Scandinavian Journal of Pain 16 (2017) 22–28

Contents lists available at ScienceDirect

Scandinavian Journal of Pain

journal homepage: www.ScandinavianJournalPain.com

Observational study

Pain provocation following sagittal plane repeated movements in people with chronic low back pain: Associations with pain sensitivity and psychological profiles

Martin Rabey*, Anne Smith, Darren Beales, Helen Slater, Peter O'Sullivan

School of Physiotherapy and Exercise Science, Curtin University, GPO Box U1987, Perth 6845, Australia

HIGHLIGHTS

- Provocative pain responses to repeated bending are heterogeneous in CLBP.
- Bidirectional pain increases were associated with greater pain sensitivity.
- No increase in pain was associated with low psychological questionnaire scores.

ARTICLE INFO

Article history:
Received 8 August 2016
Received in revised form 11 January 2017
Accepted 25 January 2017
Available online 28 February 2017

Keywords:
Chronic low back pain
Repeated movement
Pain sensitivity
Psychological
Heterogeneous

ABSTRACT

Background and aims: Provocative pain responses following standardised protocols of repeated sagittal plane spinal bending have not been reported in people with chronic low back pain (CLBP). Potential differing pain responses to movement likely reflect complex sensorimotor interactions influenced by physical, psychological and neurophysiological factors. To date, it is unknown whether provocative pain responses following repeated bending are associated with different pain sensitivity and psychological profiles. Therefore the first aim of this study was to determine whether data-driven subgroups with different, clinically-important pain responses following repeated movement exist in a large CLBP cohort, specifically using a standardised protocol of repeated sagittal plane spinal bending. The second aim was to determine if the resultant pain responses following repeated movement were associated with pain and disability, pain sensitivity and psychological factors.

Methods: Clinically-important ($\geq$2-points, 11-point numeric rating scale) changes in pain intensity following repeated forward/backward bending were examined. Participants with different provocative pain responses to forward and backward bending were profiled on age, sex, pain sensitivity, psychological variables, pain characteristics and disability.

Results: Three groups with differing provocative pain responses following repeated movements were derived: (i) no clinically-important increased pain in either direction ($n = 144$, 49.0%), (ii) increased pain with repeated bending in one direction only (unidirectional, $n = 112$, 38.1%), (iii) increased pain with repeated bending in both directions (bidirectional, $n = 38$, 12.9%). After adjusting for psychological profile, age and sex, for the group with bidirectional pain provocation responses following repeated spinal bending, higher pressure and thermal pain sensitivity were demonstrated, while for the group with no increase in pain, better cognitive and affective psychological questionnaire scores were evident. However, these associations between provocative pain responses following movement and pain sensitivity and psychological profiles were weak.

Conclusions: Provocative pain responses following repeated movements in people with CLBP appear heterogeneous, and are weakly associated with pain sensitivity and psychological profiles.

Implications: To date, suboptimal outcomes in studies examining exercise interventions targeting directional, movement-based subgroups in people with CLBP may reflect limited consideration of broader multidimensional clinical profiles associated with LBP.

* Corresponding author.
E-mail addresses: martinrabey@gmail.com (M. Rabey), Anne.Smith@exchange.curtin.edu.au (A. Smith), D.Beales@curtin.edu.au (D. Beales), H.Slater@curtin.edu.au (H. Slater), P.OSullivan@curtin.edu.au (P. O'Sullivan).

http://dx.doi.org/10.1016/j.sjpain.2017.01.009

This article describes heterogeneous provocative pain responses following repeated spinal bending, and their associated pain sensitivity and psychological profiles, in people with CLBP. These findings may help facilitate targeted management.

For people with no increase in pain, the lack of pain provocation following repeated spinal bending, in combination with a favourable psychological profile, suggests this subgroup may have fewer barriers to functional rehabilitation. In contrast, those with pain provoked by both forward and backward bending may require specific interventions targeting increased pain sensitivity and negative psychological cognitions and affect, as these may be may be important barriers to functional rehabilitation.

1. Introduction

Clinicians commonly evaluate pain responses to repeated movement in people with chronic low back pain (CLBP), particularly sagittal plane spinal bending [1]. It has been reported that for some individuals, pain is not influenced by repeated movement, for some there is a unidirectional (UD) response to either repeated forward or backward bending, and for others there is a bidirectional (BD) response to both repeated flexion and extension [2–5].

The classification of subgroups within the population of people with CLBP is a research priority, which may facilitate targeted management strategies and improved treatment outcomes [6,7]. CLBP classification systems may be described as: (1) based upon clinical opinion, (2) based on theoretical models derived from experimental observation, (3) purely data driven [8]. The majority of movement-based classification systems [1,9,10] can be considered to be in the first two of these categories. While heterogeneous pain responses to a standardised protocol of directional repeated movements have been demonstrated [2], subgrouping based upon such movements is based upon clinical assessment underpinned by a theoretical model [1] and therefore cannot be regarded as purely data driven [8]. To date, the majority of studies examining pain responses to repeated movements have also involved samples including, or exclusively made up of, people with acute LBP +/− leg pain [11–18].

Potential differing pain responses to movement, such as those described above, likely reflect complex sensorimotor interactions influenced by physical, psychological and neurophysiological factors as highlighted in recent literature [19,20]. Investigations in people with CLBP support this premise. For example, in people with CLBP demonstrating pain provocation with repeated lifting, pain intensity has been positively associated with kinesiophobia, catastrophizing and depression [21]. People with CLBP reporting "disproportionate" pain responses to spinal movement, demonstrated greater pressure and cold pain sensitivity and higher levels of psychological distress than people with CLBP and "proportionate" pain responses [22]. Another study examining repeated lifting in people with CLBP demonstrated increasing pain intensity and pressure pain sensitivity over 25 repetitions [23].

Previously we have utilised data-driven methods to derive subgroups based upon pain sensitivity [24] and psychological factors [25] in the same CLBP cohort. Data-driven subgrouping involves statistical (broadly defined as the systematic organisation of numerical data) subgroup derivation, and does not rely upon clinical opinion or underlying theoretical models, but allows data collected from people with CLBP "speak for itself" [8].

Therefore the first aim of this study was to determine whether data-driven subgroups with different, clinically-important pain responses following repeated movement exist in a large CLBP cohort, specifically using a standardised protocol of repeated sagittal plane spinal bending. The second aim was to determine if the resultant pain responses following repeated movement were associated with pain and disability, pain sensitivity and psychological factors. To date these concepts have not been specifically investigated in the literature. This knowledge would provide increased insight to factors underlying pain responses to repeated movement in CLBP, which may enhance more specific targeted management.

2. Materials and methods

This research was approved by the Human Research Ethics Committees of Curtin University, Royal Perth Hospital, and Sir Charles Gairdner Hospital, Western Australia. All participants gave written, informed consent.

This cross-sectional study involved people with CLBP ($n = 294$, 57.1% female; median age 50 years), recruited via multimedia advertisements circulated throughout metropolitan and regional Western Australia (77.6%), and from private metropolitan physiotherapy clinics (20.1%), public metropolitan hospitals (1.4%); and private metropolitan pain management and general practice clinics (1.0%), between November 2012 and January 2014.

Participants contacted one researcher (MR) and were sent an inclusion/exclusion criteria questionnaire. Ambiguous responses were clarified by telephone.

Inclusion criteria were: aged 18–70 years; LBP > 3-months duration; ≥2-points on a numeric rating scale (NRS) (0–10) for pain intensity (past week); ≥5-points on the Roland Morris Disability Questionnaire (RMDQ) [26]; at least 60% LBP on the question [27]: "Which situation describes your pain over the past 4 weeks the best? 100% of the pain in the low back; 80% of the pain in the low back and 20% in the leg(s); 60% of the pain in the low back and 40% in the leg(s)", etc.

Exclusion criteria were: previous extensive spinal surgery (>single-level fusion/discectomy), spinal surgery within the past six-months, serious spinal pathology (cancer, inflammatory arthropathy, etc.), diagnosed neurological disease, bilateral dorsal wrist/hand pain, pregnancy, inability to understand English.

A total of 586 potential participants contacted the research team, of whom 349 met the inclusion/exclusion criteria. Fifty-five of these potential participants declined completion of the baseline assessment, leaving a sample of 294 included participants.

3. Sagittal plane movement tasks

Participants performed two repeated bending tasks in the following order:

1. Twenty forward spinal bends to pick up a pencil from the floor, and place it back down.
2. Twenty backward spinal bends to view a marker on the ceiling behind them.

Repeated forward bending is a valid and reliable test of pain provocation for people with CLBP [28,29]. Repeated backward bending was included as a common component of the examination for CLBP, and to determine whether pain provocation is influenced in a directional manner [1,9,30].

Participants could refuse to undertake these movements, or to complete 20 repetitions, should they feel their pain became too great, or feared symptom exacerbation. The number of repetitions completed was recorded.

Participants received standardised instructions:

1. For forward bending, participants were asked to pick up a pencil on the floor in front of them (first forward bend), then place the pencil back on the floor (second forward bend). They repeated this until 20 bends were completed. Participants were told they could undertake this task however they wished, and at whatever speed they wished.
2. For backward bending, participants were instructed to sight a ceiling marker approximately 60 cm behind them however they wished, at whatever speed they wished, without turning around, then return to neutral before repeating the task up to 20 times.

Assessment of whether repeated movement influenced participant's perception of CLBP intensity, was undertaken by asking them to rate pain intensity on an NRS (0–10) before task commencement, then every five repetitions [21].

3.1. Profiling variables

Age and sex were collected for each participant.

Pain intensity (past week) was rated using the previously described, valid and reliable NRS [31].

Low back pain-related disability was measured using RMDQ [26], comprising 24 items, which the participant ticks to indicate items relevant to their presentation (maximum score 24 indicating high disability). Items examine effects of LBP on activities of daily living. It is valid and reliable [26,32,33].

Low back pain duration (months) was reported by each participant.

3.2. Pain sensitivity

For this cohort, pain sensitivity subgroups have been previously determined, using latent class analysis of quantitative sensory testing data [24]. Three subgroups were derived: cluster 1 (31.9%) was characterised by average to high temperature and pressure pain sensitivity, cluster 2 (52.0%) by average to high pressure pain sensitivity, and cluster 3 (16.0%) by low temperature and pressure pain sensitivity. Cluster membership was considered as a profiling variable.

3.3. Psychological profiles

For this cohort, subgroups with differing psychological profiles have been previously determined, using latent class analysis of a broad range of psychological data [25]. Three subgroups were derived: cluster 1 (23.5%) was characterised by low cognitive and affective questionnaire scores, with the exception of fear-avoidance beliefs, cluster 2 (58.8%) was characterised by relatively elevated thought suppression, catastrophizing and fear-avoidance beliefs, but low depression, anxiety and stress, and higher pain self-efficacy. Cluster 3 (17.7%) had the highest scores across cognitive and affective questionnaires, indicating greatest psychological distress. Cluster membership was considered as a profiling variable.

The sample size in this study, of approximately 300 participants, has been suggested to be adequate for studies involving latent class analysis [34], which was used to derive the pain sensitivity and psychological subgroups.

3.4. Statistical analysis

Missing data is detailed in Table 1. For questionnaires, data management was undertaken as in original manuscripts where described. Otherwise, the mean of other items was imputed in the case of one missing item, and the score considered missing in the case of two or more missing items.

Examination of pain responses following sagittal plane spinal bending was undertaken as follows: a score for change in pain intensity was determined by subtracting the participant's score on the NRS after the last set of repetitions completed (maximum 20) from the baseline score [35]. Pain was deemed to have changed only if it changed by the MCID of ≥two-points [36]. For each individual, it was determined whether their pain intensity had changed by ≥two-points following repeated bending in neither direction (No increase in pain (NIP)), in only one direction (unidirectional (UD)) or in both directions (bidirectional (BD)). Preliminary analysis revealed ameliorative responses were relatively uncommon. Therefore participants experiencing decreases in pain with either forward or backward bending were considered to have no increase in pain in that direction for classification purposes. Subgrouping was subsequently based solely on pain provocation responses.

Unadjusted differences in profiling variables between groups with differing provocative pain responses following sagittal plane spinal bending were examined using analysis of variance for normally distributed variables, Kruskal–Wallis one-way analysis of variance for variables with skewed data, and chi-squared analysis for categorical data.

Multinomial logistic regression was used to examine multivariable associations between provocative pain response group membership (modelled as a dependent variable) and pain sensitivity/psychological cluster membership (modelled as independent variables), adjusting for age and sex.

Statistical analysis was performed using Stata 13.1 (Statacorp, TX, USA).

4. Results

For forward bending, 284 (96.6%) participants completed 20 repetitions. Those not completing all repetitions were (n (%)): 0 repetitions completed: 2 (0.7); 5 repetitions completed: 2 (0.7); 10 repetitions completed: 4 (1.4); 15 repetitions completed: 2 (0.7). For backward bending 277 (94.2%) participants completed 20 repetitions. Those not completing all repetitions were (n (%)): 0 repetitions completed: 2 (0.7); 5 repetitions completed: 7 (2.4); 10 repetitions completed: 6 (2.0); 15 repetitions completed: 2 (0.7).

Two participants declined to undertake the forward or backward bending task for fear of symptom exacerbation. For these participants these movements were assumed to be provocative.

Membership of derived subgroups was as follows: NIP 49.0% (n = 144), UD 38.1% (n = 112), BD 12.9% (n = 38) (Fig. 1).

Regarding ameliorative responses, only nineteen participants (6.5%) displayed decreases in pain intensity with backward bending of ≥two-points; while thirteen participants (4.4%) displayed decreases in pain intensity of ≥two-points with forward bending. For the 31 participants in total reporting a decrease in pain during forward and/or backward bending, eight were classified as NIP and 23 as UD pain provocation pattern.

4.1. Profiling variables

BD provocative pain responses were associated with significantly higher pain intensity and lower pain duration (Table 1). NIP was significantly associated with lower disability levels. The univariable association between differing pain provocation responses

Table 1
Profiles associated with differing provocative pain responses to repeated sagittal spinal bending.

Variable	NIP (n = 144, 49.0%)	UD (n = 112, 38.1%)	BD (n = 38, 12.9%)	p-Value
Age, years, median (IQR) (min, max)	50[a] (40, 59) (21, 69)	52[a] (39, 62) (18–70)	42[b] (29, 57) (18, 70)	**0.042**[d]
Female, n(%)	72 (50.0)	71 (63.4)	25 (65.8)	0.051[f]
Pain intensity in the previous week (NRS), mean (SD) (min, max)	5.6[a] (2.0) (2, 9)	5.9[a] (1.8) (2, 10)	6.7[b] (1.6) (3, 10)	**0.002**[e]
Duration of CLBP, months, median (IQR) (min, max)	120[a] (42, 264) (3, 624)[g]	120[a] (48, 240) (3, 720)[h]	51[b] (24, 96) (7, 480)[g]	**0.001**[d]
RMDQ Score, median (IQR) (min, max)	8[a] (6, 11) (5, 20)	10[b] (7, 14) (5, 21)	9[b] (7, 13) (5, 24)	**0.002**[d]
Baseline pain intensity (NRS) before commencing spinal bending, median (IQR) (min, max)	2 (1, 3) (0, 7)	2 (0, 3) (0, 8)	2 (1, 3) (−1, 5)	0.76[d]
Pain sensitivity (n (%))				
1. Average to high temperature and pressure pain sensitivity	39 (27.1)	34 (30.4)	21 (55.3)[c]	**0.024**[f]
2. Average to high pressure pain sensitivity	80 (55.6)	60 (53.6)	13 (34.2)	
3. Low temperature and pressure pain sensitivity	25 (17.4)	18 (16.1)	4 (10.5)	
Psychological profile (n (%))				
1. Low cognitive and affective scores	47 (32.6)[c]	19 (17.0)	3 (7.9)	**0.002**[f]
2. Relatively high cognitive scores, lower affective scores	80 (55.6)	68 (60.7)	25 (65.8)	
3. High cognitive and affective scores	17 (11.8)	25 (22.3)	10 (26.3)	

Bold values are statistically significant.
[a,b] Superscripted letters define significantly different subgroups, i.e. results with different letters are significantly different.
[c] Supercript denotes cell with Pearson's chi-square > 4, indicating cells contributing to the overall statistically significant chi-square test.
[d] Kruskal–Wallis one-way analysis of variance.
[e] Analysis of variance.
[f] χ^2 analysis.
[g] Missing in one case.
[h] Missing in two cases.
NIP, no increase in pain; UD, unidirectional increase in pain; BD, bidirectional increase in pain; NRS, numeric rating scale; RMDQ, Roland Morris Disability questionnaire.

following repeated sagittal spinal bending and pain sensitivity subgroups was statistically significant (p = 0.014, Table 1), with higher than expected frequencies observed for those with BD and average to high temperature and pressure pain sensitivity. The univariable association between differing pain provocation responses following repeated sagittal spinal bending and psychological subgroups was statistically significant (p = 0.002, Table 1), with higher than expected frequencies observed for those with NIP and low cognitive and affect scores.

Table 2 presents the associations between differing pain provocation responses following repeated sagittal spinal bending and pain sensitivity subgroups, adjusted for psychological subgroup membership, and vice versa, estimated using a multinomial logistic regression model. This model was also adjusted for potential confounding by age and sex (Table 1). A fully saturated model estimating pain sensitivity*psychological subgroup interaction could not be estimated due to cells from this three-way association having very low frequency or no observations. The results from Table 2 show that average to high temperature and pressure pain sensitivity was significantly associated with BD pain provocation following repeated bending when referenced to either NIP or UD (p-value 0.012 and 0.026 respectively) after adjusting for psychological subgroup membership, age and sex. In addition, low cognitive and affective scores were significantly associated with NIP when referenced to either UD or BD pain provocation following repeated bending (p-value 0.003 and 0.019 respectively), after adjusting for pain sensitivity subgroup membership, age and sex. However, estimates of group contrasts had wide confidence intervals and associations although significant were not strong, with the pseudo R^2 of the overall model (0.071) only improving by 0.048 over a model with gender and age alone (0.023).

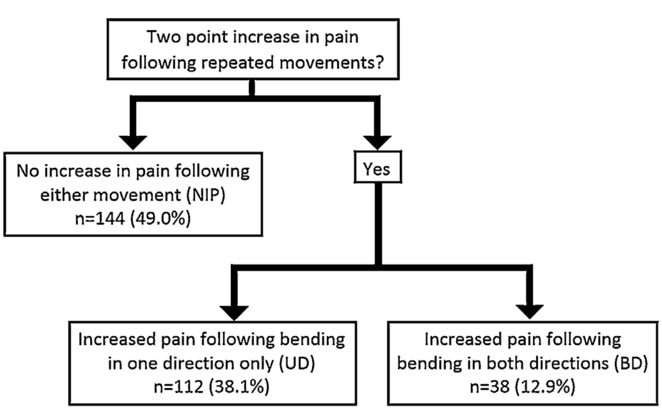

Fig. 1. Flow chart showing three groups of varying responses following repeated spinal bending (numbers and percentages of participants).

A sensitivity analysis was conducted to determine whether inclusion or exclusion of participants with ameliorative responses significantly altered the results of this study. This was not the case. For example, when participants with ameliorative pain responses were excluded from analysis the relative risk ratio (95% CIs) for pain sensitivity, UD vs. NIP, cluster 1 vs. 3 was 0.86 (0.37–2.03); while for age, BD vs. NIP it was 0.98 (0.95–1.00) (Table 2).

5. Discussion

5.1. Provocative pain responses following repeated spinal bending

This large CLBP study considered directional pain provocation responses following a standardised protocol of repeated sagittal plane bending utilising a data-driven approach The majority of previous reports of directional patterns of pain amelioration and provocation that included subjects with CLBP have been based more upon clinical examination and judgement rather than standardised testing [11,12,14,16,37,38], possibly introducing bias [8].

Pain intensity prior to movement was similar across subgroups, indicating this was unrelated to pain provocation responses following repeated movement. The proportion of participants (10.9%) demonstrating pain amelioration with repeated spinal bending, is less than reported in a recent systematic review of centralisation and directional preferences [39]. This may reflect differences in subjects' pain duration (acute/sub-acute LBP vs. CLBP) [39], the movement testing procedures utilised (only undertaken in standing in this study) [1], and/or use of a minimum two-point change in pain intensity for deriving subgroups in the current study.

The NIP subgroup has not been previously described. Previous studies have reported participants with a bidirectional

Table 2
Relative risk ratios (95% CIs) for multivariable association of pain sensitivity cluster and psychological cluster membership with movement subgroups adjusted for age and gender.

	UD vs. NIP	BD vs. NIP	BD vs. UD
Pain sensitivity	0.843[a]	0.012[a]	0.026[a]
1 vs. 3	0.93 (0.42–2.08)	2.32 (0.67–8.02)	2.49 (0.71–8.71)
2 vs. 3	0.82 (0.40–1.72)	0.67 (0.19–2.37)	0.82 (0.23–2.91)
1 vs. 2	1.13 (0.62–2.04)	**3.44 (1.51–7.86)**	**3.05 (1.36–7.00)**
Psychological profile	0.003[a]	0.019[a]	0.448[a]
2 vs. 1	**2.35 (1.24–4.46)**	**5.42 (1.50–19.58)**	2.30 (0.61–8.73)
3 vs. 1	**4.08 (1.75–9.47)**	**7.29 (1.71–31.12)**	1.79 (0.41–7.79)
3 vs. 2	1.73 (0.85–3.54)	1.34 (0.52–3.50)	0.78 (0.11–1.64)
Age (yrs)	1.01 (0.99–1.03)	0.98 (0.95–1.00)	0.96 (0.37–1.93)
Female sex	1.90 (1.11–3.25)	1.61 (0.72–3.61)	0.85 (0.37–1.93)

Bold values are statistically significant.
Pain sensitivity clusters: (1) Average to high temperature and pressure pain sensitivity; (2) average to high pressure pain sensitivity; (3) low temperature and pressure pain sensitivity.
Psychological clusters: (1) Low cognitive and affect scores; (2) relatively high cognitive scores; (3) high cognitive and affect scores.
[a] Overall group contrast *p*-value.

improvement in symptoms [2] or no change in pain distribution [14,16–18] with repeated movements, but this does not appear analagous to the NIP subgroup. The results of this study are also in contrast with studies where pain responses following repeated sagittal spinal bending were assumed to be homogeneous, reporting increased pain intensity with repeated movements [23,35]. The proportion of participants with NIP is substantial, potentially reflecting methodological differences. Stipulation of the MCID for pain intensity of 2-points as the cut-off for subgrouping, such that people with <2-point increase in pain intensity were classified as NIP, could have a significant influence on subgrouping. The bending tasks utilised in this study did not involve external loads in addition to body weight, such that people subgrouped as NIP may have been subgrouped differently under greater load [35]. Also, participants were deliberately not instructed to move in a standardised manner, allowing various movement strategies including protective behaviours. While the frequency of protective behaviours was not different across subgroups, we cannot exclude that this subgroup may have adopted movement strategies perceived as effective in reducing pain provocation. Finally, while this subgroup did not report increased pain *following* every five repetitions, they may have experienced increased pain *during* movement, or a latent exacerbation, that was unrecorded.

NIP was associated with statistically significantly lower levels of disability, however the magnitude of the differences may not be clinically-important (Table 1) [40]. The centralisation phenomenon (where spinal loading, possibly including repeated movements causes progressive, distal-to-proximal abolition of pain [1]), is generally associated with improved outcomes (and vice versa) [39]. A directional preference (where a particular direction of repeated movement improves symptoms, and vice versa [1]) appears to be a significant treatment effect modifier for directional exercise interventions [39]. No studies have shown that people with CLBP and NIP following repeated spinal bending have lower disability levels, or have a different prognosis with regard to disability than those with increased pain following repeated movement.

The BD subgroup was associated with statistically significantly higher pain intensity, however the magnitude of the differences may not be clinically-important (Table 1) [36]. Subjects in the BD subgroup were younger and had a longer duration of CLBP than the other subgroups. These associations have not been examined previously, and the implications of this finding in terms of different putative mechanisms are unclear.

These subgroups should be considered in light of strengths and limitations of the methodology in the study. Forward and backward bending were chosen because previous manuscripts have reported variable responses to these movements in people with CLBP [2–5]. However, other movements such as side bending or rotation, may also have provoked pain responses, had they been examined. Further, examination of movement patterns previously associated with directional pain responses [41] were not examined. Inclusion criteria required participants having dominant LBP [27], minimizing the likelihood of radiculopathy which may also have influenced our findings compared to previous studies.

5.2. Provocative pain responses following repeated spinal bending and their relationship to pain sensitivity clusters

The examination of pain sensitivity in subgroups with differing provocative pain responses following repeated sagittal spinal bending was a novel feature of this study. BD was associated with greater relative risk ratios for average to high temperature and pressure pain sensitivity, after adjusting for psychological profile, age and sex (Table 2). This equated to those with BD having more than three times the risk of having average to high temperature and pressure pain sensitivity compared to those with NIP or UD. Since self-reported pain intensity may not be considered to have reached a clinically important difference between the subgroups, this study suggests that future investigations should consider the association between pain responses following repeated movements and pain sensitivity. Combined with elevated pain sensitivity, multidirectional pain responses to movement have previously been postulated to indicate an increased contribution of central pain mechanisms to the disorder [22,42].

5.3. Provocative pain responses following repeated spinal bending and their relationship to psychological clusters

The examination of psychological clusters in subgroups with differing provocative pain responses following repeated sagittal spinal bending, is another novel feature of this study. NIP was associated with greater relative risk ratios for low cognitive and affective psychological scores (Table 2), after adjusting for pain sensitivity, age and sex. Those with NIP were 2.4–7.2 times more likely to have a more positive psychological cluster membership, than those with UD or BD. Given the cross sectional nature of this study, the direction of this relationship is not known, however, it suggests an interaction between psychological distress and provocative pain responses to movement [43,44]. This is consistent with a previous report that fear of movement, which was significantly different across the three psychological clusters [25], is positively associated with pain intensity following a repeated lifting task [35].

6. Implications

While this study documented relationships between directional provocative pain responses following repeated spinal bending movements and pain sensitivity and psychological profiles, these relationships were not strong (Table 2). A BD provocative pain response does not predict with confidence that a person will have high psychological scores or elevated pain sensitivity, highlighting the danger of making clinical decisions on the basis of a single examination finding alone. This highlights the need for a flexible multidimensional framework which guides careful and systematic consideration of the relative contribution of multiple relevant factors when assessing and managing an individual with CLBP [5].

Assessment of pain responses following repeated movement has been advocated to help inform movement-based and targeted management [1]. Numerous studies have examined exercise interventions targeting directional, movement-based subgroups in people with CLBP. However, targeted management of this type has not demonstrated superiority to unmatched (exercises deemed appropriate for a different directional subgroup) or control, generalised exercise treatments [11,45–48]. Suboptimal outcomes in these studies may reflect limited consideration of broader multidimensional clinical profiles associated with the LBP presentation. There is early evidence that an intervention targeting broader multidimensional profiles alongside directional, functional movement retraining may show greater improvements in pain and disability than ‘one size fits all’ guideline based care [38].

For people with NIP, the lack of pain provocation following repeated spinal bending, in combination with a favourable psychological profile, suggests this subgroup may have fewer barriers to functional rehabilitation. In contrast, the BD subgroup may require specific interventions targeting increased pain sensitivity and negative psychological cognitions and affect, as these may be may be important barriers to functional rehabilitation.

Funding sources

Martin Rabey was supported by a Musculoskeletal Association of Chartered Physiotherapists Doctoral Award, Chartered Society of Physiotherapy Charitable Trust, Curtin University Postgraduate Scholarship and Australian Postgraduate Award.

Darren Beales was supported by a National Health and Medical Research Council of Australia Early Career Research Fellowship. These funding sources had no role in study design; data collection, analysis or interpretation; in writing of this manuscript; or the decision to submit the article for publication.

Ethical issues

All participants gave written informed consent. This research was approved by the Human Research Ethics Committees of Curtin University, Royal Perth Hospital, and Sir Charles Gairdner Hospital, Western Australia.

Conflict of interest

The authors declare that there are no conflicts of interest relating to this manuscript.

Acknowledgements

Martin Rabey was supported by a Musculoskeletal Association of Chartered Physiotherapists Doctoral Award, Chartered Society of Physiotherapy Charitable Trust, Curtin University Postgraduate Scholarship and Australian Postgraduate Award.

Darren Beales was supported by a National Health and Medical Research Council of Australia Early Career Research Fellowship.

References

[1] McKenzie R, May S. The lumbar spine: mechanical diagnosis and therapy, vol. 1, 2nd ed. Waikanae, New Zealand: Spinal Publications New Zealand Ltd.; 2003.
[2] Donelson R, Grant W, Kamps C, Medcalf R. Pain response to sagittal end-range spinal motion. A prospective, randomised, multicentred trial. Spine 1991;16:ps206–12.
[3] Hidalgo B, Hall T, Nielens H, Detrembleur C. Intertester agreement and validity of identifying lumbar pain provocative movement patterns using active and passive accessory movement tests. J Manip Physiol Ther 2014;37:105–15.
[4] Fujiwara A, Nohara Y, Kobayashi N, Saiki K. Classifying patients with low back pain: factors aggravating or relieving patient’s symptom. Spine 2010:257.
[5] Rabey M, Beales D, Slater H, O’Sullivan P. Multidimensional pain profiles in four cases of chronic non-specific axial low back pain: an examination of the limitations of contemporary classification systems. Man Ther 2015;20:138–47.
[6] Rusu A, Boersma K, Turk D. Reviewing the concept of subgroups in subacute and chronic pain and the potential of customizing treatments. In: Hasenbring M, Rusu A, Boersma K, Turk D, editors. From acute to chronic back pain: risk factors, mechanisms, and clinical implications. Oxford: Oxford University Press; 2012. p. 485–511.
[7] Costa L, Koes BW, Pransky G, Borkan J, Maher C, Smeets R. Primary care research priorities in low back pain. An update. Spine 2013;38:148–56.
[8] Kent P, Keating J, Leboeuf-Yde C. Research methods for subgrouping low back pain. BMC Med Res Methodol 2010;10:p62.
[9] Sahrmann S. Diagnosis and treatment of movement impairment syndromes. St. Louis, Missouri: Mosby, Inc.; 2002.
[10] O’Sullivan PB. Masterclass. Lumbar segmental ‘instability’: clinical presentation and specific stabilizing exercise management. Man Ther 2000;5:2–12.
[11] Long L, Donelson R, Fung T. Does it matter which exercise? A randomized control trial of exercise for low back pain. Spine 2004;29:2593–602.
[12] Long A, May S, Fung T. The comparative prognostic value of directional preference and centralization: a useful tool for front-line clinicians? J Man Manip Ther 2008;16:248–54.
[13] Werneke M, Hart D. Centralization phenomenon as a prognostic factor for chronic low back pain and disability. Spine 2001;26:758–65.
[14] Werneke MW, Hart DL, George SZ, Stratford PW, Matheson JW, Reyes A. Clinical outcomes for patients classified by fear-avoidance beliefs and centralization phenomenon. Arch Phys Med Rehabil 2009;90:768–77.
[15] Edmond S, Werneke M, Hart D. Association between centralization, depression, somatization, and disability among patients with nonspecific low back pain. J Orthop Sports Phys Ther 2010;40:801–10.
[16] Werneke M, Hart D, Cutrone G, Oliver D, McGill T, Weinberg J, Grigsby D, Oswald W, Ward J. Association between directional preference and centralization in patients with low back pain. J Orthop Sports Phys Ther 2011;41:22–31.
[17] Werneke M, Hart D. Centralization: association between repeated end-range pain responses and behavioral signs in patients with acute non-specific low back pain. J Rehabil Med 2005;37:286–90.
[18] Werneke M, Hart D, Cook D. A descriptive study of the centralisation phenomenon. A prospective analysis. Spine 1999;24:676–83.
[19] Hodges P, Smeets R. Interaction between pain, movement, and physical activity: short-term benefits, long-term consequences, and targets for treatment. Clin J Pain 2015;31:97–107.
[20] Ung H, Brown JE, Johnson KA, Younger J, Hush J, Mackey S. Multivariate classification of structural MRI data detects chronic low back pain. Cereb Cortex 2014;24:1037–44.
[21] Sullivan MJL, Thibault P, Savard A, Catchlove R, Kozey J, Stanish WD. The influence of communication goals and physical demands on different dimensions of pain behavior. Pain 2006;125:270–7.
[22] O’Sullivan P, Waller R, Wright A, Gardner J, Johnston R, Payne C, Shannon A, Ware B, Smith A. Sensory characteristics of chronic non-specific low back pain: a subgroup investigation. Man Ther 2014;19:311–8.
[23] Falla D, Gizzi L, Tschapek M, Erlenwein J, Petzke F. Reduced task-induced variations in the distribution of activity across back muscle regions in individuals with low back pain. Pain 2014;155:944–53.
[24] Rabey M, Slater H, O’Sullivan P, Beales D, Smith A. Somatosensory nociceptive characteristics differentiate subgroups in people with chronic low back pain: a cluster analysis. Pain 2015;156:1874–84.
[25] Rabey M, Smith A, Beales D, Slater H, O’Sullivan P. Differing psychologically-derived clusters in people with chronic low back pain are associated with different multidimensional profiles. Clin J Pain 2016;32:1015–27.
[26] Roland M, Morris R. A study of the natural history of back pain. Part I: development of a reliable and sensitive measure of disability in low-back pain. Spine 1983;8:141–4.
[27] Wai E, Howse K, Pollock W, Dornan H, Vexler L, Dagenais S. The reliability of determining “leg dominant pain”. Spine J 2009;9:447–53.
[28] Reneman MF, Jorritsma W, Schellekens JMH, Göeken LNH. Concurrent validity of questionnaire and performance-based disability measurements in patients with chronic nonspecific low back pain. J Occup Rehabil 2002;12:119–29.
[29] Brouwer S, Reneman MF, Dijkstra PU, Groothoff JW, Schellekens JMH, Göeken LNH. Test–retest reliability of the Isernhagen Work Systems Functional Capacity Evaluation in patients with chronic low back pain. J Occup Rehabil 2003;13:207–18.

[30] O'Sullivan P. Diagnosis and classification of chronic low back pain disorders: maladaptive movement and motor control impairments as underlying mechanism. Man Ther 2005;10:242–55.
[31] Dworkin RH, Turk DC, Farrar JT, Haythornthwaite JA, Jensen MP, Katz NP, Kerns RD, Stucki G, Allen RR, Bellamy N, Carr DB, Chandler J, Cowan P, Dionne R, Galer BS, Hertz S, Jadad AR, Kramer LD, Manning DC, Martin S, McCormick CG, McDermott MP, McGrath P, Quessy S, Rappaport BA, Robbins W, Robinson JP, Rothman M, Royal MA, Simon L, Stauffer JW, Stein W, Tollett J, Wernicke J, Witter J. Core outcome measures for chronic pain clinical trials: IMMPACT recommendations. Pain 2005;113:9–19.
[32] Roland M. The Roland-Morris disability questionnaire and the Oswestry disability questionnaire. Spine 2000;25:3115–24.
[33] Kuijer W, Brouwer S, Dijkstra P, Jorritsma W, Groothoff J, Geertzen J. Responsiveness of the Roland/Morris Disability Questionnaire: consequences of using different external criteria. Clin Rehabil 2005;19:488–95.
[34] Swanson S, Lindenberg K, Bauer S, Crosby R. A Monte Carlo investigation of factors influencing latent class analysis: an application to eating disorder research. Int J Eat Disord 2012;45:677–84.
[35] Sullivan MJL, Thibault P, Andrikonyte J, Butler H, Catchlove R, Larivière C. Psychological influences on repetition-induced summation of activity-related pain in patients with chronic low back pain. Pain 2009;141:70–8.
[36] Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. Eur J Pain 2004;8:283–91.
[37] Dankaerts W, O'Sullivan P, Burnett A, Straker L, Davey P, Gupta R. Discriminating healthy controls and two clinical subgroups of nonspecific chronic low back pain patients using trunk muscle activation and lumbosacral kinematics of postures and movements: a statistical classification model. Spine 2009;34:1610–8.
[38] Vibe Fersum K, O'Sullivan P, Skouen JS, Smith A, Kvåle A. Efficacy of classification-based cognitive functional therapy in patients with non-specific chronic low back pain: a randomized controlled trial. Eur J Pain 2013;17:916–28.
[39] May S, Aina A. Centralization and directional preference: a systematic review. Man Ther 2012;17:497–506.
[40] Stratford PW, Binkley J, Solomon P, Finch E, Gill C, Moreland J. Defining the minimum level of detectable change for the Roland-Morris questionnaire. Phys Ther 1996;76:359–65.
[41] Dankaerts W, O'Sullivan P. The validity of O'Sullivan's classification system (CS) for a sub-group of NS-CLBP with motor control impairment (MCI) overview of a series of studies and review of the literature. Man Ther 2011;16: 9–14.
[42] Smart CB, Staines A, Doody C. Clinical indicators of 'nociceptive', 'peripheral neuropathic' and 'central' mechanisms of musculoskeletal pain. A Delphi survey of expert clinicians. Man Ther 2010;15:80–7.
[43] Moseley GL, Vlaeyen J. Beyond nociception: the imprecision hypothesis of chronic pain. Pain 2015;156:35–8.
[44] Zusman M. Associative memory for movement-evoked chronic back pain and its extinction with musculoskeletal physiotherapy. Phys Ther Rev 2008;13:57–68.
[45] Van Dillen L, Norton B, Sahrmann S. Classification-specific versus non-classification-specific treatment for people with low back pain. In: 8th Interdisciplinary World Congress on Low Back and Pelvic Pain. 2013.
[46] Henry SM, Van Dillen LR, Ouellette-Morton RH, Hitt JR, Lomond KV, DeSarno MJ, Bunn JY. Outcomes are not different for patient-matched versus nonmatched treatment in subjects with chronic recurrent low back pain: a randomized clinical trial. Spine J 2014;14:2799–810.
[47] Sheeran L, van Deursen R, Caterson B, Sparkes V. Classification-guided versus generalized postural intervention in subgroups of nonspecific chronic low back pain. A pragmatic randomized controlled study. Spine 2013;38: 1613–25.
[48] Saner J, Kool J, Sieben JM, Luomajoki H, Bastiaenen CHG, de Bie RA. A tailored exercise program versus general exercise for a subgroup of patients with low back pain and movement control impairment: a randomised controlled trial with one-year follow-up. Man Ther 2015;20:672–9.