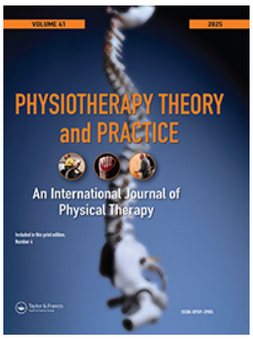

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CASE REPORT

Understanding responsiveness to an exercise intervention for people with persistent low back pain and lateral abdominal muscle impairments. A mixed methods study

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ABSTRACT

Background: Exercise consistently demonstrates a small effect size for patients with persistent low back pain (PLBP). Determining patient characteristics that influence intervention responsiveness may improve treatment allocation and effect sizes. An exercise intervention for patients with PLBP and maladaptive changes in lateral abdominal muscle (LAM) contraction was recently trialed.

Objective: To identify factors predicting responsiveness to an exercise intervention for patients with PLBP and why.

Methods: This was a secondary mixed methods analysis of results from a feasibility randomized controlled trial with 50 participants. The 12-week program included individualized motor control and graded activity exercise. Regressions were performed to understand potential associations between characteristics (demographic, condition-specific signs and symptoms, compliance with exercise, and beliefs about exercise) and outcomes (pain, function, disability, and LAM contraction). Interview transcripts were analyzed for characteristics unique to participants that responded most and least to the intervention. Data was integrated for complementarity.

Results: At baseline, females, participants with lower BMIs, decreased chronicity, fewer areas of pain, who had less previous interactions with healthcare professionals, and who were more positive about the potential for exercise to improve their pain had greater responsiveness (Adjusted R^2 ranged from 0.17 to 0.66). During and after the program, increased physical activity levels was a positive predictor.

Conclusion: Responsiveness to the intervention may have been mediated by several baseline factors which may have affected participants' engagement with the intervention and continuation with exercise post intervention. Such characteristics may assist clinicians identifying whether this may be an appropriate intervention for patients with PLBP.

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Introduction

Various forms of exercise are consistently recommended in clinical practice guidelines for the treatment of persistent low back pain (PLBP) (National Institute for Health and Clinical Excellence UK, 2016, Zaina et al, 2023). However, systematic reviews remain inconclusive regarding whether there is a superior exercise prescription (Bystrom, Rasmussen-Barr, Johannes, and Grooten, 2013; Ford et al, 2020; Gomes-Neto et al, 2017; Searle, Spink, Ho, and Chuter, 2015; Shanbehzadeh, Hides, Ebrahimi Takamjani, and Rasouli, 2022; Zhang et al, 2021). Additionally, such reviews commonly find generically applied exercise programs demonstrate small effect sizes for patients with PLBP (Hayden J, 2005; Saragiotto et al, 2016). Therefore, researchers have suggested that treatment effectiveness may be improved where exercise is tailored to the individual's presentation (Van Dieen et al, 2019a). Consistent with this, a meta-regression found that tailored exercise programs have larger effect sizes in a PLBP population (Hayden, van Tulder, and Tomlinson, 2005). Therefore, research is now prioritizing the investigation of whether people with PLBP and certain characteristics respond better to specific treatments (Costa et al, 2013; Hodges, 2019).

A characteristic present in some individuals with PLBP is maladaptive changes in trunk muscle activation or contraction (Van Dieen et al, 2019b). Such changes may be due to nociception (Hodges, Moseley, Gabrielsson, and

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Gandevia, 2003), injury to tissues with sensory receptors (Panjabi, 2006), and functional adaptations (Linek et al, 2020). Maladaptive muscle activation may then perpetuate pain due to increased or altered loading of the lumbar spine tissues (Van Dieen et al, 2019b). For pragmatic reasons, studies often limit their investigation of the many trunk muscles into muscle groups. One muscle group that has received attention in the literature is the lateral abdominal muscles (LAM, transversus abdominis [TrA], internal [IO], and external oblique [EO]). Published exercise frameworks that consider maladaptive changes in motor control include Specific Treatment of Problems of the Spine protocol (STOPS.physio group), Motor Control Training (Hodges, 2016), The McGill Method (McGill, 2007), The Integrated Systems Model (Lee, Lee, and Vleeming, 2011), and the Movement Systems Impairment Syndromes of the Lumbar Spine (Sahrmann, 2002). Such frameworks have many similarities regarding individualizing assessment, treatment, and developing therapeutic rapport. However, they emphasize different aspects of exercise prescription, for example, whether to incorporate specific muscle activation exercises (Hodges et al, 2013).

Preliminary evidence suggests that allocation of individuals with maladaptive changes in motor control to such motor control exercise programs may be associated with increased effectiveness. For example, improved one-year follow-up TrA slide was associated with reductions in pain for participants who had low baseline TrA slide (Unsgaard-Tondel, Lund Nilsen, Magnussen, and Vasseljen, 2012). Also, patients with a higher score on a questionnaire indicative of clinical lumbar instability were more likely to respond better to motor control exercises compared to graded activity (Macedo et al, 2014). However, to the best of our knowledge, no research has examined the effectiveness of exercise in a specific sample of patients with PLBP and maladaptive LAM contraction.

Recently, a framework for individualizing exercise prescription was developed for such patients. This framework was based upon two reviews of the literature and a Delphi study in consultation with clinical practice guidelines (manuscripts under consideration). It incorporates individualized motor control and graded activity exercise. A feasibility study was undertaken to produce preliminary insights into how participants responded to the exercise framework. This included consideration of quantitative data on changes in LAM contraction. LAM contraction was measured during the abdominal drawing in maneuver using various methods including: ultrasound imaging of changes in muscle thickness and TrA slide, pressure biofeedback, and manual palpation with the Deep Muscle Contraction Scale (Oliveira et al, 2017). The reliability of all measures was tested prior to the study with moderate to good reliability for ultrasound imaging measures of muscle thickness (ICC 0.6–0.8), poor reliability for muscle slide (ICC 0.4), and moderate reliability for pressure biofeedback and the Deep Muscle Contraction Scale (ICC 0.7). Additionally, data was collected on patient reported outcome measures as well as qualitative data on participant experiences (manuscripts under consideration). Quantitatively, it was anticipated that the homogenous study population (i.e. patients with maladaptive changes in LAM contraction) would demonstrate an increased treatment effect, compared to previous studies, but this was not evident from the study results. While the program has the potential to improve desired outcomes, such as pain and function, individuals demonstrated varying responses.

To understand why participants responded inconsistently to this framework, a secondary analysis of the data was preplanned. The rationale for this analysis was twofold. First, knowing characteristics that affect responsiveness to this framework could further improve treatment allocation. Second, to determine if any refinements should be made to the framework to improve effectiveness for patients that are less likely to respond.

Whilst either quantitative or qualitative methods can be used to examine responsiveness, the authors decided that neither was superior to address the aims of this study. Therefore, the authors considered it advantageous to mix quantitative and qualitative data to achieve complementarity (Greene, Caracelli, and Graham, 1989). Simply stated, the two methods had the potential to examine similar, but different facets of "responsiveness" to yield a more comprehensive understanding. Due to the integration of quantitative and qualitative methods within the one study, this study was classified as a mixed methods rather than a multi-methods design. The purpose of these analyses was exploratory in nature. However, changes in LAM contraction were hypothesized as predictors of changes in pain, disability, and function. This is because the intervention aimed to improve LAM impairments under the assumption these may be contributing to participants' PLBP. This was limited to changes in LAM contraction, as, participants mostly did not display atrophy or hypertrophy in LAM thickness compared to asymptomatic people without PLBP.

The aims of this study included: 1) To identify any quantitative associations between participant characteristics and changes in pain, disability, function, and LAM contraction outcomes. 2) To identify if there were any unique qualitative themes among participants that demonstrated the most and least improvements in pain, disability, function, and

LAM contraction from the intervention. 3) To integrate the above quantitative and qualitative findings to identify what factors predict responsiveness to the intervention and why.

Materials and methods

This study utilized a convergent parallel mixed-methods approach (Creswell and Plano Clark, 2018). Qualitative and quantitative data were collected and analyzed separately and then merged for interpretation (Figure 1). Quantitative and qualitative findings were of equal importance. The researchers followed the theoretical perspective of pragmatism. This enabled mixing quantitative and qualitative data through several assumptions. The first being abduction, connecting the different data points by moving between deductive and inductive reasoning (Morgan, 2007). Second, considering factors that contributed to "responsiveness" to be neither completely objective nor subjective, instead

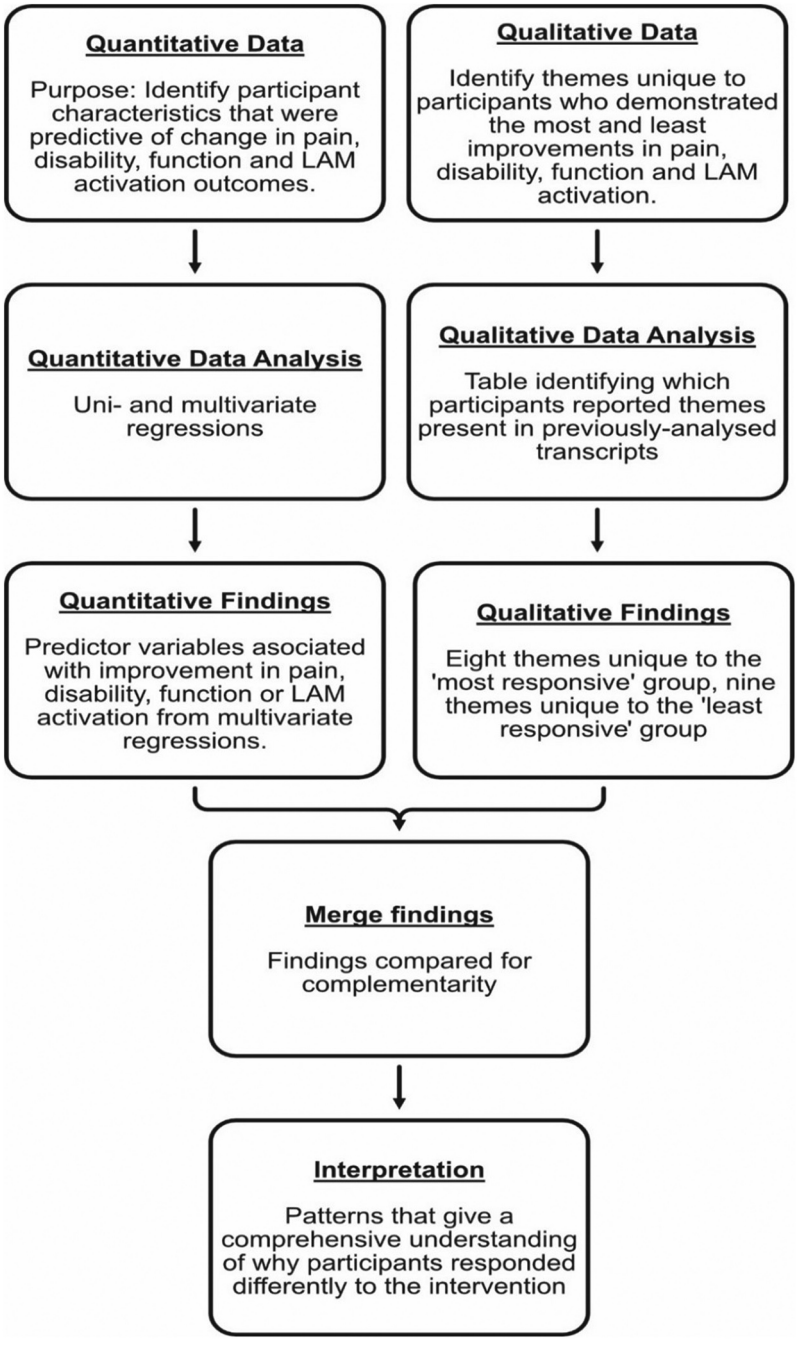

Figure 1. Convergent mixed methods design used during this feasibility study. Based upon the design proposed by Creswell and Plano Clark (Creswell and Plano Clark, 2018).

emphasizing an intersubjective approach (Morgan, 2007). Finally, inferences from data were not believed to be context-dependent (qualitative assumption) or generalizable (quantitative assumption). Instead, findings were considered potentially transferrable if a similar program was conducted in a different context (Morgan, 2007). This study follows the mixed methods reporting in rehabilitation and health sciences checklist (Appendix A) (Tovin and Wormley, 2023). Data analysis was undertaken by CP who also conducted quantitative and qualitative data collection.

Intervention

Data from this study were from a feasibility study evaluating participant responses to an individualized exercise program designed for participants with PLBP and maladaptive changes in LAM contraction. The trial was prospectively registered on the Australian and New Zealand Clinical Trial Registry (ACTRN12622001284752) and approved by the University of South Australia Human Research Ethics Committee (204929). Table 1 describes the intervention. All data were collected at the University of South Australia and interviews were audio recorded.

Participants

Convenience sampling was used. To capture a range of participants, participants were recruited through flyers, word of mouth, and social media advertisements posted on Facebook, at the University campus, and the University volunteer research website. Flyers and advertisements were posted via the lead researcher (CP) and the University research marketing team. These broad range of recruitment methods were used to recruit a variety of participants. All participants provided informed consent prior to the study. The eligibility criteria for the feasibility study can be found in Table 2.

Sample size

As understanding responsiveness was considered secondary to evaluating the intervention's feasibility, a priori sample size calculation was performed for the aims of the feasibility study. Sample size calculations were conducted according to the framework Lewis et al. (2021) proposed for feasibility studies. The required sample size assuming an alpha of 0.05 and power of 80% for the feasibility outcomes described below were as follows: to determine participant retention – 56, to determine exercise compliance – 34 (for experimental arm, therefore a total of 68 participants). It was decided to use the criterion requiring the highest numbers (exercise compliance). Assuming potential attrition of up to 15%, it was aimed to recruit 80 people.

Retention and exercise compliance outcomes were assessed using several assumptions. Retention was considered feasible if: At least 85% of people enrolled in the study were retained. Retention was not considered feasible if: Less than 70% of people enrolled in the study were retained. These criteria were developed considering attrition bias is unlikely to affect the study where attrition does not exceed 20% and 15%, respectively (Furlan et al, 2009;

Table 1. Description of the exercise intervention.

Brief Name	Individualised exercise for patients with persistent low back pain and maladaptive changes in lateral abdominal muscle contraction
Why	Persistent low back pain creates a substantial personal and economic burden and is extremely prevalent. While education and exercise are recommended, optimal exercise prescription/s remain unclear. A program developed for patients with maladaptive changes in lateral abdominal muscle contraction has been developed, but not yet evaluated
What materials	Individual appointments with a physiotherapist to design and progress an individualized exercise program. The program incorporated posture, movement, muscle activation, cardiovascular and resistance exercises Pain neuroscience-based education about low back pain Diary to record exercise compliance
What procedures	Participants were randomized to experimental or control groups using simple randomization. All participants met with the physiotherapist in person for the first appointment to collaboratively develop the program. Subsequent appointments were in person, or via telehealth. Appointments were weekly for the first month, fortnightly in the second month and on one occasion in the final month. During each appointment the program was adjusted or progressed according to the individual's needs and education was provided regarding the rationale for the exercises Participants in the control group completed the same program, but the physiotherapist did not discuss/attempt to incorporate the participant's preferred type of exercises into the program
Who provided	A physiotherapist (tertiary qualified) who designed the program
How	In subsequent appointments, the program was modified and progressed according to individual needs
Where	At the University of South Australia Clinical Trial Facility
When and how much	All participants received seven sessions with the physiotherapist The initial consultation was 60 mins and subsequent appointments were 30 mins
Tailoring	The program was individualized to participant's symptoms, impairments, fitness, abilities and lifestyle. Participants in the experimental group had their preferred types of exercise incorporated in the program. This was not discussed with the participants in the control group.

Table based on the Template for Intervention Description and Replication Checklist (reference (Hoffmann et al, 2014).

Table 2. Eligibility criteria.

Inclusion	Having pain for at least 12 weeks, located between the buttock crease and lower ribs, with or without pain in one or both legs. (Hartvigsen et al, 2018)
	Aged 18 years or above.
	Able to speak English to communicate with a physiotherapist.
	Considered "ready to exercise" based on screening with the Physical Activity Readiness Questionnaire.(Warburton, Jamnik, Bredin, and Gledhill Nobot, 2011)
	Demonstrated maladaptive changes in LAM contraction and/or thickness
Exclusion	Demonstrated two or more signs of nerve root compromise for the same nerve root (weakness, loss of sensation or changes in reflexes)(Macedo et al, 2021).
	Were pregnant or had given birth within the last year.
	Had potential or diagnosed serious pathology (cancer, cauda equina syndrome, fractures, infections).
	Had systemic inflammatory conditions such as rheumatoid arthritis.
	Had abdominal skin conditions which would preclude participants from having LAM ultrasound imaging.
	Had comorbidities which prevented participants from participating in exercise e.g. spinal cord injury, or an assessment by a general practitioner found that the participant was unsuitable to participate in the exercise program. Participants were advised to seek medical assessment if required from the results of the Physical Activity Readiness Questionnaire (Warburton, Jamnik, Bredin, and Gledhill Nobot, 2011).

PEDro scale, 1999). Exercise compliance was considered feasible if: Participants completed on average at least 85% of scheduled exercise sessions. Exercise compliance was not considered feasible if: Participants completed on average less than 65% of their scheduled exercise sessions. These assumptions were generated considering compliance with prescribed exercise in participants with PLBP has been demonstrated to range between 15% and 95% (Krkoska et al, 2023; Peek, Carey, Mackenzie, and Sanson-Fisher, 2019). As the program was designed to be individualized to participants' lifestyle with regular monitoring and modification, the researchers hypothesized that exercise compliance would be at the higher end of that spectrum. The authors determined that the program would be considered "feasible with modifications" if feasibility outcomes fell between the feasible and not feasible thresholds. Post hoc calculations were then performed using G Power (Faul, Erdfelder, and Lang, 2009) to determine whether regression analyses were sufficiently powered (see results).

For the qualitative data, the original interviews were continued until data saturation. Data saturation was defined as the point at which the interviews were no longer contributing novel information. Thirty-nine participants (19 control and 20 experimental participants) were interviewed.

Quantitative data selection

Quantitative analysis aimed to determine whether characteristics of participants predicted a change in outcome/s. Data from all participants who began the intervention ($n = 60$) contributed to the regression analysis. Outcomes considered the change during the intervention (post-intervention score minus baseline score). Outcomes included pain (measured using the Numeric Rating Scale), disability (measured using the Roland Morris Disability Questionnaire), function (measured using the Patient-Specific Functional Scale), and LAM contraction (measured using ultrasound imaging, pressure biofeedback, and manual palpation). Change in pain, disability, and function was also considered at short term follow-up (three-month score – post-intervention score). Additionally, the authors hypothesized that an improvement in LAM contraction would be associated with an improvement in pain, disability, and function. The outcomes and participant characteristics evaluated for their association with the outcomes are described in Table 3.

Statistical analysis

Analyses were conducted using JASP © (Version 0.18.1 JASP Team 2023 Computer software). Participant characteristics and outcomes were analyzed using descriptive statistics including means and standard deviations for normally distributed data.

Linear regression models were created using the linear regression model commands in JASP. Models were created separately for each outcome. All analyses were conducted via intention to treat.

Univariate testing

To determine the association between participant characteristics and outcomes, the models included the change in an outcome as the dependent variable and the predictor (participant characteristic) and baseline score for the dependent variable as covariates. To determine the association between a change in objective (LAM contraction) and subjective outcomes (pain, disability, and function), the models included the change in a subjective outcome as the dependent variable and a change in a LAM contraction outcome and the baseline score for the dependent variable as covariates. Only predictors that provided a p value <0.1 continued to multivariate testing for their associated outcome.

Table 3. Characteristics that may affect patient reported or lateral abdominal muscle outcomes.

Characteristic	Reason for evaluating each characteristic
Demographics	Age has previously been demonstrated to predict pain intensity (Oliveira et al, 2018).
Age	
BMI	BMI has previously been identified as a risk factor for PLBP (Shiri et al, 2010).
Sex	Females have a greater risk of chronicity in PLBP (Nieminen, Pyysalo, and Kankaanpää, 2021). Asymptomatic females have previously demonstrated greater ability to recruit TrA compared to males (Rho et al, 2013)
Condition specific signs and symptoms:	Greater duration of symptoms has found to be predictive of future PLBP chronicity (NNieminen, Pyysalo, and Kankaanpää, 2021). Lumbar Spine Instability Questionnaire can predict responsiveness to different forms of exercise treatments (Macedo et al, 2014). It was therefore hypothesized that other condition specific signs and symptoms may influence responsiveness to the intervention.
Symptom duration;	
Previous back surgery;	
Number of health professionals seen for PLBP;	
PLBP distribution and referral defined as central, unilateral, unilateral with referral to above knee, unilateral with referral to below knee, PLBP with bilateral lower limb referral;	
Presence of paraesthesia/anesthesia due to PLBP;	
Baseline lumbar instability – LSIQ	
General health measures	Self-report physical activity is predictive of decreased pain and disability (Pinto et al, 2014).
Number of pain areas – Nordic Body Chart;	
Baseline physical activity – IPAQ	
Compliance with the exercise intervention	Intervention designed to improve patient reported and lateral abdominal muscle outcomes.
Participants baseline beliefs regarding potential effectiveness of the intervention	Pre-existing beliefs may influence people with PLBP's perceived effectiveness of exercise (Natoli et al, 2024).
Change in LAM function	Literature reports variable results regarding the relationship between LAM outcomes and patient reported outcome measures (Mannion, Pulkovski, Caporaso, and Sprott, 2010; Vasseljen and Fladmark, 2010)
Outcomes Assessed	Reliability of outcomes
Pain measured using the Numeric Rating Scale	Evidence for reliability and construct validity in PLBP population (Maughan and Lewis, 2010; Nugent et al, 2021)
Disability measured using the Roland Morris Disability Questionnaire	Evidence for reliability and content validity in PLBP population (Burbridge, Randall, Abraham, and Bush, 2020; Maughan and Lewis, 2010)
Function measured using the Patient Specific Functional Scale	Evidence for reliability and construct validity in PLBP population (Maughan and Lewis, 2010, Nazari et al, 2022)
USI measures of LAM contraction using the preferential activation, preferential activation modified, TrA and oblique contraction ratios	Evidence for reliability and construct validity with electromyography in PLBP population (Koppenhaver, Hebert, Parent, and Fritz, 2009; Oliveira et al, 2017; Valentin-Mazarracin et al, 2021).
PBU measurement of TrA contraction	Evidence for reliability and some evidence for concurrent validity with electromyography in PLBP population (de Paula Lima et al, 2011; Hodges, Richardson, and Jull, 1996).
Palpation and observation of TrA contraction using the DMC scale	Evidence for reliability and some evidence for concurrent validity with USI in PLBP population (Oliveira et al, 2017).

Abbreviations: BMI, body mass index; DMC, deep muscle contraction scale; IPAQ, international physical activity questionnaire; LAM, lateral abdominal muscles; LSIQ, lumbar spine instability questionnaire; PBU, pressure biofeedback unit; PLBP, persistent low back pain; TrA, transversus abdominis; USI, ultrasound imaging.

Outcome measurement references:.

Numeric Rating Scale (Ostelo et al. 2008).

Roland Morris Disability Questionnaire (Nussbaum et al. 2001).

Patient Specific Functional Scale (Pengel et al. 2004).

USI measures of LAM contraction using the preferential activation, preferential activation modified, TrA, and oblique contraction ratios (Oliveira et al. 2017).

PBU measurement of TrA contraction (Richardson et al. 1999).

Palpation and observation of TrA contraction using the DMC scale (Oliveira et al. 2017).

Multivariate testing

All predictors with a p value <0.1 from the univariate models were entered into the multivariate model for their associated outcome. A backward selection procedure was used to create each model whereby in each subsequent model, the predictor with the largest p value was removed. Further models were created until remaining predictors demonstrated a p value of <0.05. The final models were check for collinearity issues between eligible predictors using the variance inflation factor. Residuals were checked for normality. No breaches of assumptions or collinearity issues were detected in the final models.

For the pressure biofeedback (PBU) outcome, numerical pressure scores were converted to categorical outcomes of "no change," "above optimal," "below optimal," or "optimal." Optimal was considered a decrease in pressure between 4 and 10 mmHg as per Richardson, Jull, Hodges, and Hides (1999). Therefore, for PBU, logistic regression model commands were used in JASP ©. All subsequent procedures were identical to procedures outlined above for linear regressions; however, multivariate testing was not required.

Qualitative data selection

Qualitative data included the interviews which explored participants' experiences of the intervention. Interview questions were developed from an initial survey provided to participants. This survey asked participants to rate their acceptability of the program and describe factors that were favorable and areas for improvement. Broadly, the interview questions explored: 1) Participant's desired outcomes and how well the program was able to address those (relevant to perceived effectiveness acceptability construct), 2) How well the program was individualized (relevant to affective attitude and self-efficacy acceptability constructs), 3) What participants learnt from the program (relevant to self-efficacy acceptability construct) 4) How the program structure/design contributed to participation (relevant to self-efficacy acceptability construct), and 5) Influence of the health professional on their experience with this program (relevant to affective attitude acceptability construct). Questions were piloted with two members of the research team and one participant. Only minor changes were made to questions to improve clarity meaning further piloting was not warranted.

Interviews were conducted by the physiotherapist who administered the program (CP) within 1 month of participants completing the intervention. Interviews were 8–40 min in duration (20 min average) and not returned to participants for feedback. The remaining researchers who assisted with data analysis included physiotherapists (CF female, SM male) and an occupational therapist (NMW, female) who have completed PhDs.

Phenomenology was the underlying methodological orientation. Interviews were previously transcribed and thematically analyzed using interpretive phenomenological analysis (see Appendix B for a full description of the interview agenda).

In keeping with a phenomenological approach, interpretive phenomenological analysis (Smith and Osborn, 2007) was used for coding and creating the thematic structure. Whilst reading a transcript, researchers initially noted any patterns or significant statements. Notes were then converted to concise phrases (codes). Codes were then compiled and connected, producing emergent themes. This was repeated for each transcript. After dual coding, transcripts were exported to NVivo qualitative analysis software (QSR International Pty Ltd. Version14) and emergent themes were documented referencing supporting quotations. Emergent themes were continually revised through discussion with the research team. Once all transcripts were completed, related emergent themes were clustered under superordinate themes. These were reviewed against the transcripts to ensure alignment.

Two researchers undertook thematic analysis of all transcripts. During the interviews and thematic analysis, CP was blinded to participants' post-intervention data other than the DMC and PBU which she administered. However, during the intervention, some participants discussed perceived changes in outcomes, such as pain, to CP. During the thematic analysis, the second raters (CF, SM, or NMW) were also blinded to all quantitative results. Analysis for the present study only included transcripts from participants that responded most and least to the intervention.

Participants were categorized as "most responsive" to objective measures where their LAM contraction had increased more than the minimal detectable change score (MDC) for two or more measures (inclusive of USI, DMC, or PBU). As it is currently unclear what the minimally clinically important difference is for these variables, using the MDC was appropriate to ensure that participants had definitively responded or not to the intervention. Participants were classified as "least responsive" to objective measures where LAM contraction had declined more than the MDC for one measure. There were no participants whose objective measures reduced more than the MDC for multiple LAM measurements. Participants whose LAM contraction had "no change" were not included in the least responsive group as "no change" was below the MDC.

Participants were considered most responsive to subjective outcomes where they demonstrated an improvement above the minimally clinically important difference for at least two of the three outcome variables: an improvement of 2 points for pain (Ostelo et al, 2008), 5 for disability (Ostelo et al, 2008), and 2.3 (Maughan and Lewis, 2010) for function. To reduce the number of participants meeting this criterion, the change for those variables was required to be in the top 25% percentile of all participants' changes. Least responsive to the subjective outcomes was defined as a change in at least two of the variables that was below the minimally clinically important difference (change may have been improvement, no change, or decline).

Qualitative data analysis

To determine data unique to the most and least improved groups, a matrix coding query was established in NVivo © (QSR International Pty Ltd. Version 14). Each participant transcript was assigned an attribute labeled "responded to intervention." Transcripts were then marked as "yes" for participants that responded

most, "no" for participants that responded least, or N/A for any remaining participants whose transcripts were analyzed for the feasibility study. This produced a table identifying how many participants in the most and least responded groups contributed to each code and/or sub-theme. The authors classed a code and sub-theme as "unique" where it was only present in the most or least responsive groups. Appendix C discusses the rigor of the initial collection and analysis of qualitative data.

Integration

Qualitative and quantitative data were merged to achieve complementarity (Greene, Caracelli, and Graham, 1989). Quantitative predictors found from the multivariate modeling and qualitative themes unique to each group were juxtaposed to demonstrate how findings may converge or diverge. Then, qualitative themes were sought to explain predictor variables. This was achieved via a joint display table showing quantitative and qualitative findings and meta-inferences (Guetterman, Fetters, and Creswell, 2015). Meta-inferences describe the authors understanding of the integrated quantitative and qualitative data (Tashakkori and Teddlie, 2008). Inferences were presented in isolation for quantitative and qualitative data where there was insufficient overlap between the methodologies to produce meta-inferences.

While there are various frameworks to convey validity in mixed methods, for the purpose of this study, the legitimation model proposed by Onwuegbuzie and Johnson (Onwuegbuzie and Johnson, 2006) was used (Table 4).

Results

Of the 60 participants who began the intervention, 50 completed it. Seventeen of those were most responsive to objective outcome measures. Eight of those were also most responsive participants to subjective outcome measures. Only three participants met criteria for being least responsive to the objective measures and another eight participants were considered least responsive to the subjective measures. All identified participants had completed post-intervention data collection and an interview.

Due to substantial overlap between participants who had responded on subjective and objective outcome measures, the themes overlapped. The authors therefore decided to compare themes between all participants who responded most (subjectively ± objectively) against those who improved least (subjectively ± objectively).

Table 4. Legitimation of this mixed methods study.

Type of legitimation	
Sample Legitimation	The aim is transferability rather than making statistical generalizations from the sample to the population of people with PLBP. Researchers/clinicians should consider the comparability of their sample/group of patients and context. This will enable determination of whether results from this study may be transferrable to their situation. There was overlap between participants in the qualitative and quantitative phases. However, the subsample of qualitative participants was much smaller. This was necessary to identify unique qualitative characteristics about the responders/non-responders to the intervention. This reduces generalizability of the meta-inferences.
Inside–outside legitimation (the use of insider and observer views for description and explanation)	Peer researchers that did not deliver the intervention or have any contact with participants examined the data and interpretations made. Participants did not review the data or interpretations. However, to some extent insider-outsider legitimation was achieved through separately analyzing the quantitative (outsider view), the qualitative (insider view) and then mixing of both data sets.
Weakness minimization legitimation	How the strengths and weaknesses of each approach were addressed through use of a mixed methods research design.
Sequential legitimation	Not applicable – convergent parallel design used
Conversion legitimation	Not applicable – data conversion was not used.
Paradigmatic mixing legitimation	A pragmatic approach was taken during this study to ensure both methodologies could be successfully integrated.
Commensurability legitimation	In creating a joint display table of findings, researchers were able to switch between looking at the data using quantitative and qualitative lenses and subsequently produce a third viewpoint of the findings.
Multiple validities legitimation	A discussion of the psychometric properties of the quantitative outcomes can be found in the manuscript. A discussion of the "validity" of the qualitative approach (credibility, trustworthiness etc) can be found in the appendices. Other forms of legitimation relevant to meta-inferences are discussed in this table.
Political legitimisation	The same researchers were used across quantitative and qualitative phases, therefore reducing this source of tension. Differences in perspectives regarding interpretation, comparison and integration of quantitative and qualitative findings were discussed until a consensus was reached.

Abbreviation: PLBP, persistent low back pain.

Table 5. Demographic characteristics of participants in the mixed methods study.

Characteristic	All participants ($n = 60$) – Quantitative Analysis	Most Responsive Group ($n = 20$) – Qualitative Analysis	Least Responsive Group ($n = 11$) – Qualitative Analysis
Sex	40 F 20 M	15 F 5 M	3 F 8 M
Age	54.7 (14.3)	54.1 (13.0)	54.2 (16.2)
BMI	27.6 (6.3)	26.8 (6.2)	26.1 (3.5)
Group allocation	29 Control 31 Intervention	11 Control 9 Intervention	3 Control 8 Intervention
Symptom duration (years)	12.9 (9.7)	14.0 (11.5)	12.01 (7.6)
Previous back surgery	57 N 3 Y	19 N 1 Y	11 N 0 Y
Number of health professionals seen about low back pain	2.5 (1.2)	1.9 (1.3)	3.5 (1)
Pain areas	2.2 (1.1)	2.2 (1.2)	2 (1)
Number of participants with unilateral low back pain	50 N 10 Y	17 N 3 Y	10 N 1 Y
Number of participants with unilateral pain spanning to above knee	52 N 8 Y	18 N 2 Y	9 N 2 Y
Number of participants with unilateral pain spanning to below knee	52 N 8 Y	17 N 3 Y	11 N 0 Y
Number of participants with bilateral low back and lower limb pain (above or below knee)	54 N 6 Y	19 N 1 Y	9 N 2 Y
Number of participants with central low back pain	13 N 47 Y	3 N 17 Y	1 N 11 Y
Number of participants with referred pain (lower limb)	36 N 24 Y	12 N 8 Y	7 N 4 Y
Number of patients with anaesthesia/paresthesia	49 N 11 Y	18 N 2 Y	10 N 1 Y
Do you think this intervention will help your low back pain? (5 Yes, 4 Possibly, 3 Unsure, 2 Possibly not, 1 No)	4.3 (1.0)	4.6 (0.8)	3.7 (1.5)
Baseline IPAQ score	1297.9 (1294.1)	956.5 (634.7)	2288.8 (1542.0)
Baseline RMDQ score	7.1 (4.6)	7.3 (3.76)	3.4 (3.2)
Baseline NRS score	4.6 (1.9)	5 (1.6)	2.7 (2)
Baseline PSFS score	4.4 (2.1)	4.1 (1.7)	5.5 (2.7)

Note all values are presented as mean (standard deviation) unless stated otherwise.
Abbreviations: BMI, body mass index; IPAQ, international physical activity score (MET mins per week) F, female; M, Male; N, No; NRS, numeric pain sating scale; PSFS, pain specific functional scale; RMDQ, Roland Morris disability questionnaire; Y, Yes.

Demographic characteristics of the participants can be found in Table 5. Appendix D lists the characteristics of the individual participants who participated in the qualitative component.

Quantitative results

Assuming a medium effect size of 0.15, an alpha of 0.05, and a sample size of 60, univariate regression analyses were sufficiently powered (0.84). For multivariate regressions, however, analyses were underpowered (two predictor variables: 0.75, three predictor variables). Up to three predictor variables remained in the final models of multivariate regressions.

Across the LAM and self-report outcomes, statistically significant ($p < .05$) treatment effect modifiers from the univariate analyses included demographic factors such as BMI and sex, PLBP characteristics such as symptom duration and the number of healthcare professionals previously seen for PLBP, and intervention factors such as group allocation and the compliance with motor control exercises. There were no variables that significantly predicted the binary outcome of a change in PBU score to "optimal."

For a change in pain from post intervention to three-month follow-up, group allocation, and the level of agreement with the following statements were statistically significant predictors: "I can effectively fit physical activity into my life," "I feel confident to continue with regular physical activity without the supervision of a physiotherapist," "My back pain has improved in the 3 months after finishing the program." For a change in disability, sex, and participant beliefs regarding potential effectiveness of the intervention were statistically significant predictors. For a change in function, participants with pain referred into one or both lower limbs was statistically significant. Univariate analyses are shown in Appendix E.

For multivariate modeling, further variables were included due to yielding p values <0.1 for the univariate analyses. However, for predicting a change from baseline to post intervention in all the LAM outcomes, only the statistically significant ($p < .05$) variables described above remained in the final models. For the self-report outcomes, remaining statistically significant factors included BMI, participant beliefs regarding potential effectiveness of the intervention, compliance with the prescribed exercise, and symptom duration. Results of these multivariate analyses can be found in Table 6.

Several variables remained in the multivariate models predicting self-report outcome changes from post intervention to 3-month follow-up. These included the statement "I can effectively fit physical activity into my life," participant sex, participant beliefs regarding potential effectiveness of the intervention, post-intervention physical activity levels, and the number of pain areas. Table 7

Table 6. Significant variables predicting changes from baseline to post-intervention in multivariate analyses – for an intervention for people with persistent low back pain and lateral abdominal muscle impairments.

Measure	Unstandardised regression coefficient	95% (CI)	*p* value	R	Adjusted R^2
Change in LAM PA Ratio					
Number of HCP seen for PLBP	−0.009	−0.018 – −102.64	0.029	0.535	0.258
Change in LAM PAM Ratio					
BMI	−0.002	−0.004 – −54.06	0.014	0.648	0.386
Sex	0.029	0.003–0.055	0.028		
Change in LAM TrA ratio					
Number of HCP seen for PLBP	−0.077	−0.128 – − 0.025	0.004	0.62	0.349
Group allocation	−0.145	−0.268 – − 0.022	0.021		
Change in LAM oblique ratio					
PLBP with bilateral LL pain	0.169	0.04–0.299	0.011	0.482	0.203
Change in DMC					
Sex	0.65	0.12–1.179	0.017	0.822	0.661
Change in TrA slide					
Compliance with motor control exercise	0.006	6.992×10^{-4} – 0.012	0.029	0.465	0.184
Change in Pain					
BMI	0.099	0.025–0.173	0.01	0.674	0.421
Beliefs regarding potential effectiveness of the intervention	−0.687	−1.165 – −0.21	0.006		
Change in Disability					
Beliefs regarding potential effectiveness of the intervention	−1.23	−1.944 – −0.516	0.001	0.739	0.518
Compliance with cardiovascular exercise	−0.043	−0.079 – −0.007	0.021		
Change in Function					
Symptom duration	−0.159	−0.25 – −0.069	<.001	0.657	0.411

Abbreviations: BMI, body mass index; DMC, deep muscle contraction; HCP, healthcare professionals; LAM, lateral abdominal muscles; LL, lower limb; PA, preferential activation; PAM, preferential activation modified; PLBP, persistent low back pain; PSFS, pain-specific functional scale; NRS, numeric rating scale; RMDQ, Roland Morris disability questionnaire; TrA, transversus abdominis.

Bolded variables are dependent, non-bolded variables are predictors. Baseline score for each variable included in final model as a covariate.

Seeing less HCP, having a lower BMI, female sex, being in the control group, not having PLBP with bilateral LL pain, increased compliance with motor control exercises, being more optimistic about the potential effectiveness of the intervention, increased compliance with cardiovascular exercise, and decreased symptom duration were associated with a greater improvement in their respective outcomes.

Predictors in the final models of the multivariate analysis which were common to multiple outcomes included the number of healthcare professionals seen for PLBP, BMI, sex, and beliefs regarding the potential effectiveness of the intervention at baseline.

An improvement in all LAM contraction variables except for TrA slide and PBU significantly predicted an improvement in pain. However, for an improvement in disability, only an improvement in TrA slide and DMC were significant predictors. Changes in LAM variables did not significantly predict a change in function. Strength of significant correlations were moderate-to-good for R^2 and fair for adjusted R^2. Due to the relationship between the LAM contraction variables, the final multivariate model only contained one predictor for pain and disability. Changes in LAM endurance were not predictive of changes in pain, disability, or function. Multivariate analyses results can be found in Table 7.

No changes in LAM contraction or endurance during the intervention were predictive of further changes in pain, disability, or function from post-intervention to the 3-month follow-up. Multivariate analyses for predicting changes from post intervention to 3-month follow-up can be found in Table 8.

Table 7. The association between lateral abdominal muscle and subjective variables: significant variables predicting changes from baseline to post intervention in multivariate analyses – for an intervention for people with persistent low back pain and lateral abdominal muscle impairments.

Measure	Unstandardised regression coefficient	95% (CI)	*p*-value	R	Adjusted R^2
Change in Pain					
Change in PAM ratio	−15.841	−24.348 – −7.334	<.001	0.666	0.444
Change in disability					
Change in DMC	−0.583	−1.115 – −0.051	0.032	0.61	0.338

Abbreviations: BMI, body mass index; DMC, deep muscle contraction; LAM, lateral abdominal muscles; L, left; LL, lower limb; LSIQ, lumbar spine instability questionnaire; PA, preferential activation; PAM, preferential activation modified; PBU, pressure biofeedback unit; R, right; TrA, transversus abdominis.

Bolded variables are dependent, non-bolded variables are predictors.

An improvement in PAM ratio and the DMC were associated with an improvement in their respective outcomes.

Table 8. Significant variables predicting changes from post intervention to 3-month follow-up in multivariate analyses – for an intervention for people with persistent low back pain and lateral abdominal muscle impairments.

Measure	Unstandardised regression coefficient	95% (CI)	*p* value	R	Adjusted R^2
Change in Pain					
Likert scale response at 3 M F/U I can effectively fit physical activity into my life	−0.796	−1.226 – −0.366	<.001	0.473	0.208
Change in Disability					
Beliefs regarding potential effectiveness of the intervention	1.118	0.386–1.851	0.004	0.561	0.271
Post study physical activity	5.090×10^{-4}	$1.883 \times 10^{-4} - 8.296 \times 10^{-4}$	0.003		
Sex	1.571	0.061–3.081	0.042		
Change in Function					
Sex	−1.668	−2.805 – −0.53	0.005	0.455	0.173
Number of pain areas	0.54	0.087–0.993	0.02		

Abbreviations: 3 M F/U, 3-month follow-up.
Bolded variables are dependent, non-bolded variables are predictors.
Greater agreement with the statement "I can effectively fit physical activity into my life," greater optimism about the potential effectiveness of the intervention, greater physical activity levels post intervention, female sex, and less pain areas were associated with an improvement in their respective outcomes.

Qualitative results

Table 9 lists the unique themes from participants in the most and least responsive groups and the supporting quotes.

Integration of quantitative and qualitative results

Table 10 represents participant characteristics associated with responsiveness to the exercise intervention based on the qualitative and/or quantitative data. For the group that responded positively to the intervention, meta-inferences revealed participants came to the study contemplating change: they were unhappy that PLBP was impacting their quality of life, but believed that becoming physically active could help with their PLBP. Such participants were more engaged in the program through increased compliance and learnt how exercise could be used to self-manage their PLBP. Hence, by the end of the study, they were implementing steps to maintain this behavior beyond the study.

For group that were the least responsive to the intervention, they were less optimistic about the program potential. This appeared to be due to the length of time in pain and perceived biological contributing factors. Potentially ineffective and dissatisfactory previous experiences with health professionals affected their pessimism. Completing less exercise during the study may be explained by increased barriers, relying on more extrinsic motivators, and some beliefs that general exercise is irrelevant to PLBP. Post-intervention some participants in this group were looking for further investigations or treatments for their PLBP.

Female sex, having a lower BMI, not having bilateral lower limb pain, and a change in LAM function were associated with greater improvements in subjective and/or objective outcomes.

Discussion

This study aimed to identify characteristics associated with responsiveness to the individualized exercise intervention. Statistical results were underpowered which increases the potential for Type 1 error. Implications of underpowered results are discussed in the limitations section. Despite this, results suggest that responsiveness to the intervention may have been mediated by several baseline factors such as participants' beliefs regarding the potential effectiveness of the program. Beliefs regarding the potential effectiveness of the program may have affected participants' engagement with the intervention and continuation with exercise following completion of the intervention program.

Participants' beliefs regarding the potential effectiveness of the program appeared to be affected by their preexisting beliefs and attitudes regarding their pain, and experiences with exercise. The least improved group of participants entered the program with a focus on diagnoses for their pain and poor experiences with health professionals. Similarly, participants who were least responsive to a pain science education intervention reported the importance of diagnoses and finding the right clinician (Leake et al, 2021). Previous diagnoses, while considered valuable by patients, relate to how patients perceive pain, ADLs, and expectations on prognosis (Bonfirm et al, 2021). In this study, least improved participants reported frustration due to the absence of or undefined diagnoses, or being told they have "structural" problems which contributed to the perception that the program would be unlikely to assist. Poor

Table 9. Qualitative themes and supporting quotes.

Theme	Supporting quotes
Unique themes from the participants most responsive to subjective and objective outcomes	
Some participants in this group had not been to physiotherapy before	*"[I had] always thought about going [to physiotherapy]"* Maggie *"I never got a chance to look into one [physiotherapist]"* Chloe
PLBP was impacting my quality of life	"*you get more and more depressed [thinking] 'I'll never get better'"* Dean. "*It was just miserable. I remember there was a time that I was . . . just I couldn't even move and the problem is I don't know what to do.*" Chloe "*walking the dog is a social event for us . . . and it's really hard to keep that smile on my face and not grimace when your back sort of locks up and you sort of start walking like a wooden, Marionette and people want to say oh, what's wrong with you? And I find that very embarrassing..*" Jenny
I realized that I needed to exercise	"*I was just thinking about it, it was always just in my head, I keep reminding myself, I gotta do this, I gotta do this. It's just never, I never actually started*" Chloe "*I knew, kind of knew myself that if I sat around and did nothing, it would get sorer*" Doug
Exercise can improve my pain	"*that was my history anyway. If there's prolonged periods of doing a little exercise, then you know, at the end of it, there's going to be an episode of back pain*." Doug "*I know that there are times when my muscles are stronger, that I have been pain free in the past. And so I know that that's something to aspire to*" Heather
The program reinforced/demonstrated that some consistent exercise can help with PLBP	"*I think, just that guidance to, to do something every day it's pushing me towards somewhere that I haven't been for a long time . . . the back pain has improved out of sight*" Doug. "*It was more just concreting things that I already sort of knew I should be doing*" Paula "*it just shows that very minimal effort can really produce a lot of rewards for your health, I guess. Yeah*." Indigo
Understanding when I should/not push through pain:	"*it's all got me thinking, and it's just a matter of retraining myself. And being aware and being able to say no, doesn't have to be done today. Or not quite so much today*" Jana "*I think it's the major crack was in a sense, like when I accepted that I can do it, push through carefully. . . because otherwise, it's stagnation and I will never progress or improve on that*." Tina
I am now more physically active:	*"Yeah, I'm certainly going out and walking more, participating in the exercise classes, doing the daily exercises."* Paula "*like getting back into running, that wasn't expected when I started. Which I'm pretty happy about*" Doug
I am prioritizing and aim to progress my exercise	"*I've got a really good exercise mat on the floor. And that is just all my space that that stays there, it doesn't get packed up . . . yeah, and the lycra pants go onto the bath so that I can grab them and put them on and do my exercises"* Jana; *"It's a goal to be doing those harder exercises . . . the Les Mills stuff that is just bodyweight . . . that's what I want to aim for. I want to do one of those classes at some stage." Kim* *"changing your routine and what you fit in . . . we all have 24 hours in a day, we all can make the time, so you've got to make the time . . . Sometimes it's not as long as I like . . . but I'll make sure I do at least a 30 minute brisk walk and that I will continue, so that's really good."* Terry
Unique themes from the participants least responsive to subjective and objective outcomes	
I was not optimistic about the program:	"*No [I was not optimistic due to] how long I have had it*" Thomas, *"I was not sure, given the fact that the injuries I have had go beyond repetition or muscular base problems."* Steven
I have had poor experiences with health professionals previously	"*one doctor recommended that I do cortisone injections, which I rejected because I didn't think it was addressing any of the problems . . . And another physio completely misdiagnosed it. The osteo that I went to see, I think was a quack . . . I think that when you present to a General Practitioner with back pain you just go on the medical carousel of scans and things like that*" Thomas *"when they see a patient, they only have maybe 20 minutes to half an hour, then they're on to the next. They wouldn't be able to make time to sit down to understand how come I'm getting a recurring, getting this recurring pain. It's hard to develop a program for it . . . . they're [exercises] given, but there hasn't been time for explanation"* Leonard *"So I've been physios before . . . But there's been no feedback on, on measuring how your muscles are strengthened or your ability to do things for longer. . . you need to be giving metrics and feedback so people know that they're improving and they've got a sense of, of goal achievement."* Terrance *"A lot of medical professionals and ones I've even dealt with, they've got fixed in their mind what's gonna help or what the problem is, they won't listen to the patient . . . . Often they're the best way of you finding out how to treat them is having to listen to them. . . it seems to be a one size fits all approach for a lot of places . . . I could have been a store dummy. And they'd be giving the same thing to the store dummy instead of a individual person to suit their lifestyle as well as their goals"* Patrick
I wanted a different perspective on my pain:	"*fresh set of set of eyes*" Patrick *"this this took a different approach, and I thought that I needed a different approach."* Thomas
Motivation came from the program or fear of or experiencing worsening symptoms/abilities	*"[A motivation was having a] structured program"* Thomas *"[A motivation was] knowing from the start, this was going to get measured again*" Terrance *"Being a pleasant, likable, personable person, it means I'm more likely to want to do the exercises. If I had a cold clinical x y z, then that might be less there. It's just a task"* Jack. "*I don't want to be old with a sore back and decrepit and not able to do things, let alone early onset of that."* Thomas
Trust and positivity were favorable therapist characteristics	*"[the therapist was] positive"* Steven *"[someone whom] instilled confidence and trust"* Terrance.

(*Continued*)

Table 9. (Continued).

Theme	Supporting quotes
Time, pain and conflicting advice from other health professionals were barriers to exercising:	*"some instruction [from another health care professional] to stop doing stuff [exercise] all together."*Steven *"time constraints"* Costa
Further investigations or treatments are required:	*"Probably not much [that I learnt from the program] I'm going to [get more scans and] see another physio now. Again, hopeful, yeah, yeah. I think whatever is, if they can fix that – the clicking in the spine and that – that's probably got something to do with that bit . . . no [I wouldn't recommend it to other people], unless you know, they kind of knew what was wrong"* Trixi
My core is/was weak	*"my core has always been a weak point"* Steven. *"I clearly didn't have good muscle mechanics or hygiene around that. I wasn't utilizing those muscles"* Jack
General fitness is not relevant to PLBP:	*"There will also be some things that I'll do just for general fitness, nothing really to do with the back, but you know, I aim to continue to strengthen or at least maintain core strength. And I know there's a way to go yet on that"* Caleb

experiences with previous healthcare professionals may have contributed to their pessimism, as previous research indicates people with PLBP's perceptions of exercise are predominantly informed by healthcare professionals (Natoli et al, 2024). Additionally, the authors hypothesized that because the least improved participants in the present study had higher baseline physical activity, they may have had decreased optimism for the potential effectiveness of a physical activity intervention. Previous research has suggested that preexisting beliefs may influence people with PLBP's perceived effectiveness of exercise (Natoli et al, 2024). The association found between responsiveness to the intervention (post intervention and at the 3-month follow-up) and belief in the intervention at the beginning of this study supports this hypothesis.

In contrast, the most improved participants wanted to increase their physical activity levels and had seen less practitioners for their PLBP compared to the least improved participants. They also demonstrated factors commonly associated with a better prognosis, such as less areas of pain and decreased duration of symptoms. Qualitatively, it appeared most improved participants demonstrated a greater internal locus of control, believing exercise could improve their PLBP. Locus of control can be defined as the degree to which one has amotivation, internal, or external motivation (Ryan and Deci, 2000). Potentially participants' locus of control affected how the groups engaged with and progressed differently during the program. Previous moderate-level evidence has found a higher health locus of control to be associated with greater exercise adherence (Beinart et al, 2013). As anticipated, the participants in the most improved group were more compliant with the exercise program.

Natoli et al. (2024) has suggested that if exercise prescription does not align with a person's preexisting beliefs, they may have reduced engagement with exercise. The least improved group in this study may have been less compliant due to beliefs that general fitness and exercises were not relevant to PLBP. Despite this, this intervention provided education and used techniques to aid behavior change such as monitoring progress and goal setting for the required amount of exercise per week. Such strategies have been found to improve compliance (Beinart et al, 2013). Thus, more detailed education on the benefits of the proposed physical activity for the individual, closer monitoring and discussion of barriers could be implemented for individuals less likely to respond to the program for future research and clinical intervention.

Unique to the most improved participants was the theme that the program reinforced, or demonstrated, that consistent exercise was beneficial for PLBP. This may have contributed to their higher levels of physical activity, and prioritization of exercise compared to the least improved participants by the end of the intervention. Conversely, some participants in the least improved groups wanted further investigations or treatment, again suggesting a lower internal locus of control.

The changes demonstrated by participants over the intervention parallel the Transtheoretical Model of Change (TTMOC) (Prochaska et al, 1994). The stages of change identified in this model include precontemplation (when the individual is not thinking about making a change), contemplation (in which the individual is thinking about making a change within 6 months), preparation (in which individuals are preparing to make a change in the next month), action (0–6 months in which individuals make a change), and maintenance (in which individuals are maintaining the behavior change) (Prochaska et al, 1994). Upon entering the study, the most improved participants appeared to be contemplating change regarding the potential for self-management, compared to pre-contemplation in the least improved participants. Most improved participants then undertook greater action and steps to maintain their new behavior. Several previous interventions for people with PLBP were based upon the TTMOC. In the first, a TTMOC-based motivation and exercise

Table 10. Integration of quantitative and qualitative data.

Stage	Interpretation	Meta-inferences: Characteristics which may be associated with responsiveness to the exercise intervention	Supporting quantitative variables from multivariate modeling and what they predict	Supporting/related qualitative themes
Baseline	Participants who had less experiences with healthcare professionals and those with less negative experiences with health care professionals were more likely to improve from the program	Experiences with healthcare professionals	Number of HCP seen for PLBP predicts a change in LAM PA ratio, TrA ratio	Poor experiences with previous HCP relating to accurate diagnoses, education and treatment (least improved group). Some participants in the most improved group had not been to physiotherapy before
	Participants who were more optimistic that exercise could improve their back pain were more likely to improve from the program.	Experiences and beliefs about exercise		Exercise can improve my back pain (most improved group). General fitness is not relevant to PLBP (least improved group). My core is/was weak (least improved group)
		Motivations for joining the program		I realized that I needed to exercise (most improved group). PLBP was impacting my quality of life (most improved group). I wanted a different perspective on pain (least improved group)
		Expectations on effectiveness	Greater optimism regarding the potential effectiveness of the program predicts a greater improvement in pain and disability (disability post intervention and at 3 month follow up)	Exercise can improve my pain (most improved group). Decreased optimism for program due to length of time in pain and as pathology is beyond "muscular" issues (least improved group)
	Participants who had more pain areas and had low back pain for longer were less optimistic about the program and less likely to respond to the program.	Chronicity and number of pain areas	Lesser symptom duration predicts the more likely function would improve from the program. Less pain areas predicted greater function 3 months after the program	Decreased optimism due to length of time in pain (least improved group)
		Presence of bilateral LL pain	Presence of bilateral LL pain predicts an increase in oblique ratio	
	Females were more likely to respond to the program.	Sex	Female sex predicts a greater improvement in PAM ratio, DMC score post intervention and decreased disability and increased function 3 months later	
	Participants with lower BMIs were more likely to respond to the program	BMI	Lower BMI predicts greater improvement in PAM ratio and pain	
	Participants in the control group were more likely to improve in one marker of abdominal muscle contraction	Group allocation	Group allocation predicted an improvement in TrA ratio	

(*Continued*)

Table 10. (Continued).

During program	Participants who had greater engagement with the program due to improved education about the role of exercises and less barriers to exercise were more likely to improve	Engagement with exercise	Greater compliance with motor control exercise predicts an increase in TrA slide post intervention Greater compliance with cardiovascular exercise predicts decreased disability post intervention	Time, pain and conflicting advice with other health professionals were barriers to exercising (least improved group). External motivators (program structure, therapist) and fear of worsening symptoms (least improved group). General fitness is not relevant to PLBP (least improved group). Understanding when I should and not push through pain (most improved group). The program reinforced or demonstrated that consistent exercise can help with PLBP (most improved group)
	Participants who demonstrated an improvement in LAM contraction were more likely to improve in self-report measurements	Change in LAM function	Positive change in LAM outcomes predicts greater improvement in pain, disability and function	
Post-intervention	Participants who continued to prioritize exercise after the intervention were more likely to improve compared to those who those who believed other investigations and treatments were needed	Prioritisation of physical activity		I am more physically active (most improved group). I am prioritizing exercise (most improved group)
		Locus of control		Further investigations or treatments are required (least improved group). I am prioritizing exercise (most improved group)
3-Month follow-up		Prioritisation of physical activity	The more participants agreed that they could effectively fit physical activity into their life, the lower their pain. Higher physical activity levels post intervention predicted decreased disability three months later	

Abbreviations: BMI, body mass index; DMC, deep muscle contraction; HCP, healthcare professional; LAM, lateral abdominal muscles; LL, lower limb; PA, preferential activation; PAM, preferential activation modified; PLBP, persistent low back pain; TrA, transversus abdominis.

intervention was not found to be superior to an exercise and placebo intervention for physical activity levels and functional capacity (Basler et al, 2007). However, this may have been influenced by over 50% of participants in both groups being at action, maintenance, or preparation stages when beginning the study. Another study compared "conventional physiotherapy" with an intervention incorporating patient preferred recreational aerobic exercise and education related to their current stage of change. The intervention group demonstrated significantly greater improvements in disability, suggesting addressing an individual's stage of change and incorporating their preferred activity may be more effective (Ben Ami et al, 2017). Patient preferred exercise was incorporated into the experimental group's program in the present study. However, group allocation was not predictive of greater improvements in patient reported outcome measures. In another study, participants were provided with identical education and exercises, but the experimental group was provided with support related to their individual stage of change (Thanawat and Nualnetr, 2017). Experimental group participants demonstrated greater improvements in muscle endurance, function, and pain (Thanawat and Nualnetr, 2017). Together, these studies indicate that incorporating education and discussion targeted to an individual's stage of change can improve the effectiveness of an exercise intervention. While this study's intervention may be appropriate for individuals in the contemplative stage of change, it was not as effective for individuals at the pre-contemplation phase. Supporting this notion, previous research has identified that individuals in the pre-contemplative phase are less likely to finish treatments (Gersh, Arnold, and Gibson, 2011). Potentially use of educational and motivational strategies as described in previous research (Beinart et al, 2013; Soderland, Elven, Sandborgh, and Fritz, 2020) could be used to enhance this framework.

Alternatively, patients may require a more psychologically informed treatment to address unhelpful pain cognitions, behaviors, and other psychosocial features. This may involve cognitive behavioral therapies or acceptance-based therapies to address unhelpful beliefs or behaviors related to pain (Hodges, 2019). To assist with identifying participants that require an adjusted program or psychologically informed treatment, therapists could ask patients to complete validated questionnaires such as the Pain Stages of Change (Kerns et al, 1997; Mun et al, 2020) and Fear Avoidance Beliefs questionnaires (Williamson, 2006). Similarly, Hodges et al.'s hybrid approach to treatment tailoring for PLBP (Hodges, 2019) recommends greater psychologically informed intervention for individuals with predominantly central pain. However, this approach does not consider assessment of an individual's pain stage of change and has yet to be tested in a randomized controlled trial. Hence, it is unclear whether this process would improve treatment allocation and therefore responsiveness.

To the best of our knowledge, this is the first study to demonstrate that at least one measure of LAM contraction significantly predicts improvements in pain and disability. Previous literature has demonstrated inconsistent results regarding the relationship between these measures in samples with PLBP. Vasseljen and Fladmark (2010) found TrA contraction ratio was not significantly improved after stabilization, sling (lumbopelvic exercises were performed with the subject's pelvis held in neutral with the assistance of a sling), or general exercises. However, reduced pain was significantly related (adjusted R^2 .18) to increased TrA contraction and decreased IO contraction. In a cross-sectional study, a fair association (adjusted R^2 .45) between PBU contraction measures of TrA (in prone and supine) and the 6-min walk test have been observed (Polat, Demirsoy, and Tokgoz, 2022). Additionally, a fair but significant correlation has been found between an improvement in TrA recruitment using USI and disability (Ferreira et al, 2010). In contrast, no significant associations between baseline LAM function (voluntary contraction and anticipatory contraction) nor improvement in LAM function and disability were found after a stabilization exercise program (Mannion, Pulkovski, Caporaso, and Sprott, 2010). Also, non-significant associations were found between pain and functional scores and changes in feedforward postural activity of TrA after a similar intervention (Tsao and Hodges, 2008). Wide confidence intervals in some significant correlations contribute to the uncertainty about the accuracy of correlations. Also, like our study, adjusted R^2 values have been fair at best, suggesting that changes in LAM contraction only accounts for a small amount of the variance. It remains unclear whether the clinical effects from motor control exercise trials are distinctly related to changes in motor control (Van Dieen et al, 2019a). Together, the results from this and the previous studies demonstrate some relationship is present. Due to the complexity of PLBP and pain perception being influenced by a range of other variables including psychological factors (Turk, 1996), it would be unlikely that the association would be strong. To determine if a variable modifies or mediates the effect of this specific intervention, future trials require a comparison group participating in a different intervention and/or no intervention.

Quantitative predictors that were not related to qualitative themes included participant sex, BMI, and having PLBP with bilateral lower limb pain. Females were more likely to have improved disability, function, and TrA contraction as measured by the DMC, and PAM USI ratio from the intervention. Compared to males, asymptomatic females have previously demonstrated a greater change in TrA thickness during the ADIM using USI (Rho et al, 2013). Another study found TrA contributed to a greater proportion of total LAM thickness at rest and during contraction in women (Springer, Mielcarek, Nesfield, and Teyhen, 2006). Authors of the latter study hypothesized that women may have an improved ability to preferentially contract TrA (Springer, Mielcarek, Nesfield, and Teyhen, 2006). If females had greater capacity to contract TrA at baseline, potentially this facilitated improved motor learning (TrA contraction) over the intervention which was found to be predictive of improved disability. Having a lower BMI was predictive of a greater improvement in pain and the PAM USI ratio in this study. This may be due to higher BMI being a risk factor for PLBP (Shiri et al, 2010) and poorer USI quality (Shumlewitz, Teefey, and Robinson, 1993). Poorer USI quality may have affected the ability to detect a change in LAM function. It is unclear why participants with bilateral lower limb pain were more likely to have greater oblique muscle contraction post intervention. No previous research supports or refutes this finding, however, this may reflect a Type 1 error.

The final factor to consider is the potential for some of these variables to be prognostic, that is, likely to impact a patient's outcome regardless of the treatment provided. For example, some variables found from analyses in this study such as sex, BMI, and psychosocial factors including personal controllability (Foster et al, 2010), have previously demonstrated an influence on prognosis for individuals with PLBP (Hill and Fritz, 2011).

Limitations

The authors acknowledge that an exploratory approach was taken to data analysis. That is, the authors did not have a priori hypotheses for which variables may be predictive of greater and lesser responsiveness to the program. An exploratory approach was considered appropriate for the qualitative analysis to allow the themes to emerge from the transcripts. The quantitative findings must be treated with caution as the findings could be due to type 1 error. Although a multivariate stepwise backward selection procedure was used to minimize type 1 error, only univariate regressions were sufficiently powered. Thus, it is unclear whether the findings are generalizable beyond the sample used in this study. Therefore, significant findings can only be considered preliminary and require replication with a fully powered sample.

When comparing groups in qualitative research, it is recommended that samples are matched as closely as possible (Lindsay, 2018). While participants were recruited from the same sample relevant to this study, they were chosen based on quantitative indicators of responsiveness. Due to the small sample size of the overall feasibility study, it was not possible to match participants across both groups. However, matching participants may have limited exploration of characteristics and themes that were different between the groups. Additionally, there is the potential for findings to be influenced by bias. This is because the interviews were completed by the researcher who conducted the trial. While the researcher encouraged participants to express their views freely, due to the therapeutic relationship built during the intervention, participants may have responded in an attempt to please the researcher. Additionally, this researcher took part in data analysis. Thus, her experience of the intervention may have biased her analysis of the data. To minimize this, other researchers participated in data analysis. Finally, meta-inferences were unable to be generated for all quantitative and qualitative findings due to poor overlap of concepts and data collected.

In conclusion, this study found multiple factors have potential to influence participant responsiveness to the intervention. At baseline, females, participants with lower BMIs, decreased chronicity, and fewer areas of pain were more likely to improve from the intervention. Additionally, participants who had less previous interactions with healthcare professionals and those that were more positive about the potential for exercise to improve their pain had greater responsiveness. During and after the program, participant engagement in physical activity was a positive predictor. Such characteristics may assist clinicians identifying whether this may be an appropriate intervention for patients with PLBP. Future trials should have a sufficiently powered sample size to confirm findings and have other treatment arms to determine whether identified predictors of responsiveness are unique to this intervention.

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