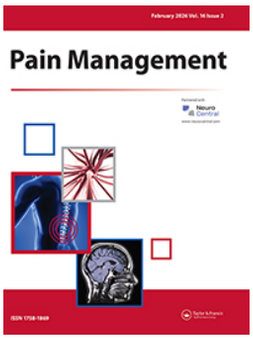

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RESEARCH ARTICLE

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Aquatic therapy compared to standard care for chronic low back pain: a randomized controlled trial

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ABSTRACT

Background: Anxiety, depression, and pain-related fears are highly prevalent among individuals with chronic low back pain (CLBP). While aquatic therapy is a promising treatment modality for CLBP, its effects on psychological factors remain poorly understood.
Objective: To compare the effects of aquatic therapy (AT) versus standard care (SC) on psychological outcomes, pain, and disability in CLBP.
Methods: In this two-arm randomized controlled trial, 34 participants with CLBP were assigned to AT ($n = 18$) or SC ($n = 16$). Both groups received bi-weekly individual sessions over 10 weeks. Pain, disability, quality of life, anxiety, depression, pain catastrophizing, kinesiophobia, and sleep disturbance were assessed using the following validated questionnaires; Numerical Pain Rating Scale, Modified Oswestry Low Back Pain Disability Index, Short-Form 12 Item Survey Questionnaire, Hospital Anxiety and Depression Scale, Pain Catastrophizing Scale, Tampa Scale of Kinesiophobia and Insomnia Severity Index, respectively.
Results: Mixed-design analysis of covariance revealed no significant group*time interactions for any outcomes (all $p > 0.05$). Both groups improved significantly in pain, disability, quality of life, pain catastrophizing, and anxiety (all $p < 0.05$). Only AT demonstrated significant reductions in kinesiophobia ($p = 0.002$) and sleep disturbance ($p = 0.001$).
Conclusions: Aquatic therapy may offer a more comfortable treatment alternative to address psychological factors associated with CLBP.
Clinical trial registration: www.clinicaltrials.gov identifier is NCT05823857

PLAIN LANGUAGE SUMMARY

Low back pain is a disabling disease and a public health concern. Aquatic exercise is a promising therapy as it reduces weight on the spine, allowing exercise that may be challenging on land. Despite its benefits in improving pain, function and quality of life, the influence of aquatic therapy on the psychological factors of chronic low back pain are underexplored. Exploring this area could provide valuable insights into how aquatic therapy may help the mental burden of chronic low back pain, leading to better outcomes for patients. People with chronic low back pain were randomly placed in an aquatic exercise program or received the standard treatment for low back pain in an athletic therapy clinic. The programs were 10 weeks, twice per week and were supervised by athletic therapists. People reported their pain, functional level, quality of life, pain-related feelings, depression, anxiety and sleep quality using questionnaires before and after the program. Both aquatic therapy and standard treatment for low back pain showed improvements in pain, function, quality of life, and anxiety/depression. For pain-related feelings, both groups showed improvements in the way they think about their pain. However, only the aquatic therapy group showed an improvement in their fear of movement or physical activity. Furthermore, only the aquatic therapy group showed improvements in sleep quality. Overall, aquatic therapy may be a more comfortable treatment alternative to address mental factors associated with chronic low back pain. The data from this project will be used to design an accessible community program to better support individuals that desire to adopt healthier lifestyles.

ARTICLE HISTORY

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KEYWORDS

Aquatic therapy; low back pain; chronic pain; quality of life; patient-reported outcomes; psychology

1. Introduction

Low back pain (LBP) is the most common musculoskeletal condition worldwide and the leading cause of disability [1]. Recent international estimates place the average annual direct costs per population for LBP ranging between 2.3 and 2.6 billion Euros, with indirect costs range from 0.24 to 8.15 billion Euros [2], reflecting difference in methodologies, population sizes, and the scope of indirect costs considered across studies (e.g., productivity losses, absenteeism, disability-related costs). Chronic low back pain (CLBP) is defined as pain in the area between the lower ribs and gluteal folds, with or without radiating leg pain, that persists for more than 3 months [3]. Chronic LBP can be categorized into

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Article highlights

- Anxiety, depression, pain catastrophizing, kinesiophobia, and sleep disturbance are highly prevalent in individuals with chronic nonspecific low back pain yet remain underexplored as primary outcomes in exercise trials.
- In this two-arm randomized controlled trial, 34 adults with chronic nonspecific low back pain completed a 10-week program of either aquatic therapy or standard care, delivered twice weekly in an athletic therapy clinical setting.
- Both interventions significantly reduced pain catastrophizing, anxiety, and depression, suggesting that multimodal, exercise-based care can positively affect psychological factors in chronic low back pain.
- Only the aquatic therapy group demonstrated significant reductions in kinesiophobia and sleep disturbance, indicating that exercising in a buoyant, low-load water environment may provide additional benefits for fear of movement and sleep.
- No between-group differences were found for any outcomes, indicating that aquatic therapy and standard do not have significantly different effects on CLBP.
- These findings add to the limited evidence on psychological outcomes in aquatic therapy for chronic low back pain.

specific and nonspecific types. Specific LBP is caused by a known lesion site, whereas nonspecific LBP occurs without a clear and identifiable nociceptive cause [1]. Nonspecific LBP stems from a complex interplay of biological, psychological, and social factors [4] and accounts for roughly 90% of all LBP cases [5], presenting significant challenges in its management. Despite the rising popularity of the biopsychosocial approach to treatment for CLBP [6], a recent review of CLBP guidelines showed that all clinical guidelines provided detailed recommendations on the biological domain, while only half addressed biological, psychological and social domains [7].

Previous research consistently highlights the importance of considering psychological factors, such as depression, anxiety, pain-catastrophizing and kinesiophobia in the treatment of nonspecific CLBP [5], as they are highly prevalent among individuals with CLBP [4,8]. Pain-related fears, particularly pain catastrophizing and kinesiophobia, are key psychological factors to address in CLBP treatment, as they can perpetuate the cycle of chronic pain [9]. More specifically, the fear avoidance model explains how musculoskeletal pain can become chronic as patients with pain-related fears foster a pattern of movement protective behaviors to avoid the perceived painful threat or injury, which in turn contributes to greater disability, disuse and pain [10]. This directly interferes with recovery and begins a vicious cycle. Previous research has found pain-related fears to be predictors of both the development of CLBP and disability [11]. Addressing these psychological factors is essential to breaking the cycle and improving outcomes for individuals with CLBP.

Current first-line treatment guidelines for CLBP emphasize exercise therapy as a primary conservative intervention [12–14]. However, the impact of various exercise therapy modes on psychological factors associated with CLBP remains poorly understood [15]. Among available approaches, therapeutic aquatic exercise, or aquatic therapy, has emerged as an effective mode for improving pain, disability, quality of life, and potentially psychological outcomes [16,17]. Previous aquatic therapy interventions commonly consist of 30 to 60-minute therapist supervised sessions combining aerobic, strengthening, balance and stretching exercise. Interventions varied, with some placing more emphasis on aerobic exercise [18,19], others on trunk stabilization [20,21], and some utilizing deep water running [22–24]. Aquatic therapy is widely used across all stages of musculoskeletal rehabilitation [25]. The buoyancy of water reduces spinal loading [25], enabling individuals with CLBP to move with greater confidence and less discomfort, while the viscosity of water provides adaptable resistance, making it ideal for individualized strengthening exercises [25]. Beyond physical benefits, aquatic therapy may also reduce fear of movement by enabling safe participation in exercise, while the supportive and immersive environment can promote confidence, relaxation, and mood regulation, potentially improving psychological outcomes in CLBP [26].

Evidence suggests aquatic therapy may offer advantages over land-based exercise. In elderly adults with CLBP, water-based perturbation balance training has been shown to produce significantly greater reductions in pain and fear-avoidance behaviors compared to land-based training [27]. Similarly, patients with CLBP report less pain during aquatic exercises than comparable land-based exercises [28], with a follow-up study indicating that aquatic sessions are generally perceived as pain-free [29]. Furthermore, a recent randomized clinical trial demonstrated that a 3-month aquatic exercise program led to greater improvements in disability and clinically important reductions in pain compared to a physical therapy modalities program [26].

Despite its benefits in improving pain, disability and quality of life, the influence of aquatic therapy on psychological factors – such as pain catastrophizing, kinesiophobia, anxiety, depression, and sleep disturbance remains underexplored. Psychological outcomes remain underexplored because exercise interventions are typically designed to address biomedical aspects of pain, with little attention given to their broader impact. Yet these outcomes are clinically important, as they strongly influence chronicity and long-term disability in CLBP. Chronic LBP was chosen because it is highly prevalent and strongly shaped by the influence of psychological and behavioral factors. This context makes it a suitable population for examining how an aquatic exercise intervention influences psychological outcomes in CLBP. To our knowledge, when investigating people with CLBP, two aquatic exercise randomized controlled trials examined kinesiophobia [26,30], one water-based perturbation exercise randomized controlled trial looked at fear-avoidance beliefs [27], one aquatic exercise randomized controlled trial assessed sleep quality [26], and none have specifically investigated pain catastrophizing. Although the effects of aquatic therapy on pain and disability in CLBP are well established, they remain the clinical benchmark to determine the effectiveness of an exercise-based intervention. Focusing on pain and disability ensures that improvements in psychological outcomes can be anchored to clinically meaningful changes in physical health. Standard care was chosen as the comparator because it reflects the multimodal rehabilitation strategy typically provided to patients with CLBP in clinical practice, combining manual therapy and exercise prescription. This makes it an appropriate and ecologically valid benchmark against which to

compare aquatic therapy, providing clinically meaningful insight into whether aquatic therapy offers advantages over a commonly delivered form of treatment.

Therefore, the primary aim of this study was to compare the effects of an aquatic therapy intervention to a standard care intervention on psychological factors in individuals with CLBP. The secondary aim was to compare the effects of these interventions on pain intensity, disability, and quality of life. We hypothesized that both groups would experience improvements in psychological factors, pain, disability, and quality of life, with the aquatic therapy group showing greater improvements across all outcomes.

2. Methods

2.1. Study design and setting

The study was a two-arm randomized controlled trial. The research team consisted of clinicians and researchers with expertise in musculoskeletal rehabilitation, aquatic therapy, and clinical trials. Two certified athletic therapists (NV and CM) administered the interventions sessions and collected outcome measures. A separate researcher (BR), not involved in treatment delivery, performed participant screening, randomization procedures, and maintained allocation concealment. All research activities took place at the School of Health at Concordia University in Montreal. This study was registered on clinicaltrials.gov on 27 April 2023 (registration number NCT05823857) and was approved by the Central Ethics Research Committee of the Quebec Minister of Health and Social Services (# CCER-21- 22–35) in March 2022. The study protocol of the parent trial was published and can be accessed for more information [31]. Prior to the start of the study, written informed consent to participate in the study was obtained from each participant. The present study examined secondary outcomes of the parent randomized controlled trial examining paraspinal muscle morphology in CLBP [31,32]. The study was reported following the CONSORT guidelines [33].

2.2. Participants

Participants were recruited using a convenience sampling method via the School of Health website, poster advertising and social media advertising. If participants were interested to participate in the study, a research team member contacted them to review the study and confirm eligibility. Participants were selected if they met the following inclusion criteria: 1) Chronic nonspecific LBP (> 3 months); 2) Currently seeking care for LBP; 3) Aged between 18 to 65 years old; 4) Ability to communicate either in English or French; 5) Have a score of "moderate" or "severe" disability on the modified Oswestry Low Back Pain Questionnaire (21–60%); 6) Does not currently engage in sports or fitness training specifically for the lower back muscles (3 months prior the beginning of the trial). Potential participants were excluded if they met one of the following exclusion criteria: 1) Evidence of nerve root compression or reflex motor signs deficits (e.g., weakness, reflex changes, or sensory loss with same spinal nerve); 2) Previous spinal surgery or vertebral fractures; 3) Other major lumbar spine structural abnormalities (e.g., spondylolysis, spondylolisthesis, or lumbar scoliosis > 10°); 4) Comorbid health conditions that would prevent active participation in exercise programs (e.g., screened with Physical Activity Readiness Questionnaire); 5) Missing more than 7 out of the 20 exercise intervention sessions. Participant recruitment began in October 2022 and data collection was completed in December 2023.

2.2.1. Randomization and blinding

After providing informed consent, participants were randomly allocated to either the aquatic therapy program or the standard care program. Randomization was achieved using a random computer-generated allocation sequence with permuted blocks, pairing each participant number with a corresponding group (1:1). Group allocations were enclosed in opaque envelopes labeled with numbers. The allocation sequence, participant enrollment, and participant group assignments were carried out by a researcher (BR) who was not involved in administering the intervention or measuring the outcome measures. Participants and therapists (NV and CM) were not blinded to group allocation, as it is generally not possible in exercise intervention trials [34]. The therapists who administered the interventions (NV and CM) also served as assessors, and therefore, could not be blinded to the group assignment when collecting outcome measures.

2.2.2. Procedures

Participants were initially screened over the phone to confirm eligibility by a researcher (BR) who was not involved in administering the intervention or group allocation. In cases where eligibility was uncertain, a certified athletic therapist (NV or CM) conducted a clinical assessment to verify the presence of CLBP and rule out any potential neurological involvement. Each participant underwent a baseline assessment prior to starting the study, which included completing questionnaires. The intervention period was 10 weeks and had a frequency of 2 times per week, which is in accordance with past exercise trials for people with CLBP [35]. Two certified athletic therapists (NV and CM) led the interventions and supervised all training sessions (~60 minutes) in a one-on-one fashion. The one-on-one delivery format eliminated any opportunity for participants to interact across groups, thereby preventing contamination. The aquatic therapy intervention was conducted at the Swim Ex therapeutic pool, while the standard care group received LBP treatment in the Athletic Therapy clinic and conditioning floor. Information regarding pain medication, co-interventions, or adverse events were recorded throughout the study. Participants in both groups were asked to avoid other back-specific treatments and exercises (e.g., occupational therapy, osteopath, physiotherapy, massage, chiropractor).

2.2.3. Exercise interventions

Each exercise intervention has been reported in greater detail in past publications [31]. Table 1 presents a comparison of each intervention.

Table 1. Comparison of intervention protocols.

Intervention	Aquatic therapy intervention	Standard care intervention
Frequency	2 sessions/week for 10 weeks.	2 sessions/week for 10 weeks.
Duration	60 minutes per session.	60 minutes per session.
Exercise Intensity	Moderate, guided by therapist and participant tolerance (Borg RPE 3–5/10).	Moderate, guided by therapist and participant tolerance (Borg RPE 3–5/10).
Content	Aerobic conditioning (30%): walking, jogging, circuit training. Resistance training (60%): dynamic lumbar stabilization and functional exercises. Stretching and mobility training (10%).	Manual therapy (30%): massage, myofascial release, soft tissue release, muscle energy techniques, joint mobilizations. Exercise therapy (70%): resistance training, trunk stabilization, aerobic conditioning, and stretching.
Progression	Increased sets and repetitions, modified lever arms, speed or increased ROM to increase resistance, and external increase in resistance (larger hand paddles and aqualogix dumbbells).	Progression to more advanced version of exercise, increased weight, increased sets and repetitions.
Mode of delivery	One-on-one, supervised sessions in heated therapeutic pool.	One-on-one, supervised sessions in clinical rehabilitation setting.
Providers	Certified Athletic Therapists.	Certified Athletic Therapists.

2.2.4. Therapeutic aquatic exercise intervention

Participants in the aquatic therapy group received a standardized aquatic therapy program [31]. Each session lasted 60 minutes, beginning with a 10-minute warm-up, followed by 40 minutes of strengthening, and finishing with a 10-minute cool-down. The warm-up consisted of aerobic activity such as walking and marching, dynamic stretching, and muscle activation of upper and lower body muscles. The 40-minute strengthening focused on a circuit format of dynamic lumbar stabilization exercises, core strengthening exercises, hip strengthening exercises, aerobic conditioning, and general strengthening exercises, with little amount of rest between the exercises to increase cardiovascular demand. Rest periods were not standardized; instead, participants were encouraged to progress through the circuit continuously, but brief breaks were permitted if needed to recover and ensure proper movement execution. The 10-minute cool-down consisted of a brief relaxation period (walking, floating), static stretching, and mobility exercises. Each exercise had a modification to decrease difficulty and a progression to increase difficulty. We monitored the difficulty of each training session via the 10-point Borg rating of perceived exertion scale and a verbal pain rating scale (0 [no pain] to 10 [worst pain imaginable]). The target rating of perceived exertion varied depending on the condition of each participant and where they were in their rehabilitation process. The supervising Athletic Therapist monitored the pain levels of participants and demonstrated sound clinical judgment to avoid unnecessary exacerbation of symptoms. Participants in the aquatic therapy group did not have any home exercise program during the 10-week intervention. After completing the intervention, participants were provided with a land-based home exercise program to support ongoing rehabilitation. Please refer to the supplementary file for a detailed breakdown of the aquatic exercise program [31].

2.2.5. Standard care intervention

Participants in the control group received standard care treatment in the School of Health Athletic Therapy clinic and conditioning floor. We did not standardize the standard care intervention but rather personalized each intervention to the needs of each participant. The objective of the standard care intervention was to replicate care that would otherwise be seen in a real-world clinical setting using the best conservative treatment methods available. Treatment was tailored to each patient's presentation, including symptoms, movement patterns, and limitations. Treatment components were determined based on a comprehensive assessment conducted during the first session by a certified Athletic Therapist. Interventions were personalized to target identified deficits, functional impairments, and patient-specific needs. Load was introduced as appropriate once exercises were initiated and deemed suitable for the participant's condition. The treatment modalities focused on exercise therapy and manual therapy. The hands-on portion of the treatment plan, within the athletic therapy scope of practice, included the following treatment modalities: spinal mobilizations, muscle energy techniques, massage therapy, myofascial releases, soft tissue releases, proprioceptive neuromuscular facilitation stretching, and heat application. Therapists selected modalites according to therapeutic objectives rather than following a standardized sequence. Heat application was often used at the beginning of the session to increase blood flow, promote relaxation and decrease pain. Each technique served a specific purpose based on assessment findings. For instance, reduced hamstring flexibility might first be addressed with a myofascial release to target superficial tissues, followed by a deeper active soft-tissue release, and completed with a proprioceptive neuromuscular stretch. Similarly, if a sacroiliac dysfunction was identified, surrounding structures such as the psoas, and piriformis muscles were first released using a soft-tissue technique, before applying the appropriate muscle energy technique to correct the dysfunction. The early phases of the rehabilitation plan mostly focused on manual therapy with basic strengthening exercises to improve spine health, which were demonstrated and given as a home exercise program. Commonly prescribed early-phase exercises targeted thoracic and hip mobility, as well as strengthening of the glutes, transverse abdominis, obliques, and spinal extensors (glute bridges, bird dog, dead bug, waiter's bow, and modified curl-ups). Each exercise followed a structured progression. For example, the dead bug advanced from arms-only, to legs-only, to alternating limbs. Progression criteria included completing up to three sets of 10 repetitions with proper form, no increase in symptoms, and a Borg RPE <3/10. As participants met these criteria, a greater proportion of sessions emphasized exercise therapy, with more

advanced multi-joint functional exercises introduced as appropriate, including squats, deadlifts, plank exercises, anti-rotation exercises, and resisted trunk rotations. These were further progressed by increasing sets, repetitions, or external resistance to ensure Borg RPE remained > 3/10 without an accompanied increase in symptoms.

2.3. Outcome measures and data collection

After randomization, demographic characteristics were collected at baseline with a self-reported questionnaire. All outcome variables were then collected for participants in both intervention groups. The outcome measures included pain, disability, quality of life, pain catastrophizing, kinesiophobia, depression, anxiety, and sleep disturbance, and were acquired with self-reported questionnaires. All self-reported questionnaires were completed on paper and in person. All assessments at baseline were repeated at 10 weeks (post-intervention).

2.3.1. Pain

Pain intensity was assessed using the Numerical Pain Rating Scale (NPRS), a widely accepted and validated tool for measuring perceived pain. Participants rated their pain on a scale from 0 (no pain) to 10 (worst possible pain) in the past 7 days. The NPRS is a valid and reliable measure for detecting changes in pain levels [36,37].

2.3.2. Disability

A participant's self-reported disability related to their CLBP was assessed using the Modified Oswestry Disability Index (ODI) (version 2.0). This 10-item questionnaire evaluates the impact of pain on daily activities, with each item rated on a scale from 0 to 5. A score of 0 indicates no disability, while a score of 5 reflects severe functional impairment. The ODI covers key domains, including pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sexual activity, social life, and traveling. Based on total scores, disability levels are categorized as minimal, moderate, severe, completely disabled, or bedridden. Due to its strong reliability and validity, the ODI is widely recognized as a core outcome measure for assessing disability in individuals with low back pain [38,39].

2.3.3. Quality of life

Quality of life was evaluated using the 12-item Short Form Health Survey (SF-12), a widely validated tool that measures both physical and mental well-being. The SF-12 assesses eight domains: (1) limitations in physical activities due to health conditions, (2) restrictions in social interactions caused by physical or emotional issues, (3) limitations in role-related activities due to physical health problems, (4) bodily pain, (5) overall mental health, (6) limitations in role-related activities due to emotional health issues, (7) vitality, and (8) general health perceptions. Given its reliability and validity, the SF-12 is a valuable measure of health-related quality of life [40,41].

2.3.4. Pain catastrophizing

Pain catastrophizing was assessed using the Pain Catastrophizing Scale (PCS), which focuses on pain-related thoughts (rumination), exaggeration of painful stimuli (magnification), and adopting hopeless orientations with coping (helplessness). This is a 13-item questionnaire, in which each item is scored from 0 to 4 for a total possible score of 52. A higher score indicates increased levels of catastrophizing, with scores that are above 30 being considered clinically significant. This questionnaire has been found to be both reliable and valid [42–44].

2.3.5. Kinesiophobia

Kinesiophobia, a participant's fear of movement or reinjury, was assessed using the short-form Tampa Scale of Kinesiophobia (TSK-11). This 11-item questionnaire includes 11 sentences related to kinesiophobia, including "I am afraid I might injure myself if I exercise." Each sentence is scored with a Likert scale from 1 to 4 for a total possible score of 44. A higher score indicates a higher level of kinesiophobia. This questionnaire has both high reliability and validity [45].

2.3.6. Depression and anxiety

A participant's level of depression and anxiety was assessed using the Hospital Anxiety and Depression Scale (HADS). This is a 14-item questionnaire, in which 7 items are related to depression and 7 are related to anxiety. The questionnaire focuses on cognitive, behavioral, and emotional symptoms. Each item is scored from 0 to 3, with depression or anxiety being scored between 0 and 21, for a total possible score of 21 for each. A higher score represents a higher level of depression and anxiety. A score between 0–7, 8–10, and 11–21 is considered as normal, borderline, and abnormal for each category, respectively. This questionnaire is considered both reliable and valid [46].

2.3.7. Sleep

Sleep disturbance was assessed using the Insomnia Severity Index (ISI). This questionnaire consisted of 7 questions evaluating a participant's ability to fall and stay asleep, and the daily effects of sleep. Each question is scored with a Likert scale from 0 to 4 for a total possible score of 28. A higher score indicates a lower quality of sleep. A score between 0–7, 8–14, 15–21, and 22–28 is considered as non-clinically significant insomnia, subthreshold insomnia, moderate insomnia, and severe insomnia, respectively. The cutoff score of 14 is commonly used to detect primary insomnia. This questionnaire is considered both reliable and valid [47].

2.4. Sample size calculation

The sample size calculation was based on the primary outcome of the parent trial (e.g., mean effect size 0,73, $\alpha = 0.05$ and 80% power) [31], which was paraspinal muscle morphology. The current study investigates a secondary outcome of the parent trial, and therefore a separate sample size calculation was not performed. Given the power consideration of the parent trial, the sample size ($n = 34$) is considered adequate for the exploratory analysis of this secondary outcome.

2.5. Statistical analysis

Baseline demographic means and standard deviations were calculated, and compared between each group to ensure the samples were homogenous. More specifically, continuous variables were compared using an independent samples t-test, and categorical variables using a chi-square test. All outcome measures were analyzed to verify normality of data. Mixed-design analysis of covariance (ANCOVA) was used to measure between-group and within-group differences from pre-intervention to post-intervention in pain, disability, and psychological outcomes, while adjusting for age, sex, BMI, and LBP duration. All assumptions were verified and met. Given the design (two groups, two time points, complete data), mixed-design ANCOVA was selected as the most parsimonious and statistical appropriate approach. Given that we had only two groups and two time points, post-hoc testing was not performed; instead, effect sizes were reported for group*time interactions and main effects. All statistical tests were performed using SPSS version 29.0 (IBM Corp., Armonk, NY, USA); a p-value of < 0.05 was considered statistically significant.

3. Results

3.1. Participants

One hundred eighty-one potential participants were screened for eligibility, and 39 were initially included and randomized to the aquatic therapy or standard care group (Figure 1). The main reasons for exclusion were self-reported disability (ODI) scores below the minimum threshold or preexisting spinal abnormalities. We excluded an additional 3 participants after randomization following incidental findings on their baseline MRI. Because individuals with neurological signs and structural abnormalities were excluded from the trial, our results apply specifically to

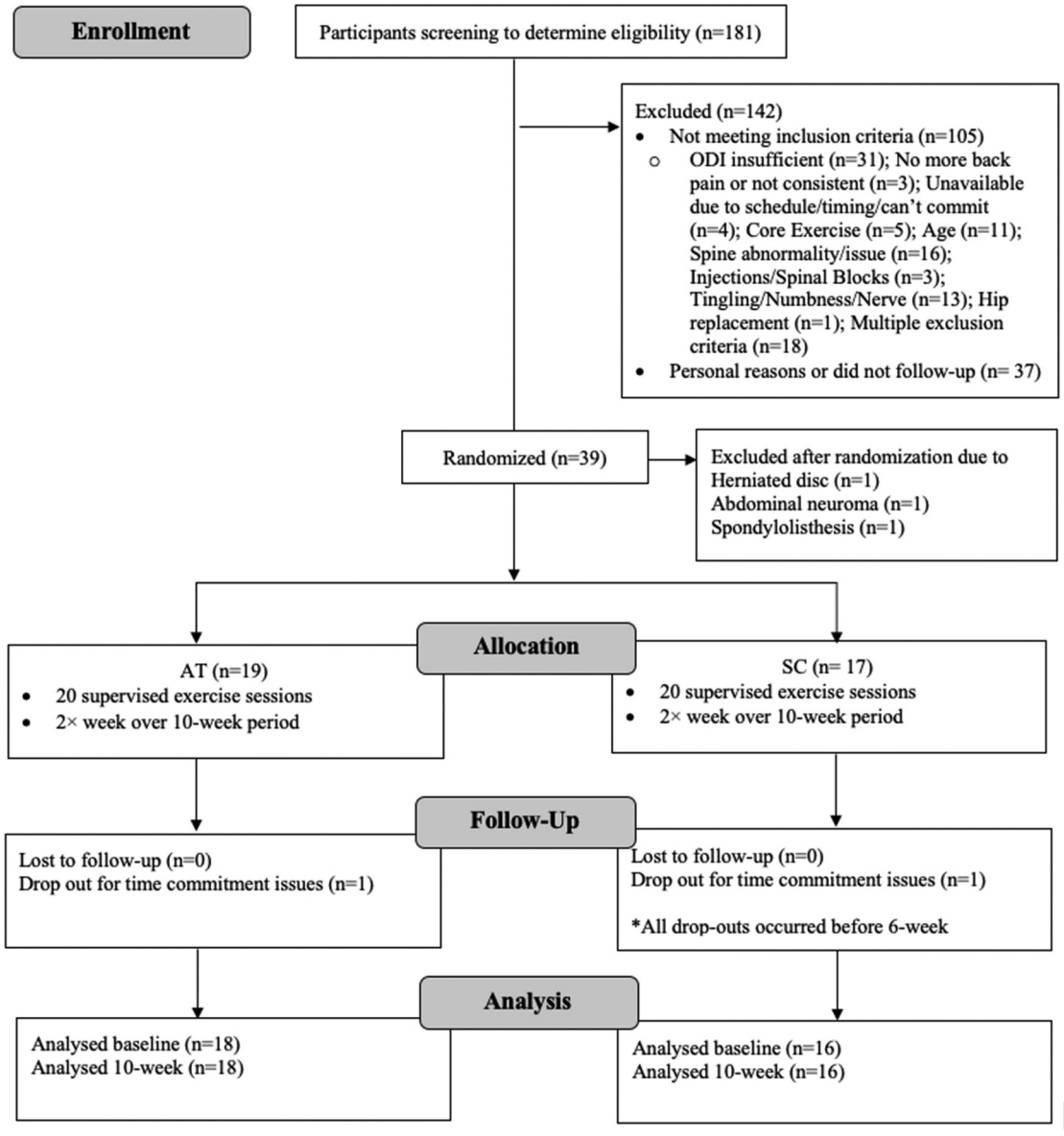

Figure 1. CONSORT flow diagram.

Flow diagram outlining recruitment, eligibility assessment, randomization, allocation, follow-up, and analysis for participants in the aquatic therapy and standard care groups.

Table 2. Demographics and baseline characteristics.

		All ($n = 34$)	Aquatic therapy ($n = 18$)	Standard care group ($n = 16$)	p-value
Age		36.9 ± 9.9	36.4 ± 10.4	37.4 ± 9.6	0.789[#]
Height (cm)		171.5 ± 9.1	171.4 ± 7.4	171.6 ± 11.0	0.971[#]
Weight (kg)		75.3 ± 13.6	77.8 ± 13.1	72.6 ± 14.0	0.275[#]
BMI		25.5 ± 3.8	26.4 ± 3.8	24.6 ± 3.6	0.164[#]
IPAQ (MET)		2845.8 ± 2140.7	2506.5 ± 2183.8	3206.2 ± 2102.3	0.356[#]
*ODI		28.1 ± 8.8	31.7 ± 10.4	24.0 ± 3.5	0.008[#]
Sex (n)	Male	15 (34%)	9 (50%)	6 (38%)	0.464[†]
	Female	19 (56%)	9 (50%)	10 (62%)	
Education (n)	College or less	10 (29%)	3 (17%)	7 (44%)	0.213[†]
	Undergraduate	9 (26%)	6 (33%)	3 (19%)	
	Graduate	15 (44%)	9 (50%)	6 (37%)	
*LBP duration (n)	3–5 months	1 (3%)	1 (6%)	0 (0%)	0.007[†]
	6–11 months	4 (12%)	0 (0%)	4 (25%)	
	1–5 years	13 (38%)	11 (61%)	2 (13%)	
	5+ years	16 (47%)	6 (33%)	10 (62%)	

Categorical variables are shown as number (%) and numerical data are shown as mean ± SD.
*– $p < 0.05$, [#]Based on independent samples t-test. [†]Based on chi-square test.
Abbreviations: BMI: body mass index; IPAQ: international physical activity questionnaire; LBP: low back pain; ODI: oswestry disability index.

chronic nonspecific low back pain and cannot be generalized to other specific causes of low back pain. In total, we recruited 36 participants and randomly allocated them to each group ($n = 19$, aquatic therapy; $n = 17$ standard care). One participant from each group dropped out due to the time commitment of the study, so 34 participants completed the study ($n = 18$, aquatic therapy; $n = 16$ standard care). The mean attendance rate was 17.61 ± 2.17 sessions for the aquatic therapy group and 17.56 ± 1.47 sessions for the standard care group, out of 20 possible sessions. Furthermore, reported co-interventions included exercise (17.6%), non-steroidal anti-inflammatory drugs (5.9%), massage therapy (5.9%), physiotherapy for elbow tendinopathy (2.9%), chiropractor for neck (2.9%), and cannabis (2.9%). No adverse events were reported. As shown in Table 2, the baseline demographic characteristics were similar between groups for age, sex, BMI, level of physical activity (IPAQ) and education level. However, we found significant differences across groups for LBP duration ($p = 0.007$) and self-reported disability (ODI, $p = 0.008$), which we accounted for in the statistical analysis.

3.2. Effect of aquatic therapy and standard care on pain, disability, quality of life, pain catastrophizing, kinesiophobia, depression, anxiety, and sleep

Table 3 shows the effect of aquatic therapy and standard care on pain, disability, quality of life, pain catastrophizing, kinesiophobia, depression, anxiety, and sleep disturbance. There were no significant group*time interactions for all outcomes (all $p > 0.05$).

3.2.1. Pain

Both the aquatic therapy (MD: −2.95, SE: 0.49, F = 36.44, $p < 0.001$, $\eta_p^2 = 0.57$) and standard care (MD: −3.19, SE: 0.52, F = 37.68, $p < 0.001$, $\eta_p^2 = 0.57$) group had a significant within-group decrease in pain intensity (NPRS). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

3.2.2. Disability

Both the aquatic therapy (MD: −18.04, SE: 1.84, F = 96.45, $p < 0.001$, $\eta_p^2 = 0.78$) and standard care (MD: −12.54, SE: 1.95, F = 41.24, $p < 0.001$, $\eta_p^2 = 0.60$) group had a significant within-group decrease in disability (ODI). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

3.2.3. Quality of life

Both the aquatic therapy (MD: 8.26, SE: 2.33, F = 12.56, $p = 0.001$, $\eta_p^2 = 0.31$) and standard care (MD: 8.38, SE: 2.48, F = 11.42, $p = 0.002$, $\eta_p^2 = 0.29$) group had a significant within-group increase in physical quality of life (SF-12 physical). Interestingly, neither the aquatic therapy (MD: 4.73, SE: 2.77, F = 2.92, $p = 0.098$, $\eta_p^2 = 0.10$) nor the standard care (MD: 4.07, SE: 2.94, F = 1.91, $p = 0.177$, $\eta_p^2 = 0.06$) group had a significant improvement in mental quality of life (SF-12 mental). In both SF-12 physical and mental, no significant between-group mean difference or main effect of group was found ($p > 0.05$). However, both the aquatic therapy (MD: 13.00, SE: 2.58, F = 25.43, $p < 0.001$, $\eta_p^2 = 0.48$) and standard care (MD: 12.45, SE: 2.74, F = 20.64, $p < 0.001$, $\eta_p^2 = 0.42$) group had a significant within-group increase in total quality of life (SF-12 total). Per-protocol analysis also revealed a significant main effect of group in total quality of life (SF-12 total, $p = 0.039$).

3.2.4. Pain catastrophizing

Both the aquatic therapy (MD: −9.21, SE: 1.41, F = 42.88, $p < 0.001$, $\eta_p^2 = 0.61$) and standard care (MD: −8.34, SE: 1.45, F = 33.04, $p < 0.001$, $\eta_p^2 = 0.55$) group had a significant within-group decrease in pain catastrophizing (PCS). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

3.2.5. Kinesiophobia

Only the aquatic therapy (MD: −4.84, SE: 1.45, F = 11.12, $p = 0.002$, $\eta_p^2 = 0.28$), not the standard care (MD: −2.75, SE: 1.54, F = 3.18, $p = 0.085$, $\eta_p^2 = 0.10$) group, had a significant within-group decrease in kinesiophobia (TSK-11). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

3.2.6. Depression and anxiety

Both the aquatic therapy (MD: −3.97, SE: 0.87, F = 21.04, $p < 0.001$, $\eta_p^2 = 0.43$) and standard care (MD: −2.66, SE: 0.92,

Table 3. Adjusted Mean Results with Standard Error for Pain, Disability, Quality of Life and Psychological Outcomes.

Outcomes		Aquatic therapy group (n = 18)	Standard care group (n = 16)	Between-group MD (95% CI)	Main effect of group	Group*time interaction
Pain	Baseline (Std. Error)	5.14 ± 0.41	5.84 ± 0.44			
(NPRS)	10-weeks (Std. Error)	2.20 ± 0.42	2.65 ± 0.45	0.46 (−0.83 to 1.74)		
	Within-group MD (95%)	−2.95 (−3.95 to −1.95)*	−3.19 (−4.25 to −2.12)*	$p = 0.472$	$p = 0.259$	$p = 0.744$
	Main effect of time	$p < 0.001$	$p < 0.001$	F = 0.53	F = 1.33	F = 0.11
		F = 36.44	F = 37.68	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.019$	$\eta_p^2 = 0.045$	$\eta_p^2 = 0.004$
Disability	Baseline (Std. Error)	31.34 ± 1.95	24.46 ± 2.07			
(ODI)	10-weeks (Std. Error)	13.30 ± 2.07	11.92 ± 2.20	−1.38 (−7.69 to 4.92)		
	Within-group MD (95%)	−18.04 (−21.80 to −14.28)*	−12.54 (−16.54 to −8.54)*	$p = 0.657$	$p = 0.132$	$p = 0.054$
	Main effect of time	$p < 0.001$	$p < 0.001$	F = 0.20	F = 2.41	F = 4.04
		F = 96.45	F = 41.24	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.007$	$\eta_p^2 = 0.079$	$\eta_p^2 = 0.126$
SF-12 Physical	Baseline (Std. Error)	35.82 ± 1.41	39.26 ± 1.50			
	10-weeks (Std. Error)	44.08 ± 2.08	47.64 ± 2.21	3.56 (−2.78 to 9.90)		
	Within-group MD (95%)	8.26 (3.49 to 13.04)*	8.38 (3.30 to 13.46)*	$p = 0.260$	$p = 0.090$	$p = 0.974$
	Main effect of time	$p = 0.001$	$p = 0.002$	F = 1.32	F = 3.08	F = 0.001
		F = 12.56	F = 11.42	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.045$	$\eta_p^2 = 0.099$	$\eta_p^2 = 0.000$
SF-12 Mental	Baseline (Std. Error)	41.74 ± 2.62	45.35 ± 2.80			
	10-weeks (Std. Error)	46.48 ± 2.24	49.42 ± 2.38	2.94 (−3.88 to 9.77)		
	Within-group MD (95%)	4.73 (−0.94 to 10.41)	4.07 (−1.96 to 10.1)	$p = 0.384$	$p = 0.283$	$p = 0.873$
	Main effect of time	$p = 0.098$	$p = 0.177$	F = 0.78	F = 1.20	F = 0.026
		F = 2.92	F = 1.91	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.027$	$\eta_p^2 = 0.041$	$\eta_p^2 = 0.001$
SF-12 Total	Baseline (Std. Error)	77.56 ± 2.54	84.61 ± 2.70			
	10-weeks (Std. Error)	90.56 ± 2.39	97.06 ± 2.54	6.50 (−0.78 to 13.79)		
	Within-group MD (95%)	13.00 (7.72 ± 18.28)*	12.45 (6.84 to 18.06)*	$p = 0.078$	$p = 0.039$	$p = 0.887$
	Main effect of time	$p < 0.001$	$p < 0.001$	F = 3.34	F = 4.69	F = 0.02
		F = 25.43	F = 20.64	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.107$	$\eta_p^2 = 0.143$	$\eta_p^2 = 0.001$
Catastrophizing	Baseline (Std. Error)	19.8 ± 2.50	17.79 ± 2.57			
(PCS)	10-weeks (Std. Error)	10.58 ± 2.80	9.44 ± 2.89	−1.14 (−9.62 to 7.34)		
	Within-group MD (95%)	−9.21 (−12.09 to −6.32)*	−8.34 (−11.32 to −5.37)*	$p = 0.785$	$p = 0.681$	$p = 0.682$
	Main effect of time	$p < 0.001$	$p < 0.001$	F = 0.08	F = 0.17	F = 0.17
		F = 42.88	F = 33.04	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.003$	$\eta_p^2 = 0.006$	$\eta_p^2 = 0.006$
Kinesiophobia	Baseline (Std. Error)	24.95 ± 1.09	23.12 ± 1.16			
(TSK-11)	10-weeks (Std. Error)	20.11 ± 1.49	20.38 ± 1.58	0.26 (−4.28 to 4.81)		
	Within-group MD (95%)	−4.84 (−7.81 to −1.86)*	−2.75 (−5.91 to 0.41)	$p = 0.906$	$p = 0.633$	$p = 0.342$
	Main effect of time	$p = 0.002$	$p = 0.085$	F = 0.01	F = 0.23	F = 0.93
		F = 11.12	F = 3.18	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.001$	$\eta_p^2 = 0.008$	$\eta_p^2 = 0.032$
Anxiety & Depression	Baseline (Std. Error)	14.32 ± 1.45	11.89 ± 1.54			
(HADS)	10-weeks (Std. Error)	10.35 ± 1.56	9.23 ± 1.66	−1.12 (−5.87 to 3.63)		
	Within-group MD (95%)	−3.97 (−5.74 to −2.20)*	−2.66 (−4.55 to −0.78)*	$p = 0.633$	$p = 0.416$	$p = 0.320$
	Main effect of time	$p < 0.001$	$p = 0.007$	F = 0.23	F = 0.68	F = 1.03
		F = 21.04	F = 8.38	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.008$	$\eta_p^2 = 0.024$	$\eta_p^2 = 0.035$
Sleep Disturbance	Baseline (Std. Error)	12.53 ± 1.26	11.44 ± 1.30			
(ISI)	10-weeks (Std. Error)	7.46 ± 1.48	8.76 ± 1.53	1.29 (−3.17 to 5.75)		
	Within-group MD (95%)	−5.06 (−7.97 to −2.16)*	−2.69 (−5.68 to 0.31)	$p = 0.557$	$p = 0.952$	$p = 0.262$
	Main effect of time	$p = 0.001$	$p = 0.077$	F = 0.36	F = 0.004	F = 1.32
		F = 12.79	F = 3.38	df = 1	df = 1	df = 1
		df = 1	df = 1	$\eta_p^2 = 0.013$	$\eta_p^2 = 0.000$	$\eta_p^2 = 0.046$

Abbreviations: CI: Confidence Interval; MD: Mean Difference; HADS: Hospital Anxiety and Depression Scale; ISI: Insomnia Severity Index; NPRS: Numerical Pain Rating Scale; ODI: Oswestry Disability Index; PCS: Pain Catastrophizing Scale; SF-12: 12-item Short Form Health Survey; TSK: Tampa Scale of Kinesiophobia.
*The mean difference is significant at the 0.05 level.

F = 8.38, $p = 0.007$, $\eta_p^2 = 0.23$) group had a significant within-group decrease in anxiety/depression (HADS). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

3.2.7. Sleep

Only the aquatic therapy (MD: −5.06, SE: 1.42, F = 12.79, $p = 0.001$, $\eta_p^2 = 0.32$), not the standard care (MD: −2.69, SE: 1.46, F = 3.38, $p = 0.077$, $\eta_p^2 = 0.11$) group, had a significant within-group decrease in sleep disturbance (ISI). No significant between-group mean difference or main effect of group was found ($p > 0.05$).

4. Discussion

The current study aimed to evaluate the effects of aquatic therapy compared to standard LBP care on pain, disability, quality of life and the psychological factors associated with CLBP. Our findings revealed that both the aquatic therapy and standard care interventions were effective in improving pain, disability, and physical quality of life with no significant differences between interventions. Interestingly, when comparing aquatic therapy to land-based exercise in people with CLBP, past studies showed no significant differences in improved pain intensity or function between the two exercise types [48–50]. Furthermore, two recent systematic reviews and meta-analyses analyzed the impact of aquatic therapy on pain intensity, disability and quality of life in individuals with LBP [16,17]. Our findings corroborate with both reviews, as the authors similarly found that aquatic exercise significantly improved pain, disability and the physical component of quality of life.

In the context of CLBP, analyzing the clinically significant change for each outcome is important. A 2-point change on the NPRS represents the minimal clinically important difference (MCID) [37], which both the aquatic therapy and standard care groups met. Prior research has also identified the MCID of the ODI, representing self-reported disability, to be approximately a 10 point decrease [51], which both groups met as well. Although the difference was not significant, the aquatic therapy group showed a greater reduction in ODI scores compared to the standard care group (−18.04 vs − 12.54). While this may have been due to a difference in baseline scores, the possibility of aquatic therapy being a more comfortable treatment alternative to improve self-reported function should be further investigated. The aquatic therapy intervention focused on dynamic lumbar stabilization and adapted resistance training. By generating omnidirectional, limb driven velocity dependent perturbations under conditions of low axial compression, aquatic therapy trains co-contraction of deep trunk muscles to elicit dynamic lumbar stabilization during movement. Dynamic lumbar stabilization exercises and resistance training have been shown to be the most effective exercise modes for improving function in CLBP [52]. Dynamic lumbar stabilization exercises target the trunk musculature to improve proprioception, motor control, and stability of the spine and pelvis during functional movements [52]. Furthermore, the ODI is closely related to function, as it measures the impact of pain and disability on daily activities [38,53]. If participants in the aquatic therapy group were able to complete exercises in the water where movements are often less challenging due to buoyancy, it could have facilitated improvements in their functional ability, ultimately leading to better ODI scores. However, the aquatic therapy group also had significantly higher self-reported disability at baseline, which left more room for improvement. Additionally, both groups had a significant improvement in the SF-12 physical composite score and SF-12 total score, with no significant change in the SF-12 mental composite score. These results suggest that although the overall quality of life improved, most of the improvements were due to improvements in physical health. Indeed, each group had similar improvements in physical quality of life, and met the MCID for the SF-12 physical composite score in CLBP at 3.29 points [54]. Because both programs used progressive trunk stabilization and resistance exercises with similar supervision, they likely produced similar neuromuscular and pain-relief adaptations, minimizing between-group differences in most physical outcomes. The standard care intervention mimicked the standard LBP treatment and personal rehabilitation plan a person with LBP receives at the School of Health Athletic Therapy clinic. While participants in the aquatic therapy group performed trunk stabilization with a variety of exercises and progression was individualized to each participant. A recent systematic review and meta-analyses investigated the benefits of individualized exercise in CLBP [55]. The authors found that individualized exercise had relevant effects on pain intensity and disability, with small to medium effects compared to other passive or active interventions.

In regard to psychological factors, our findings revealed that both aquatic therapy and standard care were effective in improving depression, anxiety, and pain catastrophizing with no significant differences between interventions. While both groups did not have significant improvements in the mental composite score of quality of life, an improvement in mental health was reflected in the anxiety and depression (HADS) scores. The benefits of exercise therapy on mental health are well documented, and these are reflected in the results of our study. Meta-analyses have determined exercise to have a moderate to large antidepressant effect in individuals with depressive disorder [56]. Although the data is limited, some studies suggest aerobic exercise to be the most effective exercise mode to reduce depression and anxiety in CLBP [52]. The aquatic therapy protocol in our study was designed to increase cardiovascular demands by incorporating dynamic exercises with low rest time between exercises to maintain an elevated heart rate. A potential mechanism for improvement in depression and anxiety is through endogenous opioid B-endorphin release and modulation [57,58]. B-endorphins are responsible for modulating stress responses and producing a feeling of well-being [59]. Studies have reported a decreased B-endorphin secretory capacity [60] and diminished B-endorphin levels in circulation in CLBP [61]. Aerobic exercise of sufficient intensity acutely increases B-endorphin levels [62]. Increased B-endorphin levels have been associated with decreased symptoms of depression, improved coping with stress [59], and decreased CLBP

intensity [63]. Therefore, improving the regulation of B-endorphins through aquatic therapy could have contributed to improving symptoms of depression and anxiety in CLBP.

Both interventions had beneficial effects on pain catastrophizing. In CLBP, the MCID for the PCS is 8 to 11 points [64], which both groups met. The primary focus of both interventions was to provide a reduction in pain and disability. The improvement in pain-related fears may have partly been through self-efficacy improvements. Since both interventions were effective to improve pain and disability, this progress can enable individuals to reclaim activities they once avoided due to pain or fear of pain. Consequently, they may adopt a more proactive and resilient perspective toward their condition, partly through the enhancement of self-efficacy via exercise [65]. Self-efficacy refers to an individual's belief in their capacity to complete a task [66]. Poor self-efficacy leads to anxiety, depression, pain catastrophizing, and a poor outlook on one's condition [67]. In the context of pain, pain self-efficacy is best described as one's confidence in their ability to function properly despite being in pain. As they progress, they may be able to enjoy longer walks without exacerbating their pain, do household chores that were previously too difficult and attend social gatherings previously avoided due to pain-related isolation. These milestones are partially reflected in the ODI disability questionnaire, including components like self-reported increased walking capacity, pain-free completion of chores, attending social gatherings, and pain-free personal care. Our results suggest aquatic therapy and standard care may provide an effective way through which individuals with CLBP feel like they are actively taking control of their condition. By changing individuals' perspectives on their condition, their way of thinking may have been steered toward a more constructive outlook. In essence, the cumulative effect of pain alleviation, functional improvements and greater self-efficacy empowers individuals to engage in meaningful activities once again, giving them a sense of accomplishment leading to an improvement in depression, anxiety, overall quality of life and pain catastrophizing [68,69].

Interestingly, only the aquatic therapy group significantly improved kinesiophobia, the fear of movement or reinjury, and sleep disturbance. Water-based exercise has significantly improved pain-related fear and fear avoidance behaviors compared to land-based exercise in people with CLBP [27]. Additionally, people with CLBP have reported less anxiety after an aquatic exercise intervention [70]. Key differences between land and water exercise come from water's physical properties and the unique physiological effects of aquatic therapy. During water immersion, buoyancy counteracts the forces of gravity acting on the body and consequently reduces up to 60% of compressive forces on the intervertebral joints of the spine [25]. Shallow water functional exercises allow users to mimic land-based exercises through a greater range of motion that might otherwise be painful on land. Despite the effects of buoyancy, aquatic exercise has been shown to produce similar levels of muscle activation of the erector spinae, multifidus, gluteus and abdominal muscles compared to land-based exercises [28]. Aquatic exercise can, therefore, yield similar results to land-based exercise to improve strength without provoking pain. Additionally, the viscosity of water allows for a safe and controlled progression of resistance exercises [71]. Being able to move through full range of motion and progressing through exercises while being in less pain could have allowed participants in the aquatic therapy group to feel safer and more comfortable in a water setting. Therefore, the aquatic therapy group was potentially able to overcome their fears more than the standard care group, leading to high participation and confidence.

In summary, our findings highlight the potential of both aquatic therapy and standard care to improve psychological outcomes in individuals with CLBP, with some unique benefits observed in the aquatic group. While both interventions led to improvements in depression, anxiety, and pain catastrophizing, likely due to the well-documented mental health benefits of exercise and enhanced self-efficacy through functional gains [52], only the aquatic therapy group demonstrated significant improvements in kinesiophobia and sleep disturbance. These unique benefits may be attributed to the supportive properties of water, which can facilitate pain-free movement, reduce fear of reinjury, and promote a sense of safety and confidence during exercise [25]. These factors, combined with the individualized therapeutic approach, may have contributed to the psychological improvements observed, supporting the value of aquatic therapy in addressing both physical and psychological dimensions of CLBP.

The multifactored nature of CLBP requires a good understanding of the individual factors that may be contributing to each person's condition. A good therapeutic alliance between the patient and the clinician is a strong predictor of better patient outcomes in CLBP [72]. A strength of this study was the one-on-one nature of each session with a certified athletic therapist. Individual sessions allow for more targeted care and better support for each person's specific needs, which improves the therapeutic alliance between the patient and the therapist. Common complaints from individuals with CLBP include unfulfilling interactions with healthcare professionals, partly from a perceived lack of support [73]. Providing individuals with CLBP with support and dedicated time demonstrates a commitment to prioritizing their well-being. Regular one-on-one sessions allow the therapist to guide the patient through the rehabilitation process, addressing and alleviating any fears or barriers related to pain and exercise as they arise.

4.1. Limitations

Although the present study focused on chronic nonspecific low back pain, emerging evidence highlights the importance of differentiating nonspecific CLBP from other specific conditions such as lumbosacral plexopathies and sacroiliac joint – mediated pain. Recent reviews have emphasized that lumbosacral plexopathies [74] and SI joint dysfunction [75] present with distinct clinical features that require targeted diagnostic and treatment approaches. Our eligibility criteria excluded participants with neurological signs, radiculopathy, and structural abnormalities, thereby limiting generalizability to these subgroups. Nonetheless, the mechanisms explored in our study, particularly in reductions of pain-related fears, may be

relevant for future investigations evaluating exercise-based interventions in these populations. This study had a relatively small sample size; therefore, we did not perform a sex-based analysis, and larger studies are needed to confirm the generalizability of these results. Due to resource limitations, the assessors responsible for overseeing the post-intervention testing also administered the interventions, meaning they were not blinded and could increase the risk of observer bias. Furthermore, as the current study investigated secondary outcomes from a parent randomized controlled trial [31], the results remain exploratory in nature and should be interpreted accordingly. While the sample size was powered for the primary outcome of the parent trial, it may not be sufficient to detect smaller effects for this secondary outcome, increasing the risk of Type II error. Furthermore, because this study focused on secondary and exploratory outcomes (pain, disability, SF-12, psychological measures), no adjustment for multiple comparisons (e.g., Bonferroni correction) were applied, which may increase the risk of Type I error. The baseline physical activity levels were higher than expected, with both groups exceeding, or nearly exceeding, the threshold of high physical activity (3000 METs per week), despite most participants not engaging in regular strength training as per the inclusion criteria. The IPAQ relies on self-reported measures of physical activity and tends to overestimate the time spent on moderate and vigorous physical activity [76]. Differences between interventions may have influenced the results, as the aquatic therapy group did not receive a physical examination, potentially impacting the therapeutic alliance between participants and therapists.

5. Conclusion

Both the aquatic therapy and standard care groups showed significant improvements in pain, disability, quality of life, depression, anxiety, and pain catastrophizing, with most patient-reported outcomes reaching clinically meaningful thresholds. Notably, only the aquatic therapy group experienced a significant reduction in sleep disturbance and in kinesiophobia, though its clinical significance remains uncertain due to the absence of established cutoff scores. Our findings provide preliminary evidence suggesting that aquatic therapy may be a more comfortable treatment alternative for addressing pain, disability, physical quality of life and psychological outcomes in CLBP. Future research is warranted to confirm these observations and to better understand the underlying mechanisms.

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Author contributions

NV: Conceptualization, data curation, formal analysis, investigation, methodology, writing – original draft. CM: Conceptualization, data curation, investigation, methodology, writing – review & editing. BR: Conceptualization, data curation, investigation, project coordination, formal analysis, writing – review & editing. MF: Conceptualization, investigation, methodology, funding acquisition, project coordination, resources, supervision, writing – review & editing. All authors approved the final version of the manuscript.

Disclosure statement

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Ethical declaration

The project was approved by the Central Ethics Research Committee of the Quebec Minister of Health and Social Services (# CCER-21- 22–35). Written informed consent to participate in the study was obtained from each participant. All methods were carried out in accordance with relevant guidelines and regulations.

Data availability statement

The data that support the findings of this study are available from the corresponding author, MF, upon reasonable request.

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