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LACK OF EXERCISE INDUCED HYPOALGESIA TO REPETITIVE BACK MOVEMENT IN PEOPLE WITH CHRONIC LOW BACK PAIN

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ABSTRACT

Purpose: To investigate whether people with chronic low back pain (LBP) show dysfunctional exercise induced hypoalgesia (EIH) in response to repeated contractions of their back muscles during a lifting task.

Methods: In this cross-sectional observational study conducted on asymptomatic participants (n=18) and participants with chronic LBP (n=21), quantitative sensory testing (QST) was applied extensively over the lumbar region and a remote area before and after repeated task which involved lifting a 5kg box for ~7 minutes. QST included pressure pain thresholds (PPT), thermal detection and pain thresholds and measures of temporal summation. Topographical maps of the percentage change in PPT detected at 16 locations over the lumbar region were generated to explore regional differences and compared between groups.

Results: Mean (SD) PPT measured from 16 sites over the lower back, changed significantly in asymptomatic participants (+29.78kPa(41.4)) following task completion indicative of EIH, whereas no significant change was observed for the LBP group (-14.87kPa(61.2)). No changes were detected at the remote site for either group. No changes were revealed for the thermal tests. Temporal summation data revealed decreasing pain sensitivity as the test progressed but the test response did not change after the exercise for either group

Conclusion(s): Unlike asymptomatic individuals, participants with LBP lacked EIH over the lumbar erector spinae muscles following repeated lifting. Although these results should be considered in relation to the study limitations, particularly the absence of a control group, the findings support impaired EIH in patients with LBP.

Key words: Exercise Induced Hypoalgesia, Quantitative Sensory Testing, Low Back Pain

INTRODUCTION

The effects of exercise induced hypoalgesia (EIH), a short-term endogenous pain inhibitory response after exercise, are well documented in healthy individuals [1]. The EIH response can be detected with quantitative sensory testing (QST); revealed as a change in pain threshold after exercise. The extent of the EIH response depends on several factors including the type, dosage and intensity of the exercise [2 3].

Studies have revealed that EIH can be impaired in different musculoskeletal pain disorders including whiplash, osteoarthritis of the knee or shoulder pain [4-7], which can explain the varied response to exercise and has important implications for exercise prescription. On the contrary, very few studies have examined EIH in people with low back pain (LBP), even though exercise is recommended as a fundamental treatment for the management of LBP in national and international guidelines [8 9]. Two studies evaluated EIH in people with relatively mild LBP and both showed a similar analgesic response in people with LBP compared to a control group following submaximal aerobic exercise on an ergometer for ~30 minutes [10 11]. In contrast, a three-minute repeated lifting task which was designed to target activation of the back muscles, led to higher pain sensitivity to pressure over the lumbar region in participants with mild chronic LBP and no changes in the control group [12] suggesting that EIH to back-specific tasks could be impaired in LBP. However, this task was likely of inadequate intensity to produce EIH, since no change in pain sensitivity occurred in the asymptomatic control group. A further study examined the response to a 2-minute isometric back extension exercise (Biering Soerensen test) and showed evidence of EIH at remote but not local sites [13], however this study was limited to asymptomatic individuals. Further research is therefore needed to fully understand the analgesic response to back-specific exercise and whether this is affected in people with chronic LBP.

The aim of this study was to quantify, via QST assessed at local and remote sites, whether asymptomatic people demonstrate EIH in response to repeated movement of the trunk and whether the response is dysfunctional in participants with chronic LBP. Based on the earlier study by [12], we used a task which involved repeated lifting a 5kg box for ~7 minutes. This knowledge gained from this study may facilitate a greater understanding of the mechanisms contributing to varied response to exercise in people with LBP (i.e. those that lack EIH) and the exacerbation of symptoms in some people with LBP following repeated mechanical work [14-17].

METHODS

Study design and setting

This observational cross-sectional study was approved by the Ethics committee of the University of Birmingham (ERN_16-1389) and was conducted according to the Declaration of Helsinki. All tests were conducted in a single session by the same two investigators (PK and AS) between July 2017 and March 2018. This report follows the STROBE statement for observational studies [18].

Participants

Participants with chronic LBP and asymptomatic controls were recruited from the University staff and student population. All participants gave written consent prior to data collection. Inclusion criteria for both groups were age between 18 and 65 years, not being pregnant and able to communicate in English. Participants were considered asymptomatic if they had no previous history of back or lower limb pain which warranted treatment from a health care practitioner and no neurological disorders.

Inclusion criteria for the participants with chronic LBP were back pain lasting more than three months, and pain experienced on more than 90 days out of the past six months. A history of spinal fractures or spinal stenosis and radiating leg pain were exclusion criteria as

were concurrent systemic, rheumatic, or neurological disorders which may have confounded testing. They should not have been undergoing active management for chronic LBP or on higher doses of pain medication (> 30 mg of morphine equivalent dose).

Questionnaires

A custom designed questionnaire was firstly completed by the LBP participants to assess their average of the last 24hrs, during their latest episode, as well as their current pain intensity, all rated on an 11–item Numerical Rating Scale (NRS), with 0 for no pain and 10 for the worst pain imaginable [19]. LBP participants were also asked to rate their perceived disability with the Oswestry Disability Index (ODI) [20]. In addition, the following established questionnaires were used to describe the study population: The International Physical Activity Questionnaire (IPAQ) [21]; perception of health and wellbeing (SF-36v2), comprising of the Physical and Mental Component Scale [22]; the 21-item depression, anxiety and stress scale (DASS-21) [23], the fear avoidance beliefs questionnaire (FABQ)[24]; and pain catastrophizing scale (PCS) [25].

Quantitative Sensory Testing (QST)

QST was performed in a consistent order which was pressure pain threshold (PPT) testing followed by thermal detection and thermal pain threshold testing starting at the periphery and finishing at the back. Temporal summation of repeated thermal stimuli was performed last. The tests were chosen based on previous studies and pilot testing [12 26 27]. Reliability of QST has been demonstrated previously and it is an established method to evaluate EIH [1 28-31].

Pressure Pain Thresholds (PPTs)

After a familiarisation period, PPTs were measured with an algometer (1 cm^2 probe, 30kPa/sec) (Somedic Production, Stockholm, Sweden). Firstly, PPT were tested over the

thenar eminence on the right side for the asymptomatic group, and on the most painful side for the LBP participants. In the case of bilateral and symmetrical pain, the right side was selected. A grid, orientated on the spinous process of the 5th lumbar vertebrae, was used to mark 16 testing locations over the lumbar region (Fig. 1) to explore regional differences in PPT changes following the exercise. This was based on a similar approach used previously [12] but applied bilaterally, with two vertical rows of four points on each side. The medial row was directly placed over the erector spinae muscles. Testing was alternated across participants in four different patterns. For all PPT tests, the participants were instructed to push a button as soon as they perceived that the sensation of pressure had turned to one of pain. The mean of two consecutive readings over each site was used for data analysis. Topographical maps of the percentage change in PPT for each location were generated as previously described (Falla et al., 2014).

Thermal detection and pain thresholds

A Thermal analyser TSA-II (Medoc, Israel) with a 30x30mm Peltier thermode was applied over the thenar eminence on the right or most painful side as described above, after a demonstration on the contralateral side. Three randomised stimuli of either warm or cold were applied for the detection threshold and then for the pain threshold. Baseline temperature was set at 32°C, and the temperature increased or decreased by 1°C and returned with a rate of 8°C/s with a 5 seconds inter-stimulus interval. For the pain threshold an increase / decrease of 1.5°C/s and return of 8°C/s with 10 seconds interval was chosen to avoid temporal summation. The minimum temperature was set to 0°C and the maximum to 50°C. The same test was then conducted for both groups over the back on the right side corresponding to the PPT locations 11-16 (Fig. 1). For analysis the mean of three measurements was taken for each site.

Temporal summation

Firstly, a familiarisation test was performed on the contralateral side with five stimuli of 46°C with the same thermal tester described above. Participants were asked to rate their perceived pain on an NRS from 0-100 for each of the stimuli with 0 for no pain and 100 as worst pain imaginable. Then the thermode was placed under the volar mid-forearm on the right or most painful side. Ten consecutive stimuli were applied starting at a baseline temperature of 40°C increasing within 8°C/s to 48°C, and at the same rate to return to baseline. Inter stimulus interval was set as 2.5s adapted from a protocol by Owens et al. [26].

Repeated lifting task

Measurements of the sternomanubrial joint line for the top shelves, and the height of the lateral epicondyle of the femur for the lower shelves, and the length from the acromion to the head of the ulna for distance from the feet to the shelves were taken to determine the set-up for the lifting task (Fig. 2A).

Participants performed ten cycles lifting a 5kg box (35.5 cm x 29 cm x 13.5 cm) with reinforced handles between six different shelves for approximately seven minutes in total. To the beat of a metronome, the participant lifted the box to the top shelf over 2 seconds and then could rest for 2 seconds with the box on the shelf. Fig. 2B shows the pattern for each cycle. The task was based on a task described in a previous study [12], but was extended to represent a more functional movement by adding rotation using six instead of two shelves. During the task the participant was asked every minute to rate their pain on an NRS from 0-10 and their perceived exhaustion after the lifting task on a printed Borg scale [32]. They were informed that they could end the lifting task at any time.

Within 5 minutes of completion of the lifting task, the QST tests were repeated as described above, but in the following order: Lumbar PPTs followed by thermal tests over the

lumbar area with the participant in supine. Then the PPTs and thermal measurements were performed over the hand. This sequence was selected for efficiency of testing, to minimise movement of the participant and prioritise testing of the lumbar region. Temporal summation testing was conducted last avoiding any potential interference with the other tests. The duration of the pre-test protocol was slightly longer than the post-test protocol because of the familiarisation period. The entire duration varied between 20 to 30 minutes.

Statistical analysis

Independent t-tests were applied to detect possible differences between the participant characteristics of the two groups, (IBM SPSS Statistics Version 24). Data were analysed for normality and if necessary, outliers were removed from the analysis based on a z-score >3.29 and reported as such [33].

A mean of the PPT across the 16 locations of their back was calculated for each participant and in addition, the percentage change in PPT was determined for each location. For the thermal testing, if any reading did not meet the pain threshold at 0/50 °C (limit of the equipment), then the data were excluded from further analysis.

A two-way repeated measurement analysis of variance (RM-ANOVA) was conducted to evaluate changes in PPT detected over the hand with group (asymptomatic/LBP) and time (pre/post) as factors. A three-way RM-ANOVA was conducted for the lumbar PPT with group, time and location (locations 1-16) as factors. Two-way RM-ANOVAs were also applied for the thermal detection - and pain thresholds with group and time as factors. For temporal summation a three-way RM-ANOVA with group, time, and sequence of heat impulse (1-10) was applied. Significant differences were followed by Student Newman Keuls (SNK) post hoc analyses and Bonferroni corrections (BC) for multiple comparisons.

Finally, we tested the correlation of pain, perceived exertion, and change in percentage for the QST measurements using the Pearson correlation coefficient. Significance was set as $P < .05$.

RESULTS

Participants

Participant characteristics of 18 asymptomatic participants (8 men, 10 women) and 21 participants with chronic LBP (9 men, 12 women) are presented in Table 1. One further participant was recruited but only pre QST measurement were taken due to technical issues and this participant was therefore excluded. The ODI indicated minimal disability in the group with LBP and only two participants reported moderate disability. Participants with LBP reported significantly higher scores on the Borg Scale (controls: 11.1, (SD: 2.2), LBP: 13.1 (1.7); P=.005).

In contrast to all asymptomatic participants who successfully completed the full task, three LBP participants terminated the task due to provocation of their LBP during the 4^{th}, 6^{th} and 9^{th} cycle. However, as participants performed the task for as long as they could, their data were retained in the analysis and QST was still performed after their final task cycle.

Pain

Four control participants experienced LBP during the task (peak pain intensity of 2/10 reported by 3 participants and 8/10 by one participant, group mean: 0.8(SD: 2.0)). Overall, the reported peak pain intensity during the task was 4.78 (SD: 2.0) for the LBP group and only one LBP participant did not perceive LBP during the task.

PPTs (local and remote)

For PPT collected over the lower back, the overall scores (mean of 16 locations) were pre-test 341.39kPa (SD:116.9) and post-test 371.16kPa (130.4) for asymptomatic (n=18) and

320.08kPa (113.7) and 305.20kPa (101.0) for participants with LBP (n=20). This led to a difference of 29.78kPa (41.4) for the asymptomatic participants and -14.87kPa (61.2) for the participants with LBP. The percentage changes in PPT are displayed in Fig. 3 illustrating a mean change for the asymptomatic group of +9.43% (SD: 13.4, CI [2.8, 16.1]) and -2.10% (SD: 18.4, CI [-10.7, 6.5]) for the LBP group.

A three-way RM-ANOVA showed significant interactions for location, location and group, and time and location (F= 1.85 – 10.81, *P*=.000 – .025). The significance of location/ time and location indicates the heterogeneous response of different test sites over the lumbar area. However, for the purposes of this study, the most relevant finding was a group and time interaction (F=6.78, *P*=.001) and the post hoc analysis revealed a significant increase in PPT after the task but only for the control group (controls: SNK: *P*=.019; LBP: SNK = *P*=.228). However, Bonferroni correction for multiple comparisons revealed no significant interaction for time and group (controls: +29.78 (SE: 12.44) *P*=.132 [-5.0, 64.5]; LBP: -14.87(SE: 11.80) *P*=1.00 [CI: -47.8, 18.1]).

Topographical maps showing the percent change in PPT between pre- and post-test over the 16 different locations over the lumbar spine are presented in Figure 4. Based on observation of the topographical maps, we undertook further analysis to evaluate changes only within the cranial half of the map. There was an interaction of time and group (F=10.23, *P*=.003; SNK: controls: *P*=.002, LBP: *P*=.265). Correction for multiple comparisons confirmed changes for the asymptomatic group only (controls: +43.05 (SE: 13.03) *P*=.132 [CI: 6.69, 79.42]).

By separating the medial and lateral row, a significant change was observed over the medial (PPT test sites 5-12) column only. A significant interaction between time and group was observed (F= 8.12, *P*=.007). The post-hoc analysis showed a significant change only for

the asymptomatic group (SNK: controls: *P*=.001, LBP: *P*=.643). Adjustment for multiple comparisons confirmed a significant post-task increase in PPT only for the asymptomatic group (controls: +46.93 (SE: 13.5) *P*=.008, [CI: 9.18, 84.68]).

For PPT measured over the thenar eminence, the mean (SD) pre-test values were 259.33 kPa (77.8) and post-test values 281.94 kPa (117.4) for the asymptomatic group with a difference of +22.61 kPa (93.1). For participants with LBP the mean pre-test value was 276.55 kPa (88.84) and 278.50 (72.2) for the post-test with a difference of +1.95 kPa (40.2). A two-way RM-ANOVA revealed no significant differences between groups and no significant change over time.

There was a significant correlation between change in the PPT percentage over the hand and the back only in asymptomatic participants (r=.783, *P*=.000, n=18). ~~Furthermore, in asymptomatic participants there was a high negative correlation between NRS during lifting and PPT change in percentage over the medial columns (r=-.716, *P*=.001, n=18).~~ However, in both groups there was no significant correlation between baseline PPT and the percent change in PPT indicating that an EIH response was not dependent on baseline sensitivity.

Thermal Testing

Results for the cold and warm detection and pain thresholds are presented in Table 2. Two CDT readings from the hand and one from the back were identified as outliers (z-score> 3.29) and were removed from the analysis. A two-way RM-ANOVA revealed a significant difference for group (F=4.18, *P*=.049) for the CDT detected over the hand yet further post-hoc analysis revealed no further significant differences between groups and there was no effect of time. No significant differences and interactions between group or time were observed for the CDT performed over the lumbar region nor warm detection over the hand and the lumbar area.

Due to limitations of the device with a safety limit of 0 °C/ 50°C completed data sets were limited in both groups for the CPT. The difference in CPT between pre- and post-tests was +1.6 °C (5.6) for the asymptomatic participants and a +2.5°C (4.9) for LBP group. A two-way RM-ANOVA showed a significant change over time (F=5.31, *P*=.028) for both groups but there were no differences between groups.

For the lumbar area a RM-ANOVA showed no significant group difference, although the overall change between pre- and post-task measures across both groups was close to significant (F=4.24, *P*=.054). Imputing 0°C for the missed scores did not affect the result.

For the thenar WPT the overall difference between pre- and post-test was -1.2°C (2.5) for the asymptomatic group and -1.1°C (2.7) for those with LBP. A two-way RM-ANOVA showed a significant interaction between group and time (F=8.739, *P*=.006) with the post-hoc analysis confirming a reduction of the WPT for the asymptomatic group only (SNK: *P*=.037). However, correction for multiple comparisons showed no significance (BC: *P*=.144). There was no significant change in WPT measured over the lumbar region for either group.

Temporal summation

TS data was obtained from 15 asymptomatic and 18 participants with LBP. Overall, a reduction in pain sensitivity to the same stimulus was found over time (Fig. 5). A three-way RM-ANOVA revealed interactions for sequence only (F= 22.69, *P*=.000) with the post hoc analysis revealing significant changes between the 1^{st} and $3\text{-}10^{th}$ stimulus (SNK: *P*< .034). No differences were observed between groups and there was no effect of the task on temporal summation.

DISCUSSION

This is the first study to rigorously utilise different quantitative sensory measures to evaluate whether a repeated lifting exercise induces EIH and whether this effect differs in people with chronic LBP. Our findings confirmed that the hypoalgesic effect gained from back-specific exercise induced by repeated lifting is impaired in participants with chronic LBP which has important implications for those performing repeated lifting in an occupational setting.

The study population comprised mainly people with minimal disability due to their LBP (ODI≤20). At baseline, we did not observe any consistent differences in any of the QST measures between groups indicating that our sample of people with LBP did not show obvious signs of peripheral or central sensitisation. This is in contrast with previous work using multiple PPT over the lumbar region which showed lower PPT for people with LBP in a comparable population [12 34]. The high inter-individual differences and the relatively low levels of pain and disability in our sample could explain this. Moreover, we did not observe a correlation between baseline PPT and changes in PPT post-task in our study population, indicating that the extent of EIH was independent of baseline sensitivity.

The task was perceived by the participants as easy to moderate exercise according to the Borg Scale. This is in contrast to most other studies which have examined EIH in response to more demanding exercise [1 35]. Yet the current study clearly demonstrated an EIH response for the asymptomatic population as seen by the significant increase in lumbar PPT measured after completion of the repetitive task.

Furthermore, our results are in contrast to previous studies that did not find evidence of impaired EIH in people with LBP, however no other study has examined the response to exercise specifically targeting the back muscles [10 11]. In a study which evaluated changes

in PPT following a lifting task albeit of shorter duration and only lifting in the sagittal plane [12], a significant local decrease in PPT over the lumbar area was shown in people with LBP. The trend was shown in our study. However, changes were not statistically significant.

Differences were observed for the change in PPT between medial and lateral testing sites in the asymptomatic group with significant changes observed only for medial sites. This is likely because the lateral column was located to a lesser extent over the erector spinae, i.e. the iliocostalis lumborum, which were engaged in the task [36]. Moreover, EIH was more evident at cranial sites. This underlines the importance of topographical PPT mapping, as changes might not be depicted if only a single test site is used.

The absence of EIH in our cohort of people with LBP does not necessarily imply that the people with LBP lacked descending pain inhibition. It rather could be caused by their erector spinae muscles becoming sensitised after the task due to localised muscle fatigue. Especially since studies indicate that the erector spinae are more fatigable in people with LBP and changes in muscles activity were found with fatigue or pain [37-39].

Research on changes in pain sensitivity over the lumbar region after exercise is limited. Comparing our results with the findings from Gajsar et al. [13], we found similar baseline scores and changes in lumbar PPT (absolute change: men: 34.2 kPa: women: 18.9 kPa from Gajsar et al [13]). However, in the study by Gajsar et al.[13], the increase in PPT over the lower back after exercise did not reach statistical significance, unlike our current findings. The isometric back extension task used in this previous study also engages the hip extensor muscles, over which they found a significant increase in PPT. Additionally, Gajsar et al.[13] examined the PPT at only one site over the lumbar region (adjacent to L3). Our findings indicate that test site has a significant influence on outcome and that testing sites directly over the muscle belly are more likely to demonstrate a change.

We did not identify a significant change in pressure pain sensitivity measured at a remote site (hand), likely because of the low intensity and duration of the task since remote changes are typically seen after excessive or vigorous exercise [2 3].

In contrast to pressure testing, the sensitivity to thermal stimuli did not show a clear pattern and was restricted by the temperature range of the equipment used. In line with our study, most other studies have used PPT as an outcome measurement for EIH which seems more responsive as an outcome measurement [1]. This is likely because mechanical pressure stimulates receptors within an exercised muscle, whereas the thermal stimuli stimulate superficial receptors of the skin. Changes in temperature pain thresholds may be caused by exercise-induced changes in skin or body temperature rather than inhibitory pain mechanisms [1]. Furthermore, the randomisation of stimuli might have affected the results [40].

The temporal summation of heat stimuli did not differ between groups and did not change pre- and post- exercise but did decrease over the series of stimuli. These results are in contrast to a similar protocol in a similar population without an exercise intervention [26]. Other studies also showed an increase in pain intensity using different protocols [41 42]. However, consistent with our findings, a reverse effect of temporal summation has been reported in other studies as a reduced wind-up or habituation in healthy controls [43 44]. We therefore cannot infer any changes in temporal summation as the protocol we used did not induce temporal summation.

It is worthwhile to note that there was large variability in QST responses. Some participants with chronic LBP did show increased PPT after the task reflecting the large variability in presentation found in any chronic LBP cohort [45]. However, our findings highlight that even people experiencing chronic symptoms of low severity and normal baseline sensitivity can lack an EIH response. It is relevant in future research to investigate if

the absence of EIH is associated with poorer outcome to exercise interventions in people with LBP. Potentially, the response to a short bout of back-specific exercise could be used to understand whether or not a patient is likely to have a positive analgesic response to an exercise programme targeting their back muscles. Although, subgrouping based on EIH response needs to be fully investigated in future work.

Strengths and Limitations

This is the first study to assess the effects of repetitive lifting on pain sensitivity with an extensive QST test battery including tests of sensitivity to both mechanical and thermal stimuli. Nevertheless, there are some methodological considerations that should be noted. An a priori sample size was not determined and it is therefore possible that the sample size prevented some differences from reaching statistical significance. It could be argued that the average change in PPT measured from the 16 sites over the lower back for the asymptomatic participants (i.e. +29.78kPa) is low and although statistically significant, is not a relevant change. Moreover, based on the RM-ANOVA there was no interaction at the remote test site for time (controls: +22.61kPa/ LBP: +1.95kPa), even though change in the asymptomatic group is somewhat similar to the change over the lumbar region. Nevertheless, it should be noted that the average change in PPT for the LBP group was in the opposite direction (i.e. -14.87kPa) suggesting a real and relevant difference in response between groups.

No control condition was included in this study; thus, it is uncertain whether the changes in PPT are actually due to the exercise performed. The change in PPT at the back could be partially attributed to habituation, due to induction of pain itself from the extensive psychophysical testing or even expectation effects. We verbally encouraged and instructed participants to lift with their back. Therefore, changes in QST might be influenced by

underlying biomechanical or muscular activations pattern which weren't considered in this study. We recruited participants from a University environment and therefore our data cannot be generalised to other LBP populations including those exposed to manual labour and heavy lifting or to people with more severe LBP.

Even in the control group, the task produced mild back pain in some participants. This suggests firstly that the task targeted the right region. On the other hand, the duration and intensity of the task might not have been extensive enough to produce high levels of EIH, especially indications of a systemic effect measured at the remote site.

Missing data were due to technical limitations of the equipment used but were relatively even between groups and thus this did not likely have a significant effect on the results. The order of QST was the same for both groups and cannot explain group differences. However, we cannot out rule that different test modalities have an effect on the subsequent test. Finally, the full QST was completed within 30 minutes, which has been indicated as the minimum persistence of EIH [1]. As thermal tests were performed last, any effects might have been disappeared by that time. Although we do not know how long the effects were maintained and this should be explored in future studies.

Conclusion

Asymptomatic people responded favourably to a short repeated lifting task displaying evidence of EIH as revealed by a significant reduction in pressure pain sensitivity over the erector spinae. In contrast, this phenomenon was absent in participants with chronic LBP, even though they presented with low severity pain and disability.

Declaration of interest

All authors declare no conflicts of interest.

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TABLES

Table 1 Demographic characteristics of the study population

Characteristic/Questionnaire	Asymptomatic		LBP		Group Difference
	Mean	SD	Mean	SD	*P*
Age	28.2	12.5	31.7	13.3	= .406
BMI	23.3	4.0	25.4	3.4	= .084
DASS21 (Range: 0 to 126)	9.4	10.1	19.3	22.5	= .095
FABQ (0 to 96)	2.6	5.7	27.2	11.6	< .001*
PCS (0 to 52)	5.7	6.9	14.9	9.2	< .001*
Peak Pain Lifting (0 to 10)	0.8	2.0	4.8	2.0	< .001*
Borg Scale Lifting (6 to 20)	11.1	2.2	13.1	1.7	=.004*
SF36-PCS	58.43	3.9	49.36	5.3	< .001*
SF36-MCS	51.82	4.4	46.51	13.0	= .091
IPAQ	14 high, 4 med.		18 high, 4 med.		=.0525
ODI (0 to100; ≤20% = minimal disability)			16.0	6.8	
Pain last 24hrs			3.9	2.1	
Pain before task			3.1	2.0	
Pain episode			4.9	1.9	

Diff. =Difference, BMI=Body Mass Index, DASS21= Depression Anxiety Stress Scales, FABQ= Fear Avoidance Believe Questionnaire, PCS= *Pain* Catastrophizing Scale, SF36-

PCS= Short Form Health Survey Physical component score, SF36-MCS= Short Form Health Survey Mental Component Scale; all independent t-test, except Kruskal-Wallis for IPAQ

Table 2 Results for thermal detection and pain threshold testing.

		Asymptomatic			LBP		
Test	Site	N	Mean (°C)	SD	N	Mean (°C)	SD
CDT pre	Hand	17	30.2	1.0	20	30.5	0.7
CDT post			29.9	1.1		30.5	0.6
WDT pre		18	33.9	1.1	21	34.1	0.9
WDT post			33.8	0.8		33.9	0.6
CPT pre		16	14.0	7.5	18	15.4	7.6
CPT post			15.8	8.5		17.8	6.2
WPT pre		14	43.0	2.9	21	43.5	3.9
WPT post			41.2	3.7		42.4	2.5
CDT pre	Lumbar	18	29.6	2.0	20	29.8	1.6
CDT post			29.7	2.0		29.3	2.0
WDT pre		18	35.3	1.3	21	35.5	1.1
WDT post			35.0	1.1		35.2	1.4
CPT pre		12	21.5	6.1	8	24.8	4.4
CPT post			19.6	6.8		22.7	6.8
WPT pre		17	43.3	3.9	20	43.7	4.1
WPT post			43.7	3.5		43.5	3.0

CDT= cold detection threshold, WDT= warm detection threshold, CPT= cold pain threshold, WPT= heat pain threshold, pre= pre-test, post= post-test

FIGURE LEGENDS

Fig. 1 Schematic representation of the area over the lumbar region for pressure pain threshold testing. The distance between two testing sites was 2.5 cm, and the first sites were 2.5 cm cranial to the spinous process of L5.

Fig. 2 (A) Participant demonstrating the starting position of the lifting task **(B)** Schematic illustration of the lifting sequence.

Fig.3 Boxplot of the percentage change in pressure pain sensitivity measured over the back from pre- to post-test based on the overall mean of 16 locations for each individual within the two groups. A higher percentage change represents signs of exercise induced hypoalgesia. At the group level, the mean change (illustrated by the x) was +9.43% (13.4) for the asymptomatic group and -2.10% (18.4) for the participants with LBP. The lower and upper extreme was -19.80% and 28.20% for asymptomatic compared to -35.95% and 28.13% for the group with LBP.

Fig. 4 Topographical maps showing the percent change in PPT between pre- and post-test over the 16 different locations over the lumbar spine as determined in Fig. 1. The vertical line represents the midline of the spine.

Fig. 5 Results of Temporal Summation. The graph shows pain scores (NRS 0-100) over ten heat pulses (Sequence) in healthy asymptomatic participants and in those with low back pain (LBP) pre- and post- the repetitive lifting task. Asymptomatic participants started with an average pain score of 60.93(SD 26.1) and rated the tenth stimulus as 49.4(21.7) in the pre-test, and respectively 66.67 (21.4) and 50.80(20.2) for the post-test. The LBP group changed from 63.67 (20.0) to 43.28 (21.9), and in the post test from 68.94 (22.3) to 42.33(21.2). There was neither a significant difference between pre- and post-task test nor between the two groups.