pain-free population and has poor correlation with disability and pain"*.<br>3) Address and correct **fear-based maladaptive movement behavior**: video analysis was discussed and guided behavioral experiment implemented in order to increase self-assurance: "Bending in a relaxed way feels good, what does that tell you?"<br>**4) Coping strategies:** active coping strategies were provided to cope with pain exacerbation: posterior pelvic tilt and roll down in sitting, relaxation and breathing techniques.<br>5) Therapy-contract was signed to declare therapy goals and therapy duration twelve months.<br>**Goal setting:** 1.ST*** regain his back mobility to dress himself, 2.MT*** walking 30′ without limitations, 3. LT***finding employment |

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| Sam | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| | Seated cycle ergometer with 5′ at 50W, then with 1–2′ increment increase duration each time. Start with exercises on machines (added one-by-one per session), seated machine row, roll down with 1 kg, lat pull, abdominal curl, leg press, leg extension. Explain PAT principles# to make him able to perform progressive machine training independently. | |
| **Module 2 (M2)**<br>**Pacing Strategies:** Progress to gardening in kneeling position with slumped lumbar spine: 3x20'/day, integration of pain reducing strategies: performing functional home exercises if pain increases.<br>Improve pacing of daily activities with "Polar A360 tracking watch" to prevent irritation of Lx tissue.<br>**Physical activity:** Progression of daily "walking protocol": 10′ walk with 1 break, without folding chair.<br>**Sleep quality:** Repetition of strategies to reduce sleep disturbance. Improved sleeping quality was also aimed for with increased activity levels in daily life and physical exercise. | **1:1 Therapy: Graded exposure and Functional re-training***+<br>Integration of relaxed and flexed spinal movement behavior to regain body confidence within functional tasks: practicing progressively pain-provoking activities in a non-threatening way. Provide insight into maladaptive movement with video analysis feedback; 1) in sitting: rolling down*+ (with equal weight transfer of both limbs) with progression to standing up; 2) standing and step forward with right/left leg*+<br>**1:1 Therapy: Exercise training***+<br>Progressive walking ABC*+: walk with Lx bending/stretching, crossing legs; progression of exposure to Lx flexion: posterior pelvic tilt in sitting and standing position without muscle guarding (back and abdominal muscles)*+.<br>**1:1 Therapy: Relaxation**<br>Integration of breathing techniques into limited daily activities such as sit-to-stand 3x5 repetitions, progression: 1 rep. more/day.<br>**1:1 Manual Therapy**<br>Progression of massage with mobilization in Lx flexion in child position, PPIVMs in Lx flexion.<br>**HEP***+ Progression of functionally oriented HEP; incremental walking protocol*+<br>**MTT**#+ Progressive machine strength training with variations (progression from two-arm/leg to single-arm/leg version and to free sitting)#+. Ergometer endurance training#+ with 1–2′ increment increase duration each time. | 1) Sam's understanding of "making sense of pain" was checked and unclear parts were clarified. Correct negative illness beliefs: reassure that movements are safe through positive movement experiences and repeat hurt $\neq$ harm.<br>2) Replace passive coping strategies (lying down) through active coping strategies e.g., regular functional home exercises. Sam knows his pain-triggers and can therefore change his movement behaviors: less Lx Ext in standing/walking activities (see "exposure with control").<br><u>**Review of goals:**</u> 1.ST partially achieved, 2.MT not yet achieved 3.LT not yet achieved |
| **Module 3 (M3)**<br>**Pacing Strategies:** Progression of functional capacity: gardening in standing and bent-over position with relaxed Lx: 3 × 30 min/day, performance of HEP if pain increased.<br>**Physical activity:** Increase daily walking time with the "walking protocol": 25′ walk without break/folding chair; start doing groceries by foot. | **1:1 Therapy: Graded exposure and Functional re-training***+<br>1) sit to stand: left leg in front to load up the right leg*+; 2) rolling down from standing position in relaxed and flexed Lx position and pick up light object (2 kg)*+; 3) getting down on the floor on knees and standing up*+<br>**1:1 Therapy: Exercise training***+<br>Progressive walking ABC: walking with bending/stretching diagonally*+; high knee lifts, butt-kicks, crossing legs, side-to-side stepping*+; integration of throwing exercises: bend-over throwing variations for lower back*+.<br>**1:1 Therapy: Relaxation**<br>Integration of breathing techniques into limited daily activities: lifting something from the floor, 3x10 repetitions, progression: 1 rep. more/day.<br>**1:1 Manual Therapy**<br>Progression of massage with mobilization in Lx flexion in half-kneeling position, PPIVMs in Lx flexion.<br>**HEP***+ Progression of functionally oriented HEP; incremental walking protocol*+<br>**MTT**#+ Progression of machine strength training to cable strength training#+: seated cable row (relaxed Lx position), roll down with 4 kg, lat pull with integrated Lx Flex/Ext, cable abdominals in supine, Lx Ext on Roman chair, squats, hip abduction in standing position | Repeat importance of active coping strategies and new pain strategies: practice breathing and light mobilization exercises.<br>Reflect on achieved progress by showing the gradual progression of the documented HEP and compare video analysis of M1 with M3.<br><u>**Review of goals**</u>: 1.ST achieved, 2.MT not yet achieved 3.LT not yet achieved |
| **Module 4 (M4)**<br>**Pacing Strategies:** Progression of functional capacity: gardening in standing and bent-over position: 3x60'/day.<br>**Physical activity:** Progression of daily "walking protocol": 30′ walking with one break; Sam was encouraged to meet family once/week. | **1:1 Therapy: Graded exposure and Functional re-training***+<br>1) sit to stand on right leg*+; 2) lifting medium heavy (5 kg) object from the floor up to table, forward and sideward*+; 3) Walking stairs forward and sideways 2 steps*+<br>**1:1 Therapy: Exercise training***+<br>Walking-ABC*+ (see M3) with increased speed and stride length, progressive throwing exercises: half kneeling one arm deceleration catch to integrate spine rotation<br>**1:1 Therapy: Relaxation** | Cognitive factors were significantly reduced, and Sam was encouraged to continue newly learnt exercises and principles.<br><u>**Review of goals**</u>: 1.ST achieved, 2.MT achieved 3.LT not yet achieved |

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| Sam | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| | 1) Integration of breathing techniques into limited daily activities such as climbing stairs, 3x15 stairs, progression: 1 rep. more/day.<br>**1:1 Manual Therapy**<br>Not necessary anymore as spinal tension is significantly reduced.<br>**HEP***+ Progression of functionally oriented HEP and walking protocol*+<br>**MTT**#+ Progression of cable machine to free weight training: one-armed dumbbell row, standing shoulder press, bent over barbell rows, dumbbell squats, dumbbell standing trunk rotation; Cross trainer endurance training#+. | |
| **Module 5 (M5)**<br>**Pacing Strategies:** Progression of functional capacity: gardening in standing and bent-over position with relaxed Lx: 3x90'/day, performing HEP if pain increased.<br>**Physical activity:** Progression of daily "walking protocol": 45′ walking with one break | **1:1 Therapy: Graded exposure and Functional re-training***+<br>Lifting heavy (10–15 kg) object from the floor up to a cupboard, forward and sideward*+<br>**1:1 Therapy: Exercise training***+<br>Walking-ABC: Slow-jogging ABC drill forward/backward (very low intensity!); jumping variations (vertical/forward/sideward) with equal weight distribution*+<br>**1:1 Therapy: Relaxation**<br>Discuss the integration of learned breathing and relaxation techniques in stressful and painful situations<br>**HEP***+ Progression of functionally oriented HEP; walking protocol*+<br>**MTT**#+ Progression of simple free weight training to unilateral free weight training#+; Cross trainer endurance training#+ was progressively increased (intensity/time). | See M4.<br>Review of goals: 1.ST achieved, 2.MT achieved 3.LT partially achieved as work attempt was possible |
| **Module 6 (M6)**<br>**Pacing Strategies:** no limitations in gardening were evident.<br>**Physical activity** walking 1 h with one break was possible. Possible to join social events. | Functional capacity was significantly enhanced. Persistent LBP, right leg pain, paresthesia and loss of control resolved completely. Sam was encouraged to apply the learnt exercises and principles.<br>**Booster sessions of 1:1 therapy** included Exercise training+* and MTT#+ to make further corrections and progress. | Discharge and pain exacerbation plan was discussed:<br>- Hold on and evaluate identify potential triggers: not enough relaxation/sleep, stress, activity plan/movement overdone (frequency, intensity, or duration), "old" behaviors<br>– Make a new plan: apply newly learnt strategies (relax, breathe, move gently) and gradually increase<br>– Telephone contact if self-management does not help<br>Review of goals: 1.ST achieved, 2.MT achieved 3.LT partially achieved as work trial was possible |

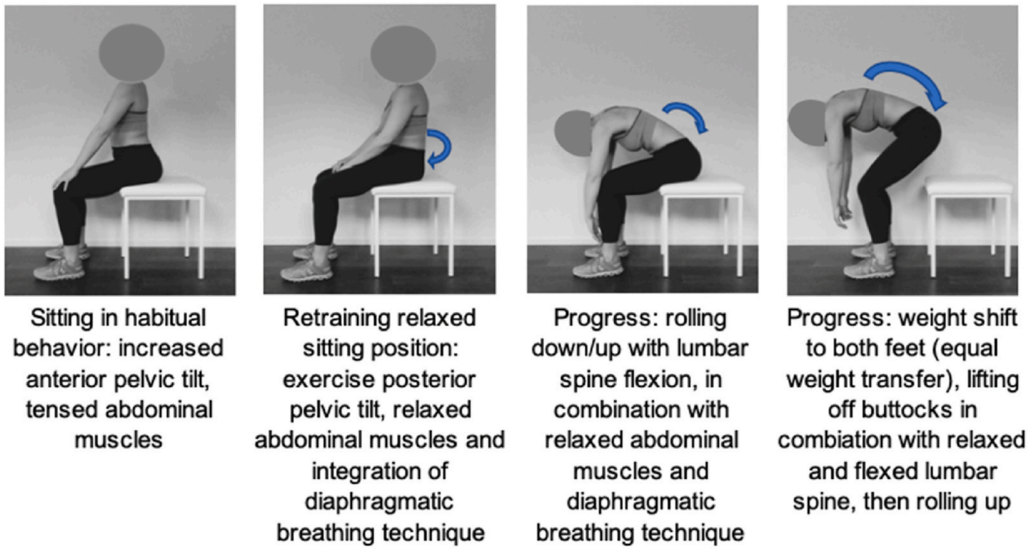
* = Exposure with control: According to the 24-h and "documented functional exercise" principle, as explained in section CFT intervention. For the actual exercise execution, see Appendix 5.6 for the HEP.
+ = Analyzing and correcting maladaptive movement behavior based on the following criteria: symmetry (if applicable), fluency, effortlessness, and execution in a natural way.
# = Medical Training Therapy (MTT) was executed according to the PAT (progressive adaptive training) principle.
***ST = short term, MT = medium term, LT = long term.
M = Module; SNS: sympathetic nervous system; Lx = lumbar spine, PPIVMs = passive physiological intervertebral movements.

*To address social and emotional factors a cooperation with a job and mental coach was initiated*

**Social factors:** Physical prerequisites for social reintegration were worked on from M1. Start re-engaging and socializing: going out for dinner with his son once a week was the goal for M1. As his job loss ten years ago was a relevant life stress event which led to social isolation, integration of job coaching with a focus on job applications and support with administrative difficulties was a focus in M2. In M3, jobs with suitable physical demands were identified and applied for. Guidance in job interviews was a focus in M4. An attempt to attend at work while on sick leave for six weeks was possible during M5. "Work trial while on sick leave" was successful and a permanent position was in progress in M6.

**Emotional factors:** Sam received mental and job coaching to address major emotional and social factors. Collaboration with a mental coach and GP led to optimal dosage of antidepressants to stabilize Sam's emotional status in M1. Mental coaching firstly addressed daily routine strategies such as no daily sleep time and regular wake up time. Focus in module 2: 1) Agreement of protocolized increase of loading to build confidence and decrease movement anxiety, 2) Stress reduction: start breathing exercises at home (in bed, supine) and therapeutic environment to reduce stress, 3) demonstrate management plan regarding support for job search to reduce fear of the future (due to financial problems and unemployment). In module 3: evaluation of the non-harmful effect of "normal" movement behavior (increased and normal loading, see "exposure with control" module 1, which thereby provided body reassurance. Breathing, mindfulness, and relaxation exercises were extended to 'out-of-home' situations, e.g., when shopping, to counter negative thinking and strengthen positive emotions. Mindful movement and progressive relaxation exercises were integrated into newly learnt movement behavior (see 1:1 Therapy: Functional re-training M1). Module 4 achieved benefits of loading and progress towards a positive mindset was discussed. Emotional stress was significantly reduced as positive advances regarding job search were attained. In M5, emotional stress was significantly reduced at this stage and continuation of intervention of M4 was discussed if necessary.

**Picture 1.** How to retrain "sit to stand" in a relaxed movement behavior




Sequence of retraining movement behavior observed in a workshop by P. O'Sullivan, adapted and own photos.

| Dean | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| **Module 1 (M1)** | | |
| **Pacing Strategies:** Introduction of helpful activity pacing to minimize symptom "flare-ups" (which in turn can influence his mood in a negative way) by composing pacing chart with light duties *"doing small things often"*: lifting a light bottle, tying shoes.<br>**Physical Activity:** Instruction in and agreement of "activity protocol" with specific activity goals:<br>1) Progressively increase daily activity (use "Polar A360 tracking watch")<br>2) do daily "walking protocol" starting with 3x5′ walking/day outside. Document daily/weekly progression.<br>3) Integrate your arm in daily light duties (see pacing strategies)<br>**Sleep habits:** Explanation and instruction of "sleep hygiene rules". Sleep quality was tracked with "Polar A360 tracking watch".<br>**Mental coaching: The patient received mental coaching and relaxation training.* | **1:1 Therapy: Graded exposure and functional retraining***+<br>Focus on lifting the arm up to 60° G/H Flex/Abd*+ in a non-threatening way to integrate in daily activities with progression from movement in supine to sitting and standing: 1) Combing of hair*+ up to 30°–60° G/H Flex/Abd; 2) reaching for and moving a light bottle (0.5L) on a table (without lifting); 3) standing up from sitting with integration of both arms*+.<br>**1:1 Therapy: Exercise training***+<br>Start with relaxation with movements (integrate diaphragmatic breathing technique) to replace a habit with a new habit *"move with less tension and relax"*. Mobility training: unloaded active trunk and neck movement*+ in all directions in supine and standing position; promote arm swing in walking ABC*+: sideward/backwards walking, farmer's walk with elbow to knee with integrated arm swing to correct protective behavior. Visual feedback by video and mirror; static stability and loading exercise: two-armed push-up training on table.<br>**1:1 Therapy: Relaxation**<br>Introduction of diaphragmatic breathing technique *"breathing is important because it helps you to relax"* and mindfulness exercises in supine and sitting position: breathing 4 s in and out with closed eyes and focus on speed and depth, relax face and hands, 5 Min.<br>**1:1 Manual Therapy**<br>Passive and assistive scapulothoracic mobilization techniques in side-lying position to reduce tension and enhance perception and confidence in shoulder movements (link to emotional factors).<br>**HEP***+ Determine functional loading capacity, progression of one repetition/day to avoid pain flare up; document daily progress to enhance self-efficacy (see Appendix 5.6).<br>**MTT**#+ Cycle ergometer for 15′ at 50W; arm cycle 1′, then with 1–2′ increment, increase duration each time. Strength training exercises (machine) are added one by one per session: seated machine row, roll down with 1 kg, rowing (two armed) and abdominal curl. Explain PAT principles to enable independent performance of progressive machine training. | **1) Making sense of pain:** a) Dean was provided with personalized multifactorial analysis (see clinical reasoning). Management plan was elaborated, aligned with multifactorial analysis, and discussed with Dean. Reflecting questioning was integrated *"does that make sense to you?"* b) **Change of negative illness beliefs** through reassurance, behavioral learning (see exercises in exposure with control module 1) and safety message *"if it hurts- relax and breathe; movement is good"; "lifting your arm is safe and the screws won't break"*; "*when you anticipate pain, your body is tensing up – try to breathe and relax"*.<br>2) Address and correct fear-based **maladaptive movement behavior** (see exercise training in exposure with control module 1).<br>3) Reinforce **active coping strategies**: start exercise forms with "gentle" shoulder loading: e.g., arm cycling to reduce tension and pain.<br>4) Discuss the importance of **goal setting** and agreement of short-, medium- and long-term goals:<br>**Goal setting:** 1.ST*** put t-shirt on and take it off without pain and in a normal movement behavior, 2. MT*** combing of hair without any limitations, 3.LT*** swimming without any limitations |

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| Dean | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| **Module 2 (M2)**<br>**Pacing Strategies:** Discuss the response to daily light activities and provide instructions for progression: cleaning table, daily food shopping and carrying light shopping bags (max 2 kg).<br>**Physical Activity:** Reinforce activity engagement: increase of daily activity up to 3000 steps/day tracked by Polar Activity Tracker.<br>**Sleep habits:**<br>Reinforce and discuss sleep hygiene rules. | **1:1 Therapy: Graded exposure and functional retraining**[*+]<br>Progress through graded exposure to challenge false expectations. Progressive reduction of guarded moving behavior and practice new non-provocative movement strategies (diaphragm breathing, relaxation of neck and shoulder muscles): 1) combing of hair[*+] up to 90° G/H Flex in combination along with external rotation 2) reaching for and lifting a 1.5L bottle on a table[*+] up to 90° G/H Abd/Flex 3) lifting light object (2 kg) from the floor[*+] 4) swimming exercises[*+]: breaststroke movements up to 90° G/H Abd/Flex<br>**1:1 Therapy: Exercise training**[*+]<br>Practice progressive mobility training: walking ABC[*+] (increasing intensity and integrating arm movements; squat lunges with thoracic rotation); integration of computer based coordinative training[*+] (Iso-Lift TecnoBody[R]) to facilitate positive movement experience; proprioceptive and precision exercises (laser pointer/ joint position error exercise) with ROM up to 60° G/H Abd/Flex; dynamic stability and loading capacity of shoulder girdle: moving arms alternately in elevation[*+] on all fours; progression of static stability and loading exercise: two-armed push-up training on the wall (incline wall push-up); two-arm throwing exercises[*+]: start by simulating two-hand throwing motion; throw between the legs.<br>**1:1 Therapy: Relaxation**<br>Check and continue as M1 to modulate sympathetic arousal.<br>**1:1 Manual Therapy**<br>Normalize ROM with active and passive exercises/ techniques in lying and sitting position up to 90° G/H Flex/Abd; reduce tension and myofascial pain points of rotator cuff muscles.<br>**HEP**[*+] Evaluation and progression of functional training in daily activities. Emphasize the importance of gradual progression to avoid pain flare-ups.<br>**MTT**[#+] Increase exercise diversity and progressivity on machines (progression from two- arm to single-arm version and to free sitting)[#+]: alternated seated machine row with thoracic rotation, butterfly front, latissimus pull-down, seated machine pull-over, rotary, roll down, abdominals, back extension roman chair (arms crossed in front of chest); progressively increase local endurance training on arm cycle (intensity/time). Independence in machine training was gradually achieved. | **1) Making sense of pain:** a) determine Dean's current understanding of his cycle of pain and disability by reflective questioning: normalization of breathing pattern and implementation of active coping strategies (HEP) reduced pain and enhanced ROM, b) Explanation of physical reaction after exercising to reduce anxiety: light pain is not harmful. Emphasize that movement is not harmful to increase self-assurance.<br>**2) Coping strategies:** encourage change from passive to active pain management strategies: replace lying down with functional home exercises to reduce tension in the shoulder.<br>3) Integration of partner into therapy to support his goals.<br>**Review of goals**: progress towards and barriers to achieving goals:<br>1. partially achieved as over the head was not possible yet, 2. partially achieved as he can comb his hair on the side. 3. not yet achieved |
| **Module 3 (M3)**<br>**Pacing Strategies:** Progressive increase of everyday activities: carrying up to 5 kg, lifting overhead and vacuuming.<br>**Physical Activity:** 1) Reinforce activity engagement: increase of daily activity up to 5000 steps/day tracked by Polar Activity Tracker.<br>2) Regular and independent exercising at home and in the gym. | **1:1 Therapy: Graded exposure and functional retraining**[*+]<br>Gradually increase exposure to overhead movements and reinforce new behaviors: 1) combing of hair[*+] up to 100° G/H Flex along with external rotation 2) lifting and pouring1.5L bottle[*+] 3) lifting medium weight object[*+] (5 kg) from the floor up to 100° G/H Flex/Abd 4) lying down and getting up from the floor with focus on loading affected arm[*+] 5) squatting with arm integration 6) swimming exercises[*+].<br>**1:1 Therapy: Exercise training**[*+]<br>Progressive mobility training: walking ABC[*+]: dynamic walking with bending/stretching with 3D lumbar flexion movements and integration of arm movements; plyometric exercises with two-arm throwing exercises[*+]: two hand chest pass and two hand side-to-side pass; computer based coordinative training (Iso-Lift TecnoBody[R])[*+] with increased ROM/velocity and weight on the wrist; progression of static stability and loading exercise: two-armed push-up training on the floor; progression of proprioceptive and precision exercises with laser pointer by increasing time and ROM up to 100° G/H Flex/Abd. | 1) Evaluation of fear-based maladaptive movement behavior by video analysis of avoided/painful activities: lifting a bottle, carrying loads, drinking, and combing of hair. Massive reduction of fear and anxiety due to positive movement experience was observed. Change of negative illness beliefs and enhanced self-efficacy was apparent.<br>2) Clarification of pacing strategies: progression of only one repetition per day (HEP) to avoid pain flare-up. Explanation of an "exacerbation plan" to reinforce new ways of pain response.<br>3) Reflecting progress achieved by showing gradual progression of documented HEP and comparison of video analysis module 1 with 3.<br>**Review of goals**: 1. achieved, 2. achieved, 3: not yet achieved |

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| Dean | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| | **1:1 Therapy: Relaxation**<br>Integrate a relaxed breathing pattern into functional and exercise training.<br>**1:1 Manual Therapy**<br>Progressive active and passive ROM exercises and manual therapy techniques in sitting position up to 120° G/H Flex/Abd.<br>**HEP***+ Evaluate and progress functional training of daily activities.<br>**MTT**#+ Progression of machine strength training to cable strength training, two-armed#+: two arm cable rows with thoracic rotation; butterfly front overhead with thoracic Flex/Ext; rotary with Cx counter rotation; lat pulldown with Cx Ext/Flex, cable squats, abdominals, back extension Roman chair (arms in 90° Abd). Progressively increase local/global endurance training on stepper (intensity/time)#+. | |
| **Module 4 (M4)** | | |
| **Physical Activity:** Goal of 9000 steps/day was achieved, and performing regular moderate daily activities was part of everyday life: e.g., carrying shopping bags, vacuuming. | **1:1 Therapy: Graded exposure and functional retraining***+<br>Improvement of dynamic loading capacity with overhead activities: 1) lifting medium to heavy object*+ (7 kg) from the floor up to a cupboard 120°–160° G/H Flex/Abd 2) progressive loading capacity*+ with push-ups on the floor and on the wall, two-armed 3) swimming exercises*+: progression by exercising crawling motion. Dean reports no fear of lifting his arm anymore.<br>**1:1 Therapy: Exercise training***+<br>Progressive mobility training: walking ABC*+: fast walking with weights, slow-jogging ABC drill and changing directions (with arm integration), jumping variations (vertical/forward/sideward); progressive one-arm throwing exercises*+: single arm rotational throw up to overhead motion; progression of static stability and loading exercise: one-armed push-up training on the floor and then on unstable surfaces; improvement of dynamic stability and coordination by TRX training: pulling/pushing exercises*+ in 120°–160° G/H Abd/Flex<br>**1:1 Therapy: Relaxation**<br>Continuation of M3 and apply self-massage of shoulder complex with foam roller if necessary.<br>**1:1 Manual Therapy**<br>Progressive active and passive ROM exercises and manual therapy in sitting position up to 160° G/H Flex/Abd.<br>**HEP***+ Evaluation and progression of functional training of daily activities (see Appendix 5.6).<br>**MTT**#+ Progression to cable strength training#+ one-armed variations (see exercises M3), cable squats, abdominals, back extension Roman chair (arms in 90° G/H Abd). Progressive increase local/global endurance on rowing machine (intensity/time). | Cognitive factors are significantly reduced, Dean is encouraged to continue newly learnt exercises and principles.<br>**Review of goals**: 1. achieved, 2. achieved, 3: not yet achieved |
| **Module 5 (M5)** | | |
| **Physical Activity:** Goal of 10,000 steps/day was achieved and performing regular highly demanding daily activities (carrying heavy shopping, hanging laundry overhead) was possible. | **1:1 Therapy: Graded exposure and functional retraining***+<br>Improvement of dynamic loading capacity: pulling and pushing heavy object (10 kg) (vertical/forward/sideward), progressive loading capacity*+ with push-ups on the floor and on the wall one-armed; progression of swimming exercises: crawl stroke.<br>**1:1 Therapy: Exercise training***+<br>Progressive mobility training: walking ABC*+: football passing variations (standing/sideward/forward/backward walking), jumping variations*+ (vertical/forward/sideward), 1-legged bounces with two-hand support (vertical/sideward); progressive (of dynamic stability and loading capacity) one-arm throwing exercises*+: half kneeling one arm deceleration catch, exercising tennis fore- and backhand.<br>**1:1 Therapy: Relaxation**<br>Continued control of learned techniques to reduce muscle tension.<br>**HEP***+ Evaluation and progression of functional training in daily activities.<br>**MTT**#+ Progression of cable machine to free weight | 1) Discuss discharge and pain exacerbation plan:<br>- Hold on and evaluate identify potential triggers: not enough relaxation/sleep, stress, activity plan/movement overdone (frequency, intensity, or duration), "old" behaviors<br>– Make a new plan: apply newly learnt strategies (relax, breathe, move gently) and gradually increase<br>– Telephone contact if self-management does not help<br>2) Reinforcement of improved physical condition: evaluation by video analysis module 1–5.<br>All goals achieved. Dean found a full-time job in a different but desired field. |

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| Dean | | |
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| Lifestyle change | Exposure with control | Making sense of pain |
| | strength training#+: one-armed dumbbell row, dumbbell incline butterfly, standing shoulder press, bent over barbell rows, dumbbell squats, dumbbell standing trunk rotation. Local/global endurance on rowing machine was progressively increased (intensity/time)#+. | |
| **Module 6 (M6)**<br>**Physical Activity:** Daily exercises and active lifestyle with integration of former hobbies such as swimming and biking are practicable. Joining social events was possible. | Functional capacity was significantly enhanced and right anterolateral shoulder pain with tension in the neck-shoulder region resolved completely.<br>**Booster sessions of MTT#+:** Progression of simple free weight training to unilateral free weight training# | No treatment of cognitive factors needed.<br>Discuss pain exacerbation plan and clarify questions. |

* = Exposure with control: according to the 24-h and "documented functional exercise" principle, as explained in section CFT intervention. For the actual exercise execution, see Appendix 5.6 for the HEP.
+ = Analyzing and correcting maladaptive movement behavior based on the following criteria: symmetry (if applicable), fluency, effortlessness, and execution in a natural way.
# = Medical Training Therapy (MTT) was executed according to the PAT (progressive adaptive training) principle.
***ST = short term goal, MT = medium term goal LT = long term goal.
G/H = glenohumeral; Abd = Abduction; Flex = Flexion; Cx = cervical spine.

*To address social and emotional factors, a cooperation with mental and job coach was initiated*

**Emotional factors** were addressed in various treatment methods both during physiotherapy sessions and with a mental coach. As Dean's pain experience was related to emotional distress, strategies to control his pain such as relaxation/breathing techniques and mindfulness exercises were included. In M1 the non-harmful effect of increased and normal loading (see "exposure with control" module one) was discussed to provide reassurance in his body. Breathing techniques were instructed and practiced in a home-based and therapeutic environment to reduce stress: "breathe deeply when you feel an increased stress level related to shoulder movements." Mindfulness exercises were also introduced in module one with a "Body Scan exercise" twice a week. His afore mentioned life stress event (stillbirth) was addressed, and processing strategies discussed. Progression in M2 was as follows: discussion of the experienced mindfulness exercises and extension through the "Five Senses Exercise". Dean reported that discussing his fears about the future and providing support in finding a job reduced emotional stress massively. Improved sleep habits and regulated his daily routine, as well as reducing his low mood significantly in M2. The non-harmful effect of normal movement behavior was evaluated. In M3, mindful movement and progressive relaxation exercises were integrated into functional tasks. Retrieving self-awareness due to accompanied coaching of emotional factors was observed. Achieved benefits of loading his body without fear resulted in a positive mindset, which was discussed in M4. In addition, emotional stress was significantly reduced as positive advances regarding his job search were attained. After completing M4 it was no longer necessary to address emotional factors.

**Social factors:** Cooperation with the job coach mainly addressed reintegration and related support during the job application process, as these were relevant social factors. Composing job applications and support with administrative difficulties were addressed in M1. As soon as the physical loading capacity was increased in M2/3, the job application process started. Jobs with suitable physical demands were identified and applied for. In M4, positive feedback was received, and several job interviews were conducted. In M6 Dean received a job offer and started new employment after completing the CFT program.

| Ann | | |
|---|---|---|
| Lifestyle change | Exposure with control | Making sense of pain |
| **Module 1 (M1)**<br>**Physical activity:** Instruction in, and agreement of "activity protocol" with specific activity goals. She was instructed to:<br>1) go out (5 days a week) for a walk with the support of a cane and a friend (use "Polar A360 tracking watch"), and<br>2) start walking without a cane at home.<br>**Pacing Strategies:** a walking protocol was used to prevent irritation and simultaneously improve functional loading capacity*.<br>**Sleep habits:** Explanation and instruction in "sleep hygiene rules"; Mindfulness and breathing exercises in supine position in bed to reduce anxiety before sleeping (create body awareness with breathing observation; inspiration and expiration for 4 s for 5 min to reduce breathing frequency and thereby calm down the SNS).<br>**Mental coaching: The patient received mental coaching and relaxation training to counter the anxiety causing the disturbance in sleep quality.* | **1:1 Therapy: Graded exposure and functional re-training***+<br>1) Sitting*+; 2) Standing up from sitting*+; 3) Standing+ (in front of a mirror, weight on the right limb was gradually increased); 4) Step forward with right limb; 5) bending to pick something up from the floor*+<br>**1:1 Therapy: Exercise training***+ Mobility training: unloaded knee flexion/extension in supine movement*+; unloaded active trunk movement in all directions in standing and lying position; promote arm swing in walking ABC.<br>**1:1 Therapy: Relaxation** as in case 1 M1. Relaxation was integrated with functional exercises whenever tension (physical or mental) was starting to build up. Unloaded movement of the knee with a focus on relaxation of the body and abdominal breathing was exercised.<br>**1:1 Therapy: Manual therapy**<br>Reduce tension and myofascial pain points of the M. rectus femoris, CFM of medial collateral ligament.<br>**HEP***+ Improve functional loading capacity of the knee+; Continuous walking time*+, the initial continuous walking time was 5′ and could be increased by 2'/day.<br>**MTT**#+ Start with endurance training*# on a cycle ergometer with 3′ at 50W, then with 1–2′ increment | 1**) Making sense of pain:** a) Ann was provided with a multifactorial analysis of the current situation (see clinical reasoning Appendix 5.4), b) **Change of negative illness beliefs** through reassurance, behavioral learning (see exercises in "exposure with control" Module 1)<br>2) Address and correct fear-based **maladaptive movement behavior**<br>3) **Reinforce active coping strategies:** use unloaded knee movements in supine position and exercise forms with "gentle" knee loading (e.g., cycling, swimming, etc.) to cope with exacerbations. |

(*continued on next page*)

(*continued*)

| Ann | | |
|---|---|---|
| Lifestyle change | Exposure with control | Making sense of pain |
| | duration was increased to 15'. If 15′ was achieved, the wattage was slowly increased*. After the 24-h reaction of the initial ergometer training was evaluated as "ok", strength training exercises were added one by one: e.g., leg press (both legs), seated machine row. | |
| **Module 2 (M2)**<br>**Pacing Strategies:** Discuss the response to agreed light daily activities and instruct progression:<br>**Physical Activity**<br>1) Start doing groceries on foot.<br>2) Take walks outside alone.<br>**Sleeping Quality**<br>*See 'Mental Coaching'.*<br>Improved sleeping quality is also aimed for with increased activity levels in daily life and physical exercise. Continuation of relaxation exercises was encouraged. | **1:1 Therapy: Graded exposure and functional retraining***+<br>1) Standing up from sitting alternated right/left leg in front*+ 2) Step up a small ridge (10 cm initially, then the height was progressively increased*+; 3) Knee flexion/extension in sitting position*+ 4) bending to pick something up from the floor*+<br>**1:1 Therapy: Exercise training***+<br>Static stability and low dose exercises: 1-leg standing, squats, lunges with and without unloaded trunk movements and ball throwing variations; progressive walking ABC*+ (sideward walking, backwards walking, lifting the knee, farmer's walk); promote descending/ascending stairs+.<br>**1:1 Therapy: Relaxation**<br>Control and continue as M1 in order to modulate sympathetic arousal.<br>**1:1 Therapy: Manual therapy**<br>Reduce tension and myofascial pain points of the M. rectus femoris, CFM of medial collateral ligament. Normalize ROM with active and passive exercises/techniques in lying and sitting position.<br>**HEP***+ Evaluation and progression of functional training of daily activities. Emphasize the importance of gradual progression to avoid pain flare ups. Progression of continuous walking duration to reduce irritation of the involved structures*+<br>**MTT**#+ Explain PAT principle to enable independent and safe progressive machine training#. Increase diversity in machine strength training (progression from two-leg to single-leg version and to free sitting)#+: leg press, leg extension and hamstring curls one leg, integrate full body workout: alternated seated machine row with thoracic rotation, butterfly front, latissimus pulldown, rotary, roll down, abdominals; progressively increase local endurance training*# on cycle ergometer (intensity/time). Independence in machine training was gradually achieved. | **1) Reflective questioning** to gain insight into and improve patient's understanding of the multifactorial analysis of the current situation.<br>**2)Correct negative illness Beliefs**<br>Reflect on the inverse relationship of the increased activity and decreased symptom levels to underline the benefits of physical activity.<br>3)Continue point 3 of M1. |
| **Module 3 (M3)**<br>**Physical Activity and pacing strategies:**<br>Increase continuous walking time by protocol (increase 5'/day) and the 24-h rule. Reinforce regular and independent exercising at home and in the gym.<br>**Sleeping Quality**<br>Mental coaching and continuation of relaxation exercises before sleeping; relaxation principles were integrated into daily life. | **1:1 Therapy: Graded exposure and functional retraining***+<br>1) Knee flexion/extension in standing position (one and two legged) 2) lifting light object*+ (2 kg) from the floor<br>**1:1 Exercise Therapy***+<br>Promote knee extension dynamically*+ (toe & heel walking variations); relaxation dynamically (hip-swinging exercise variations); strength, stability and loading capacity of the involved limb*+ (1-leg stance + hip movement variations; toe bounces; side walking in squat position; squat bounces; star excursion exercise); Bend-over-throwing variations for the lower back*+.<br>**1:1 Manual therapy**<br>CFM of m. rectus femoris tendon and medial collateral ligament; manually assisted PNF stretches to improve knee joint ROM.<br>**HEP***+ Progression of continuous walking duration+* and functional loading capacity.<br>**MTT**#+ Progression of machine to cable machine strength training# with progression of resistance according to the PAT principle: cable squats, cable hamstring exercise, cable hip abduction in standing position, cable abdominals in supine position, seated cable row (relaxed Lx position), roll down with medium weight, lat pull with integrated Lx Flex/Ext, Roman chair. | The achieved and documented functional progression was reflected upon to demonstrate the health benefits gained from increased and adaptive loading. The motto "loading, not unloading is helpful" was thematized during the 1:1 therapy exercises (see M3 exposure with control). |
| **Module 4 (M4)**<br>Physical Activity<br>1) Ann was encouraged to take the train alone. She achieved this goal in M4.<br>2) Walking outside for 45'. | **1:1 Therapy: Graded exposure and functional retraining***+<br>1) lifting medium heavy object*+ (5 kg) from the floor, integrate different variations; 2) one leg step up/down*+ | Like M3.<br>Ann's second goal "take walks of 2.5 h" was achieved. |

(*continued on next page*)

(*continued*)

| Ann | | |
|---|---|---|
| Lifestyle change | Exposure with control | Making sense of pain |
| | **1:1 Exercise Therapy***+ Hip stability (movements with contralateral leg in all directions during 1-leg stance); progressive walking-ABC*+ (see M2), increase of intensity of execution (speed and stride length); with support of both hands: toe-bounces, deep squats, sidesteps with knee in 30°, squat (mini-) jumps*+; low intensity football passing; lunge-bounces; slow jogging (a few steps).<br>**1:1 Therapy: Manual Therapy** Improve knee extension (PNF stretches, arthrokinematics); massage for reducing myofascial pain points.<br>**HEP***+ Progression of continuous walking duration+* and functional loading capacity.<br>**MTT**#+ Progression of cable machine to free weight training#+: squat lunges with dumbbells, imbalanced squats with dumbbells, one-armed dumbbell row, bent over barbell rows, dumbbell squats, dumbbell standing trunk rotation. The cross trainer was added to the ergometer endurance training, intensity/time progressively increased#+. Foam roller massage of the upper leg and hip muscles were added to the exercise program. | |
| **Module 5 (M5)** | | |
| Daily exercises and active lifestyle with integration of former hobbies. It was possible to join social events. | **1:1 Therapy: Graded exposure and functional retraining***+ 1) Lifting heavy object*+ (7–10kg) from the floor; 2) taking two steps down/up*+<br>**1:1 Exercise Therapy***+ Progress walking ABC*+; toe-bouncing variations*+ (vertical, forward, sideward, backward); slow-jogging ABC drill*+ (very low intensity!) (high knee lifts, butt-kicks, side to side stepping); football passing variations (standing and with sideward/forward/backward walking); jumping variations*+ (vertical/forward/sideward); 1-legged bounces with two-hand support*+ (vertical/sideward).<br>**HEP***+ 1) Apply self-massage of the lower limb with a Pilates foam roller at home; 2) Improve pacing strategies of ADL with lifestyle tracker to improve activity management and prevent irritation of lower limb tissue; 3) Continue to normalize ROM (as in M3-4)<br>**MTT**#+ Progression of simple free weight training to unilateral free weight training#. Start of medium intensity interval training on the cross trainer. | Cognitive factors were significantly reduced. Ann was encouraged to continue to apply the learnt exercises and principles.<br>Ann's goals were achieved:<br>1) To be "fit for work"<br>2) Take walks of 2.5 h<br>3) Be "independent" in daily life, e.g., buy groceries, do household tasks, etc. |
| **Module 6 (M6)** | | |
| | Functional capacity was significantly enhanced, and right anteromedial knee pain and additional left anterior hip pain completely resolved.<br>**Booster sessions of MTT#+:** Progression of simple free weight training to unilateral free weight training. | Discharge and pain exacerbation plan was discussed:<br>- Hold on and evaluate identify potential triggers: not enough relaxation/sleep, stress, activity plan/ movement overdone (frequency, intensity, or duration), "old" behaviors<br>– Make a new plan: apply newly learnt strategies (relax, breathe, move gently) and gradually increase.<br>– Telephone contact if self-management does not help. |

* = Exposure with control: According to the 24-h and "documented functional exercise" principle, as explained in section CFT intervention. For the actual exercise execution, see Appendix 5.6 for the HEP.

+ = Analyzing and correcting maladaptive movement behavior based on the following criteria: symmetry (if applicable), fluency, effortlessness and executed in a natural way.

# = Medical Training Therapy was executed according to the PAT (progressive adaptive training) principle.

CFM = cross-frictional massage; M = Module; SNS: sympathetic nervous system.

*To address social and emotional factors a cooperation with a job and mental job coach was initiated*

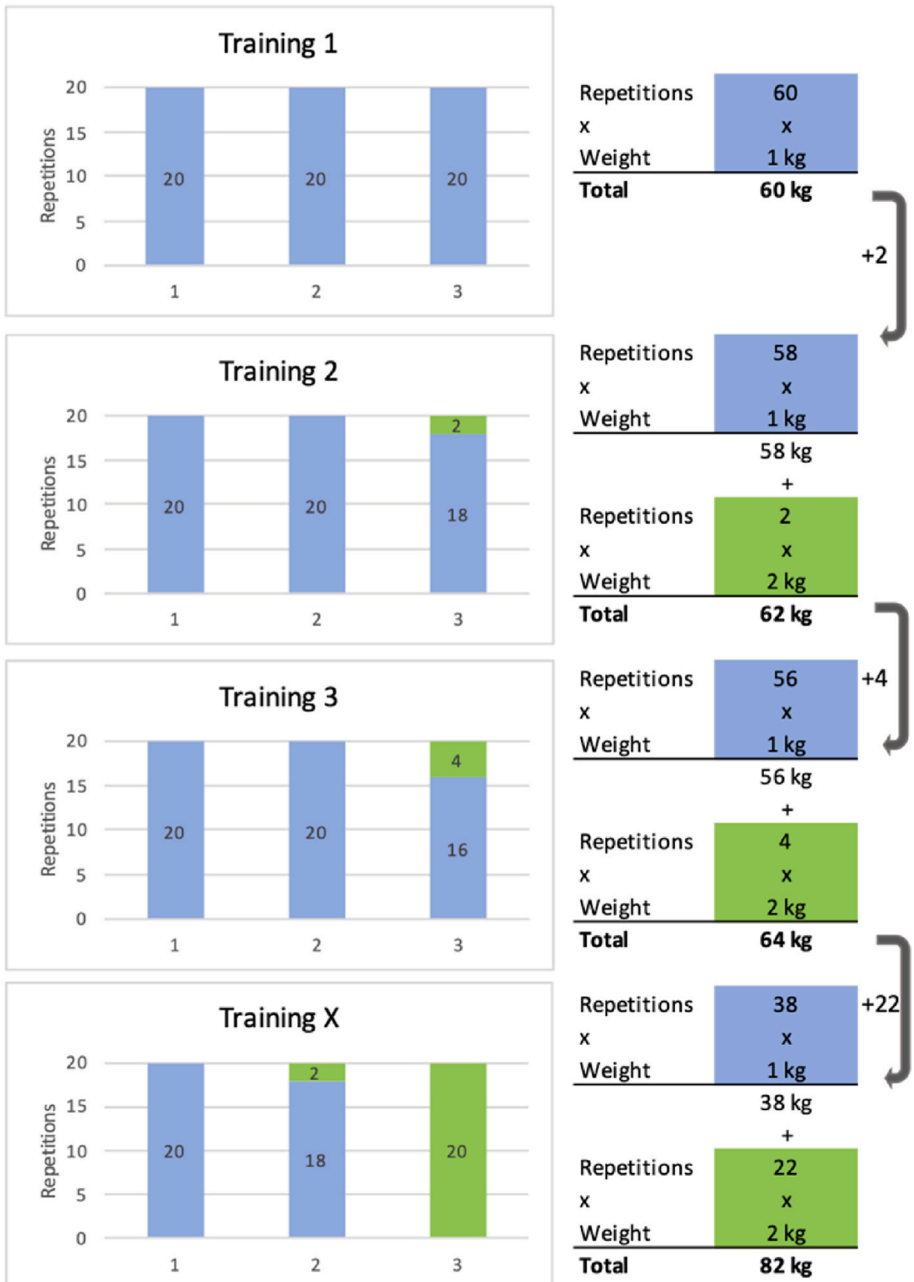
**Emotional factors** see progression of mindfulness exercises and breathing techniques in Dean's journey.

**Social factors:** Cooperation with job coach mainly addressed the reintegration and related support offered during the job application process, as these were relevant social factors. Composing of job applications and support with administrative difficulties were addressed in M1. As soon as the physical loading capacity was increased in M2/3, the job application process started. Jobs with suitable physical demands were identified and applied for in M4.

### 5.8. *Progressive Adaptive Training (PAT)*

Example of a Progressive Adaptive Training.

| Date | May 3rd | May 6th | May 8th | May 10th | May 13th | May 15th | May 18th |
|---|---|---|---|---|---|---|---|
| Repetitions | 3x20 | +2 | +4 | +6 | +8 | +10 | +12 |
| Weight | 1 kg | 2 kg | 2 kg | 2 kg | 2 kg | 2 kg | 2 kg |
| Total | 60 kg | 62 kg | 64 kg | 66 kg | 68 kg | 70 kg | 72 kg |




Own visualization, design based on workshop by *PhysioNetzwerk* GmbH (*Delmenhorst*)

### 5.9. Psychometric properties of outcome measures

| | Reliability (ICC, r or rho) | Validity | Minimal clinically important difference | Scale |
|---|---|---|---|---|
| $NRS_{pain}$ | r = 0.96 (Ferraz et al., 1990) | Criterion validity: NRS and VAS: r = 0.93 (Thong et al., 2018) | 2 points or 30% MCID (Farrar et al., 2001) | 0-100 high = bad |
| PSFS[#] | ICC = 0.91 (Maughan and Lewis, 2010)<br>ICC = 0.97 (Stratford et al., 1995) | Concurrent validity: PSFS with RMQ: r = −0.67 (Stratford et al., 1995) | 2 points (Horn et al., 2012; Maughan and Lewis, 2010) | 0-100 high = bad |
| **Questionnaires** | | | | |
| ODI | ICC = 0.96 (Mannion et al., 2006) | Construct validity: ODI and RM: r = 0.80 (Mannion et al., 2006) | 8 points (Maughan and Lewis, 2010) | 0-100 high = bad |
| VISA-P-G | ICC = 0.88 (Lohrer and Nauck, 2011) | Concurrent validity: VISA-P-G and Blazina class. System: rho = −0.81 (Lohrer and Nauck, 2011) | >13 points (Hernandez-Sanchez et al., 2014; Lohrer and Nauck, 2011) | 0-100 high = bad |
| DASH-G | rho = 0.90 (Offenbacher et al., 2003) | Construct validity: Correlations of upper extremity item score of the HAQ with the total DASH score: rho = 0.88 (Offenbacher et al., 2003) | 10.8 points (Franchignoni et al., 2014) | 0-100 high = bad |
| Video analysis for movement behavior quantification | Intersubjective | Literature based/face validity (Krasny-Pacini and Evans, 2018) | 30%* | 0-100 high = good |
| $VAS_{SOI}$ | – | – | 30%* | 0-100 high = good |
| SF12[ˆ] | ICC: PCS12 = 0.73, MCS12 = 0.64 (Hayes et al., 2017) | Construct validity: PCS12 and perceived health: r = 0.52; MCS12 and perceived mental health: r = 0.42 (Hayes et al., 2017) | MCS12: >3.77<br>PCS12: >3.29 (Diaz-Arribas et al., 2017) | 0-100 high = good |
| Multifactorial analysis[+ˆ] | Intersubjective | Literature based (O'Sullivan et al., 2018) | 30%* | 1-10 high = bad |
| Work percentage | – | – | 30%* | 0-100 high = good |
| Work status[+] | – | – | 1 | 1-9 high = good |

Abbreviations: #: consisted of minimally three different patient selected movements or activities, PSFS scores refer to the mean of the selected activities; +: ordinal scale; *: following the recommendation of Ostelo et al. (2008); ˆ: were measured only at baseline and after module 3, 5 and 6. SF12=Short Form 12, PCS12= SF12 physical component summary, MCS12= SF12 mental component summary (0 indicating lowest level and 100 highest level of health), PSFS= Patient-Specific Functional Scale – points were transformed to a 0–100 scale (0 indicating lowest and 100 highest disability), ODI= Oswestry Disability Index – ODI points were transformed to a 0–100 scale (0 indicating lowest and 100 highest disability), VISA-P-G= The Victorian Institute of Sport Assessment–Patellar Tendinopathy german version on a 0–100 scale (0 indicating lowest and 100 highest disability), DASH-G = Disabilities of Arm, Shoulder and Hand german version on a 0–100 scale (0 indicating lowest and 100 highest disability), $VAS_{SOI=}$ Subjective Overall Improvement on a 0–100 scale (0 indicating lowest and 100 highest improvement), Video analysis movement behavior quantification on a 0–100 scale (0 indicating highest and 100 lowest rated maladaptive movement behavior), Multifactorial analysis on a 0–10 scale (0 indicating no contributing factor and 10 highest contributing factor to pain), Work status on a 1–9 scale (1 indicating unable to work and 9100% in desired field.).

### 5.10. Detailed description of visual and statistical analysis

*Visual Analysis*

For visual analysis, data points within- and between phases were assessed. Analysis of level, trend, and immediacy of the effects of the graphical representation were conducted.

*Visual Analysis: Conservative Dual-Criterion (CDC) method*

Fisher et al. (2003) proposed CDC as "visual aids and structured criteria for improving visual inspection". To document a systematic change (treatment effect) in our SCED, a criterion of six data points were set. Specifically, six data points in phase B had to be below/above the criteria line (linear trend and mean of the baseline data points minus 0.25 of the standard deviation). HRQoL (SF12) was not included in CDC analysis due to the limited number of measurement points. The open source software R (R Core Team, 2013) with user written packages, for example "scan" (Wilbert and Lueke, 2019), was used for graphical representation and CDC analysis.

*Statistical analysis: Nonoverlap of All Pairs (NAP)*

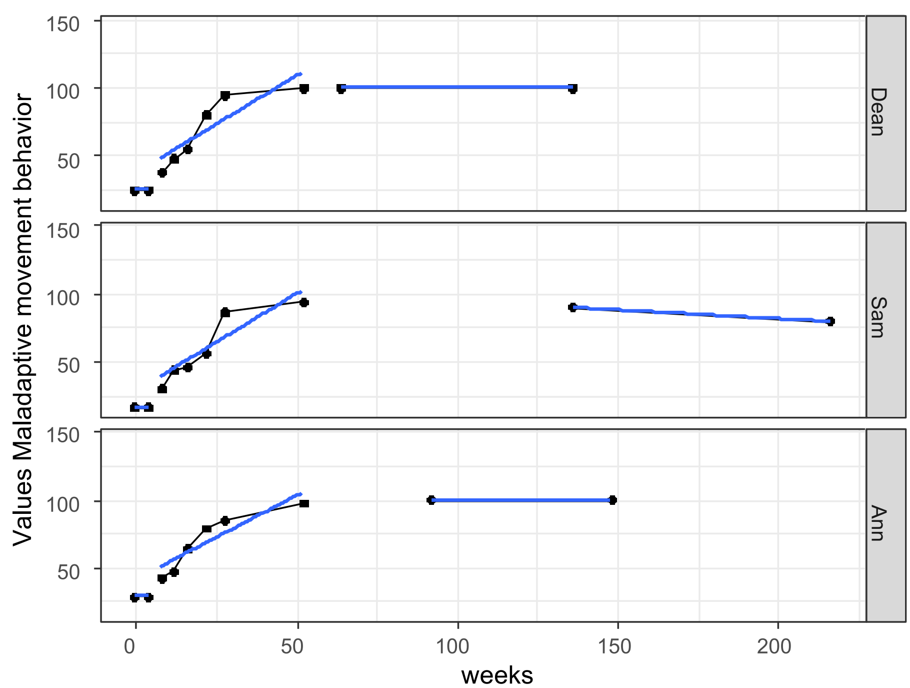
Nonoverlap of All Pairs (NAP) was considered as an effect size measure (Parker and Vannest, 2009; Pustejovsky and Ferron, 2017). NAP values on a 0–1 scale reflect the overlap between all pairs of phase A and phase B data points. Parker and Vannest (2009) stated that NAP values between 0 and 0.65 were considered as "weak," values between 0.66 and 0.92 as "medium," and values between 0.93 and 1 as "large" effects. The p-values for this non-overlap measure and 90% confidence interval were also reported. Statistical analysis (NAP) was performed using an open access website (http://www.singlecaseresearch.org/calculators/nap).

*Statistical Analysis: Simulation Modeling Analysis*

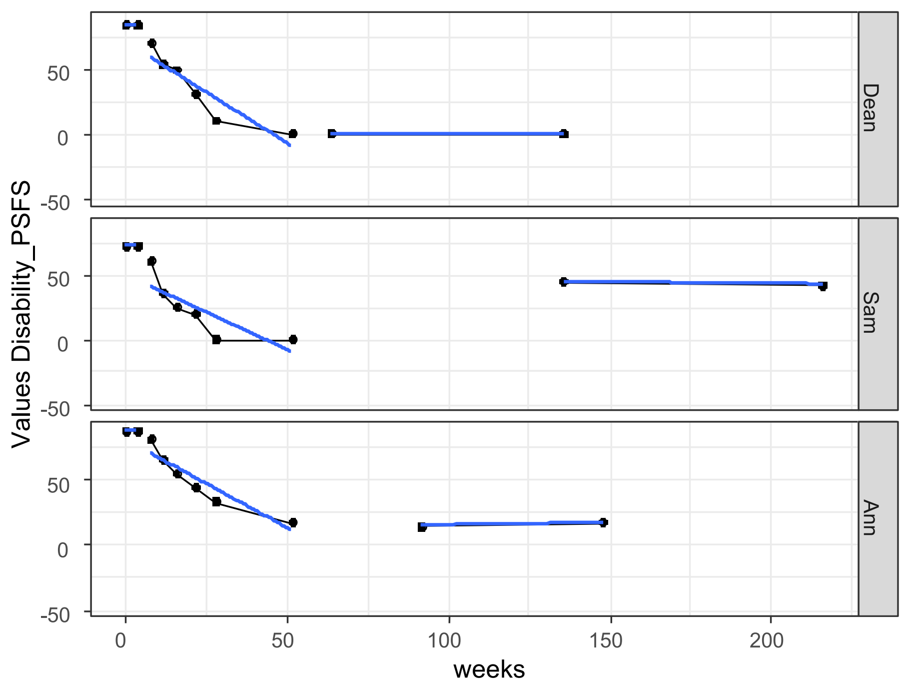
In line with recent SCED by Caneiro et al. (2019) and Wernli et al. (2020a), cross-lagged correlation analysis using Simulation Modeling Analysis (SMA) (open access download http://www.clinicalresearcher.org/software.htm) (Borckardt, 2008) was performed to analyze temporal associations and strength between two proposed outcome measures (pain, maladaptive movement behavior, disability and subjective overall improvement) over the course of the proposed intervention for the same patient. The included activities in PSFS and maladaptive movement behavior showed minor differences, therefore an additional sensitivity analysis was conducted for the most disabling activities (see Appendix 5.3 "physical factor"). SMA adjusts for autocorrelation and is proposed as an appropriate bootstrapping method for analyzing short time-series (<30 measures) (Borckardt et al., 2008). The last data point of the baseline and all data points of the intervention phase were used for the SMA as proposed by Borckardt et al. (2008). The strength of the correlation-coefficients were rated as follows: nonsignificant, small ($r = 0.10$ to $<0.30$), medium ($r = 0.30$ to $<0.50$) and large ($r = \geq 0.50$) (Cohen, 1988). Correlations were analyzed at lags $-3$ to $+3$ (measurement time points), which allowed us to observe whether a proposed outcome measure changed prior (negative lag), concurrently (lag zero) or after (positive lag) compared to the other outcome measure.

## 5.11. Trend analysis

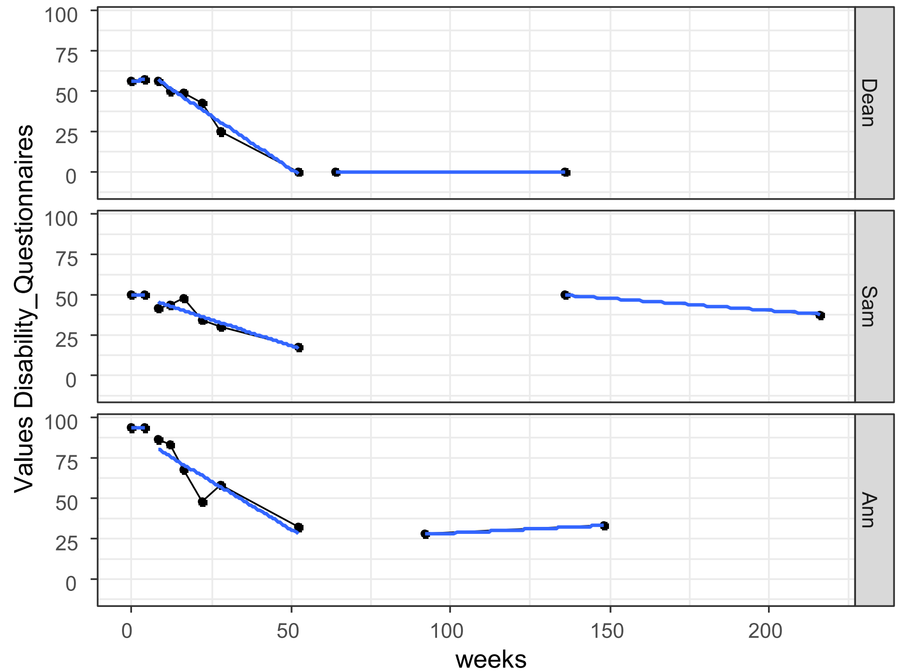
### 5.11a. Trend analysis maladaptive movement behavior



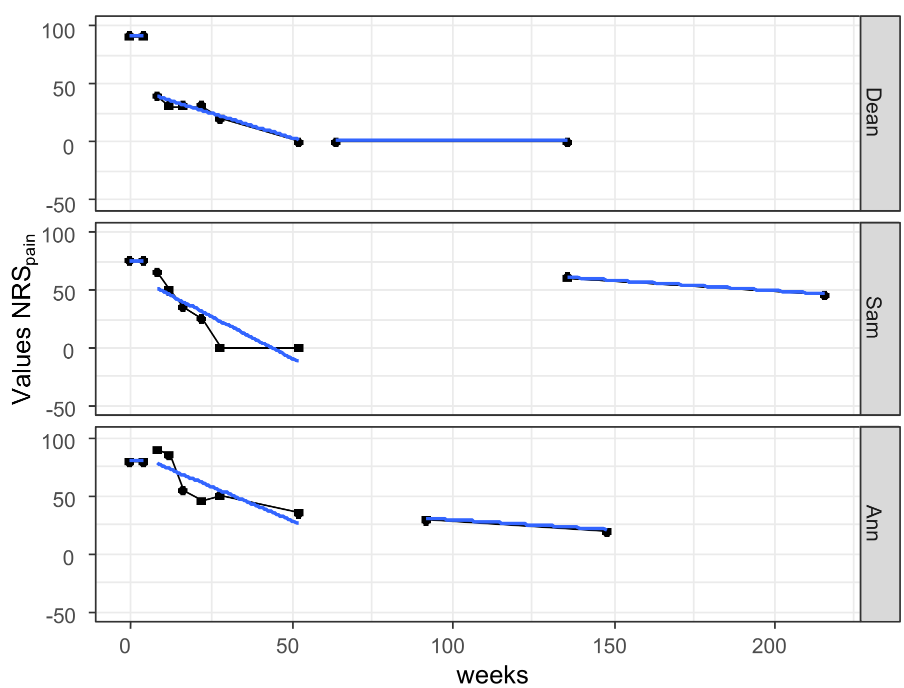
*5.11b. Trend analysis Disability_PSFS*



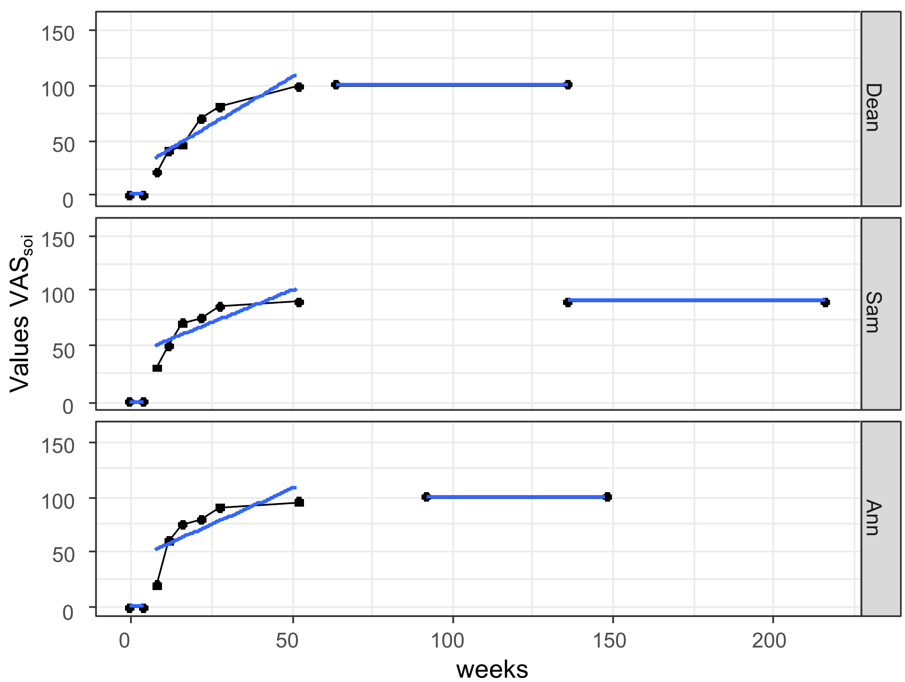
### 5.11c. Trend analysis Disability_individual questionnaires




### 5.11d. Trend analysis $NRS_{pain}$



*5.11e. Trend analysis $VAS_{soi}$*

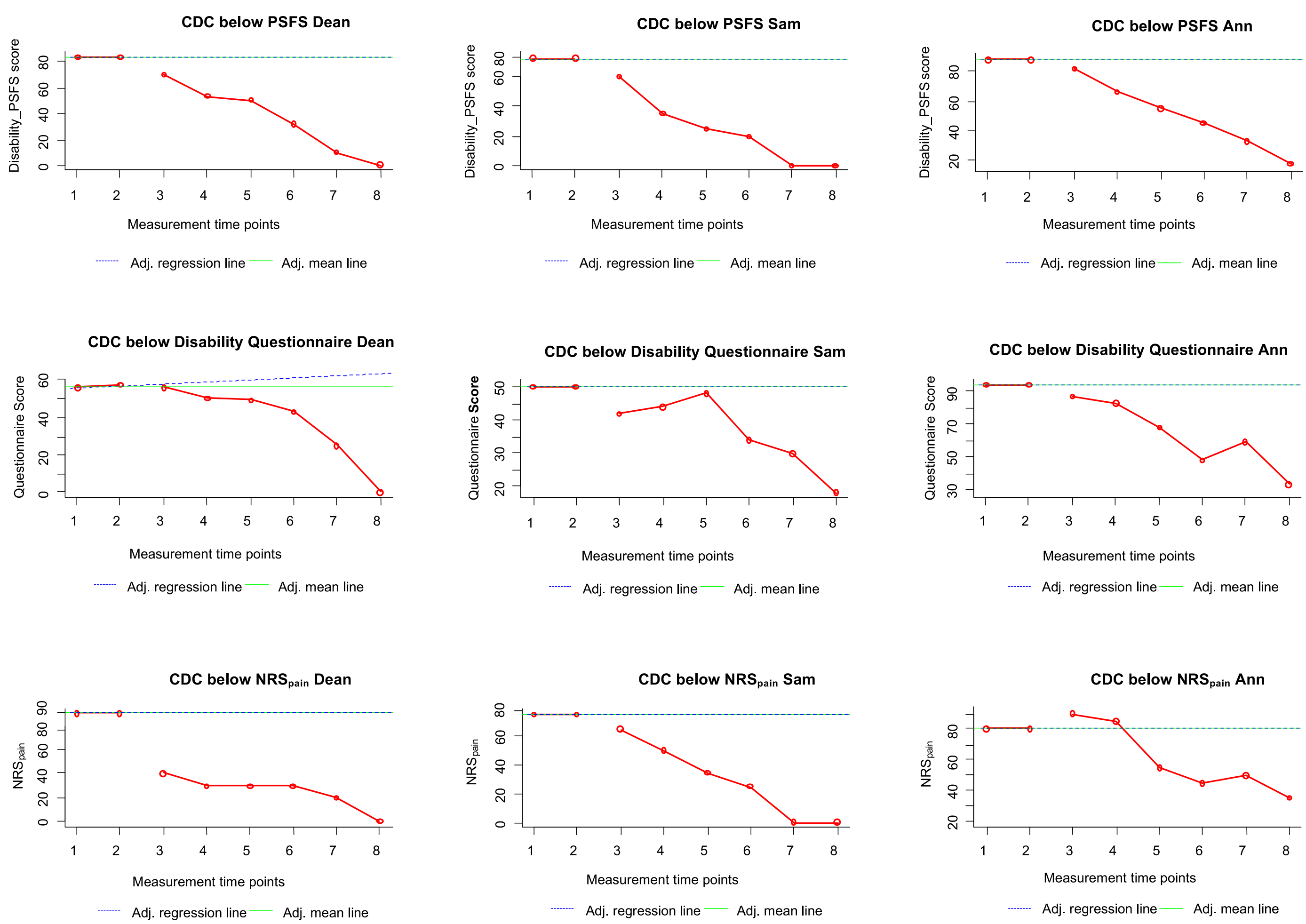


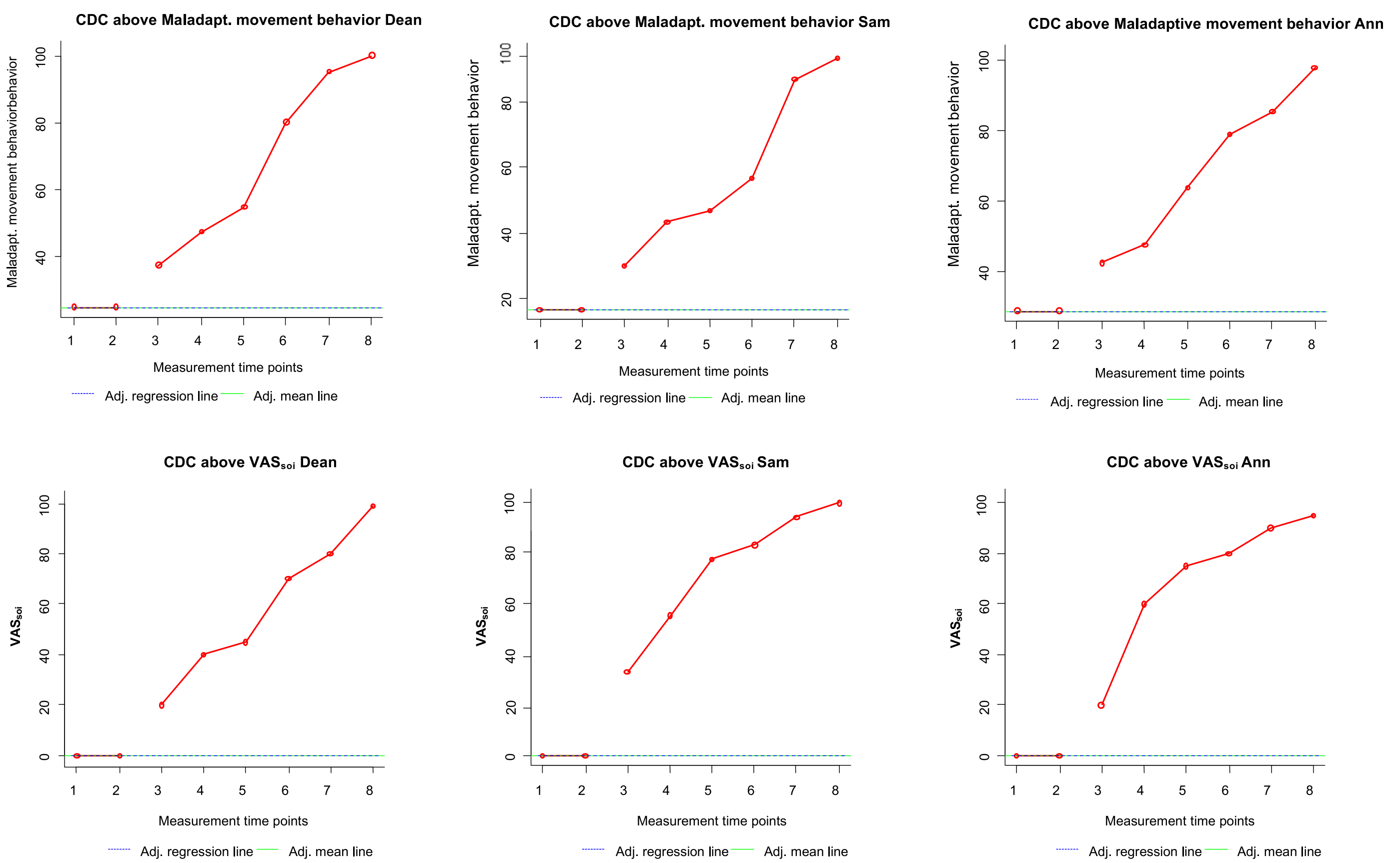
### 5.12. CDC results

| | CDC Sam | | CDC Dean | | CDC Ann | |
|---|---|---|---|---|---|---|
| | N criterion (Criterion = 6) | Effect Y/N | N criterion (Criterion = 6) | Effect Y/N | N criterion (Criterion = 6) | Effect Y/N |
| Maladaptive movement behavior | 6 | Y | 6 | Y | 6 | Y |
| $NRS_{pain}$ | 6 | Y | 6 | Y | 4 | N |
| Disability Questionnaires total score | 6 | Y | 6 | Y | 6 | Y |
| Disability PSFS total score | 6 | Y | 6 | Y | 6 | Y |
| $VAS_{soi}$ | 6 | Y | 6 | Y | 6 | Y |

Abbreviations: $NRS_{pain}$ = pain, PSFS= Patient-Specific Functional Scale, $VAS_{SOI=}$ Subjective Overall Improvement.
SF12 scores could not be included due to an insufficient number of measuring points.
N criterion describes the minimum number of measurement points in order to reveal a treatment effect (systematic change).

### 5.13. Graphical representation CDC method






Adj. regression line = subtract 0.25 of the standard deviation of the trend mean in baseline phase A, then superimpose this on the treatment phase.

Adj. mean line = subtract 0.25 of the standard deviation of the baseline mean in baseline phase A, then superimpose this on the treatment phase, allowing these lines to determine the prediction of direction that the data would take if no intervention had occurred or the treatment had had no effect (Caneiro et al., 2019).

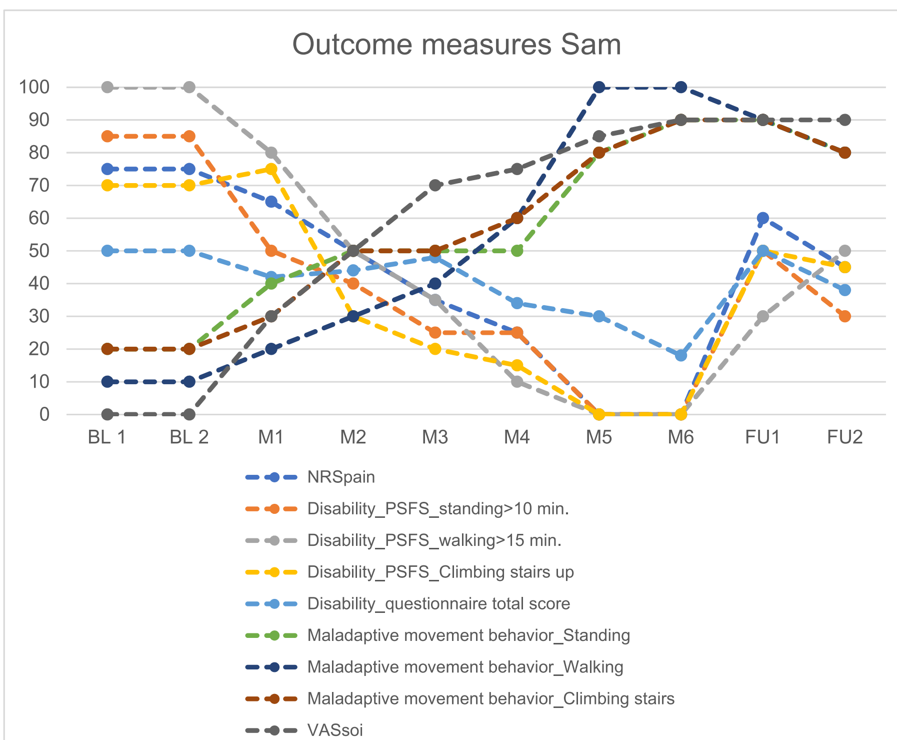
### 5.14. Summary statistic of NAP analysis with respected p-values

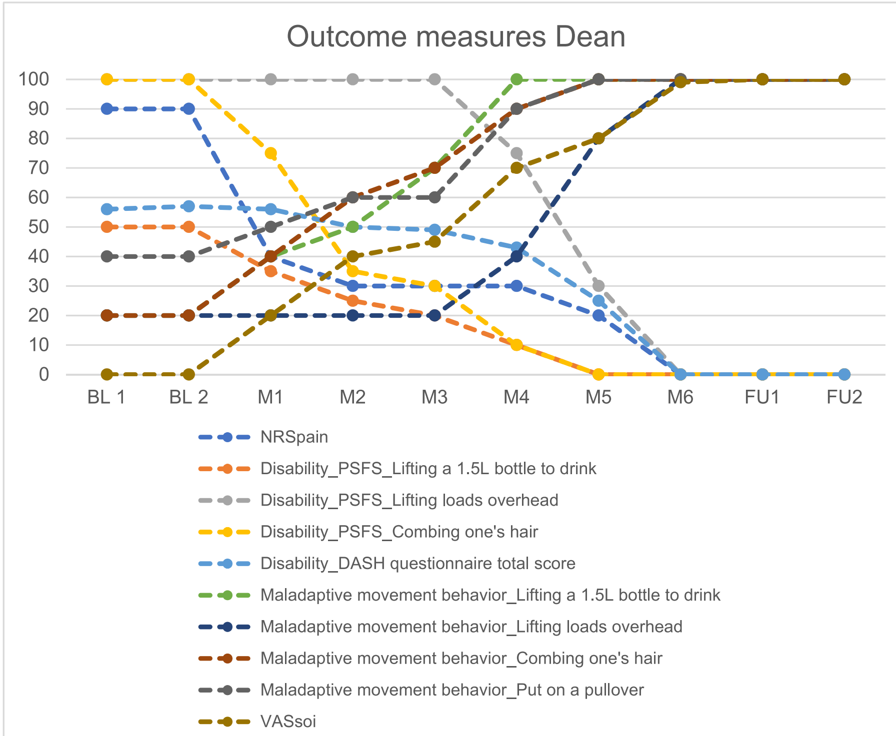
| | Sam | | | Dean | | | Ann | | |
|---|---|---|---|---|---|---|---|---|---|
| | NAP* | p-value | CI 90% | NAP* | p-value | CI 90% | NAP* | p-value | CI 90% |
| Maladaptive movement behavior | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 |
| $NRS_{pain}$ | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 | 0.667 | 0.505 | −0.489<>1 |
| Disability_Questionnaires total score | 1 | 0.046 | 0.177<>1 | 0.958 | 0.067 | 0.094<>1 | 1 | 0.046 | 0.177<>1 |
| Disability_PSFS total score | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 |
| $VAS_{SOI}$ | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 | 1 | 0.046 | 0.177<>1 |
| PCS12 | 1 | 0.083 | 0.050<>1 | 1 | 0.083 | 0.050<>1 | 1 | 0.083 | 0.050<>1 |
| MCS12 | 0.667 | 0.564 | −0.616<>1 | 1 | 0.083 | 0.050<>1 | 1 | 0.083 | 0.050<>1 |

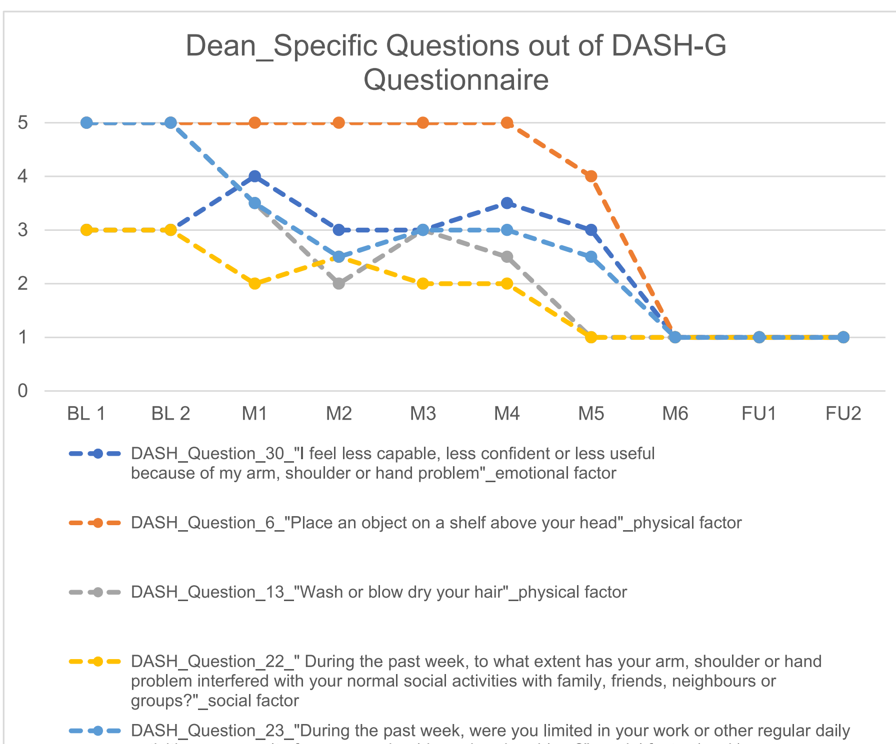
p = <0.05.

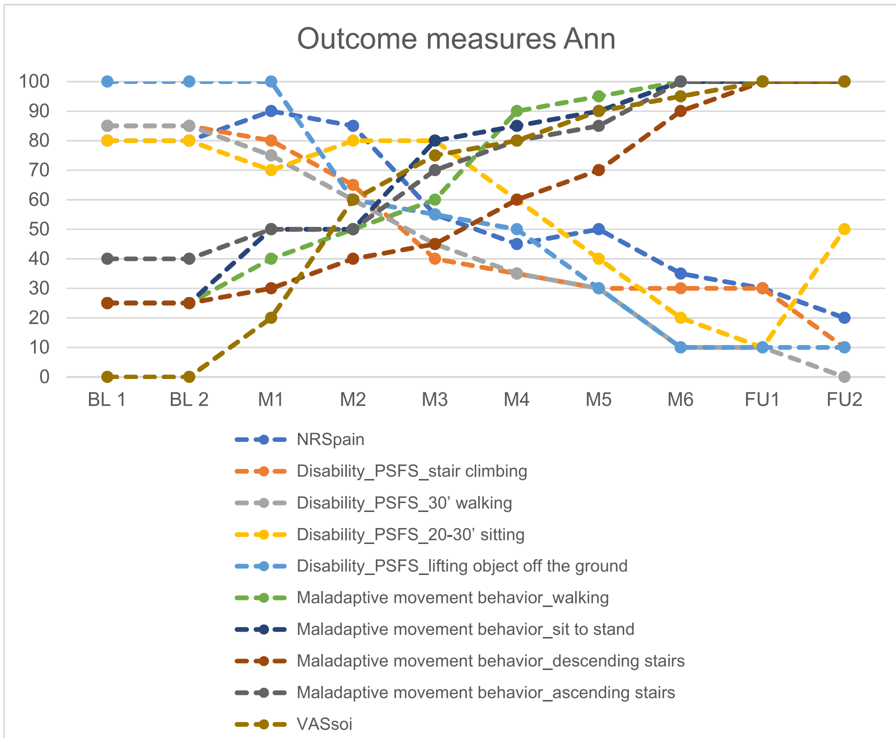
Abbreviations: $NRS_{pain}$ = pain, PSFS= Patient-Specific Functional Scale, $VAS_{SOI}$= Subjective Overall Improvement, PCS12= SF12 physical component summary, MCS12= SF12 mental component summary, CI 90% = 90% confidence interval, *NAP values 0–1, values between 0 and 0.65 are considered as "weak", 0.66–0.92 as "medium," and 0.93–1 as "large" effect

### 5.15. Individual course of proposed outcome measures




Outcome measures Dean
100
90
80
70
60
50
40
30
20
10
0
BL 1
BL 2
M1
M2
M3
M4
M5
M6
FU1
FU2
NRSpain
Disability_PSFS_Lifting a 1.5L bottle to drink
Disability_PSFS_Lifting loads overhead
Disability_PSFS_Combing one's hair
Disability_DASH questionnaire total score
Maladaptive movement behavior_Lifting a 1.5L bottle to drink
Maladaptive movement behavior_Lifting loads overhead
Maladaptive movement behavior_Combing one's hair
Maladaptive movement behavior_Put on a pullover
VASsoi


Dean_Specific Questions out of DASH-G Questionnaire
5
4
3
2
1
0
BL 1
BL 2
M1
M2
M3
M4
M5
M6
FU1
FU2
DASH_Question_30_"I feel less capable, less confident or less useful because of my arm, shoulder or hand problem"_emotional factor
DASH_Question_6_"Place an object on a shelf above your head"_physical factor
DASH_Question_13_"Wash or blow dry your hair"_physical factor
DASH_Question_22_" During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups?"_social factor
DASH_Question_23_"During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem?"_social factor (work)




## 5.16. *Cross-lagged correlations and temporal associations of proposed outcome measures*

| | | Sam | | Dean | | Ann | |
|---|---|---|---|---|---|---|---|
| | | highest corr. (r) at lag 0 | p-value | highest corr. (r) at lag 0 | p-value | highest corr. (r) at lag 0 | p-value |
| Maladaptive movement behavior | Disability PSFS total score | −0.96 | 0.002 | −0.99 | 0 | −0.99 | 0 |
| | Disability Questionnaire total score | −0.91 | 0.003 | −0.88 | 0.008 | −0.97 | 0.001 |
| | $NRS_{pain}$ | −0.98 | 0 | −0.82 | 0.016 | −0.92 | 0.002 |
| | $VAS_{SOI}$ | 0.91 | 0.005 | 0.99 | 0 | 0.93 | 0.003 |
| $NRS_{pain}$ | $VAS_{SOI}$ | −0.95 | 0 | −0.89 | 0.005 | −0.83 | 0.02 |
| Disability Questionnaire total score | $NRS_{pain}$ | 0.85 | 0.015 | 0.74 | 0.032 | 0.94 | 0.002 |
| | $VAS_{SOI}$ | −0.75 | 0.042 | −0.89 | 0.008 | −0.87 | 0.009 |
| Disability PSFS total score | $NRS_{pain}$ | 0.98 | 0 | 0.86 | 0.012 | 0.91 | 0.006 |
| | $VAS_{SOI}$ | −0.98 | 0 | −0.99 | 0 | −0.93 | 0.002 |

p = <0.05, Abbreviations: PSFS= Patient-Specific Functional Scale, $NRS_{pain}$ = pain, $VAS_{SOI=}$ Subjective Overall Improvement, corr. = correlation.

### 5.17. Sensitivity analysis cross-lagged correlation analysis

Sensitivity analysis (simulation modeling analysis) of most disabling movements.

| | | Sam: walking | | Dean: combing hair | | Ann: climbing stairs | |
|---|---|---|---|---|---|---|---|
| | | highest corr. (r) at lag 0 | p-value | highest corr. (r) at lag 0 | p-value | highest corr. (r) at lag 0 | p-value |
| Maladaptive movement behavior | Disability_PSFS total score | −0.92 | 0.004 | −0.99 | 0 | −0.88 | 0.01 |
| | Disability Questionnaire total score | −0.9 | 0.006 | −0.79 | 0.03 | −0.95 | 0.001 |
| | $NRS_{pain}$ | −0.98 | 0 | −0.87 | 0.006 | −0.89 | 0.007 |
| | $VAS_{soi}$ | 0.88 | 0.009 | 0.98 | 0.001 | 0.87 | 0.009 |
| $NRS_{pain}$ | $VAS_{soi}$ | −0.95 | 0 | −0.89 | 0.005 | −0.83 | 0.02 |
| Disability Questionnaire total score (ODI) | $NRS_{pain}$ | 0.85 | 0.015 | 0.74 | 0.032 | 0.94 | 0.001 |
| | $VAS_{soi}$ | −0.75 | 0.042 | −0.89 | 0.005 | −0.87 | 0.009 |
| Disability PSFS total score | $NRS_{pain}$ | 0.97 | 0 | 0.89 | 0.006 | 0.93 | 0.003 |
| | $VAS_{soi}$ | −0.98 | 0 | −0.96 | 0.001 | −0.97 | 0.001 |

$p = <0.05$.
Abbreviations: PSFS= Patient-specific Functional Scale, $VAS_{SOI=}$ Subjective Overall Improvement, $NRS_{pain}$ = pain, corr. = correlation.

## References


Ambrose, K.R., Golightly, Y.M., 2015. Physical exercise as non-pharmacological treatment of chronic pain: why and when. Best Pract. Res. Clin. Rheumatol. 29, 120–130.

Belavy, D.L., Van Oosterwijck, J., Clarkson, M., Dhondt, E., Mundell, N.L., Miller, C.T., Owen, P.J., 2020. Pain sensitivity is reduced by exercise training: evidence from a systematic review and meta-analysis. Neurosci. Biobehav. Rev. 120, 100–108.

Ben Simon, E., Vallat, R., Barnes, C.M., Walker, M.P., 2020. Sleep loss and the socio-emotional brain. Trends Cognit. Sci. 24, 435–450.

Bigal, M.E., 2018. Opioids vs nonopioids for chronic back, hip, or knee pain. JAMA 320, 507.

Birnbrauer, J.S., 1981. External validity and experimental investigation of individual behaviour. Anal. Interv. Dev. Disabil. 1, 117–132.

Bjorck-van Dijken, C., Fjellman-Wiklund, A., Hildingsson, C., 2008. Low back pain, lifestyle factors and physical activity: a population based-study. J. Rehabil. Med. 40, 864–869.

Borckardt, J.J., 2008. User's Guide: Simulation Modeling Analysis: Time Series Analysis Program for Short Time Series Data Streams. https://www.clinicalresearcher.org/SMA_Guide.pdf.

Borckardt, J.J., Nash, M.R., Murphy, M.D., Moore, M., Shaw, D., O'Neil, P., 2008. Clinical practice as natural laboratory for psychotherapy research: a guide to case-based time-series analysis. Am. Psychol. 63, 77–95.

Brodal, P., 2017. A neurobiologist's attempt to understand persistent pain. Scand J Pain 15, 140–147.

Bunzli, S., Smith, A., Schütze, R., Lin, I., O'Sullivan, P., 2017. Making sense of low back pain and pain-related fear. J. Orthop. Sports Phys. Ther. 47, 628–636.

Bunzli, S., Watkins, R., Smith, A., Schutze, R., O'Sullivan, P., 2013. Lives on hold: a qualitative synthesis exploring the experience of chronic low-back pain. Clin. J. Pain 29, 907–916.

Busch, V., Magerl, W., Kern, U., Haas, J., Hajak, G., Eichhammer, P., 2012. The effect of deep and slow breathing on pain perception, autonomic activity, and mood processing–an experimental study. Pain Med. 13, 215–228.

Cahill, C.M., Taylor, A.M., 2017. Neuroinflammation-a co-occurring phenomenon linking chronic pain and opioid dependence. Curr Opin Behav Sci 13, 171–177.

Cámara, R.J.A., Gharbo, R.K., Egloff, N., 2020. Age and gender as factors of pressure sensitivity of pain-free persons: are they meaningful? J. Pain Res. 13, 1849–1859.

Caneiro, J.P., Bunzli, S., O'Sullivan, P., 2021. Beliefs about the body and pain: the critical role in musculoskeletal pain management. Braz. J. Phys. Ther. 25, 17–29.

Caneiro, J.P., Smith, A., Linton, S.J., Moseley, G.L., O'Sullivan, P., 2019. 'How does change unfold?' An evaluation of the process of change in four people with chronic low back pain and high pain-related fear managed with Cognitive Functional Therapy: a replicated single-case experimental design study. Behav. Res. Ther. 117, 28–39.

Chen, Y., Campbell, P., Strauss, V.Y., Foster, N.E., Jordan, K.P., Dunn, K.M., 2018. Trajectories and predictors of the long-term course of low back pain: cohort study with 5-year follow-up. Pain 159, 252–260. https://pubmed.ncbi.nlm.nih.gov/29112007/.

Cohen, J., 1988. Statistical Power Analysis for the Behavioral Sciences. Routledge, New York.

Colvin, L.A., Bull, F., Hales, T.G., 2019. Perioperative opioid analgesia-when is enough too much? A review of opioid-induced tolerance and hyperalgesia. Lancet 393, 1558–1568.

Cowell, I., McGregor, A., O'Sullivan, P., O'Sullivan, K., Poyton, R., Murtagh, G., 2023. Physiotherapists' perceptions on using a multidimensional clinical reasoning form during psychologically informed training for low back pain. Musculoskeletal Science and Practice 66, 102797.

Darlow, B., 2016. Beliefs about back pain: the confluence of client, clinician and community. Int. J. Osteopath. Med. 20, 53–61.

Darlow, B., Dowell, A., Baxter, G.D., Mathieson, F., Perry, M., Dean, S., 2013. The enduring impact of what clinicians say to people with low back pain. Ann. Fam. Med. 11, 527–534.

de Moraes Vieira, E.B., de Goes Salvetti, M., Damiani, L.P., de Mattos Pimenta, C.A., 2014. Self-efficacy and fear avoidance beliefs in chronic low back pain patients: coexistence and associated factors. Pain Manag. Nurs. 15, 593–602.

Dean, E., Söderlund, A., 2015. What is the role of lifestyle behaviour change associated with non-communicable disease risk in managing musculoskeletal health conditions with special reference to chronic pain? BMC Muscoskel. Disord. 16, 87.

Diaz-Arribas, M.J., Fernandez-Serrano, M., Royuela, A., Kovacs, F.M., Gallego-Izquierdo, T., Ramos-Sanchez, M., Llorca-Palomera, R., Pardo-Hervas, P., Martin-Pariente, O.S., 2017. Minimal clinically important difference in quality of life for patients with low back pain. Spine 42, 1908–1916.

Duenas, M., Ojeda, B., Salazar, A., Mico, J.A., Failde, I., 2016. A review of chronic pain impact on patients, their social environment and the health care system. J. Pain Res. 9, 457–467.

Egloff, N, Klingler, N, von Kanel, R, Camara, RJ, Curatolo, M, Wegmann, B, Marti, E, Ferrari, ML, 2011. Algometry with a clothes peg compared to an electronic pressure algometer: a randomized cross-sectional study in pain patients. BMC Musculoskelet. Disord. 12, 174.

Ernstzen, D.V., Louw, Q.A., Hillier, S.L., 2017. Clinical practice guidelines for the management of chronic musculoskeletal pain in primary healthcare: a systematic review. Implement. Sci. 12, 1.

Farrar, J.T., Young Jr., J.P., LaMoreaux, L., Werth, J.L., Poole, R.M., 2001. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain 94, 149–158.

Ferraz, M.B., Quaresma, M.R., Aquino, L.R., Atra, E., Tugwell, P., Goldsmith, C.H., 1990. Reliability of pain scales in the assessment of literate and illiterate patients with rheumatoid arthritis. J. Rheumatol. 17, 1022–1024.

Finucane, L.M., Downie, A., Mercer, C., Greenhalgh, S.M., Boissonnault, W.G., Pool-Goudzwaard, A.L., Beneciuk, J.M., Leech, R.L., Selfe, J., 2020. International framework for red flags for potential serious spinal pathologies. J. Orthop. Sports Phys. Ther. 50, 350–372.

Fisher, W.W., Kelley, M.E., Lomas, J.E., 2003. Visual aids and structured criteria for improving visual inspection and interpretation of single-case designs. J. Appl. Behav. Anal. 36, 387–406.

Fordyce, W.E., 1976. Behavioral Methods for Chronic Pain and Illness. Mosby, St. Louis.

Foster, N.E., Anema, J.R., Cherkin, D., Chou, R., Cohen, S.P., Gross, D.P., Ferreira, P.H., Fritz, J.M., Koes, B.W., Peul, W., Turner, J.A., Maher, C.G., 2018. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet 391, 2368–2383.

Franchignoni, F., Vercelli, S., Giordano, A., Sartorio, F., Bravini, E., Ferriero, G., 2014. Minimal clinically important difference of the disabilities of the arm, shoulder and hand outcome measure (DASH) and its shortened version (QuickDASH). J. Orthop. Sports Phys. Ther. 44, 30–39.

Gardner, T., Refshauge, K., McAuley, J., Hübscher, M., Goodall, S., Smith, L., 2019. Combined education and patient-led goal setting intervention reduced chronic low back pain disability and intensity at 12 months: a randomised controlled trial. Br. J. Sports Med.

Garland, L., Jones, G., 2019. Effectiveness of graded exercise & graded exposure for chronic nonspecific low back pain: a rapid review. Pain and Rehabilitation - the Journal of Physiotherapy Pain Association 2020, 30–36.

Gatchel, R.J., McGeary, D.D., McGeary, C.A., Lippe, B., 2014. Interdisciplinary chronic pain management: past, present, and future. Am. Psychol. 69, 119–130.

Gong, M., Hu, X., Tan, S., Jing, S., Wang, Y., Li, Y., Li, S., 2020. Efficacy of exercise on sleep quality and insomnia–A systematic review and meta-analysis. Psychiatr. Res., 113442

Gustavsson, A., Bjorkman, J., Ljungcrantz, C., Rhodin, A., Rivano-Fischer, M., Sjolund, K. F., Mannheimer, C., 2012. Socio-economic burden of patients with a diagnosis

related to chronic pain–register data of 840,000 Swedish patients. Eur. J. Pain 16, 289–299.
Hartvigsen, J., Kamper, S.J., French, S.D., 2022. Low-value care in musculoskeletal health care: is there a way forward? Pain Pract. 22, 65–70.
Hayes, C.J., Bhandari, N.R., Kathe, N., Payakachat, N., 2017. Reliability and validity of the medical outcomes study short form-12 version 2 (SF-12v2) in adults with non-cancer pain. Healthcare (Basel) 5.
Heneweer, H., Staes, F., Aufdemkampe, G., van Rijn, M., Vanhees, L., 2011. Physical activity and low back pain: a systematic review of recent literature. Eur. Spine J. 20, 826–845.
Hernandez-Sanchez, S., Hidalgo, M.D., Gomez, A., 2014. Responsiveness of the VISA-P scale for patellar tendinopathy in athletes. Br. J. Sports Med. 48, 453–457.
Heuch, I., Heuch, I., Hagen, K., Zwart, J.A., 2016. Is there a U-shaped relationship between physical activity in leisure time and risk of chronic low back pain? A follow-up in the HUNT Study. BMC Publ. Health 16, 306.
Ho, E.K., Chen, L., Simic, M., Ashton-James, C.E., Comachio, J., Wang, D.X.M., Hayden, J.A., Ferreira, M.L., Ferreira, P.H., 2022. Psychological interventions for chronic, non-specific low back pain: systematic review with network meta-analysis. BMJ 376, e067718.
Hoffmann, T.C., Glasziou, P.P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Douglas, G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S.E., Dixon-Woods, M., McCulloch, P., Wyatt, J.C., Chan, A.-W., Michie, S., 2016. Die TIDieR Checkliste und Anleitung – ein Instrument für eine verbesserte Interventionsbeschreibung und Replikation. Gesundheitswesen 78, 175–188.
Holopainen, R., Lausmaa, M., Edlund, S., Carstens-Söderstrand, J., Karppinen, J., O'Sullivan, P., Linton, S.J., 2021. Physiotherapists' validating and invalidating communication before and after participating in brief cognitive functional therapy training. Test of concept study. Eur. J. Physiother. 25, 1–7. https://www.tandfonline.com/doi/full/10.1080/21679169.2021.1967446.
Holopainen, R., Simpson, P., Piirainen, A., Karppinen, J., Schutze, R., Smith, A., O'Sullivan, P., Kent, P., 2020. Physiotherapists' perceptions of learning and implementing a biopsychosocial intervention to treat musculoskeletal pain conditions: a systematic review and metasynthesis of qualitative studies. Pain.
Horn, K.K., Jennings, S., Richardson, G., Vliet, D.V., Hefford, C., Abbott, J.H., 2012. The patient-specific functional scale: psychometrics, clinimetrics, and application as a clinical outcome measure. J. Orthop. Sports Phys. Ther. 42, 30–42.
Horner, R.H., Carr, E.G., Halle, J., McGee, G., Odom, S., Wolery, M., 2005. The use of single-subject research to identify evidence-based practice in special education. Except. Child. 71, 165–179.
Christe, G., Crombez, G., Edd, S., Opsommer, E., Jolles, B.M., Favre, J., 2021. Relationship between psychological factors and spinal motor behaviour in low back pain: a systematic review and meta-analysis. Pain 162, 672–686.
International Association for the Study of Pain 2020 IASP Terminology.
Juurlink, D.N., 2017. Rethinking "doing well" on chronic opioid therapy. CMAJ (Can. Med. Assoc. J.) 189, E1222–e1223.
Kaiser, U., Kopkow, C., Deckert, S., Neustadt, K., Jacobi, L., Cameron, P., De Angelis, V., Apfelbacher, C., Arnold, B., Birch, J., Bjarnegård, A., Christiansen, S., CdCW, A., Gossrau, G., Heinks, A., Hüppe, M., Kiers, H., Kleinert, U., Martelletti, P., McCracken, L., de Meij, N., Nagel, B., Nijs, J., Norda, H., Singh, J.A., Spengler, E., Terwee, C.B., Tugwell, P., Vlaeyen, J.W.S., Wandrey, H., Neugebauer, E., Sabatowski, R., Schmitt, J., 2018. Developing a core outcome domain set to assessing effectiveness of interdisciplinary multimodal pain therapy: the VAPAIN consensus statement on core outcome domains. Pain 159, 673–683.
Kamper, S.J., Apeldoorn, A.T., Chiarotto, A., Smeets, R.J., Ostelo, R.W., Guzman, J., van Tulder, M.W., 2015. Multidisciplinary biopsychosocial rehabilitation for chronic low back pain: cochrane systematic review and meta-analysis. BMJ 350, h444.
Kazdin, A.E., 1977. Assessing the clinical or applied importance of behavior change through social validation. Behav. Modif. 1, 427–452.
Kazdin, A.E., 2011. Single-case Research Designs: Methods for Clinical and Applied Settings. N.Y: Oxford University Press, New York.
Keefe, F.J., Main, C.J., George, S.Z., 2018. Advancing psychologically informed practice for patients with persistent musculoskeletal pain: promise, pitfalls, and solutions. Phys. Ther. 98, 398–407.
Kent, P., Haines, T., O'Sullivan, P., Smith, A., Campbell, A., Schutze, R., Attwell, S., Caneiro, J.P., Laird, R., O'Sullivan, K., McGregor, A., Hartvigsen, J., Lee, D.-C.A., Vickery, A., Hancock, M., 2023. Cognitive functional therapy with or without movement sensor biofeedback versus usual care for chronic, disabling low back pain (RESTORE): a randomised, controlled, three-arm, parallel group, phase 3, clinical trial. Lancet 401, 1866–1877.
Krasny-Pacini, A., Evans, J., 2018. Single-case experimental designs to assess intervention effectiveness in rehabilitation: a practical guide. Ann Phys Rehabil Med 61, 164–179.
Kratochwill, T.R., Hitchcock, J., Horner, R.H., Levin, J.R., Odom, S.L., Rindskopf, D.M., Shadish, W.R., 2010. Single-case Designs Technical Documentation.
Kratochwill, T.R., Hitchcock, J.H., Horner, R.H., Levin, J.R., Odom, S.L., Rindskopf, D. M., Shadish, W.R., 2013. Single-case intervention research design standards. Remedial Special Educ. 34, 26–38.
Kratochwill, T.R., Levin, J.R., 2010. Enhancing the scientific credibility of single-case intervention research: randomization to the rescue. Psychol. Methods 15, 124–144.
Laranjo, L., Ding, D., Heleno, B., Kocaballi, B., Quiroz, J.C., Tong, H.L., Chahwan, B., Neves, A.L., Gabarron, E., Dao, K.P., Rodrigues, D., Neves, G.C., Antunes, M.L., Coiera, E., Bates, D.W., 2020. Do smartphone applications and activity trackers increase physical activity in adults? Systematic review, meta-analysis and metaregression. Br. J. Sports Med. 55, 422–432.
Levin, J.R., Kratochwill, T.R., 2021. Randomized Single-Case Intervention Designs and Analyses for Health Sciences Researchers: A Versatile Clinical Trials Companion. Therap. Innov. Regul. Sci. 55, 755–764.
Lindström, I., Ohlund, C., Eek, C., Wallin, L., Peterson, L.E., Nachemson, A., 1992. Mobility, strength, and fitness after a graded activity program for patients with subacute low back pain. A randomized prospective clinical study with a behavioral therapy approach. Spine 17, 641–652.
Lohrer, H., Nauck, T., 2011. Cross-cultural adaptation and validation of the VISA-P questionnaire for German-speaking patients with patellar tendinopathy. J. Orthop. Sports Phys. Ther. 41, 180–190.
Maher, C., Underwood, M., Buchbinder, R., 2017. Non-specific low back pain. Lancet 389, 736–747.
Mannion, A.F., Junge, A., Fairbank, J.C., Dvorak, J., Grob, D., 2006. Development of a German version of the Oswestry Disability Index. Part 1: cross-cultural adaptation, reliability, and validity. Eur. Spine J. 15, 55–65.
Manolov, R., Gast, D.L., Perdices, M., Evans, J.J., 2014. Single-case experimental designs: reflections on conduct and analysis. Neuropsychol. Rehabil. 24, 634–660.
Maughan, E.F., Lewis, J.S., 2010. Outcome measures in chronic low back pain. Eur. Spine J. 19, 1484–1494.
McGrane, N., Galvin, R., Cusack, T., Stokes, E., 2015. Addition of motivational interventions to exercise and traditional physiotherapy: a review and meta-analysis. Physiotherapy 101, 1–12.
Mitchell, T., Beales, D., Slater, H., O'Sullivan, P., 2018. Musculoskeletal clinical translation framework: from knowing to doing (eBook). https://www.musculoskeletalframework.net/get-the-ebook.
Nijs, J., Lluch Girbés, E., Lundberg, M., Malfliet, A., Sterling, M., 2015. Exercise therapy for chronic musculoskeletal pain: innovation by altering pain memories. Man. Ther. 20, 216–220.
Nijs, J., Wijma, A.J., Willaert, W., Huysmans, E., Mintken, P., Smeets, R., Goossens, M., van Wilgen, C.P., Van Bogaert, W., Louw, A., Cleland, J., Donaldson, M., 2020. Integrating motivational interviewing in pain neuroscience education for people with chronic pain: a practical guide for clinicians. Phys. Ther. 100, 846–859.
O'Halloran, P.D., Blackstock, F., Shields, N., Holland, A., Iles, R., Kingsley, M., Bernhardt, J., Lannin, N., Morris, M.E., Taylor, N.F., 2014. Motivational interviewing to increase physical activity in people with chronic health conditions: a systematic review and meta-analysis. Clin. Rehabil. 28, 1159–1171.
O'Sullivan, P., Caneiro, J.P., O'Keeffe, M., O'Sullivan, K., 2016. Unraveling the complexity of low back pain. J. Orthop. Sports Phys. Ther. 46, 932–937.
O'Sullivan, P.B., Caneiro, J.P., O'Keeffe, M., Smith, A., Dankaerts, W., Fersum, K., O'Sullivan, K., 2018. Cognitive functional therapy: an integrated behavioral approach for the targeted management of disabling low back pain. Phys. Ther. 98, 408–423.
Oesch, P., 2017. Kesseling J 2017 Teamwork in rehabilitation – it is effective but it must be financed. Swiss Med. Wkly. 147, w14449.
Offenbacher, M., Ewert, T., Sangha, O., Stucki, G., 2003. Validation of a German version of the `disabilities of arm, shoulder and hand' questionnaire (DASH-G). Z. Rheumatol. 62, 168–177.
Oliveira, C.B., Maher, C.G., Pinto, R.Z., Traeger, A.C., Lin, C.C., Chenot, J.F., van Tulder, M., Koes, B.W., 2018. Clinical practice guidelines for the management of non-specific low back pain in primary care: an updated overview. Eur. Spine J. 27, 2791–2803.
Ostelo, R.W., Deyo, R.A., Stratford, P., Waddell, G., Croft, P., Von Korff, M., Bouter, L.M., de Vet, H.C., 2008. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine 33, 90–94.
Parker, R.I., Vannest, K., 2009. An improved effect size for single-case research: nonoverlap of all pairs. Behav. Ther. 40, 357–367.
Perrot, S., Cohen, M., Barke, A., Korwisi, B., Rief, W., Treede, R.D., 2019. The IASP classification of chronic pain for ICD-11: chronic secondary musculoskeletal pain. Pain 160, 77–82.
Pustejovsky, J.E., Ferron, J.M., 2017. Research synthesis and meta-analysis of single-case designs. In: Kaufmann DPH, J.M., Pullen, P.C. (Eds.), Handbook of Special Education, 2nd Edition. Routledge., New York, NY:
R Core Team, 2013. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
Ravindra, A., Barlow, J.D., Jones, G.L., Bishop, J.Y., 2018. A prospective evaluation of predictors of pain after arthroscopic rotator cuff repair: psychosocial factors have a stronger association than structural factors. J. Shoulder Elbow Surg. 27, 1824–1829.
Richter, M., Eck, J., Straube, T., Miltner, W.H., Weiss, T., 2010. Do words hurt? Brain activation during the processing of pain-related words. Pain 148, 198–205.
Simons, L.E., Moulton, E.A., Linnman, C., Carpino, E., Becerra, L., Borsook, D., 2014. The human amygdala and pain: evidence from neuroimaging. Hum. Brain Mapp. 35, 527–538.
Simpson, P., Holopainen, R., Schütze, R., O'Sullivan, P., Smith, A., Kent, P., 2022. Becoming confidently competent: a qualitative investigation of training in cognitive functional therapy for persistent low back pain. Physiother. Theory Pract. 1–13.
Smith, B.E., Hendrick, P., Bateman, M., Holden, S., Littlewood, C., Smith, T.O., Logan, P., 2019. Musculoskeletal pain and exercise-challenging existing paradigms and introducing new. Br. J. Sports Med. 53, 907–912.
Smith, B.E., Hendrick, P., Smith, T.O., Bateman, M., Moffatt, F., Rathleff, M.S., Selfe, J., Logan, P., 2017. Should exercises be painful in the management of chronic musculoskeletal pain? A systematic review and meta-analysis. Br. J. Sports Med. 51, 1679–1687.
Stratford, P., Gill, C., Westaway, M.D., Binkley, J.M., 1995. Assessing disability and change on individual patients: a report of a patient specific measure. Physiother. Can. 47, 258–263.

Sullivan, M.J., Thorn, B., Haythornthwaite, J.A., Keefe, F., Martin, M., Bradley, L.A., Lefebvre, J.C., 2001. Theoretical perspectives on the relation between catastrophizing and pain. Clin. J. Pain 17, 52–64.

Swoboda, C., Kratochwill, T., Levin, J., 2010. Conservative Dual-Criterion Method for Single-Case Research: A Guide for Visual Analysis of AB, ABAB, and Multiple-Baseline Designs (WCER working paper No. 2010-13).

Synnott, A., O'Keeffe, M., Bunzli, S., Dankaerts, W., O'Sullivan, P., O'Sullivan, K., 2015. Physiotherapists may stigmatise or feel unprepared to treat people with low back pain and psychosocial factors that influence recovery: a systematic review. J. Physiother. 61, 68–76.

Tate, R.L., Perdices, M., Rosenkoetter, U., Shadish, W., Vohra, S., Barlow, D.H., Horner, R., Kazdin, A., Kratochwill, T., McDonald, S., Sampson, M., Shamseer, L., Togher, L., Albin, R., Backman, C., Douglas, J., Evans, J.J., Gast, D., Manolov, R., Mitchell, G., Nickels, L., Nikles, J., Ownsworth, T., Rose, M., Schmid, C.H., Wilson, B., 2016a. The single-case reporting guideline in BEhavioural interventions (SCRIBE) 2016 statement. Am. J. Occup. Ther. 70, 7004320010pp.7004320011–7004320011.

Tate, R.L., Perdices, M., Rosenkoetter, U., Wakim, D., Godbee, K., Togher, L., McDonald, S., 2013. Revision of a method quality rating scale for single-case experimental designs and n-of-1 trials: the 15-item Risk of Bias in N-of-1 Trials (RoBiNT) Scale. Neuropsychol. Rehabil. 23, 619–638.

Tate, R.L., Rosenkoetter, U., Togher, L., Horner, R., Barlow, D.H., Sampson, M., Vohra, S., Perdices, M., McDonald, S., Shadish, W., Kratochwill, T., Kazdin, A., Shamseer, L., 2016b. The single-case reporting guideline in BEhavioural interventions (SCRIBE) 2016: explanation and elaboration. Arch. Sci. Psychol. 4, 10–31.

Thomeé, R., 1997. A comprehensive treatment approach for patellofemoral pain syndrome in young women. Phys. Ther. 77, 1690–1703.

Thong, I.S.K., Jensen, M.P., Miro, J., Tan, G., 2018. The validity of pain intensity measures: what do the NRS, VAS, VRS, and FPS-R measure? Scand J Pain 18, 99–107.

Treede, R.D., Rief, W., Barke, A., Aziz, Q., Bennett, M.I., Benoliel, R., Cohen, M., Evers, S., Finnerup, N.B., First, M.B., Giamberardino, M.A., Kaasa, S., Korwisi, B., Kosek, E., Lavand'homme, P., Nicholas, M., Perrot, S., Scholz, J., Schug, S., Smith, B. H., Svensson, P., Vlaeyen, J.W.S., Wang, S.J., 2019. Chronic pain as a symptom or a disease: the IASP classification of chronic pain for the international classification of diseases (ICD-11). Pain 160, 19–27.

Utah Department of Health, 2001. Medical Outcomes Study SF-12.

Vaegter, H.B., Johansen, J.V., Sopina, L., Smith, A., Kent, P., Fuglsang, K.S., Pedersen, J. F., Schutze, R., O'Sullivan, P., Handberg, G., Fatoye, F., Ussing, K., Stegemejer, I., Thorlund, J.B., 2021. A cognitive functional Therapy+ pathway versus an interdisciplinary pain management pathway for patients with severe chronic low back pain (CONFeTTI trial): protocol for a pragmatic randomized controlled trial. Phys. Ther. 101.

Valentine, J.C., Tanner-Smith, E.E., Pustejovsky, J.E., Lau, T.S., 2016. Between-case standardized mean difference effect sizes for single-case designs: a primer and tutorial using the scdhlm web application. Campbell Systemat. Rev. 12, 1–31.

Vibe Fersum, K., O'Sullivan, P., Skouen, J.S., Smith, A., Kvale, A., 2013. Efficacy of classification-based cognitive functional therapy in patients with non-specific chronic low back pain: a randomized controlled trial. Eur. J. Pain 17, 916–928.

Vos, T., Abajobir, A.A., Abbafati, C., Abbas, K.M., Abate, K.H., Abd-Allah, F., 2017. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet 390, 1211–1259.

Walker, Matthew. What Happens to Your Body and Brain if You Don't Get Sleep | the Human Body. https://www.youtube.com/watch?v=Y-8b99rGpkM.

Wernli, K., O'Sullivan, P., Smith, A., Campbell, A., Kent, P., 2020a. Movement, posture and low back pain. How do they relate? A replicated single-case design in 12 people with persistent, disabling low back pain. Eur J Pain 24, 1831–1849.

Wernli, K., Tan, J.S., O'Sullivan, P., Smith, A., Campbell, A., Kent, P., 2020b. Does movement change when low back pain changes? A systematic review. J. Orthop. Sports Phys. Ther. 1–48.

Wieser, S., Riguzzi, M., Pletscher, M., Huber, C.A., Telser, H., Schwenkglenks, M., 2018. How much does the treatment of each major disease cost? A decomposition of Swiss National Health Accounts. Eur. J. Health Econ. 19, 1149–1161.

Wilbert, J., Lueke, T., 2019. Scan: Single-Case Data Analyses for Single and Multiple Baseline Designs. R package version 0.40.

Wilson, S., Chaloner, N., Osborn, M., Gauntlett-Gilbert, J., 2017. Psychologically informed physiotherapy for chronic pain: patient experiences of treatment and therapeutic process. Physiotherapy 103, 98–105.

Wolfe, K., Barton, E.E., Meadan, H., 2019. Systematic protocols for the visual analysis of single-case research data. Behav. Analyst Pract. 12, 491–502.

Yamato, T.P., Maher, C.G., Saragiotto, B.T., Moseley, A.M., Hoffmann, T.C., Elkins, M.R., 2016. The TIDieR checklist will benefit the physiotherapy profession. J. Physiother. 62, 57–58.

Young, D., Callaghan, M., Hunt, C., Briggs, M., Griffiths, J., 2019. Psychologically informed approaches to chronic low back pain: exploring musculoskeletal physiotherapists' attitudes and beliefs. Muscoskel. Care 17, 272–276.

Zangoni, G., Thomson, O.P., 2017. 'I need to do another course' - Italian physiotherapists' knowledge and beliefs when assessing psychosocial factors in patients presenting with chronic low back pain. Musculoskelet Sci. Pract. 27, 71–77.