AALBORG UNIVERSITET

Title: Feasibility of Belt Squat Training for Individuals with Chronic Non-Specific Low Back Pain and Its Impact on Pain Sensitivity

Semester: 4. Semester. (Kandidat i idræt)

Semester theme: Master's Thesis

Project period: 05/02/2024 - 31/05/2024

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Methods: A group of 10 participants with LBP and a group of 15 HI completed the same belt squat intervention, consisting of three sets of five repetitions with two sessions pr. week for six and four weeks respectively. A five repetition maximum test was conducted pre- and postintervention for both groups. PPT levels were collected before and after both tests and training sessions for both groups, along with pain ratings on a Visual Analogue Scale (VAS) for the LBP group. The LBP group also completed EQ-5D-5L, FABQ, and ODI questionnaires pre and post intervention and a feasibility questionnaire post intervention.

Results: The belt squat intervention was feasible for the LBP participants who all reported having a positive experience and feeling safe during the exercise. The majority of training sessions produced significant EIH responses for both groups. In PPT levels for LBP there was a significant 59% increase from before pretest to before posttest and a 71% increase from after pretest to after posttest. There was a significant 20% increase in PPT levels after pretest to after posttest for HI. There were significant improvements in VAS pain scores from before pretest standing (2.11±1.53) to before posttest standing (0.66±1.11) *P*=0.008, and from before pretest dynamic (3.00±1.63) to before posttest dynamic (1.00±0.81) *P*=0.038. For the health questionnaires EQ-5D-5L-Health-today (*P*=0.054), ODI (*P*=0.053) and FABQ (*P*=0.072), all measures showed a tendency of improvement in scores based on the *P*-value, although these values were not significant.

Conclusions: The belt squat intervention was feasible for LBP participants and resulted in significant improvements in both PPT levels and VAS scores, indicating reduced pain sensitivity. The HI responded similarly to LBP in terms of improvement in PPT levels, suggesting that resistance training can mediate changes in pain sensitivity, potentially explaining the mechanism behind the pain alleviating effects of the belt squat exercise in individuals with chronic non-specific LBP.

Feasibility of Belt Squat Training for Individuals with Chronic Non-Specific Low Back Pain and Its Impact on Pain Sensitivity

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Background

The prevalence of low back pain (LBP) is high and represents a significant health concern globally, constituting a leading cause of disability (Vos et al., 2016) and imposing substantial economic burdens comparable to other prevalent conditions, such as cancer and cardiovascular diseases (Maniadakis & Gray, 2000). It is estimated that nearly everyone, at some point in their life will experience pain in and around the back (Lemeunier et al., 2012; Stochkendahl et al., 2018). When no specific cause can be identified for the back pain, it is termed as nonspecific. If the pain persists for more than 12 weeks, it is classified as chronic LBP (Treede et al., 2019). When experiencing LBP, patients undergo a diagnostic triage aimed at identifying non-spinal causes that may indicate more serious underlying conditions contributing to the symptoms, which occur in less than 1% of cases. Alternatively, the evaluation assesses whether the pain is radicular in nature, accounting for 5-10% of cases, or if it falls under the category of non-specific LBP, which constitutes 90-95% of cases (Bardin et al., 2017). This triage process aids in determining the appropriate course of action for each patient. This study specifically focuses on chronic non-specific LBP. Various treatment modalities have been explored, including surgical interventions, bracing, pharmacological approaches with different medications, and conservative therapies such as pain education, cognitive therapies, and exercise (Corp et al., 2021). Guidelines predominantly recommend conservative therapies as first-line treatment, specifically exercise therapy, patient education, and advice on maintaining physical activity (Foster et al., 2018; National Guideline Centre (UK), 2016; Nicol et al., 2023). Despite the broad impact of chronic LBP and the current treatment options available, a systematic review indicates that 65% of chronic LBP patients continue to report pain one year after treatment (Itz et al., 2013), highlighting a significant knowledge gap in effective treatments.

Nevertheless, an increasing body of evidence suggests that exercise provides pain reducing benefits, with exercise regimens being promoted for various pain conditions, such as fibromyalgia, knee osteoarthritis and LBP (Geneen et al., 2017). A Cochrane-review from 2021 suggests that exercise may be one of the most effective interventions for LBP (Hayden et al., 2021). The review found “moderate-certainty evidence” that exercise treatment is more effective as treatment for chronic LBP compared to no treatment. It is also indicated that exercise is more effective than cognitive therapy alone or pain education alone. However, exercise is often treated as a singular entity, as observed in the Cochrane review (Hayden et al., 2021), highlighting the challenge of identifying specific exercises that are beneficial for LBP. Among the various exercise modalities explored for LBP treatment, dynamic resistance training has garnered attention for its potential benefits in improving physical function and musculoskeletal health (Foster et al., 2018; Maestroni et al., 2020) and alleviating pain in some populations experiencing musculoskeletal pain (Rodrigues et al., 2014). Therefore, LBP patients may also benefit from an exercise program aimed at improving physical function (Foster et al., 2018). Still, there is little guidance on the specific types of exercises that should be recommended for patients with LBP, as there is currently no evidence demonstrating superiority of one form of exercise over others (Foster et al., 2018; Smith et al., 2014). Additionally, there is a lack of clarity on which muscle groups are best targeted (Hayden et al., 2021), further compounding the uncertainty in the literature regarding the appropriate approach to exercise therapy for treating LBP. This presents a challenge in determining optimal exercise protocols for this population.

A possible explanatory mechanism underlying the pain-alleviating effect of exercise in individuals with musculoskeletal pain may be attributed to reductions in pain sensitivity (Rice et al., 2019). It has been demonstrated that engaging in just one session of resistance training triggers the body's internal mechanisms for reducing pain, both in people who do not experience pain regularly, and in those who suffer from persistent pain (Burrows et al., 2014; Koltyn & Arbogast, 1998). This leads to a temporary reduction in the sensitivity to noxious stimuli, a phenomenon known as exercise-induced hypoalgesia (EIH) (Koltyn et al., 2014). However, there is inconsistency in the research literature regarding individuals with persistent pain, with some studies reporting hypoalgesia and others indicating the presence of hyperalgesia. As an example, EIH has been observed in people suffering from osteoarthritis after a single session of resistance training (Burrows et al., 2014), and in people with LBP after engaging in a single session of aerobic exercise (Meeus et al., 2010). Studies have also been conducted that did not find any alteration in EIH in a population of fibromyalgia patients performing one session of isometric exercise (Lannersten & Kosek, 2010). Furthermore, studies have even found heightened pain sensitivity after exercise in people with whiplash-disorders following aerobic exercise (Van Oosterwijck et al., 2012) and in people with fibromyalgia after isometric training (Kosek et al., 1996). This inconsistency emphasises the necessity for further research in this field, as reduction in pain-sensitivity may depend on the pain condition and which form of exercise the individual engages in. Additionally, there is a limitation in the literature regarding the long-term effects of exercise on pain sensitivity. While EIH has been shown to mediate pain sensitivity under acute conditions (Koltyn et al., 2014), we lack insight into how pain sensitivity changes during an exercise intervention, as Song et al. (2023) highlights the necessity for more research, investigating whether exercise will lead to a stronger EIH response over an extended period of time.

Traditional resistance training exercises like the back squat, while effective for many individuals in improving life quality (FRY et al., 2003), athletic performance (Sleivert & Taingahue, 2004; Wisløff et al., 2004) and for rehabilitation (Rutland et al., 2010; Schoenfeld, 2010; Signorile et al., 1994), often pose challenges for those with persistent LBP due to the transmission of forces through the lumbar spine, potentially exacerbating discomfort (Evans et al., 2019). Many lower extremity exercises such as the back squat include a transmission of force through the lumbar spine (Evans et al., 2019), thereby presenting considerable difficulty for individuals suffering from lower back pain. When physical activity induces pain, individuals tend to engage in less exercise (LaRowe & Williams, 2022). Pain during physical exercise can therefore trigger a cycle wherein individuals become less active, ultimately exacerbating both their pain levels and their overall physical limitations (Rice et al., 2019). This cycle contradicts the first-line conservative treatment recommendations advocating for staying physically active, thereby highlighting the importance of investigating modalities of exercise that alleviate pain, as it might potentially assist patients with chronic pain conditions in becoming more physically active.

Based on pilot data from our research group, it is suggested that belt squats may be effective in alleviating pain in people with LBP. The belt squat is an exercise where the individual wears a hip belt connected to a weight stack via a cable. While holding onto handles, the person performs a squatting movement. This exercise targets hip and knee extensors as well as hip abductor muscles (Evans et al., 2019; Gulick et al., 2015). Importantly, the load is supported by the hips, reducing load on the spine, and potentially minimizing pain (Clark et al., 2012; Evans et al., 2019). Previous research has shown that the muscle groups trained with the hip belt squat exercise are weaker in people with chronic nonspecific LBP compared to healthy individuals (HI) (de Sousa et al., 2019). Therefore, belt squats potentially allow people with chronic nonspecific LBP to engage in an effective form of resistance training for these muscle groups. However, it remains uncertain whether these individuals can tolerate this type of exercise and whether it has an impact on key parameters such as pain levels and pain sensitivity. While physical training might be beneficial for LBP (Hayden et al., 2021), it needs to be determined which specific exercises are both effective and feasible for managing chronic non-specific LBP.

Therefore, this study aims to assess the feasibility of implementing the belt squat into training protocols for individuals suffering from chronic non-specific LBP, as well as investigating whether their pain levels change during the intervention. By determining the feasibility of this exercise, we aim to contribute to the development of evidence-based exercise recommendations for this population. Furthermore, our investigation aims to explore whether EIH occurs after belt squatting, and if pain sensitivity and EIH changes during a training intervention in HI, thereby possibly giving insights into the mechanisms responsible for the potential pain-alleviating effects of exercise.

Methods

Experimental design

This study took place at Aalborg University in Denmark and consisted of two different sub projects. The aim of sub project 1 was to test the feasibility of LBP participants performing the belt squat exercise, and to investigate how their pain levels changed during a 6 week intervention. The aim of sub project 2 was to examine if EIH occurs after belt squatting, and whether the magnitude of EIH and pressure pain threshold (PPT) levels, changes during a 4 week belt squat intervention in HI. Pre- and posttests for participants in both sub projects were carried out in the week before and after the intervention period (Fig. 1 & 2), and consisted of a heavy 5 repetition test in the belt squat with 1 repetition in reserve (RIR).

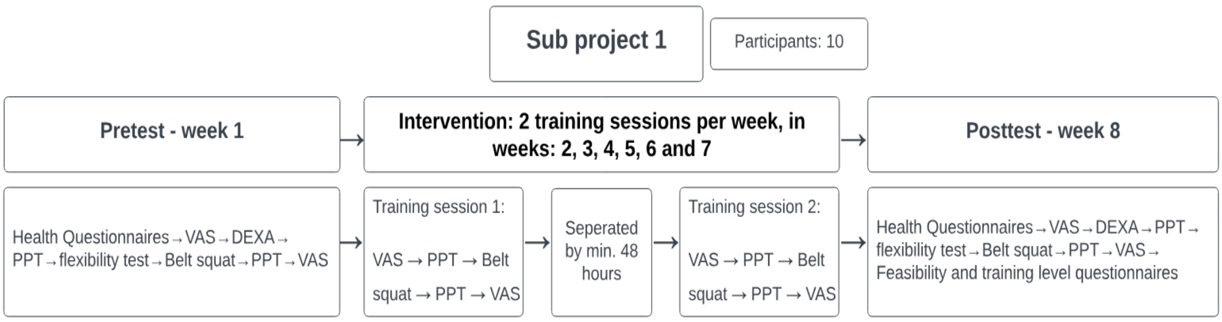


Figure 1. Experimental design of sub project 1.

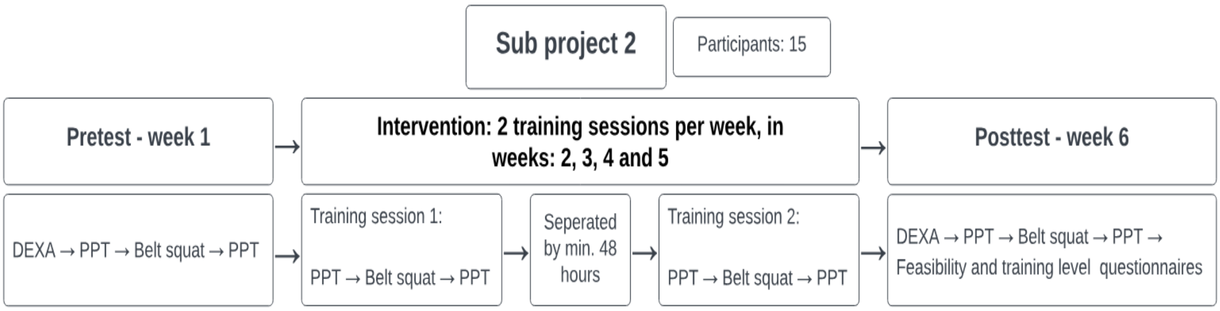


Figure 2. Experimental design of sub project 2.

Pretest and posttest

Sub project 1: Participants were instructed to arrive at least 30 minutes before both tests and training sessions if they had bicycled to the university. This was done in order to establish a washout period. Upon arrival, participants filled out the following questionnaires: The EQ-5D-5L was used to measure the health related quality of life of the participants, using five different aspects: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Furthermore, participants were asked to rate their health on that given day on a scale from 0-100 (EuroQol Group, 2009). The Fear Avoidance Belief questionnaire (FABQ), was used in order to gather information about whether the participants had fearful thoughts, about experiencing pain during physical activity and work (Waddell et al., 1993). The Oswestry Disability Index (ODI) was used in measuring the functional ability of LBP participants. ODI assesses to which degree a person's LBP impacts 10 different aspects related to daily life, namely: pain, self-care, lifting, walking, sitting, standing, sleeping, sex life, social life and travelling (Yates & Shastri-Hurst, 2017).

The visual analogue scale (VAS) was used to collect data on the development of pain both before and after the belt squat 5 RM test (Begum & Hossain, 2019). Participants were asked to rate their LBP on a scale from 0 to 10 where 0 meant no pain and 10 corresponded to the worst pain imaginable. Ratings on the VAS scale were gathered both while the participant was standing still, during a self-chosen movement known to occasionally induce pain, and as the average VAS score representing the participant's pain level since their last visit at the test site. The participants underwent DEXA scans to assess changes in whole body muscle and fat mass. The scans were performed using a GE Lunar iDXA, DEXA scanner (GE Healthcare Lunar, Madison, WI). PPT measurements were gathered right before and after the 5 RM belt squat test. PPT levels were measured with a handheld algometer (Somedic Sense Lab. (n.d.)) on the shoulder, 3 finger widths distal from acromion in a direct line from olecranon. Pressure was increased with 30 kPa pr. second and the following instructions were given to the participants: "We are now going to measure your pain sensitivity. We will gradually increase the pressure of this algometer against your shoulder, and as soon as you feel the sensation change from pressure to pain, please press the red button". Lumbar flexibility was assessed before the belt squat exercise in both the pre- and posttests. This was done by having the participant sit against a wall, and then reaching as far ahead as possible with the hands touching the floor. The distance from the wall to the fingertip of the participant indicated lumbar flexibility.

Then the belt squat five 5 RM test with one 1 RIR was carried out. Before starting, the use of RIR was explained, and participants were told to lower their body until their thighs were below parallel on each repetition. Firstly, 3 warm up sets with increasing intensities were performed and then the goal was to reach 5 repetitions with one RIR in as few sets as possible. In order to increase compliance and avoid dropout, they were informed that they could stop the test if back pain got too severe. In order to minimise time spent and improve performance, rest periods were adjusted in the following manner: 0-3 RIR warranted a 3 minute rest, 4-6 RIR warranted a 2 minute rest and 7 RIR and above resulted in a 1 minute rest period. A feasibility questionnaire (Table 1) was answered after the posttest and was developed based on five of the eight important aspects outlined in (Bowen et al., 2009). It comprised 6 questions that sought to answer the aspects of acceptability, demand, implementation, practicality and limited efficacy when testing feasibility of the belt squat exercise. Participants were asked to assess their level of agreement for each of the six feasibility questions using a 5-point likert scale, which ranged from 1 (completely disagree) to 5 (completely agree).

Table 1: Feasibility questionnaire.

A: I have had a good experience with the belt squat exercise.
B: I felt comfortable and safe when I performed the belt squat exercise.
C: I wish to incorporate belt squats into my future training routine.
D: I will continue using the belt squat exercise in the future.
E: It is easy for me to incorporate belt squats in my exercise routine.
F: I have the opportunity to incorporate belt squats in my exercise routine.

Sub project 2: Except for health questionnaires and VAS assessments, participants in sub project 2 followed these procedures and instructions in the same way as in sub project 1: Washout period, DEXA scan, PPT measurements, belt squat five RM test and PPT measurements.

Training intervention

Sub project 1: The participants engaged in 6 weeks of 2 training sessions per week, separated by at least 48 hours. Every training session consisted of 3 sets of 5 repetitions in the belt squat exercise. The aforementioned washout guidelines were also used in the intervention. VAS scores and PPT measurements were collected before and after every training session in the same way they were at the pretests and posttests. Participants completed three warm up sets with increasing intensities. Then they performed their first set of the intervention at 90% of the weight from their 5RM test. From the second and all subsequent sets in the training intervention, the training intensity was adjusted in the following manner: 0 RIR - lower the weight in the following set, 1-3 RIR - use the same weight in the following set, 4 or more RIR - increase weight in the following set. Breaks between sets were adjusted in the same manner as in the pre- and posttests.

Sub project 2: In sub project 2, participants completed 6 weeks of 2 training sessions per week and did not rate their pain on a VAS scale, besides from that, participants in both sub projects underwent the exact same training intervention.

Participants

Participants were recruited both through advertisements in Aalborg University, local hospitals, and through personal inquiries. As per the inclusion criteria of sub project 1, participants had to have LBP for more than 12 weeks without major sciatica. Additionally back pain should be greater than leg pain and both men and women aged 18-60 were included. For sub project 2, participants had to be healthy men or women aged 18-60. Exclusion criteria for both sub projects were: Leg pain greater than back pain, neuromuscular disorders, infections, spinal or lower extremity fractures, osteoporosis, cancer, dementia, pregnancy, BMI above 35, current substance abuse, former lumbar surgery, inflammatory rheumatic diseases and persistent pain syndromes other than back pain.

Demographics

Table 2: Demographics of participants in sub project 1 (LBP) and sub project 2 (HI).

Group	N	**Height, cm** (SD)	**Weight, kg** (SD)	**Age, years** (SD)	Sex, m / f
Sub project1: LBP	10	**171.5** (7.08)	**78.9** (11.52)	**40.3** (13.49)	7 / 3
Sub project 2: HI	15	**176.6** (8.21)	**87.3** (18.63)	**28.3** (3.79)	11 / 4

Table 3: Training level of participants in sub project 1 (LBP) and sub project 2 (HI).

Group	N	Beginner	Intermediate	Advanced	Highly advanced
Sub project 1: LBP	10	2	0	7	1
Sub project 2: HI	15	0	2	10	3

Statistical analysis

The sociodemographic and clinical characteristics of all participants are presented as frequencies or proportions, along with group means and standard deviations (SD). A one-way repeated measures ANOVA and paired samples t-test were employed to investigate the effect of belt squats on PPT levels. A Sidak adjustment was applied to the post-hoc tests for the ANOVA to account for family-wise error. All statistical analyses were performed using IBM SPSS Statistics (IBM Corp, 2020). A *P*-value of less than 0.05 was considered statistically significant. Effect sizes for t-tests were reported as Cohen's d and interpreted according to Cohen's guidelines (Cohen, 2013), where ≥0.20–<0.50 indicates a small effect, ≥0.50–<0.80 indicates a moderate effect, and ≥0.80 indicates a large effect. Effect sizes for ANOVA were reported as partial eta squared (n^2) and interpreted according to John T.E. (Richardson, 2011), where ≥0.01-<0.06 indicates a small effect, ≥0.06-<0.14 indicates a moderate effect, and ≥0.14 indicates a large effect.

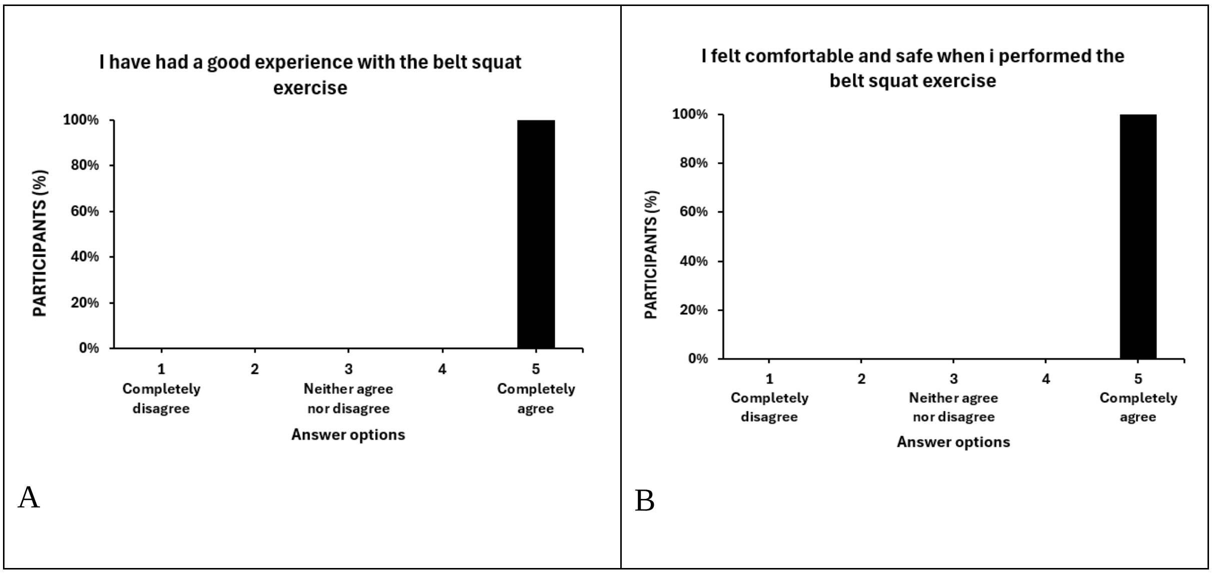
Results

Compliance with the intervention was assessed by the percentage of supervised resistance training sessions that participants successfully completed. The number of scheduled sessions completed by the participants was 96.29% for LBP (10 participants) and 98.33% for HI (15 participants).

Results for LBP group

Feasibility questionnaires

The feasibility assessment of the belt squat intervention (Fig. 3) revealed that participants generally had a positive experience, reporting feelings of comfort and safety during the exercise. The majority of respondents indicated agreement or strong agreement with the intention to continue using belt squats in the future. However, responses regarding the accessibility of the belt squat exercise were mixed, with all answer options being approximately equally represented.



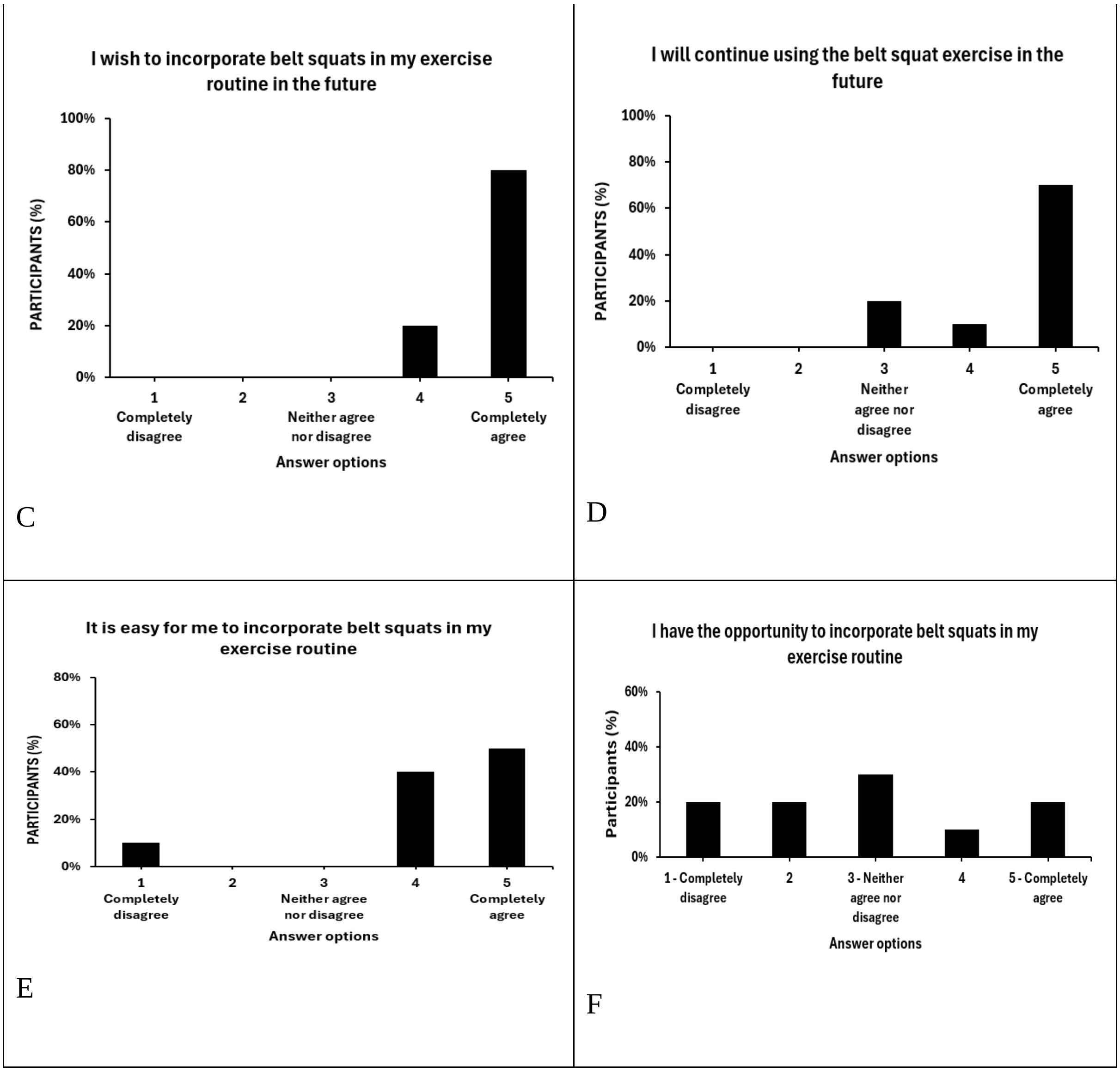


Figure 3. Feasibility questionnaires after a 6 week belt squat intervention for LBP.

Health questionnaires

There were no significant changes from pretest to posttest for the health questionnaires EQ-5D-5L (pre mean=7.4; post mean=7.1; *P*=0.591), "health today" (pre mean=78; post mean=82.5; *P*=0.054), ODI (pre mean=7.9; post mean=8.3; *P*=0.053), and FABQ (pre mean=26.8; post mean=20.3; *P*=0.072). However, the increase in "health today" and decrease in ODI and FABQ scores from pretest to posttest approached statistical significance.

Pressure Pain Threshold

For LBP the difference between the 'before pretest' (408.8 ± 169.8) and 'before posttest' (642.3 ± 187.8) measurements were significant (*P*=0.002) and showed a large effect size (1.362). The difference between the 'after pretest' (428.4 ± 236.8) and 'after posttest' (705.8 ± 245.6) measurements were also significant (*P*=0.017) and showed a large effect size (0.999) (Fig. 4).

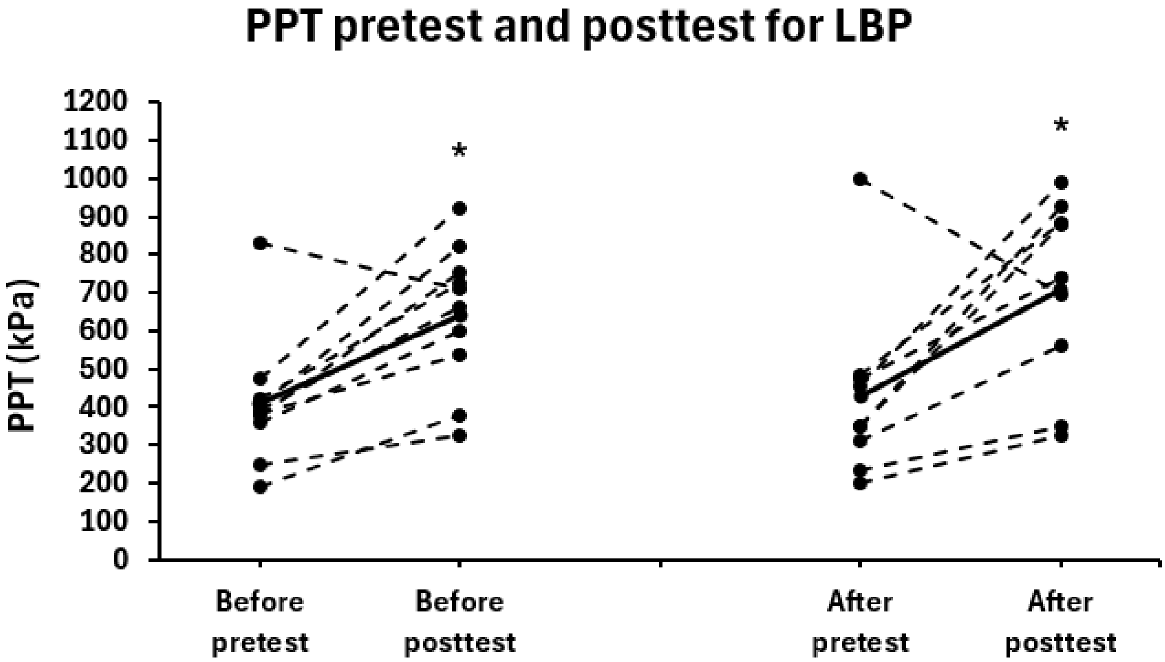


Figure 4. Each LBP participant's PPT levels before the 5 RM pretest and posttest, as well as their PPT levels after the 5 RM pretest and posttest. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means (*P*<0.05).

There were found no significant difference over time for within-subject effects in PPT measures when comparing pre-training measurements with each other (F(1.876, 7.505) = 1.716, *P*=0.243, partial η2= 0.300) and post-training measurements with each other (F(2.257, 9.027) = 2.545, *P*=0.130, partial η2= 0.389) (Fig. 5).

PPT measurements were compared from pre-training to post-training for every training session (Fig. 5). PPT levels were shown to be generally higher post training sessions compared to pre-training sessions. Significant changes were identified in all training sessions (*P*<0.05) except training session 1, 2, 3 and 4 (*P*>0.05).

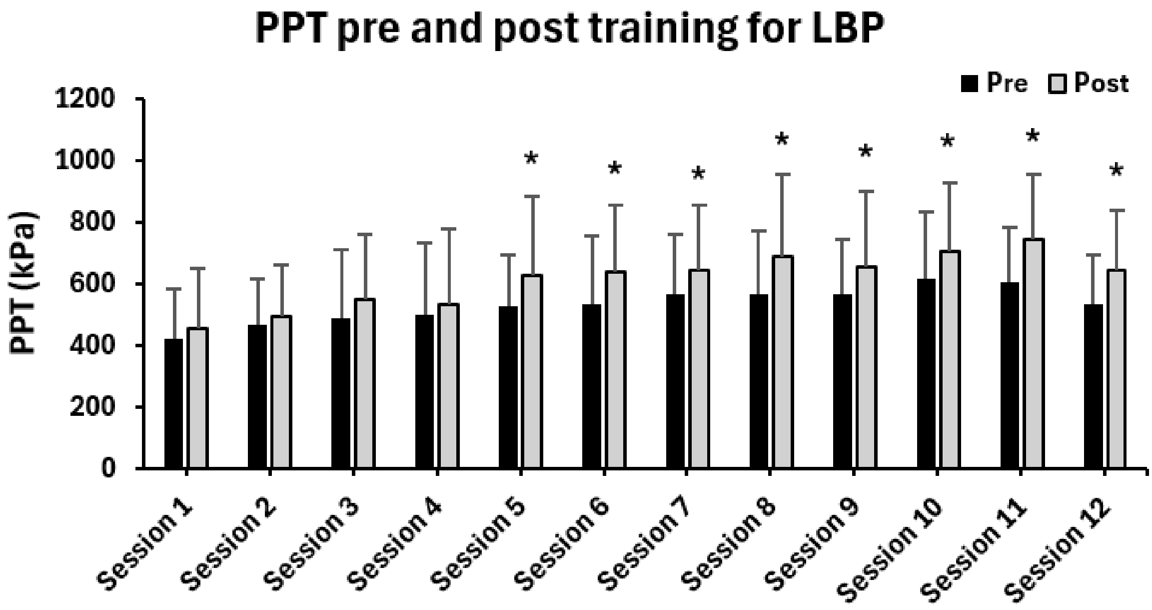


Figure 5. PPT measurements for LBP before and after each training session. *Significant difference between pre session measurement and post session measurement (*P*<0.05).

No significant differences were found in the magnitude of the EIH response (Fig. 6) during the 12 training sessions (F(3.170, 12.680)= 0.757, *P*=0.599, partial η2= 0.159).

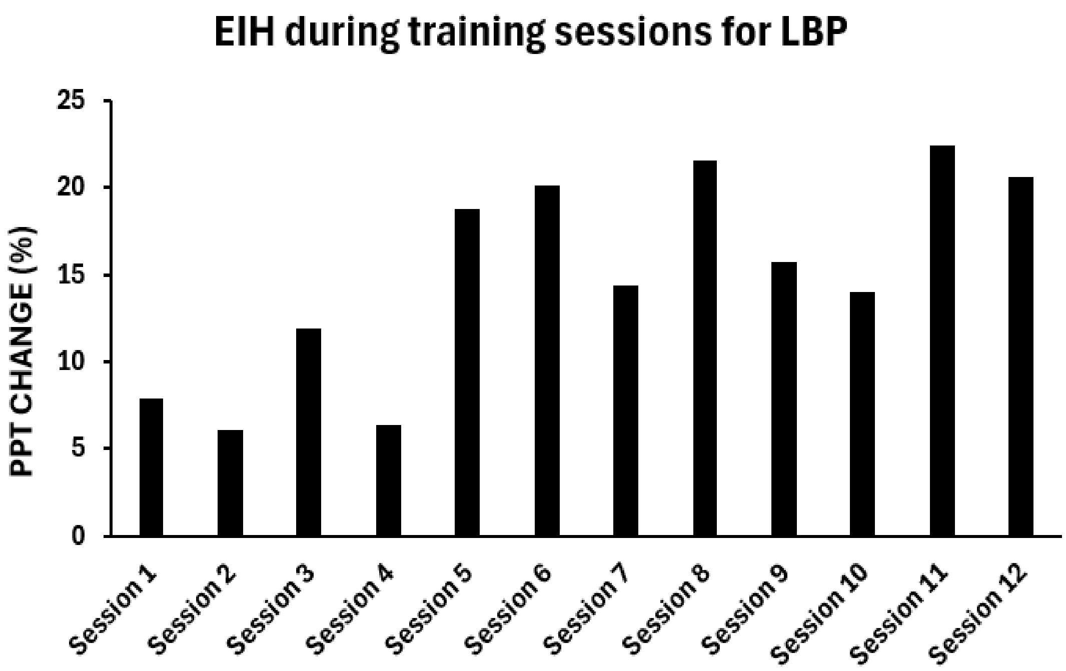


Figure 6. Percentage change in pre- and post PPT measurements (EIH) for each training session.

Standing and dynamic VAS at pre- and posttests

For VAS standing scores, significant differences were found between 'before pretest' (2.11±1.53) and 'before posttest' (0.66±1.11) with P=0.008 and a large ES of 1.169. No significant differences were found for the comparison of 'after pretest' (1.66±1.65) and 'after posttest' (0.44±0.72) with P=0.63 and a medium ES of 0.712 (Fig. 7).

For VAS dynamic scores, significant differences were found between 'before pretest' (3.00±1.63) and 'before posttest' (1.00±0.81) with P=0.038, and a large ES=1.00, as well as between 'after pretest' (2.14±1.46) and 'after posttest' (0.57±0.53) with P=0.033 and a large ES of 1.039 (Fig. 8).

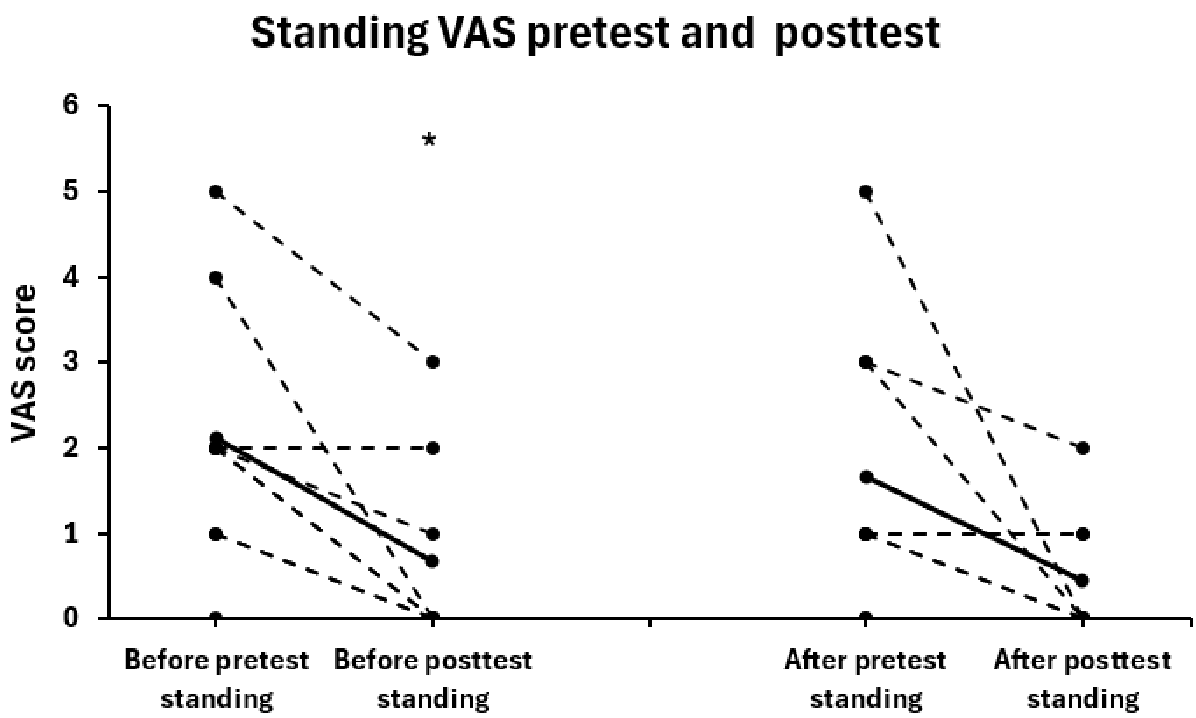


Figure 7. Standing VAS scores before and after the pre- and posttests. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means (P<0.05).

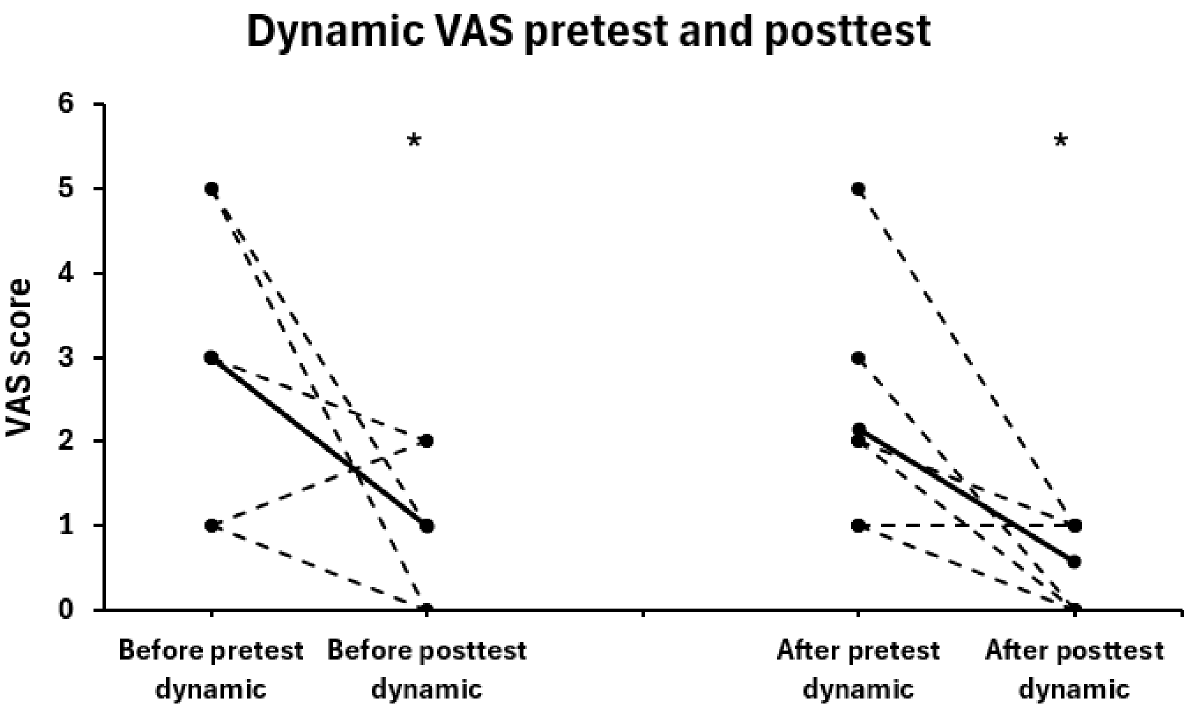


Figure 8. Dynamic VAS scores before and after the pre- and posttests. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means ($P<0.05$).

Standing and dynamic VAS at training sessions

Participants were asked to report their pain level on a Visual Analogue Scale (VAS) both while standing (Fig. 9) (sig. groups: 3, 11, 12; $P<0.05$) and during movement (Fig. 10) (sig. groups: 1, 2, 3, 4, 5, 6, 9, 10, 11, 12 $P<0.05$), before and after each training session. The numeric VAS scores were consistently lower after each training session compared to before the session, with some days eliciting a significant difference.

There was no significant difference over time in standing VAS scores for within-subject effects when comparing pre training scores with each other ($F(3.515, 24.605) = 1.145$, $P=0.356$, partial $\eta2= 0.141$) and post training scores with each other ($F(3.536, 24.749) = 1.132$, $P=0.361$, partial $\eta2= 0.139$).

Likewise, there was no significant difference over time in dynamic VAS scores for within-subject effects when comparing pre training scores with each other ($F(4.117, 24.702) = 2.135$, $P=0.105$, partial $\eta2= 0.262$) and post training scores with each other ($F(3.912, 23.471) = 1.716$, P=0.181, partial η2= 0.222).

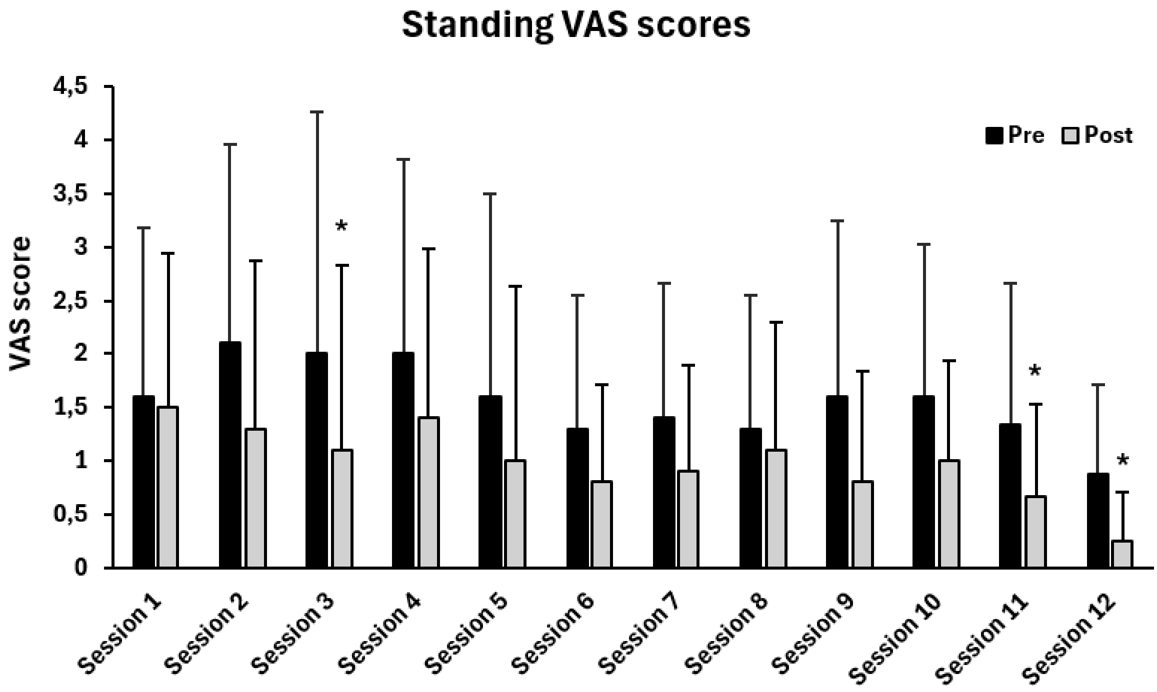


Figure 9. Standing VAS pain scores for LBP before and after each training session. *Significant difference between pre training session and post training session (*P*<0.05).

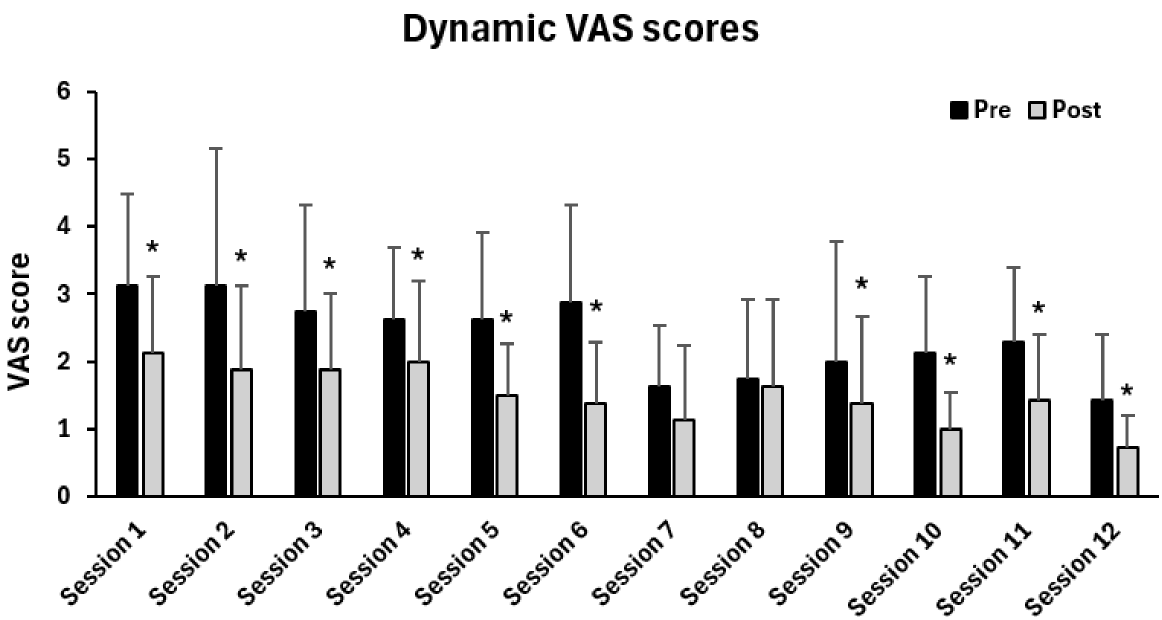


Figure 10. Dynamic VAS pain scores for LBP before and after each training session. *Significant difference between pre training session and post training session (*P*<0.05).

VAS since last session

No sessions were identified as significantly different from each other over time for "pain since last training session" in the LBP group ($F(3.793, 26.550) = 1.595$, P=0.207, partial $\eta2$= 0.186). Fig. 11 illustrates a graphical representation of the progression over all 12 training sessions.

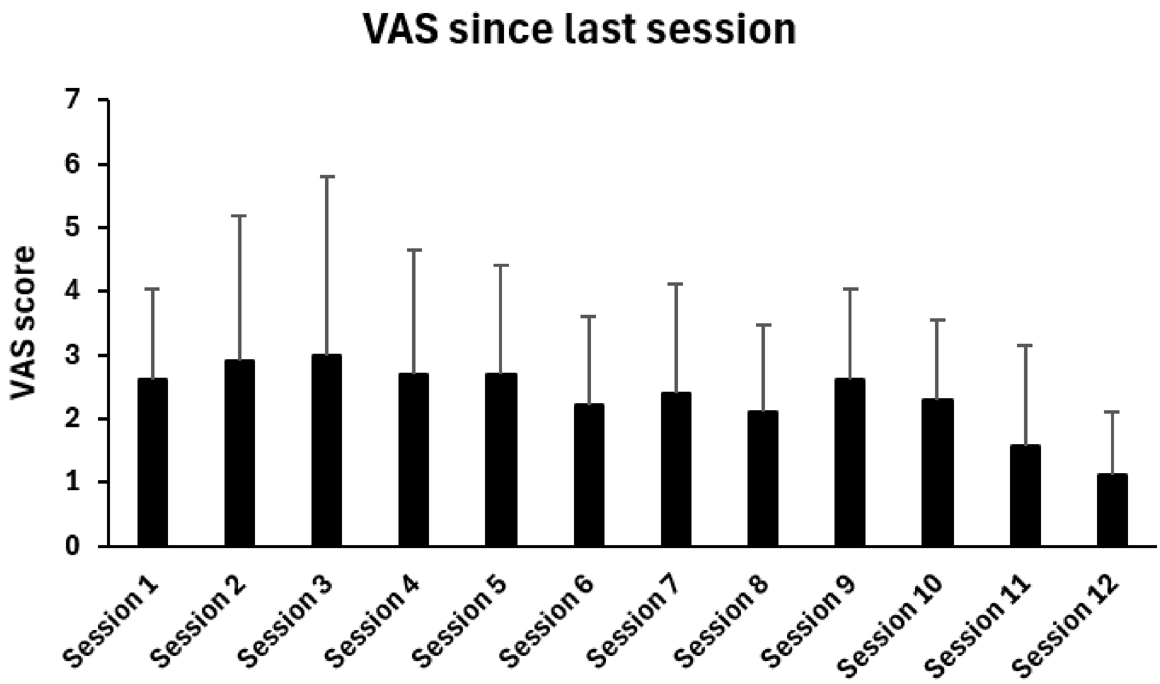


Figure 11. VAS scores for average pain since last training session.

5 RM test

The 5 RM pre- and posttests were compared (Fig. 12). There was a significant difference (P=0.001) from pretest (65.5 ± 29.7) to posttest (91.4 ± 38.8) with a large effect size (1.784).

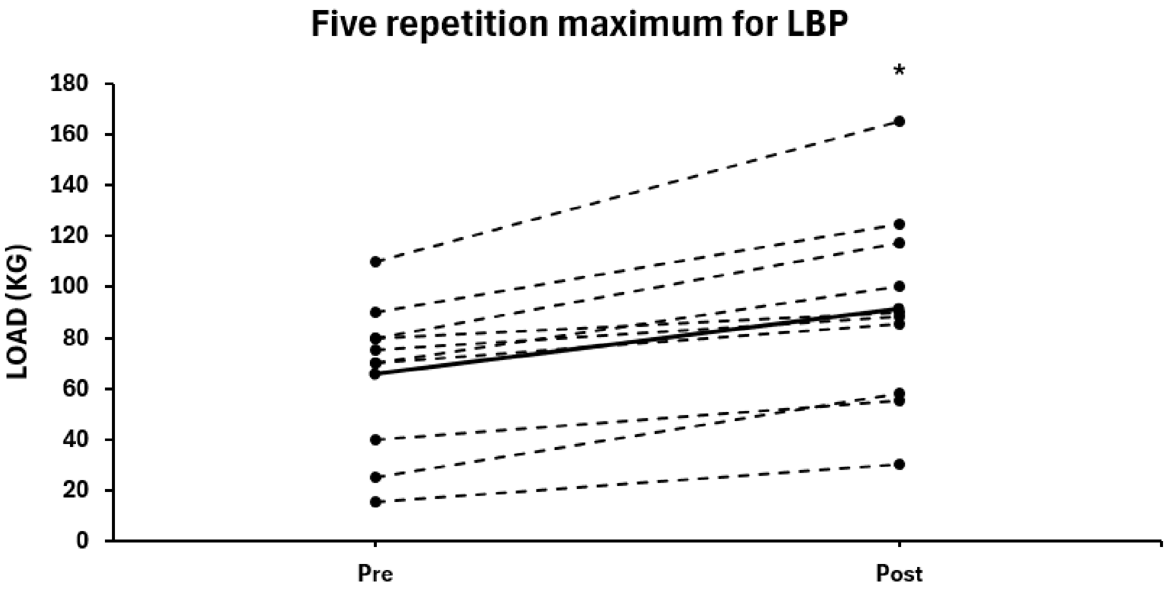


Figure 12. 5 RM measures for LBP from pretest to posttest, measured in kg. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means (P<0.05).

Body composition measurement

There appeared to be no significant changes (kg) in body composition, neither for: Fat mass (Pre = 21.23 ± 8.46; Post = 20.87 ± 8.52; P=0.144, ES = 0.506), Lean mass (Pre = 53.86 ± 10.03; Post = 54.10 ± 10.06; P = 0.213, ES = 0.424), Bone content (Pre = 3.01 ± 0.60; Post = 3.02 ± 0.60; P = 0.379, ES = 0.293) for the LBP participants.

Lumbar flexibility test

A significant increase (cm) in lumbar flexibility for LBP was found from the pretest to the posttest. The difference in flexibility from pre (90.2 ± 12.81) to post (96.4 ± 10.54) with P=0.033 was very close to eliciting a large effect size (0.798).

Healthy Individuals Results

Pressure Pain Threshold

For HI, the difference between the 'before pretest' (482.4 ± 168.6) and 'before posttest' (538.4 ± 232.1) measurements were not significant (*P*=0.161) and showed a small effect size (0.382). However, the difference between the 'after pretest' (494.5 ± 187.3) and 'after posttest' (595.8 ± 263.6) measurements were significant (*P*=0.014) and showed a medium effect size (0.726) (Fig. 13).

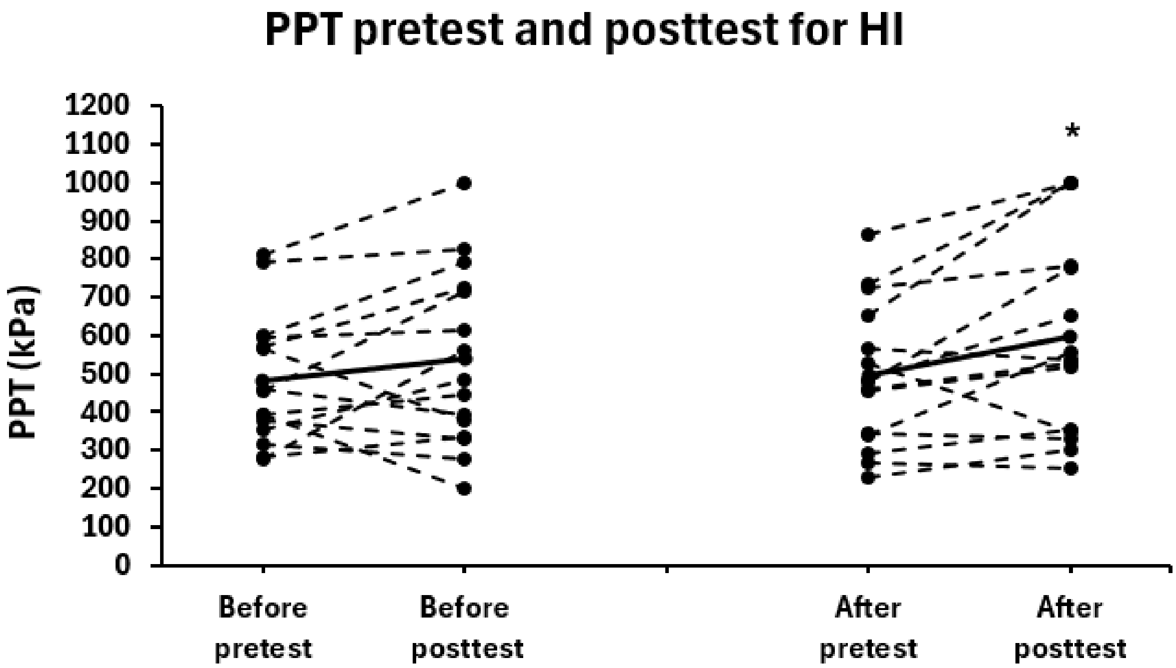


Figure 13. Each HI participant's PPT levels before the 5 RM test at pretest and posttest, as well as their PPT levels after the 5 RM test at pretest and posttest. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means (*P*<0.05).

There were found a significant difference over time for within-subject effects in PPT measures when comparing pre-training measurements with each other ($F(9, 108) = 2.496$, *P*=0.012, partial η2= 0.172) and post-training measurements with each other ($F(2.565, 30,780) = 3.363$, *P*=0.037, partial η2= 0.219) respectively. However, there were no significant differences in pairwise comparison (*P* >0.05) (Fig. 14).

PPT measurements were compared from pre-training to post-training for every training session (Fig. 14). PPT measurements were shown to be generally higher post training session compared to pre-training session. For HI, significant changes were identified in all training sessions (P<0.05) except training session 7 (P=0.170).

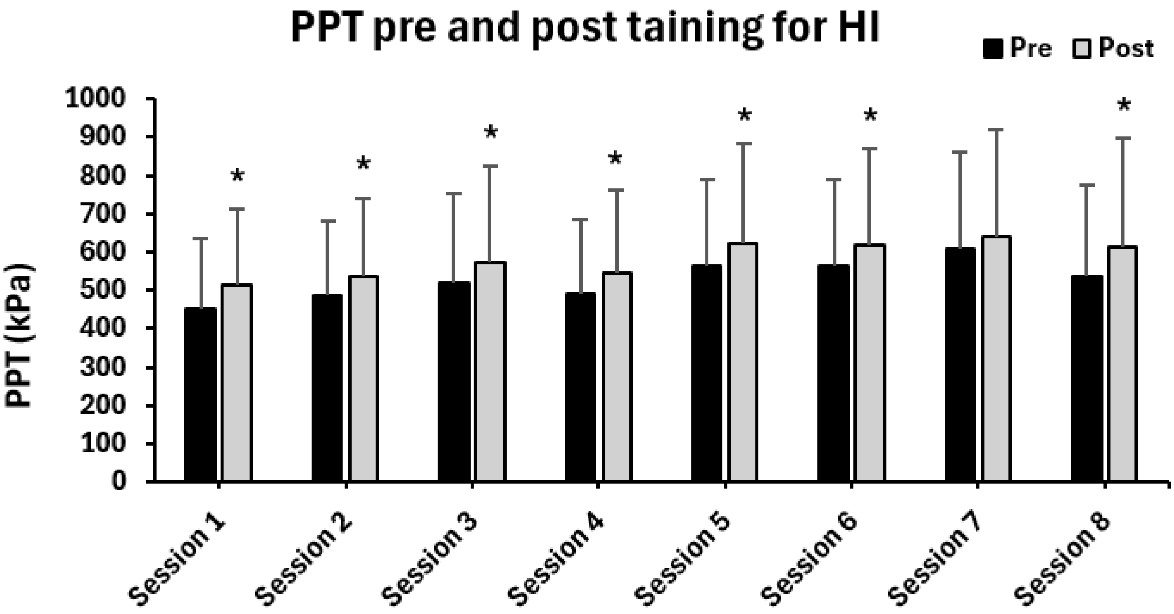


Figure 14. PPT measurements for HI before and after each training session. *Significant difference between pre training session measurement and post training session measurement (P<0.05).

No significant differences were found for HI in the magnitude of the EIH response (Fig. 15) during the 8 training sessions (F(3.116, 31.163) = 0.575, P=0.642, partial η2= 0.054).

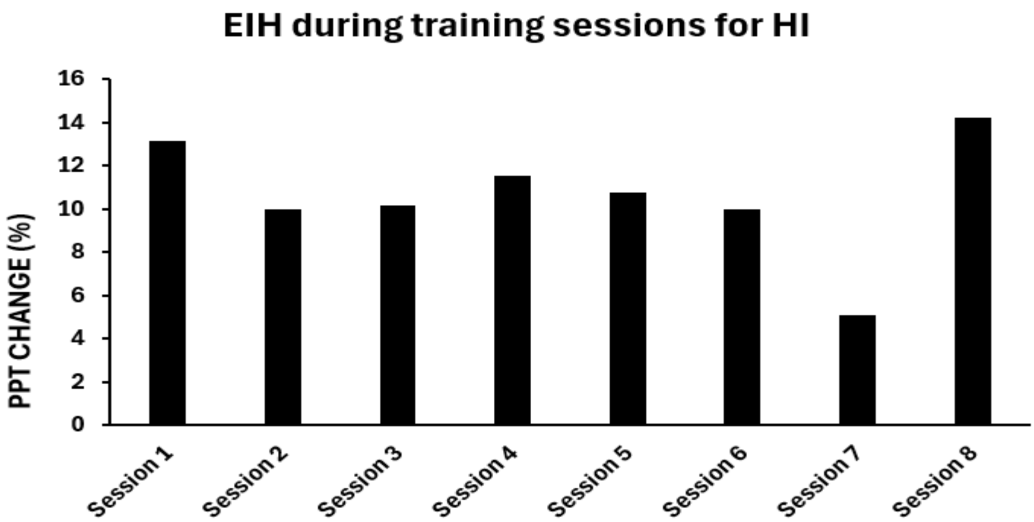


Figure 15. Percentage change in pre- and post PPT measurements (EIH) for each training session.

5 RM Test

The 5 RM pre- and posttests were compared (Fig. 16). There was a significant difference (P=0.001) from pretest (93.4 ± 39.5) to posttest (113.4 ± 40.04) with a large effect size (1.723).

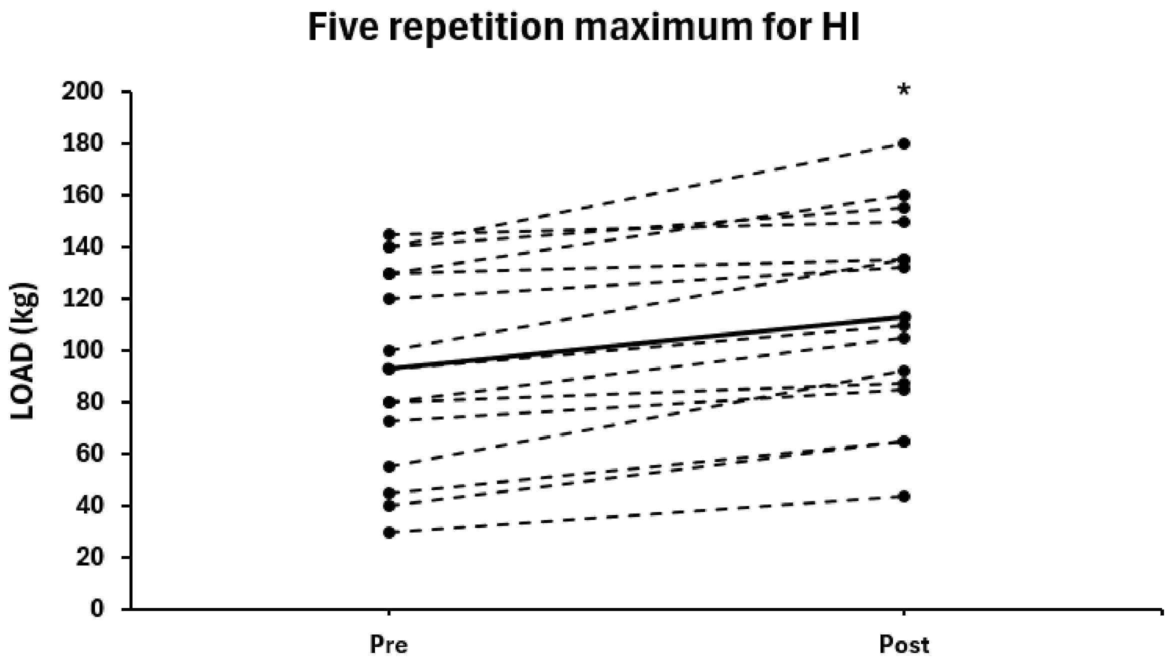


Figure 16. 5 RM measures for LBP from pretest to posttest, measured in kg. The highlighted line represents the mean difference from pretest to posttest. *Significant difference between pretest and posttest means (P<0.05).

Body composition measurement

There were no significant changes (kg) in body composition, neither for: Fat mass (Pre = 21.06 ± 9.59; Post = 20.79 ± 8.81; P = 0.452, ES = 0.200), Lean mass (Pre = 62.27 ± 12.51; Post = 62.81 ± 12.66; P = 0.131, ES = 0.414), Bone content (Pre = 3.38 ± 0.58, Post = 3.38 ± 0.58; P = 0.966, ES = 0.011) for the HI group.

Discussion

The aim of this study was to test the feasibility of LBP participants using the belt squat exercise and to investigate how their pain changed during a 6 week training intervention. A secondary aim was to investigate whether PPT measures and the magnitude of EIH changes during a training intervention. The belt squat intervention was feasible for the LBP participants who all reported having a positive experience and feeling safe using the exercise. Furthermore, most participants wanted to continue using the exercise although a minority didn't have this opportunity.

To the authors knowledge, no previous studies have assessed the feasibility of individuals with LBP engaging in the belt squat exercise, as part of an exercise protocol. However, previous research has established that resistance training is a feasible form of exercise for patients with LBP (Tjøsvoll et al., 2020; Verbrugghe et al., 2018), which is in line with the results of this study.

The fact that all LBP participants had a positive experience with the belt squat exercise (Fig. 3A) aligns well with the significant EIH responses during most training sessions and reductions in pain levels after the sessions. Pain during physical activity frequently leads to inactivity in patients with chronic pain (LaRowe & Williams, 2022), so it makes sense that an exercise which provides pain relief results in a positive perception of that exercise. Additionally, all LBP participants reported feeling comfortable and safe using the exercise. This might have been due to them not getting hurt and the reduction in pain they experienced, as well as having handles for support and the constant supervision in all training sessions. However, had the belt squats induced pain in the participants, these indications might not have been sufficient to deem it feasible. Therefore, the inherent reduction in spinal loading is a critical mechanism in differentiating belt squats from traditional back squats, increasing the suitability for individuals with LBP. The participants exercised with heavy loads for multiple sets, but were still able to tolerate the intervention, which might be partially attributed to the minimal forces on the spine acquired from the belt. These findings suggest that the use of belt squats might allow individuals with chronic non-specific LBP to exercise lower extremities with high intensity without exacerbating their pain condition, potentially guiding future recommendations in the area.

The PPT levels of the LBP group increased significantly when comparing pre- and posttests but they did not increase significantly when comparing training sessions over time. Furthermore, the belt squat intervention produced significant EIH responses within training sessions in both LBP, but no significant change was found in the magnitude of the EIH response throughout the intervention. For HI, an increase was also found on both comparisons between PPT levels in the pre- and posttests, although only significant in the comparison between the after-pretest and after- posttest measurements. All other results for HI on PPT levels are similar to the results of the LBP group. This indicates that the belt squat intervention had a measurable effect on PPT levels for HI.

EIH generally occurs in pain free subjects (Vaegter & Jones, 2020) which is in accordance with the findings of this study. However, in patients with chronic pain, exercise can lead to both hypoalgesia, reduced hypoalgesia and hyperalgesia (Vaegter & Jones, 2020). Whether the PPT levels and magnitude of EIH response increase during a training intervention of several weeks is not yet entirely known in the literature (Song et al., 2023). Nevertheless, we have demonstrated that it is indeed possible to train one's PPT level. To our knowledge, no research has previously examined this aspect of pain sensitivity longitudinally or as an intervention study like ours, which highlights the importance of the current investigation.

Even though it is not entirely clear in the literature which mechanisms might explain the EIH response, a plausible explanation for the EIH response in both groups might be due to enhanced descending inhibition through activation of opioid- and cannabinoid systems (Vaegter & Jones, 2020). When skeletal muscle contracts, the discharge of mechanosensitive afferents (A-delta and C fibres) is increased, which activates central descending opioid pain pathways (Dietrich & McDaniel, 2004; Thorén et al., 1990). Furthermore, exercise results in an increase of endogenous cannabinoids being released. The aforementioned opioid and cannabinoid pathways have receptors throughout both the peripheral and central nervous systems that produce analgesia when stimulated (Dietrich & McDaniel, 2004; Thorén et al., 1990), which might explain why pain sensitivity is lowered after the belt squat exercise in both groups.

The pre- and posttests indicate a difference in PPT levels from before to after the intervention, with most comparisons being statistically significant. Several factors may explain why we did not observe a similarly significant increase in either the magnitude of EIH or in PPT levels when comparing pre-training session levels with each other and post-training session levels with each other. One reason could be differences in the training protocols. The tests usually involved several sets at near maximum intensity in order to establish a 5 RM, while the training sessions generally had a slightly lower overall volume and progressed from lower to higher intensity over the six-week period. Moreover, we observed that a significant EIH response emerged primarily during the later training sessions for the LBP group (fig. 5), which may be linked to the gradual increase in absolute training intensity, possibly suggesting that intensity plays a role in producing significant EIH responses. Despite these variations, the significant changes between the pre- and posttest measurements suggest that PPT levels might be trainable over time.

Although we demonstrated that the current belt squat intervention increased PTT-levels from pretest to posttest, it is still possible that these LBP participants may respond differently compared to healthy individuals, due to their chronic pain condition. Nevertheless, the HI group showed that they also responded positively to the belt squat intervention, suggesting that it might be possible to train the PPT-response and, consequently, pain sensitivity, in both healthy individuals and individuals with chronic low back pain. Furthermore, the observed decrease in VAS scores, along with the improvements in ODI, FABQ, and "Health-Today" scores, support the notion that LBP participants experienced an overall improvement in these measures. These improvements across multiple measures suggest that the intervention not only impacted PPT levels but also positively affected overall pain perception and health outcomes.

For both static and dynamic VAS scores, there was a significant decrease in pain intensity when comparing pre- and posttest measurements, except for the decrease between the ‘after pretest’ and ‘after posttest’ assessments which was insignificant. For the training sessions, certain days exhibited significant changes from pre- to post-training, while others remained statistically insignificant. However, there was a consistent decrease in VAS scores across all days, with the significant changes being more pronounced in the dynamic scores. No significant results was found for the average pain since last session score, nor when comparing pre-session scores with each other or post-session scores with each other, neither for the standing nor dynamic assessment.

The results of this study correspond well with a previous study that has shown significant reductions in pain, as measured by the VAS, in participants with chronic pain after resistance training (Larsson et al., 2015).

Even though the participants of this study had relatively low VAS scores compared to participants in other studies (Aoki et al., 2012), significant positive changes in VAS scores from before training session to after training session were still observed, which corresponds greatly with the significant responses in EIH. Changes in average pain over time since last session might not have been significant due to the fact that 5 participants had several VAS scores in the lower end of the scale (0-1) which makes it less likely that significant improvements will occur. Even though this makes the belt squat exercise appear less effective in alleviating pain, the authors decided not to set a minimal limit of VAS score in order to keep the biggest possible data sample. The low VAS scores of the LBP group might be explained by the fact that people with severe debilitating back pain may not want to test out a new training intervention and therefore the LBP participants of this study are generally not too troubled by their pain.

The positive changes in VAS scores might be explained by the fact that regular exercise is known to reduce the expression of the serotonin transporter, increasing serotonin levels and additionally increasing opioids in the central inhibitory pathways which includes the Periaqueductal grey (PAG) and the Rostral ventromedial medulla (RVM). This suggests that the LBP participants are able to utilize their body's own endogenous inhibitory systems when reducing pain (Lima et al., 2017). The fact that not all training sessions produced significant positive changes in VAS scores might be explained by the balance between inhibition and excitation in the central nervous system which in turn determines whether exercise promoted analgesia or pain in the training sessions (Lima et al., 2017).

There were no significant changes for the health questionnaires ODI, FABQ, EQ-5D-5L nor in the "health today" scores. However, the improvements in "health today", ODI and FABQ scores approached statistical significance, indicating an improvement on measures for general health and functionality. Interestingly, the VAS scores and PPT levels in the pre- and posttests show the same positive tendencies as the questionnaires. This may be explained by the fact that the questionnaires, especially ODI, assess pain related factors. Additionally, Ekediegwu et al. (2024) found a correlation between pain intensity, physical activity, and disability. The results of the study showed that increases in pain intensity led to a reduction in physical activity levels, quality of life, and directly leading to an increased disability. These findings align with this study's results, which show a tendency that lower pain sensitivity and VAS-scores seem to be associated with improved scores on the questionnaires. The average ODI score for the study's participants was 7.9 at the pretest, indicating a mild disability (Fairbank et al., 1980; Fairbank & Pynsent, 2000), while the average FABQ score was 26.8, indicating a low level of fear-avoidance beliefs (Wertli et al., 2014). Although the changes from pre- to posttest "only" approached statistical significance, the intervention shows promising results, especially considering the participants' low levels of disability. It is possible that a longer intervention period and a group of participants with higher disability levels might elicit a significant change.

Although there were interindividual differences in strength gains, both groups saw significant increases from the 5 RM pretest to the 5 RM posttest. The improvements in strength gains were greater in the LBP group, which along with the results from the feasibility questionnaire signifies that the belt squat training intervention was both feasible and even more effective in improving strength in LBP than in HI.

For both fat mass, fat-free mass, and bone content, there were no significant differences from pretest to posttest in both groups. A systematic review concluded that the optimal number of weekly sets is 12-20 pr. muscle group, to optimize muscle hypertrophy in young, trained men (Baz-Valle et al., 2022). This might explain why no significant changes in muscle mass was seen in this study, as only 6 weekly sets were performed and the vast majority of the participants in both groups were advanced or highly advanced young adult trainees. Furthermore, the insignificant gains in muscle mass can be explained by the fact that the training intervention may have been too short, as it takes between 6-10 weeks before muscle mass increases to a point where it can be measured (Damas et al., 2018). Additionally, bone content did not change significantly in both groups, which corresponds with evidence suggesting that it takes at least four to six months for bone mineral density to change significantly (McNeely, 2010).

A significant increase in lumbar flexibility was found from pre- to posttest in the LBP participants. This might be attributed to resistance training being equally as effective in improving range of motion as stretching (Afonso et al., 2021). Strength training that is focused on eccentric and concentric contractions has been shown to increase the length of the fascicles (Bourne et al., 2017; Marušič et al., 2020; Valamatos et al., 2018), possibly affecting the gluteus and hamstring muscles during the belt squat intervention. The authors of this study propose that the flexibility of the hamstring and gluteus muscles may have played a role in the results of the lumbar flexibility test, as it does not measure lumbar flexibility in isolation.

Limitations

This study has some limitations. Foremost, the absence of control groups for both the LBP and HI groups makes it difficult to attribute changes in the intervention group only to the belt squat exercise, as other factors might impact the results (Joy JE et al., 2005). Therefore, we cannot infer causality from the belt squat intervention and the results seen in the dependent variables. Nevertheless, the primary aim of this study, which is to test the feasibility of LBP participants performing the belt squat exercise, showed promising results. Future studies therefore ought to address this limitation by validating the findings in a randomised controlled trial, which should include a control group and more participants.

In both groups the majority of the participants were experienced or highly experienced, and thus may have already decreased their pain sensitivity and increased the magnitude of their EIH response through their own previous training. This might possibly explain why increases in PPT levels were only significant from pre- to posttest, and not when comparing PPT levels between training sessions. Conversely, if both groups had consisted solely of beginners, there might also have been a statistically significant increase in EIH during the training intervention. Another limitation that might have impacted the results from the LBP groups is the fact that most of the participants in the LBP group exhibited a mild level of disability according to the ODI. Additionally, several participants reported some VAS scores in the lower end of the scale (0-1) and engaged in sports recreationally. No participants were unable to work due to pain or disability. This is in contrast with the typical LBP patient who is often, to a varying extent, disabled in movement and work, and experiences substantial pain (Balagué et al., 2012). This represents a discrepancy between the typical LBP patient and the LBP participants of this study, possibly diminishing the ecological validity of the results (Andrade, 2018), thereby making them harder to apply to the typical LBP patient.

Conclusions

In conclusion, the belt squat training intervention was feasible for LBP participants to perform, based on feasibility questionnaire outcomes as well as improvements in health questionnaires. The belt squat intervention revealed significant improvements in VAS-scores and PPT levels from pretest to posttest. Furthermore, a significant EIH response occurred during most sessions, although the magnitude of EIH and the average VAS score since last session did not change over time. The HI group seems to respond similarly to LBP in terms of occurrence of EIH as well as improvements in PPT levels, strength measures, and body composition. It thus appears that the belt squat training intervention can mediate a change in pain sensitivity, which might explain the mechanism behind the pain alleviating effects of resistance training in individuals with chronic non-specific LBP. The large effect sizes in pain sensitivity and strength, along with a nearly large effect size in flexibility for the LBP group suggest that the intervention is effective and practically useful for managing LBP, which highlights its potential clinical application.

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