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Influence of central aspects of pain on self-management in people with chronic low back pain

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ABSTRACT

Objective: This observational study investigated whether central aspects of pain are associated with self-management domains in individuals with chronic low back pain (CLBP) undertaking a pain management program.
Methods: Individuals with CLBP provided pain sensitivity and self-management data at baseline (n = 97) and 3-months (n = 87). Pressure pain detection threshold (PPT) at the forearm, temporal summation (TS) and conditioned pain modulation (CPM), Widespread Pain Index (WPI), and a Central Aspects of Pain factor (CAPf) were considered as central aspects of pain. Self-management was measured using the 8 domains of the Health Education Impact Questionnaire, as well as Pain Self Efficacy and Health Care Utilisation questionnaires.
Results: PPT, CPM, WPI and CAPf predicted worse performance in several self-management domains at 3-months ($r = 0.21$ to 0.54, $p < 0.05$ overall). In multivariable regression models (adjusted for baseline scores of self-management, depression, catastrophization, pain and fatigue) low PPT, high TS, and high CAPf at baseline predicted poorer self-management at 3 months ($R^2 = 0.14$ to 0.52, $\beta = -0.37$ to 0.35, $p < 0.05$).
Conclusions: Central aspects of pain are associated with impaired self-management, over and above effects of pain intensity, fatigue, depression and catastrophizing.
Practice implications: Treatments that target central aspects of pain might help improve self-management in people with CLBP.

1. Introduction

Chronic low back pain (CLBP) is the most prevalent musculoskeletal condition with significant impact on patients' quality of life and health care services [1]. Guidelines for managing CLBP prioritise the development of self-management strategies [2]. Self-management is a multidimensional concept encapsulating an individual's ability to effectively manage their treatment needs, physical, social and psychological challenges as well as lifestyle modifications [3]. Self-management interventions aim to increase quality of life by improving the ability of people to develop self-management skills [4], and may have moderate long-term benefits in reducing CLBP severity [5]. Improved self-management may be a key aim of multidisciplinary Pain Management Programs [6] and of cognitive behavioural therapy (CBT)-based group physiotherapy interventions [7].

The central nervous system (CNS) plays key roles in the pathophysiology and experience of pain, referred to previously as central aspects of pain [8]. Pain entails cognitive-evaluative, emotional and sensory dimensions [9] and people with more severe pain may self-manage less effectively [10–12], although mechanisms underlying this association are incompletely understood. Abnormal pain processing in the peripheral and central nervous systems contributes to the severity and persistence of CLBP [13,14]. Central aspects of pain have been consistently found in studies of CLBP to amplify the pain experience [13,15], in

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20–40% of the cases [16]. Central aspects of pain, when identified early, can predict pain severity, disability and negative affect in people with musculoskeletal pain [17], which suggests cognitive-evaluative, emotional and sensory impact. Sensory, emotional or cognitive malfunction can drive, generate, amplify, or even perpetuate pain in the absence of tissue pathology, a process that potentially influences the capacity of individuals to develop or adopt health-related behaviours [18].

Quantitative Sensory Testing (QST) can indicate sensitivity mediated by the CNS. Different QST modalities, static (e.g. Pain Pressure Detection Thresholds; PPT), or dynamic (Temporal Summation; TS, Conditioned Pain Modulation; CPM), assess different aspects of central pain processing [13,19]. Central aspects of pain have been associated with negative affect (anxiety, depression), catastrophizing, neuropathic-like pain, fatigue, sleep disturbance, pain distribution and cognitive impact in people with musculoskeletal pain [20–24]. Questionnaire items addressing these 8 characteristics can measure a latent Central Aspects of Pain factor (CAPf), which is associated with QST evidence of pain sensitivity [20,25]. Pain distribution, self-reported on a body manikin, may itself identify people with central aspects of pain [26–28]. Central aspects of pain may increase pain severity and impact, and is associated with alterations in brain connectivity which might underlie problems with affect [17,20,23], cognition [20] and fatigue [20,24], potentially further compromising self-management [11,12,14,29–31].

We hypothesised that central aspects of pain may be a barrier to self-management. In this study, we investigated whether central aspects of pain are associated with or predict self-management in people with CLBP participating in cognitive-behavioural-based, group intervention programs that aimed to improve self-management.

2. Methods

Study methods and results are reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement for observational studies [32].

2.1. Participants and study design

Participant characteristics, recruitment, ethical approval, and associations between pain and sensitisation outcomes in this study have been previously described [25]. In this observational prospective cohort study, community-dwelling individuals with CLBP were enrolled on day 1 (baseline) of their participation in a hospital-based outpatient or community-based group intervention program, which aimed to facilitate self-management and self-care (SM/SC). Participants received a battery of QST and completed a questionnaire booklet which included self-reported tools about SM/SC, negative affect, pain severity and comorbidities at baseline (before or on the first day of their intervention) and approximately 3 months after baseline.

2.2. Therapeutic context

A therapeutic context targeting self-management was selected in order to be able to seek associations with changing trends in self-management. All participants had enrolled in one of two distinct CBT-based group intervention programmes. Both programs were delivered in an interactive, face:face, seminar format. One was delivered by a physiotherapist (PT) alone, with a maximum duration of 6-weeks. The other was delivered by a multidisciplinary team (MDT) of physiotherapists, clinical psychologists, occupational therapists and nurses, with a maximum duration of 10-weeks. Both programs entailed a combination of neuroscience education, psychological support, relaxation techniques, pacing, exercise, pharmacological advice and goal-setting. Program allocation was by a clinical team independent of this study, in liaison with the patient. Patients reporting long-standing CLBP (>1 year), elevated levels of average daily pain (numerical rating scales [NRS] ≥ 5), and emotional distress with increased maladaptive beliefs were eligible for the MDT group intervention program, whereas everyone else was eligible for the PT group intervention program. Additional details of the therapeutic context and involved intervention have been given elsewhere [25].

2.3. Inclusion/exclusion criteria

All program participants during the study period were eligible for inclusion in the study. Individuals were eligible for program participation if they were adults (>18 y), had the ability to give informed consent, were diagnosed with CLBP and reported the lumbar region as the index site of pain, were enlisted for participation in a pain management program and were able to speak and understand English. Exclusion criteria were pregnancy; inability to give informed consent or understand key aspects of the study due to cognitive impairment; or history of additional co-morbidities such as cancer, diabetic neuropathies, fractures, or other conditions causing greater disability than their back pain.

2.4. Sample size

Sample size calculations adhered to guidelines designed specifically for prediction studies using multiple linear regression approaches [33] and were based on the estimated squared multiple correlation-coefficient (R^2). Past CLBP-related literature indicates that combinations of similar biopsychosocial variables explain 38% to 49% of the variance of SM/SC outcomes [34]. It was estimated that at least 40% ($R^2 = 0.40$) of the variation of SM/SC outcomes in the study would be explained by a combination of independent variables such as, baseline QST, age, sex, pain, depression, catastrophizing and fatigue. Based on these estimates (40%) and the number of independent variables aimed to be included in the model (5 to 7), a sample size of 90 to 120 participants was considered sufficient [33].

2.5. Assessment of self-management and self-care

The Health Education Impact Questionnaire (HEIQ) [35] is a compilation of 8 self-reported scales (4-point scales ranging from 1-strongly disagree to 4-strongly agree) designed to measure self-management in 8 discrete domains; health-directed behaviour (HEIQ-HDB – willingness of individuals to apply changes to behaviour or diet), positive engagement in life (HEIQ-PEL – capacity of individuals to be active and engage in life-fulfilling activities), self-monitoring and insight (HEIQ-SMI – ability to take appropriate actions to monitor the condition physically or emotionally), constructive attitudes and approaches (HEIQ-CAA – ability of individuals to minimise the effects of their condition without allowing it to control their life), skill and technique acquisition (HEIQ-STA – ability of individuals to apply knowledge-based skills and techniques), social integration and support (HEIQ-SIS – ability for social engagement and interaction and level of confidence for seeking support from individuals or organisations), health services navigation (HEIQ-HSN – confidence of people to communicate or share information with their health care providers) and emotional distress (HEIQ-ED – negative attitudes individuals can have towards their condition or their life, characterised by distress, frustration, anger, anxiety, and depression). The HEIQ is reliable (test-retest ICC = 0.80–0.94) [36] and valid (discriminant validity: Cronbach's $\alpha \geq 0.80$, concurrent validity: Cronbach's $\alpha = 0.88$, internal consistency: Cronbach's $\alpha \geq 0.70$) [37,38], with psychometric properties that spread across the physical, psychological and social constructs that define self-management [39]. Higher scores indicate better domain performance except HEIQ-ED where higher scores indicate higher levels of emotional distress.

The Pain Self-Efficacy Questionnaire (PSEQ) [40] is a collection of 10 separate 6-point scales (0-not at all confident to 6-completely confi-

dent – min. 0, max. 60) that has been developed for people suffering from chronic pain. It requires respondents to consider their pain when rating their self-efficacy beliefs on different aspects of daily life. PSEQ is reliable (ICC = 0.83) [41] and valid (internal consistency: Cronbach's $\alpha = 0.93$, construct validity: Cronbach's $\alpha \geq 0.80$) [42,43], and can be also used as a proxy measure of self-care [44]. Higher scores indicate higher levels of self-efficacy.

Optimal healthcare utilisation is considered an indicator of good self-care [45]. The Healthcare Utilisation Questionnaire (HCUQ) [46], developed for arthritis from the Client Service Receipt Inventory (CSRI) [47], was used as a self-report measure of number of condition-specific healthcare visits, consultations and hospitalisations as well as medication use within the previous 3 months. The CSRI has shown good concurrent validity ($\rho_c = 0.63$) with health care utilisation evaluated from GP records [48], and validity across conditions and cultures [49]. Participant unit responses regarding their CLBP-related access to health care contributed to a total score (min. 0, no max.), with higher scores indicating higher levels of health care utilisation.

2.6. Assessment of central aspects of pain

2.6.1. Quantitative sensory testing

Quantitative Sensory Testing comprised both "static" (Pressure Pain detection Threshold; PPT) and "dynamic" (Temporal Summation; TS, Conditioned Pain Modulation; CPM) modalities [13,50,51]. The brachioradialis muscle, approximately 5 cm distal to the lateral epicondyle [51], was chosen for all modalities as a site distant from the primary area of pain in individuals with CLBP. All QST was undertaken by a single observer (VG) and participants were requested to have their eyes closed. Participants were excluded from QST assessment if they reported, or, on clinical examination, displayed pain originating from neck, shoulder, elbow or forearm. Low PPT, larger positive values of TS, and lower positive or more negative CPM values (less efficient CPM) indicated higher sensitivity [52]. Additional details of the QST protocol (paradigm and reliability) have been given elsewhere [25] but modality details are also given in Supplementary Methods.

2.6.2. Pain distribution

Pain distribution was self-reported using a body manikin [20] coded in 24-sites (Supplementary Figure 1) [28] and classified according to Widespread Pain Index (WPI) criteria [26].

2.6.3. Central Aspects of Pain factor (CAPf)

A single Central Aspects of Pain factor (CAPf) was used as an indicator of "central pain mechanisms". Additional details of the factor's development have been given elsewhere where it was described as `Central Mechanisms Trait factor' [25]. It is uncertain whether a self-report questionnaire can measure 'mechanisms', and unknown whether this factor is a stable trait, or a changing state. This factor is therefore here referred to as CAPf to reduce possible misinterpretation. Briefly, CAPf was derived from 8 items measuring anxiety, catastrophizing, cognitive impairment, depression, fatigue, neuropathic-like pain, pain distribution and sleep by confirmatory factor analysis. Items were selected from questionnaires addressing clinical characteristics previously associated with centrally facilitated pain sensitivity [25]. All 8 items loaded significantly on a single factor, here labelled CAPf, which demonstrated a significant association with PPT evidence of central sensitisation [25]. Factor loadings and model fit were previously described [25].

2.7. Clinical and demographic characteristics

Age, sex, pain severity, depression, catastrophizing and fatigue, have been previously found to predict SM/SC [29,53,54], and so were a priori selected for inclusion in multivariable models. Pain Severity was measured using a 0 to 10 numerical rating scale (NRS) with the lead question; 'on average, how would you rate your pain over the last week', and anchors at 0 (no pain) and 10 (worst pain imaginable) [55]. Depression was assessed with the Hospital Anxiety and Depression Scale (HADS) – Depression subscale (possible range; 0 to 21 – higher scores indicate greater depressive symptoms) [56]. Catastrophization was assessed with the Pain Catastrophization Scale (PCS) (possible range; 0 to 52 – higher scores indicate higher levels of catastrophizing) [57], and fatigue with the Fatigue Severity Scale (FSS) (possible range; 7 to 63 – higher scores indicate higher levels of fatigue) [58]. Additional details about the measurement of clinical characteristics have been given elsewhere [25].

2.8. Analysis

Data are presented as means ± standard deviation of the mean (SDM) or median with their interquartile range (IQR). The Effect Size was calculated as the difference between baseline and follow-up measurements divided by baseline standard deviation [59]. Unadjusted associations between central aspects of pain and SM/SC outcomes are presented as Pearson's product-moment correlations or Spearman's rank-order correlations (Pearson's r or Spearman's ρ). Associations were considered little or zero, fair, moderate to good and good to excellent when r values were between 0.00 to 0.25, 0.25 to 0.50, 0.50 to 0.75 and > 0.75 respectively [60].

In regression modelling, dependent variables comprised baseline or 3-months follow-up self-management and self-care (SM/SC) data (the 8 HEIQ domains, PSEQ, HCUQ), and the independent variables comprised central aspects of pain (QST modalities, pain distribution, and the CAPf), as well as demographic variables (age, sex) and clinical measures (pain NRS, HADS-Depression, PCS, FSS). Separate models were explored for each central aspect of pain and SM/SC construct, each adjusted for age, sex, pain NRS, HADS-Depression, PCS and FSS. Because items of depression, catastrophizing and fatigue are characteristics which contribute to CAPf [25], each model for CAPf was adjusted only for pain, age, and sex. The corresponding baseline SM/SC score was included as an additional independent variable when examining the separate SM/SC constructs at follow up, to explore possible barriers to improvement in SM/SC (follow-up SM/SC adjusted for baseline SM/SC indicates the magnitude of change in SM/SC). Goodness of model fit, and the explanatory power of regression models were evaluated using coefficient of determination (adjusted R^2). $100xR^2$ gives a percentage of the variance in the dependent variable explained by included independent variables [61]. Multicollinearity was evaluated using variance inflation factor (VIF), and variables removed if VIF > 5 [61,62]. Program type (PT or MDT) was included as an additional independent variable to examine whether associations between central sensitisation indices and SM/SC outcomes may be generalizable across program types.

All analyses used R Free Software (version 3.4.2) [63] and p-values of ≤ 0.05, after adjustments for multiple comparisons [64], were taken to indicate statistical significance. Significant correlations or associations are indicated by bold font in tables.

3. Results

3.1. Demographic and clinical characteristics

Participant recruitment and retention have been previously described [25]. Out of 177 eligible individuals with CLBP, 97 (71% females, mean age 56 ± 13 years) agreed to participate and contributed baseline data, whereas 80 declined (70% females, mean age 54 ± 14 years). No eligible participants were excluded because of upper limb or cervical pathology. Nine participants (9.3%) reported forearm pain on the manikin. Patients participated in a median of 9 (IQR: 8 to 10) of the 10 MDT sessions, or 5 (IQR: 4 to 5) of the 5 PT intervention sessions.

Table 1 gives baseline demographic and clinical characteristics, and Table 2 gives baseline and follow-up SM/SC outcomes. The 87 participants who provided follow up data displayed similar characteristics to the total study population (mean age 57 (± 13) years, BMI 29.4 (26.0 to 34.5) kg/m², 67% female). Overall, mean or median baseline scores indicated moderate performance in self-management and self-care across all HEIQ domains, PSEQ and HCUQ as well as moderate pain severity, depressive symptoms, anxiety and catastrophizing.

Overall, at 3-month follow-up, participants demonstrated small improvements in self-management across all HEIQ domains (median improvements 0.2 to 0.3, scale range 0.0 to 4.0). Effect size ranged from 0.1 to 0.4 across all SM/SC measures except health-directed and self-monitoring (0.5) and health care utilisation (0.9) (Table 2).

3.2. Cross-sectional associations between baseline central aspects of pain and self-management/self-care

We have previously reported that the different central aspects of pain are inter-correlated in the expected direction in this study population [25]. Greater TS was associated with lower PPT ($r = -0.40$, $p < 0.01$), higher CAPf ($r = -0.19$, $p = 0.03$), and lower CPM ($r = -0.22$, $p = 0.03$). Higher CAPf was associated with greater pain severity, measured using NRS ($r = 0.43$, $p < 0.001$). Women and younger participants at baseline displayed higher central aspects of pain and less effective SM/SC (Supplementary Table 1).

In bivariate (unadjusted) analyses, baseline **c**entral aspects of pain were correlated with baseline SM/SC measures (Table 3). Lower baseline CPM was correlated with lower Positive Engagement in Life ($r = 0.22$, $p = 0.03$), Constructive Attitudes and Approaches ($r = 0.25$, $p = 0.03$) and Health Services Navigation ($r = 0.24$, $p = 0.04$) at baseline. Higher CAPf at baseline was correlated with lower baseline Health-directed Behaviour ($r = -0.32$, $p < 0.01$), Constructive Attitudes and Approaches ($r = -0.46$, $p < 0.01$), Skill and Technique Acquisition ($r = -0.36$, $p < 0.01$), Social Integration and Support ($r = -0.27$, $p = 0.01$), Positive Engagement in Life ($r = -0.57$, <0.01) and Self-efficacy ($r = -0.72$, <0.01) as well as with higher baseline Emotional Distress ($r = 0.68$, <0.01). Bivariate correlations between the clinical variables used in multivariable regression models (pain, symptoms of depression, catastrophizing and fatigue) and baseline SM/SC measures are given in Supplementary Table 2.

Details of multivariable regression models showing associations between the different central aspects of pain and SM/SC measures at baseline are provided in Supplementary Table 3. Each model was adjusted for baseline age, sex, and pain, and QST and WPI models were further adjusted for depression, catastrophizing and fatigue scores. Higher baseline TS was associated with lower baseline Self-monitoring and Insight. Lower baseline CPM was associated with lower Positive Engagement in Life, Constructive Attitudes and Approaches and Health Ser-

Table 1
Participant demographics and clinical characteristics at baseline.

Characteristic (Possible range)	**Baseline**
Number of participants	97
Physiotherapy-led Program	42
Multidisciplinary-led Program	55
Age (years)	56 (± 13)
Physiotherapy-led Program	57 (± 13)
Multidisciplinary-led Program	55 (± 14)
BMI (kg/m²)	29.4 (25.7 to 34.6)
Female	63 (71%)
Physiotherapy-led Program	22 (52%)
Multidisciplinary-led Program	41 (75%)
Setting	
Hospital	92 (95%)
Community	5 (5%)
Self-reported Clinical Characteristics	
Pain Numerical Rating Scale (0-10)	6 (5 to 7)
Hospital Depression Scale (0-21)	9 (5 to 12)
Pain Catastrophizing Scale (0-52)	22 (11 to 31)
Fatigue Severity Scale (7-63)	42 (29 to 52)
Quantitative Sensory Testing	
Pain Pressure detection Threshold (kPa)	205.8 (148.2 to 297.6)
Temporal Summation (0-10)	1.0 (0.4 to 2.8)
Conditioned Pain Modulation (kPa)	59.1 (5.6 to 99.3)
Widespread Pain Index (present)†	35 (36%)
Central Aspects of Pain factor (−1.2 to 1.4)	0.05 (−0.45 to 0.43)

BMI: Body Mass Index, IQ: Interquartile, kPa: Kilopascals, MCID: Minimum Clinically Important Difference, QST: Quantitative Sensory Testing, SD: Standard Deviation

† Reflects the number and percentage of participants satisfying the criteria to be classified as demonstrating widespread pain.

¥ Reflects the number and percentage of participants used each type pf medication. One participant could use more than one type of medication.

Data are presented as mean (± Standard Deviation), median (Interquartile range) or n (%)

Table 2
Participant measures of self-management/self-care at baseline and 3 months follow-up.

Characteristic (possible range)	**Baseline** (n = 97)	3 Months (n = 87)	**Change**	Change Significance WSRT (p)	Effect Size†
Health Education Impact Questionnaire Domains					
Health Directed Behaviour (1-4)	2.5 (2.3 to 3.0)	3.0 (2.8 to 3.5)	+ 0.3 (0.0 to 0.8)	**672 (<0.01)**	0.5
Positive Engagement in Life (1-4)	2.6 (2.2 to 3.0)	3.0 (2.6 to 3.2)	+ 0.2 (0.0 to 0.6)	**432 (<0.01)**	0.3
Self-monitoring & Insight (1-4)	3.0 (2.8 to 3.2)	3.0 (3.0 to 3.3)	+ 0.2 (0.0 to 0.3)	**620 (<0.01)**	0.5
Constructive Attitudes & Approaches (1-4)	2.8 (2.2 to 3.0)	3.0 (2.6 to 3.4)	+ 0.0 (0.0 to 0.4)	**535 (<0.01)**	0.1
Skill & Technique Acquisition (1-4)	2.8 (2.5 to 3.0)	3.0 (2.8 to 3.0)	+ 0.2 (0.0 to 0.5)	**639 (<0.01)**	0.4
Social Integration and Support (1-4)	2.8 (2.4 to 3.0)	3.0 (2.6 to 3.0)	+ 0.0 (−0.2 to 0.4)	**779 (0.04)**	0.1
Health Services Navigation (1-4)	3.0 (2.6 to 3.2)	3.0 (2.8 to 3.4)	+ 0.2 (−0.1 to 0.4)	**666 (0.01)**	0.3
Emotional Distress (1-4)‡	2.8 (2.3 to 3.2)	2.5 (2.0 to 3.0)	-0.2 (−0.7 to 0.0)	**2173 (<0.01)**	0.3
Self-Care					
Pain Self-Efficacy Questionnaire (0-60)	27 (20 to 41)	35 (28 to 47)	+ 5 (−2 to 11)	**791 (<0.01)**	0.4
Health Care Utilisation Questionnaire (Units)	4 (2 to 6)	9 (6 to 12)¥	+ 4 (2 to 8)	**454 (<0.01)**	0.9

IQ: Interquartile, MCID: Minimum Clinically Important Difference, WSRT: Wilcoxon Signed Rank Test (Paired)

Data are presented as median (IQ Range)

† Effect size calculated as difference between baseline and follow-up divided by the SD at baseline.

‡ The Emotional Distress scale is reversed (min: 1 = Low levels of emotional distress, max: 4 = High levels of emotional distress), with a median decrease indicating improved performance

¥ The number of program visits is included in calculations of health care utilisation

Values in **bold** indicate statistical ($p < 0.05$) significance. Changes > MCID may indicate clinical significance

Table 3
Correlation matrix between each central aspect of pain at baseline and each measure of self-management/self-care at baseline and 3-months follow-up.

SM/SC Outcomes at baseline and follow-up		Baseline indices of centrally facilitated pain sensitivity									
		PPT		**TS**		**CPM**		**WPI**		**CAPf**	
		Cor	**p-value**	**Cor**	**p-value**	**Cor**	**p-value**	**Cor**	**p-value**	**Cor**	**p-value**
Baseline	**HEIQ-HDB**	0.06	0.61	-0.01	0.93	0.07	0.52	-0.01	0.92	**-0.32**	**< 0.01**
	HEIQ-PEL	0.07	0.61	-0.15	0.17	**0.22**	**0.03**	-0.08	0.56	**-0.57**	**< 0.01**
	HEIQ-SMI	0.09	0.40	**-0.19**	**0.01**	0.19	0.48	0.13	0.30	-0.06	0.59
	HEIQ-CAA	0.04	0.72	-0.14	0.21	**0.25**	**0.03**	-0.11	0.40	**-0.46**	**< 0.01**
	HEIQ-STA	-0.04	0.73	-0.03	0.84	0.04	0.86	0.01	0.99	**-0.36**	**< 0.01**
	HEIQ-SIS	0.06	0.61	0.01	0.93	0.06	0.59	-0.07	0.60	**-0.27**	**0.01**
	HEIQ-HSN	-0.01	0.95	0.11	0.41	**0.24**	**0.04**	-0.19	0.12	-0.15	0.15
	HEIQ-ED	-0.09	0.48	-0.07	0.52	-0.14	0.25	0.18	0.14	**0.68**	**< 0.01**
	PSEQ	0.12	0.29	-0.07	0.54	0.15	0.23	-0.13	0.31	**-0.72**	**< 0.01**
	HCUQ	-0.03	0.77	-0.08	0.51	0.19	0.09	0.01	0.99	0.11	0.29
Follow-up	**HEIQ-HDB**	0.12	0.27	0.09	0.46	0.21	0.07	-0.16	0.16	**-0.25**	**0.03**
	HEIQ-PEL	**0.23**	**0.03**	-0.02	0.87	**0.31**	**0.01**	**-0.22**	**0.05**	**-0.54**	**< 0.01**
	HEIQ-SMI	0.19	0.08	-0.05	0.70	0.09	0.45	0.16	0.16	0.02	0.82
	HEIQ-CAA	0.11	0.29	-0.11	0.37	0.13	0.28	-0.10	0.38	**-0.51**	**< 0.01**
	HEIQ-STA	0.12	0.25	0.02	0.87	0.17	0.14	0.09	0.44	-0.05	0.67
	HEIQ-SIS	**0.28**	**< 0.01**	-0.07	0.60	0.11	0.34	-0.05	0.65	**-0.37**	**< 0.01**
	HEIQ-HSN	0.09	0.39	0.02	0.87	0.15	0.20	-0.10	0.38	-0.21	0.06
	HEIQ-ED	**-0.21**	**0.05**	0.21	0.07	**-0.29**	**0.01**	0.17	0.16	**0.54**	**< 0.01**
	PSEQ	0.18	0.09	0.05	0.70	0.12	0.29	-0.01	0.94	**-0.56**	**< 0.01**
	HCUQ	-0.13	0.24	-0.10	0.44	0.04	0.73	0.17	0.14	**0.46**	**< 0.01**

CAPf: Central Aspects of Pain factor, Cor: Pearson or Spearman Correlation, CPM: Conditioned Pain Modulation, HCUQ: Health Care Utilisation Questionnaire, HEIQ: Health Education Impact Questionnaire, HEIQ-CAA: Constructive Attitudes & Approaches, HEIQ-ED: Emotional Distress, HEIQ-HDB: Health Directed Behaviour, HEIQ-HSN: Health Services Navigation, HEIQ-PEL: Positive & Active Engagement in Life, HEIQ-SIS: Social Integration and Support, HEIQ-SMI: Self-monitoring & Insight, HEIQ-STA: Skill & Technique Acquisition, PPT: Pain Pressure Detection Threshold, PSEQ: Pain Self-efficacy Questionnaire, TS: Temporal Summation, WPI: Widespread Pain Index
Values calculated from n = 97 baseline participants and paired follow up data from n = 87 participants.
All p-values have been corrected for multiple comparisons (Benjamini-Hochberg).
Values in **bold** indicate statistical significance ($p < 0.05$)

vices Navigation at baseline. Baseline WPI was not significantly associated with any baseline SM/SC outcome. Higher baseline CAPf was associated with lower baseline Health-directed Behaviour, Positive Engagement in Life, Skill and Technique Acquisition, Social Integration and Support, Constructive Attitudes and Approaches as well as with higher baseline Emotional Distress and lower baseline Self-efficacy.

3.3. Longitudinal associations of baseline central aspects of pain with self-management/self-care

Bivariate analyses showed that baseline central aspects of pain were correlated with SM/SC measures at 3-months follow-up (Table 3). Lower baseline PPT was correlated with lower follow-up Positive Engagement in Life ($r = 0.23$, $p = 0.03$), Social Integration and Support ($r = 0.28$, $p < 0.01$) and higher Emotional Distress ($r = -0.21$, $p = 0.05$). Lower baseline CPM was correlated with lower follow-up Positive Engagement in Life ($r = 0.31$, $p = 0.01$) and higher follow-up Emotional Distress ($r = -0.29$, $p = 0.01$). Baseline WPI was correlated with lower follow-up Positive Engagement in Life ($r = -0.22$, $p = 0.05$). Higher baseline CAPf was also correlated with lower follow-up Health-directed Behaviour ($r = -0.25$, $p < 0.03$), Positive Engagement in Life ($r = -0.54$, <0.01), Constructive Attitudes and Approaches ($r = -0.51$, $p < 0.01$), Social Integration and Support ($r = -0.37$, $p < 0.01$), higher Emotional Distress ($r = 0.54$, <0.01) as well as with lower Self-efficacy ($r = -0.56$, <0.01) and higher Health Care Utilisation ($r = 0.46$, $p < 0.01$). Bivariate correlations between the clinical variables used in multivariable regression models (pain, symptoms of depression, catastrophizing and fatigue) and follow-up SM/SC measures are given in Supplementary Table 2. All baseline SM/SC measures were significantly correlated with their follow-up counterparts ($r = 0.34$ to 0.72, $p < 0.01$) apart from HCUQ ($r = 0.16$, $p = 0.27$).

Details of multivariable regression models showing longitudinal associations between the different baseline central aspects of pain and follow-up SM/SC outcomes are provided in Table 4. All longitudinal models were adjusted for the same baseline factors as in cross-sectional analyses, as well as for the baseline score of the SM/SC outcome that the model explored. Lower baseline PPT was associated with lower follow-up Social Integration and Support, higher baseline TS was associated with higher follow-up Emotional Distress. Baseline WPI was not significantly associated with any follow-up SM/SC outcomes. Higher baseline CAPf associated with lower Positive Engagement in Life and Constructive Attitudes and Approaches, higher Emotional Distress and higher Health Care Utilisation at follow-up.

Baseline symptoms of depression demonstrated significant associations with baseline as well as follow-up SM/SC outcomes across most models regardless of which index of centrally facilitated pain sensitivity was included as an independent variable (Table 4, Supplementary Table 3). Inclusion of program type (PT or MDT) as a variable did not affect the significant associations between central aspects of pain and SM/SC outcomes (Supplementary Table 4). No significant multicollinearity was detected between any combination of independent variables in cross-sectional as well as in longitudinal analyses (VIF = 1.19 to 2.50). Residuals were normally distributed in all examined models (Shapiro-Wilk $p > 0.05$).

4. Discussion and conclusion

4.1. Discussion

This study showed that several baseline central aspects of pain were associated with measures of self-management both at baseline and at 3-months after participation in CBT-based PT or MDT programmes for people with CLBP. Concordant associations were observed using mea-

Table 4
Multivariable models exploring the relationship between baseline measurements of central aspects of pain and each measure of self-management/self-care at 3-months follow-up adjusted for the baseline score of each dependent self-management/self-care measure.

Multivariate Models		Dependent Variables									
		HEIQ-HDB	**HEIQ-PEL**	**HEIQ-SMI**	**HEIQ-CAA**	**HEIQ-STA**	**HEIQ-SIS**	**HEIQ-HSN**	**HEIQ-ED**	**PSEQ**	**HCUQ**
		(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(1-4)	(0-60)	(Units)
		β	β	β	β	β	β	β	β	β	β
Quantitative Sensory Testing	PPT†	0.08	0.11	0.10	0.06	0.11	**0.24***	0.11	-0.13	0.11	0.02
	Depression (0-21)	-0.004	-0.23	-0.07	-0.23	**-0.38***	-0.06	-0.02	**0.33****	-0.11	**0.41****
	Adjusted R^2	0.23	0.37	0.18	0.37	0.24	0.42	0.32	0.41	0.52	0.30
	TS†	0.15	0.06	0.03	-0.07	0.03	-0.05	0.12	**0.19***	0.04	-0.18
	Depression (0-21)	0.04	-0.20	-0.06	-0.27	**-0.37***	-0.06	0.02	**0.38****	-0.10	**0.36***
	Adjusted R^2	0.24	0.36	0.18	0.37	0.23	0.38	0.32	0.43	0.51	0.33
	CPM†	0.15	0.12	0.04	-0.002	0.11	0.003	0.04	-0.02	-0.01	0.11
	Depression (0-21)	0.01	-0.24	-0.06	-0.23	**-0.37***	-0.04	-0.02	**0.33***	-0.11	**0.42****
	Adjusted R^2	0.25	0.37	0.18	0.36	0.24	0.38	0.31	0.42	0.51	0.31
Widespread Pain	WPI†	-0.15	-0.08	0.07	0.02	0.12	0.09	0.04	-0.02	0.14	-0.07
	Depression (0-21)	0.02	-0.21	-0.08	-0.24	**-0.40***	-0.05	-0.02	**0.09***	-0.13	**0.41****
	Adjusted R^2	0.25	0.36	0.18	0.36	0.24	0.38	0.31	0.40	0.52	0.30
CAPf	CAPf†	-0.07	**-0.28***	-0.02	**-0.37****	**0.25***	-0.18	-0.08	0.18	-0.06	**0.35****
	Adjusted R^2	0.25	0.38	0.14	0.39	0.18	0.39	0.32	0.37	0.50	0.26

CAPf: Central Aspects of Pain factor, CPM: Conditioned Pain Modulation, HCUQ: Health Care Utilisation Questionnaire, HEIQ: Health Education Impact Questionnaire, HEIQ-CAA: Constructive Attitudes & Approaches, HEIQ-ED: Emotional Distress, HEIQ-HDB: Health Directed Behaviour, HEIQ-HSN: Health Services Navigation, HEIQ-PEL: Positive & Active Engagement in Life, HEIQ-SIS: Social Integration and Support, HEIQ-SMI: Self-monitoring & Insight, HEIQ-STA: Skill & Technique Acquisition, PPT: Pain Pressure Detection Threshold, PSEQ: Pain Self-efficacy Questionnaire, TS: Temporal Summation

β-values represent standardised (β) regression coefficients for each listed baseline variable within multivariable regression models created to express the association between each index of centrally facilitated pain at baseline and each SM/SC outcome at 3-months follow-up for. Each model between PPT, TS, CPM and WPI and SM/SC constructs was adjusted for the same baseline variables (baseline score of each SM/SC outcome, age, sex, pain, depression, catastrophization and fatigue). Each model between CAPf and SM/SC constructs was adjusted for age, sex, pain. Multicollinearity testing yielded VIF values ranging from 1.2 to 2.5 for all independent variables indicating not significant multicollinearity between them. Values calculated from paired baseline and follow up data from n = 87 participants. All p-values have been corrected for multiple comparisons (Benjamini-Hochberg).

† Primary predictor. Values in **bold** indicate statistical significance. * ≤0.05, * * < 0.01, * ** <0.001.

sures that address different central aspects of pain and SM/SC and remained significant after adjustment for possible confounding factors.

SM/SC and central aspects of pain are both complex constructs, the multiple components of which can be measured by discrete questionnaires or tools [39,65]. We show that central aspects of pain are associated with several SM/SC domains both in cross-sectional and longitudinal analyses, within a therapeutic context which aimed (with some success) to improve self-management. Associations between the discrete central aspects of pain were often weak [25], and different central aspects of pain often associated with different aspects of SM/SC. This is consistent with central aspects of pain being a complex and heterogeneous phenomenon, and suggests that multiple central pain mechanisms might link central aspects of pain with SM/SC.

We found that central aspects of pain could predict some aspects of longer-term self-management. Baseline central aspects of pain were prospectively associated with low scores in Positive Engagement in Life, Social Integration and Support and Emotional Distress at 3-months both in bivariate correlation and in multivariable regression analyses. Higher Central Aspects of Pain factor was also associated with lower scores in Positive Engagement in Life, Constructive Attitudes and Approaches, Emotional Distress and Self-efficacy in bivariate models. Furthermore, associations of baseline central aspects of pain with follow up SM/SC remained significant after adjustment for baseline SM/SC scores, implicating central aspects of pain as potential barriers to improvements in SM/SC during CBT-based group interventions.

PPT was associated with Social Integration and Support both in bivariate and multivariable models, indicating that central aspects of pain might be barriers to social integration, as well as reducing confidence to seek support from other individuals or organisations. Individuals with increased pain sensitivity have demonstrated altered function of the anterior cingulate cortex, an area essential for affective-emotional aspects of pain, including empathy and social exclusion [66]. Central aspects of pain might therefore be implicated in generalised feelings of isolation and social exclusion or ill-conceived beliefs about lack of understanding by peers, family members or health care providers, influencing subsequently concomitant behaviours. TS was prospectively associated with emotional distress in people with musculoskeletal pain [67,68], and can predict prolonged emotional distress [17]. Pain shares similar cerebral processes with distress associated with depressive disorders, and it might be these shared brain mechanisms which are revealed by dynamic QST modalities such as TS [13].

Characteristics which are associated with the Central Aspects of Pain factor, as well as indicating central aspects of pain, might also each influence SM/SC outcomes through other mechanisms. For example, chronic pain may be associated with cognitive impairment, and neural brain systems involved in cognition are closely linked with pain processing [69,70]. A persistent nociceptive input may compete with other sensory inputs, compromising limited neurophysiological resources, causing neuroplastic changes (neural rewiring or reorganisation), and leading, ultimately, to cognitive impairment and accompanying behaviours [71,72]. Furthermore, depression was significantly associated with SM/SC in both cross-sectional and longitudinal analyses, even after adjustment for indices of centrally facilitated pain. This corroborates previous evidence that depression predicts worse SM/SC [29], as well as other outcomes, in people with low back pain [73–76].

Our study is subject to several limitations. Direct measurement of neuronal activity within the CNS is not possible within a clinical setting. We used several indices of central aspects of pain, some of them developed in populations experiencing conditions other than CLBP. Although central aspects of pain seem to be involved in the ability of individuals to self-manage, it remains possible that each association may be explained by other mechanisms. For example, cognitive factors, such as how people interpret painful stimuli might influence psychophysical experiences and QST responses [77], and might concurrently affect self-management. SM/SC is a diverse concept with no specific measurement tool for populations with CLBP. The self-management tools used in this

study, although reliable and valid across different chronic pathologies, might omit constructs more specific to the self-management of CLBP. The small loss to follow up (10.3%) was a strength of the current study, but, even so, study power for complex regression modelling was limited by the number of individuals with follow-up data (n = 87). Our analyses should be viewed as exploratory, requiring confirmation in a larger independent sample. Unmeasured variables such as work, marital and family status, job satisfaction, education levels and income may contribute to SM/SC outcomes [34,78], and, although these are not expected to be associated with central aspects of pain, inclusion in our models might have altered our findings. We found no evidence for significant effects attributable to whichever of the 2 program types were used, although 'channelling' bias between the two intervention pathways might have influenced our results.

4.2. Conclusion

Central aspects of pain, investigated early in rehabilitation pathways, can predict SM/SC outcomes. Central aspects of pain could be incorporated into future clinical prediction tools for self-management. We provide evidence that central aspects of pain influence longitudinal changes in self-management, suggesting that appropriate early targeting of central aspects of pain might improve SM/SC outcomes. Future research might confirm and extend our findings to other and larger chronic pain populations, and across different therapeutic contexts.

4.3. Practice implications

Central aspects of pain might impact an individual's ability to self-manage their condition. Other treatment modalities such as medicines [79] or supervised physiotherapy [80] and psychological therapies [81] might also be helpful in managing central aspects of pain, and, as a result, improve also self-management.

CRediT authorship contribution statement

Georgopoulos Vasileios: Writing – original draft, Project administration, Formal analysis, Data curation, Conceptualization. **McWilliams Daniel F.:** Writing – review & editing, Validation, Formal analysis. **Walsh David A.:** Writing – review & editing, Supervision, Conceptualization. **Hendrick Paul:** Writing – review & editing, Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Prof David Walsh has received research grants from Pfizer Ltd., Eli Lilly, Orion Pharma, UCB Pharma and non-personal pecuniary consultancy fees from GlaxoSmithKline plc, AKL Research & Development Limited, Pfizer Ltd, Eli Lilly and Company, Galapagos, Contura International, and AbbVie Ltd. Dr Daniel McWilliams has received research grants from Pfizer Ltd. And Eli Lilly. Dr Paul Hendrick and Dr Vasileios Georgopoulos have no relevant interests to declare.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.pec.2023.108109.

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