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Effects of acceptance and commitment therapy plus exercise for older adults with chronic low back pain: A preliminary cluster randomized controlled trial with qualitative interviews

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ABSTRACT

Chronic low back pain (CLBP) is increasingly prevalent in older adults and often leads to functional disability and depressive symptoms. This 2-arm, double-blinded, pilot cluster RCT, with semi-structured interviews, aimed to evaluate the acceptability, feasibility, and preliminary clinical efficacy of ACT plus exercise training (ACT+Ex) on improving pain-related outcomes, psychological outcomes, and physical fitness in older adults with CLBP at post-treatment and 6-month follow-up. Forty community-dwelling older adults (62–85 years) with CLBP, predominantly female, were randomized to ACT+Ex (n=20) or Education plus exercise program (Edu+Ex) (n=20) for 8 weekly group-based sessions, with assessments at baseline, post-treatment, and 6-month follow-up (primary endpoint). Self-reported outcomes included pain intensity, functional disability (Roland Morris Disability Questionnaires, RMDQ), health-related quality of life (EuroQol-5 Dimensions, EQ-5D-5L), psychological inflexibility (Acceptance and Action Questionnaire-Version 2, AAQ-II), and psychological well-being (Depression Anxiety Stress Scale). Physical fitness was assessed using the functional reach test (FRT), Timed Up and Go test (TUG), 6-minute walk test (6MWT), hand grip strength (HGS), and 30-second sit-to-stand (STS-30) test. This trial achieved high recruitment (23.5 participants per week) and completion rates (92.5%). Exploratory analyses revealed that ACT+Ex significantly improved pain intensity, disability, psychological inflexibility, HRQoL, and physical fitness at post-treatment and 6-month follow-up. Qualitative data identified 3 superordinate themes: previous healthcare experience affecting pain beliefs; acceptance strategies guiding behavioral changes; and facilitators and barriers to treatment compliance. These findings support the need for a definitive RCT and form a valuable basis for future exploration regarding the behavioral mechanisms of ACT in clinical applications.
Perspective: A multimodal therapy incorporating ACT and exercise promotes positive behavioral changes and its treatment effects are maintained at the 6-month follow-up especially for physical performance.

Introduction

Over the past three decades, chronic low back pain (CLBP) has significantly contributed to the global burden of disability, impacting 619 million individuals worldwide in 2020.[1] The affected population is anticipated to increase to 843 million by 2050, with the most significant

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proportion being older adults.[2–4] Given the uncertainty regarding the efficacy of pharmacological treatment for older adults with CLBP, as well as the potential for drug-related adverse events, non-pharmacological interventions are commonly recommended.[5–7] While there is good evidence to support that exercise therapy demonstrates low-to-moderate effects in improving pain, functional disability, and health-related quality of life (HRQoL),[7,8] adherence to traditional exercise regimens remains challenging for older adults with CLBP.[9] Older adults commonly face various age-related challenges (such as loneliness, comorbidities, and bereavement) that may cause psychological problems like self-doubt, frustration, and depression, further deteriorating compliance with exercise and engagement in daily activities.[10,11] Therefore, developing an effective multimodal treatment approach tailored for older adults is crucial.

Acceptance and Commitment Therapy (ACT) is a third-wave cognitive behavioral therapy that aims to enhance psychological flexibility through mindfulness, acceptance, and value-driven behavior changes.[12] The ACT model for chronic pain explicitly incorporates the concepts of universal suffering, reduction of struggles with pain, creating psychological distance from the pain, identification of essential life goals/values, and value-based action commitment despite the persistent pain.[13] It was reported that ACT could enhance pain acceptance and reduce depressive symptoms in older adults with chronic pain, offering greater benefits than cognitive behavioral therapy.[14] However, these improvements often diminished or worsened during 6-month follow-up, which implies that further boosters may be needed.[15]

Behavioral therapy and pain education, when combined with structured exercise, are the most effective psychological interventions for CLBP.[6,16] However, little is known about how ACT strategies and exercise interact in treating CLBP. Casey et al. found that adding ACT to supervised exercise did not further reduce pain interference compared to exercise alone in young adults with chronic pain.[17] However, studies by Fishbein et al. and Wetherell et al. suggest that age may influence the clinical efficacy of ACT.[14,15] Specifically, older adults may be more responsive to ACT, reporting greater pain relief and better adherence to its principles compared to younger adults.[14,15] Despite the potential benefits of ACT for older adults, those over 70 years old are underrepresented in studies on ACT for chronic pain. There remains insufficient attention to age-specific needs, an overreliance on patient-reported outcomes, and an under-reporting of barriers and facilitators to the

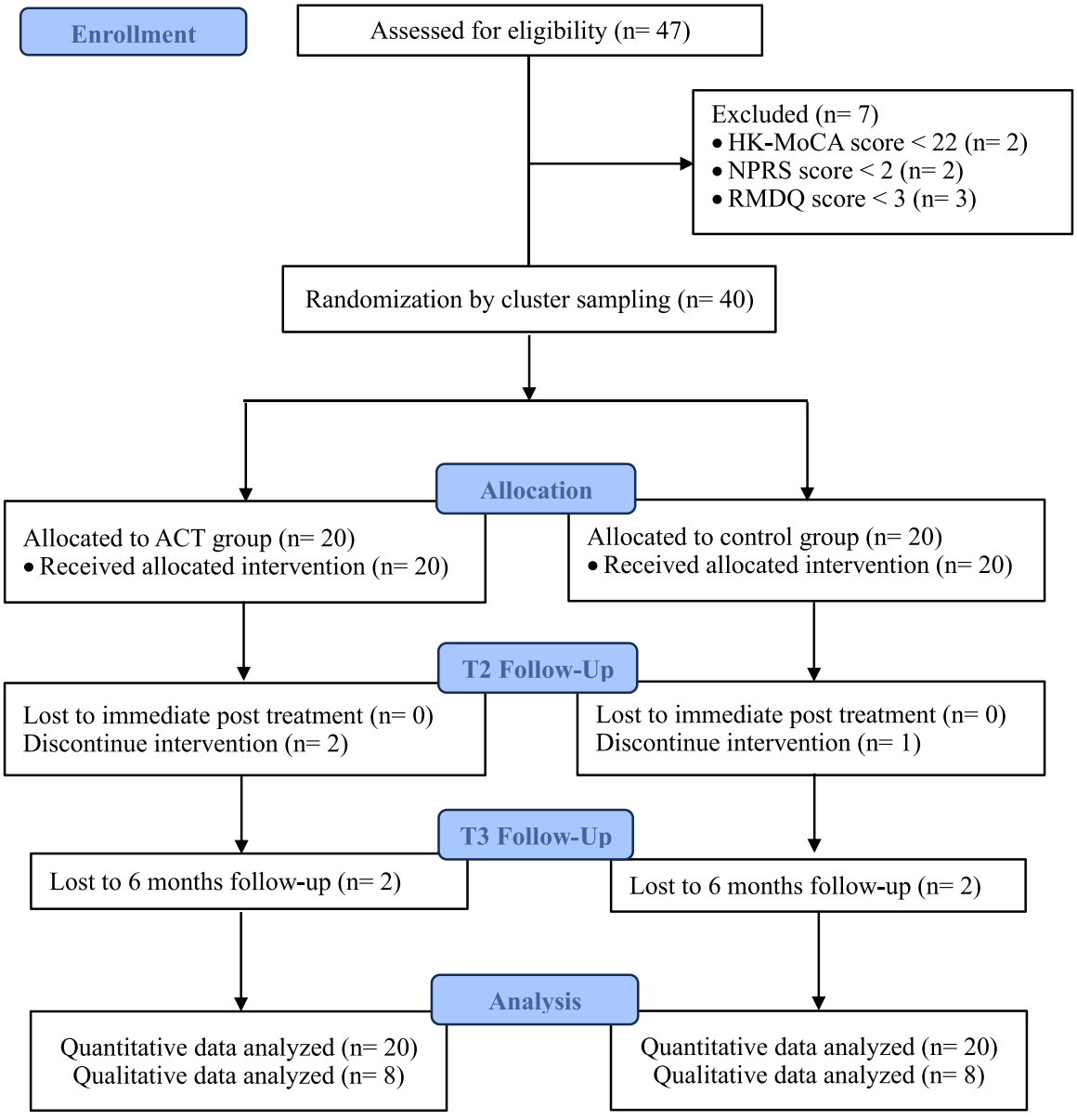

Fig. 1. A CONSORT flow diagram of the study.

implementation of ACT.

Given the above, this pilot cluster randomized controlled trial (RCT) aimed to determine the feasibility, acceptability, and comparative efficacy of an ACT plus exercise program (ACT+Ex) versus a patient education plus exercise program (Edu+Ex) among community-dwelling older adults with CLBP immediately post-treatment and at a 6-month follow-up. We also explored participant experiences and perspectives in both groups through semi-structured interviews at post-treatment and 6-month follow-up.

Methods

This study adhered to the Declaration of Helsinki, and was registered on ClinicalTrials.gov (NCT05919446). The reporting followed the CONSORT 2010 statement: extension to cluster randomized trials.[18] The study procedures were approved by the Institutional Review Board of The Hong Kong Polytechnic University (registration number HSEARS20230104002).

Study design

This study was a 2-arm pilot cluster RCT (Fig. 1). Eligible participants were contacted 2 weeks before the intervention to complete consent forms and a socio-demographic questionnaire, which gathered information on their age, gender, education level, and living status, and medical history. After providing informed consent, they were randomly assigned to either the intervention (ACT+Ex) or control (Edu+Ex) group to receive 8 scheduled weekly group sessions. Each intervention group session comprised about a 60-minute ACT course and a 30-minute group exercise session. Each control group session consisted of a 60-minute back care education session and a 30-minute group exercise session. Our retention strategy was encouraging participants to attend the sessions through weekly reminders by a research assistant and a pre-course phone call by a social worker. A research assistant made 3 attempts to contact withdrawing participants to document their reasons for dropout.

Outcome measures were assessed at baseline, immediately post-treatment, and 6-month follow-up. Participants were instructed not to take analgesic medication within 24 h before each assessment and were advised against initiating any new LBP treatments during the study period, except for those prescribed by their physicians. Semi-structured interviews were conducted post-treatment and at the 6-month follow-up to gather participants' experiences and opinions regarding their participation in the assigned groups.

We made three modifications to the original protocol. First, we planned to recruit participants (15 per group). However, due to strong interest from eligible participants during recruitment, we increased the sample size to 40 to accommodate demand and enhance statistical power. Second, we extended the intervention duration from 4 to 8 weeks before recruitment to allow older participants more time to integrate ACT principles into their daily lives.[13,19] Lastly, after the pilot trial began, new evidence suggested that older adults with chronic pain might experience significant initial improvements with ACT but could relapse by 6 months.[15] To evaluate whether this pattern would occur in our participants, we extended the follow-up period from 3 months to 6 months. This adjustment could inform the design of our future definitive RCT by suggesting the inclusion of booster treatments.

Participants

Individuals aged 60 years or above were recruited if they had: (1) non-specific CLBP between the 12th rib and the sacral crease, with or without leg pain, persisting for at least three months within the last 12 months;[20,21] (2) Numeric Pain Rating Scale (NPRS) scores $\geq$ 2 points and Roland Morris Disability Questionnaire (RMDQ) scores $\geq$ 3 points;[22,23] (3) sought medical or healthcare professional treatments for their low back pain (LBP) in the last 12 months; and (4) were able to read and write Chinese, and complete self-reported questionnaires both before and after the intervention.

Individuals were excluded if they: (1) had specific LBP (e.g., malignant pain, lumbar spinal stenosis, spinal fracture or infection, spondylolisthesis, or visceral organ pain); (2) had unstable or serious psychopathological disorders that could interfere with individual or group processes (e.g., high suicide risk, manic episodes, and substance use disorders), or (3) were currently receiving or had received psychological interventions in the past six months. Additionally, individuals with mild cognitive impairment or diagnosed dementia were excluded. Mild cognitive impairment was defined as scoring $<$ 22 on the Hong Kong version of the Montreal Cognitive Assessment (HK-MoCA).[24]

Randomization and blinding

Two community centers for older adults, located in different public housing estates for low-income families, were selected as cluster sites for participant recruitment. These clusters were randomly assigned to provide either ACT+Ex or Edu+Ex. Randomization was conducted by an independent research assistant not affiliated with the study team, using a random number generator. Each cluster recruited 20 participants. The sample size was determined based on guidance for a pilot clinical trial for a continuous outcome variable, accounting for an anticipated 20% attrition over a one-month baseline period.[25]

Participants were informed that they would receive treatment programs referred to as "ACT" or "back care education" but they were not made aware of their group allocation (intervention or control). Therapists delivering the ACT and education interventions were not blinded, as they were responsible for designing and delivering their respective treatments; however, they were unaware of the detailed content of the other group. Two trained therapists who delivered the exercise component were aware of the ACT or education content for their assigned group to ensure consistent integration with the exercise protocols. Outcome assessors, interviewers, and research assistants responsible for data collection or analysis were blinded to group allocation.

Intervention

Acceptance and commitment therapy

In this study, the strategies of applying ACT for CLBP management in older adults were based on the core processes of ACT, which have been supported by current research and were further optimized through experience implementing ACT in the primary health care settings in Chinese populations.[12,13,17,26] Specifically, the strategies include cognitive defusion, which helps older adults observe pain-related thoughts without judgment; acceptance, which encourages them to embrace pain rather than resist it; and awareness of the present moment, which promotes mindfulness to reduce anxiety. Additionally, self-as-context helps them perceive themselves beyond their pain, while values clarification assists them in identifying what is truly important and guides their behavior accordingly. Finally, committed action motivates them to set achievable goals that align with their values and improve their overall quality of life despite their pain. For an overview of the ACT intervention content and selected exercises, please refer to Appendix 1. It included psychological elements, videos and audio files, metaphors, mindfulness exercises, interactive activities, and homework assignments. For instance, mindfulness exercises were introduced to

help participants observe physical pain and thoughts with an open, non-judgmental, and accepting attitude. Experiential activities and analogies were emphasized to facilitate participants' understanding of psychological flexibility. Moreover, participants received take-home meditation audios and homework after each session to reinforce daily application. The 8 ACT treatment sessions were delivered by an experienced clinical psychologist.

Back care education

Back care education covered topics regarding risk factors for exacerbating back pain, misconceptions about LBP, conservative treatments (e.g., exercises, traditional Chinese medicine, diet, and nutrition), and social support (Appendix 2).[27] Each back care education session was delivered by a team of trained final-year physiotherapy students. These students were trained to use active listening skills to encourage participants to share their LBP-related concerns during the sessions. The students responded to participants empathetically without giving treatment advice. The strategy aimed to control for the contextual effects.[28]

Exercise training for both groups

Exercise programs were developed based on validated exercise regimens for older adults with CLBP, incorporating warm-up, strengthening exercises, and specific back stretching to improve participants' core stability, motor control, and reduce lumbar muscle tightness (Appendix 3).[9] The group-based exercise training was led by an experienced physiotherapist. Additionally, participants in both groups were instructed to perform 30-minute home exercises twice a week, supported by a take-home exercise guide (paper version and video version accessible via a social media app). The home-based exercises were designed to complement the content covered in the group training sessions. Participants received exercise logbooks with a simple checkbox format to easily record key details of their workouts.

Treatment fidelity

The fidelity of the interventions was assessed by an experienced ACT instructor (YWM) with over 10 years of experience in ACT research and an experienced LBP clinician-scientist (AW).

Study measures

The primary objective was to assess the feasibility and acceptability of the present study. The secondary objective was to estimate potential changes in pain-related, psychological, and physical fitness outcomes.

Primary outcome measures

Feasibility. Feasibility was assessed by the recruitment rate (the number of individuals who showed interest per week) and the eligibility rate (the percentage of eligible individuals among those who showed interest). The study was considered feasible if 10 participants were recruited per month and the eligibility rate was at least 70%. Compliance was assessed using class attendance records and home exercise logbooks. Adverse events were recorded.

Acceptability

As there is no consensus on determining acceptability in interventional trials, the class adherence rate and the attrition rate were used to assess the acceptability of this pilot trial.[29,30] Class adherence rate was defined as the percentage of participants attending at least seven of the eight required sessions. Attrition was defined as an individual who participated in a course of treatment but left before the treatment was completed. The intervention was considered acceptable if the class adherence rate was at least 70% and the attrition rate was less than 20%.[31]

Secondary outcome measures

Pain-related outcomes. Pain intensity was measured using an 11-point Numeric Pain Rating Scale (NPRS), ranging from 0 ("no pain") to 10 ("worst pain imaginable"), based on the question: "How would you rate your average pain over the past week?".[22] The proportion of participants achieving clinically meaningful improvements in pain was determined by the minimal clinically important difference (MCID) of 2 points in NPRS scores,[32].

Pain-related disability was evaluated using the Chinese version of the Roland-Morris Disability Questionnaire (RMDQ), a 24-item binary (yes/no) tool assessing functional limitations due to low back pain (LBP) in older adults.[23,33] The total score, ranging from 0 to 24, represents the severity of disability, with higher scores indicating greater impairment.

The Chinese version of the EuroQol-5 Dimensions, 5-Level Questionnaire (EQ-5D-5L) was used to evaluate health-related quality of life (HRQoL).[34] This 5-item instrument evaluates mobility, self-care, daily activities, pain/discomfort, and anxiety/depression, with 5 response options per item, ranging from "no problems" to "extreme problems/unable to." A normative HRQoL profile for the Hong Kong Chinese elderly has been established.[35]

The Patient Global Impression of Change (PGIC) scale was used to assess participant's overall satisfaction with health status improvements after treatment.[36] The PGIC scale is a 7-point scale depicting a patient's rating of overall improvement of activity limitations, symptoms, emotions, and overall quality of life. Patients rate their change as "1=very much improved", "2=much improved", "3=minimally improved", "4=no change", "5=minimally worse", "6=much worse" or "7=very much worse".

Psychological outcomes. The Acceptance and Action Questionnaire II (AAQ-II) is the most widely used measure of psychological inflexibility and has demonstrated satisfactory internal consistency and test-retest reliability in Chinese older adult samples.[37] Each item is scored on a 7-point scale (1 = "never true" to 7 = "always true"), with a maximum total score of 49. Considering current criticisms regarding its strong correlation with distress symptoms and its limited ability to capture the multidimensional aspects of psychological flexibility, changes in psychological inflexibility were analyzed alongside qualitative data to provide a more comprehensive understanding.[38]

The Chinese version of the Depression, Anxiety, and Stress Scales (DASS-21) was used to assess mental health, consisting of 21 items divided into depression, anxiety, and stress subscales (7 items each).[19] Items are rated on a 4-point scale (0 = "not at all" to 3 = "most of the time"), with higher scores indicating greater severity. The DASS-21 has been culturally adapted for Hong Kong and demonstrated excellent reliability and validity among elderly patients with persistent pain.[39]

Physical fitness outcomes. The functional reach test (FRT) is a quick, single-task dynamic assessment used to evaluate stability and balance in older adults.[40] It measures the distance between the length of an outstretched arm in a maximal forward reach, while maintaining a fixed base of support in a standing position. An average of three attempts was recorded.

The 30-second sit-to-stand test (30 s STS) is a measure of functional lower extremity strength in older adults.[41] The subjects were encouraged to complete sits and full stands on a chair (43 cm in height) as possible within 30 s. The number of repetitions during the entire

procedure was recorded.

The Timed Up-and-Go Test (TUG) is a simple and sensitive measure used to assess mobility, balance, and fall risk in older adults.[42] Participants were instructed to rise from a chair (42 cm in height), walk 3 m, turn, return to the chair, and sit down as quickly as possible. The total time taken to complete the task was recorded.

The six-minute walk test (6MWT) is a simple, safe, and reliable assessment used to evaluate exercise capacity and functional ability.[43] Participants were instructed to walk at their own pace for 6 min, aiming to cover as much distance as possible within the given time frame. Assessors will provide standardized encouragement during the test. The walking distance during the entire procedure was recorded.

The hand grip strength test (HGS) measures the maximum force generated by the forearm muscles and serves as a screening tool for assessing upper body strength, overall strength, and frailty in older adults.[44] The test was conducted using the JAMAR® Hydraulic Hand Dynamometer (Model J00105, Lafayette Instrument Company, the USA), with the participant squeezing the device as hard as possible, while seated, the shoulder adducted, elbow at 90° flexion (unsupported), and wrist in a neutral position.[45] The average of three readings of left and right hands were recorded.

Qualitative interviews

A research assistant contacted participants who completed the 8-week intervention to invite them to participate in semi-structured interviews. Participants were contacted sequentially to assess their interest and availability. To capture a wide range of experiences, participants were purposively sampled based on varying educational levels and durations of CLBP. The target was to recruit 16 to 18 participants to allow a final sample size of 14–16 after accounting for potential dropouts.[46]

A total of 16 participants (8 from the ACT+Ex group and 8 from the Edu+Ex group) consented to participate in the semi-structured interviews (four participants per focus group) immediately after treatment. These participants from the ACT+Ex group and the Edu+Ex group took part in the 6-month follow-up interviews again without any dropouts. Each focus group lasted 40 to 60 min and was facilitated by one of two trained research assistants. A semi-structured interview guide was developed to enhance the transparency and validity of the findings, allowing for the collection of pertinent information.[47] Participants were prompted to reflect on the training and express their (1) acceptability of the intervention procedure (i.e., duration and mode of delivery of the interventions) and (2) experience of the intervention (i.e., facilitators and barriers to the programs, perceived benefits, and implications of daily lives). Each group was conducted at the same training location.

Statistical and qualitative data analyses

Primary outcomes

Feasibility was assessed by the recruitment rate (number) and eligibility rate (percentage). Acceptability was evaluated based on adherence to the interventions (class attendance) and the attrition rate.

Secondary outcomes

For clinical outcomes, demographic data and clinical features were reported as mean and standard deviation (SD). Independent t-tests or chi-square tests were used to compare baseline characteristics between the two groups. Analyses were conducted on an intention-to-treat (ITT) basis, using all available data for each participant under the missing at random (MAR) assumption.[48] This study had a 3.3% rate of missing data, which was expected to have minimal impact on the estimation process and parameter estimates. Intervention effects were estimated using a mixed-effects model with the lme function in R (The R Project for Statistical Computing, Version 4.3.3, The R Foundation, https://www.r-project.org/).[49,50] This model considered repeated measures across groups (intervention and control) and time points (baseline, immediate post-treatment, and 6-month follow-up) as fixed factors. The 'times' variable was structured with three levels to capture the full trajectory of changes over time. A random intercept for participants was included as a random effect. The crossover effect groups × times was entered as an interaction term. Separate analyses were performed for all the primary, secondary, and exploration outcomes. All models were tested for homoscedasticity, normal distribution of the residuals, and the raw data to model fit. Visual assessment and the Shapiro-Wilk test were used for normality evaluation. The homogeneity of variance was confirmed by performing Levene's test. Pairwise comparisons were conducted using the emmeans function in R to explore significant interactions further.[51] Estimated marginal means (EMMs) were obtained by predictions from the fitted model using the effect function in R.[49,52] The significance level was set at 0.05. Effect sizes (Cohen's d) for changes between baseline, post-treatment, and the 6-month follow-up were calculated by dividing the slope coefficient by the baseline SD, with a Hedges' g correction applied for small samples.[53,54] Effect sizes were categorized as small ($d > 0.2$), medium ($d > 0.5$), and large ($d > 0.8$).[55]

Qualitative research

Regarding qualitative data, all interviews were audio recorded, transcribed verbatim in Chinese, and then translated into English. Interpretative phenomenological analysis (IPA) was chosen for data analysis because of its suitability for exploring emotionally laden and complex health-related experiences in health psychology research.[56] Two researchers independently coded the transcripts according to the IPA guidelines outlined by Willig and Smith, which involved five key stages: (1) a close interpretative reading of a participant's description where the researcher's initial responses to the text were annotated; (2) identifying emergent themes from these annotations; (3) clustering emergent themes into subordinate themes with identifying information; (4) repeating the abovementioned steps for each case; and (5) establishing patterns across cases documented in a master table of themes for the group.[47,56] Any disagreements between coders were resolved through discussion until a consensus was reached. Other researchers (AW and YWM) were consulted if consensus was not achieved. All 16 participants confirmed that the summary of findings accurately reflected their experiences of the interventions provided. NVivo 12 Plus was used for data analysis.

Patient and public involvement

Patients and the public were not involved in the study's design, conduct, or dissemination plans.

Table 1
Characteristics of the participants at baseline (N = 40).

	Control group (n=20)	ACT group (n=20)	P-value
Age (years), mean (SD)	73.6 (6.2)	72.8 (6.2)	0.666[a]
Female gender, n (%)	17 (85%)	19 (95%)	0.302[b]
Body mass index, mean (SD)	23.76 (3.69)	23.52 (3.53)	0.834[a]
Educational level			0.628[b]
Low, n (%)	14 (70%)	16 (80%)	
Intermediate, n (%)	5 (25%)	4 (20%)	
High, n (%)	1 (5%)	0 (0%)	
Living status, n (%)			0.371[b]
Living alone	9 (45%)	8 (40%)	
Living with family	11 (55%)	12 (60%)	
Duration of LBP, n (%)			0.616[b]
> 5 years	13 (65%)	12 (60%)	
1 - 5 years	6 (30%)	7 (35%)	
< 1 year	1 (5%)	1 (5%)	
MoCA score, mean (SD)	26.7 (2.43)	25.85 (2.28)	0.261[a]

NOTE. [a] independent t-test; [b] Chi-square test.
ACT, acceptance and commitment therapy; LBP, low back pain; MoCA, Montreal Cognitive Assessments, SD, standard deviation.

Results

The sample was predominantly female (95% in the ACT+Ex group and 85% in the Edu+Ex group), with ages ranging from 60 to 89 years (mean ± SD: 73.0 ± 6.0 years) and an average duration of CLBP of 12.4 years. Groups did not significantly differ in demographic characteristics at baseline (Table 1).

Feasibility and acceptability

Recruitment rate, adherence, and attrition rate

Forty-seven individuals showed interest from two centers within two weeks, with 40 participants meeting the inclusion criteria, yielding a recruitment rate of 23.5 participants per week, and an eligibility rate of 85.1%. Regarding adherence, 37 participants (92.5%) completed the interventions according to our predefined criterion of at least 7 of the 8 required sessions attendance, exceeding 90% in both groups. At the endpoint of the trial (6-month follow-up), 36 participants (90%) completed the follow-up assessment. Reasons for non-participation or attrition included caregiver responsibility (i.e., with their grandchildren or sick spouse) and medical appointments. All participants completed outcome reassessments immediately post-treatment. At the 6-month follow-up, 4 participants (2 from each group) were lost to follow-up due to loss of contact. No adverse events were reported during the trial. In addition, despite weekly reminders to complete the exercise logbook, only 2 participants in the ACT+Ex group and one in the Edu+Ex group returned their logbooks at the end of the 8-week intervention while other participants reported orally. Reported reasons for non-compliance were forgetting or losing the logbooks.

Clinical outcomes

There were no significant between-group differences in the outcome measures at the baseline level (all $P > 0.05$).

Pain-related and psychological outcomes

The analysis of pain intensity revealed a significant time effect (NPRS, $P = 0.047$), indicating improvements over time in both groups (Fig. 2A,). Half of the ACT participants achieved the MCID in pain scores immediately after treatment, contrasting with 20% in the Edu+Ex group. Analyses of functional disability, HRQoL, and psychological inflexibility showed significant group-time interaction effects (RMDQ, $P = 0.014$; EQ-5D-5L, $P = 0.016$; AAQ-II, $P = 0.016$), indicating different improvement trends between the two groups (Fig. 2B, C, and D). The ACT+Ex group showed significant improvements in disability, HRQoL, and psychological inflexibility immediately post-treatment and at the 6-month follow-up. The DASS depression and anxiety subscale scores also improved significantly immediately after treatment, although changes relapsed at the 6-month follow-up. However, no significant between-group differences were observed for these outcome variables across follow-up assessments (Table 2). A summary of the mixed effects models in outcomes changes are shown in Appendix 4.

There were no significant differences in the PGIC found between those assigned to the ACT+Ex group and the Edu+Ex group at immediately post-treatment (ACT+Ex group: 2.35 ± 0.59 vs Edu+Ex group: 2.30 ± 0.66, p = 0.827) and the 6-month follow-up (ACT+Ex group: 2.55 ± 0.76 vs Edu+Ex group: 2.50 ± 0.76, p = 0.836). Most of the participants reported a PGIC score of "1=very much improved" or "2=much improved" immediately after treatment (n=12 in each group) and at the 6-month follow-up (n=11 in the ACT+Ex group and n=8 in the Edu+Ex group). The remaining participants considered their symptoms "slightly improved" or "no change". No participants reported symptoms worsening at either time point.

There was a significant time effect on stress symptoms (DASS-21-Stress, $P = 0.002$). Specifically, the Edu+Ex group showed significant within-group improvements in stress symptoms immediately post-treatment ($P = 0.006$) and 6-month follow-up ($P = 0.007$). In addition, there were no significant findings on time effects, group effects, or group-time interaction effects observed on depression and anxiety symptoms throughout the study.

Physical fitness outcomes

Analysis of TUG speed revealed a significant group-time interaction effect ($P < 0.001$). The ACT+Ex group showed significant within-group improvements in TUG speed both at immediately post-treatment ($P < 0.001$) and at the 6-month follow-up ($P < 0.001$) (Fig. 3A). The estimated effect sizes were of moderate-to-large magnitudes, with post-treatment at g=0.87 (95% CI= 0.57 to 1.17) and the 6-month follow-up at g= 0.82 (95% CI= 0.52 to 1.11). Analyses of FRT and STS-30 measures showed significant time effects (FRT, $P = 0.035$; STS-30, $P = 0.018$), indicating improvements in mobility over time for both groups (Fig. 3B and C). There were no observed time, group, or group-time interaction effects for 6MWT and HGS throughout the study. Descriptive statistics of these outcomes are presented in Table 3. The lack of significant observed improvements in HGS may be due to the exercise focus on core stability and motor control rather than upper limb or overall strength.[44] Additionally, the lower responsiveness of 6MWT in detecting changes compared to other measures (e.g., STS, FRT), especially in populations with spinal or musculoskeletal conditions, may partly explain the results.[57]

Qualitative assessments

Acceptability of the intervention procedure

Participants in both groups unanimously considered that the study program addressed their age-specific needs effectively, both

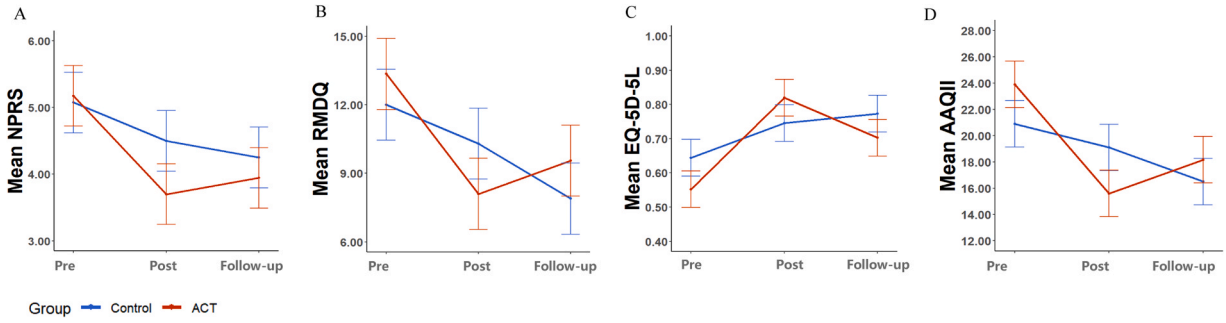

Fig. 2. Pain intensity (A), self-reported disability (B), psychological inflexibility (C), and health-related quality of life (D) for the ACT+Ex (red) and Edu+Ex (blue) groups. Estimated marginal means (y-axis) across time points (x-axis). Mean (SEM) are presented. Error bars indicate standard error. NPRS, Numeric Pain Rating Scale (0–10 points); RMDQ, the 24-item Roland Morris Disability Index; AAQ-II, Acceptance and Action Questionnaire. Version II; EQ-5D-5L, the 5-level EQ-5D version. ACT, Acceptance and Commitment Therapy; Edu, back care education; Ex, exercise therapy. Pre = baseline; Post = immediate post-treatment; Follow-up = 6-month follow-up.

Table 2
Means, SDs, and effect sizes for pain-related and psychological outcome measures.

Outcome measurements	ACT+Ex (n=20)	Edu+Ex (n=20)	Group*P* value	Time*P* value	Group x Time*P* value	Within-group effect size g (95% CI)		Between-group effect size g (95% CI)
						ACT+Ex	Edu+Ex	ACT+Ex vs Edu+Ex
NPRS			0.537	**0.047**	0.223			
Pre	5.18 (1.78)	5.08 (1.85)						
Post	3.7 (1.59)	4.5 (1.64)				0.82 (0.52, 1.12) ***	0.31 (0.04, 0.57) *	0.77 (−0.11, 1.65)
Follow-up	3.94 (2.29)	4.25 (1.72)				0.70 (0.41, 0.99) **	0.50 (0.23, 0.78) *	0.27 (−0.64, 1.18)
RMDQ			0.832	< **0.001**	**0.014**			
Pre	13.4 (4.08)	12.0 (4.9)						
Post	8.1 (4.05)	10.3 (5.2)				1.27 (0.92, 1.62) ***	0.34 (0.08, 0.61) *	1.12 (0.24, 2.0)
Follow-up	9.56 (4.94)	7.89 (5.25)				0.97 (0.65, 1.28) ***	0.86 (0.56, 1.17) ***	−0.1 (−1.0, 0.81)
EQ−5D-5L			0.56	**0.008**	**0.016**			
Pre	0.552 (0.196)	0.644 (0.214)						
Post	0.819 (0.123)	0.746 (0.166)				1.34 (0.99, 1.7) ***	0.47 (0.2, 0.74) *	1.22 (0.34, 2.1)
Follow-up	0.702 (0.211)	0.773 (0.195)				0.80 (0.5, 1.10) **	0.62 (0.34, 0.9) **	0.19 (−0.72, 1.1)
AAQ-II			0.883	**0.04**	**0.016**			
Pre	23.9 (8.85)	20.9 (9.36)						
Post	15.6 (6.94)	19.1 (6.45)				0.93 (0.62, 1.23) ***	0.19 (−0.07, 0.45)	1.27 (0.39, 2.15)
Follow-up	18.2 (8.81)	16.5 (7.45)				0.66 (0.37, 0.94) **	0.46 (0.19, 0.73) *	0.3 (−0.61, 1.21)
DASS−21-D			0.40	0.15	0.60			
Pre	7.9 (8.0)	9.3 (9.83)						
Post	3.6 (3.28)	6.7 (9.09)				0.53 (0.26, 0.81) **	0.26 (0, 0.52)	0.4 (−0.48, 1.28)
Follow-up	6.89 (6.9)	8.33 (10.5)				0.17 (−0.09, 0.43)	0.13 (−0.12, 0.39)	0.03 (−0.89, 0.94)
DASS−21-A			0.395	0.118	0.189			
Pre	11.9 (8.04)	10.5 (7.54)						
Post	6.8 (5.9)	7.8 (6.19)				0.63 (0.34, 0.91) *	0.35 (0.09, 0.62)	0.44 (−0.44, 1.32)
Follow-up	10.6 (5.26)	7.22 (5.99)				0.16 (−0.1, 0.42)	0.45 (0.19, 0.73)	−0.41 (−1.31, 0.5)
DASS−21-S			0.848	**0.002**	0.16			
Pre	11.3 (7.6)	12.9 (9.8)						
Post	7.5 (5.46)	7.7 (8.16)				0.49 (0.22, 0.77)	0.52 (0.25, 0.8) **	−0.27 (−1.15, 0.61)
Follow-up	10.8 (7.52)	7.78 (7.48)				0.10 (−0.16, 0.36)	0.54 (0.27, 0.82) **	−0.88 (−1.79, 0.04)

Note. Data expressed as mean (SD); CI, Confidence Interval; Effect sizes (Cohen's d) determined from the coefficient for the slope divided by the baseline standard deviation, with Hedges' g corrections. A positive within-group effect size indicates improvement, while a positive between-group effect size favors the ACT+Ex group. Edu+Ex, patient education plus exercises group; ACT+Ex, ACT plus exercises group; Pre, baseline; Post, immediate post-treatment; Follow-up, 6-month follow-up; NPRS, Numeric Pain Rating Scale (0-10 points); RMDQ, the 24-item Roland Morris Disability Index; AAQ-II, Acceptance and Action Questionnaire-Version II; EQ-5D-5L, the 5-level EQ-5D version for assessing health-related quality of life; DASS-21, the Chinese version of the 21-item Depression (D), Anxiety (A), Stress (S) Scale; **Bold** indicates a statistically significant time, group, or interaction effects.
* indicates $p < 0.05$; **indicates $p < 0.01$; ***indicates $p < 0.001$.

individually and collectively. The ACT recipients enjoyed the course but preferred shorter ACT sessions (i.e., less than one hour). In the Edu+Ex group, participants favored the education components related to posture correction, nutrition, diet, and acupressure massage, which seemed to be more memorable and practical compared to information on spinal anatomy and diagnosis. Notably, one participant (EP6) reported that the knowledge about lumbar differential diagnosis made him more apprehensive. Emergent themes and illustrative quotes from the ACT+Ex group participants (AP) and the Edu+Ex group participants (EP) are presented in Appendix 5.

Participants' experience of the interventions

Participant information from both the ACT+Ex group and the Edu+Ex group was deidentified. There were no significant differences in demographic data or NPRS scores at baseline between the two groups of participants who took part in the qualitative interviews. Their demographic data and NPRS scores at baseline, immediately post-treatment, and at the 6-month follow-up are provided in Appendix 6. Emergent themes are detailed in Appendix 5, with three superordinate themes and 10 subordinate themes emerging from the cross-case analysis (Table 4): (1) previous healthcare experience affecting pain beliefs; (2) ACT strategies guiding behavioral changes; (3) facilitators and barriers to compliance with the treatment programs. A visual representation of these themes is shown in Fig. 4.

Discussion

The results of this study supported the feasibility, acceptability, and potential effectiveness of 8-week ACT+Ex on improving pain, disability, psychological inflexibility, HRQoL, and physical fitness in older adults with CLBP. At the 6-month follow-up, participants in ACT+Ex had improved physical fitness (especially with the increase in the TUG speed achieving a moderate-to-large effect size), whereas Edu+Ex experienced no change.

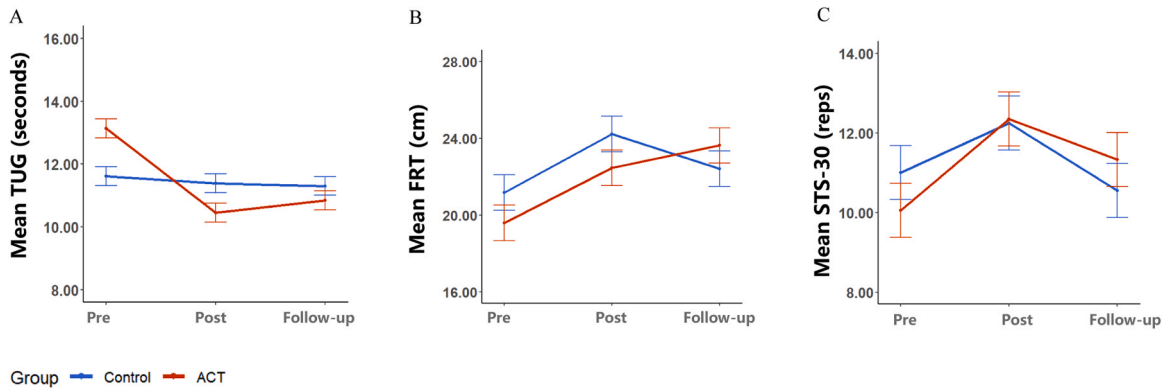

Fig. 3. Parameters of physical fitness tests for the ACT+Ex (red) and Edu+Ex (blue) groups. Estimated marginal means (y-axis) across time points (x-axis). Mean (SEM) are presented. Error bars indicate standard error. TUG, Timed Up and Go test; FRT, function reach test; STS-30, 30 s sit-to-stand test; reps, repetitions. ACT, Acceptance and Commitment Therapy; Edu, back care education; Ex, exercise therapy. Pre = baseline; Post = immediate post-treatment; Follow-up = 6-month follow-up.

Table 3
Means, SDs, and effect sizes for parameters of physical fitness tests.

			Group*P* value	Time*P* value	Group x Time*P* value	Within-group effect size g (95% CI)		Between-group effect size g (95% CI)
Outcome measurements	ACT+Ex (n=20)	Edu+Ex (n=20)				ACT+Ex	Edu+Ex	ACT+Ex vs Edu+Ex
FRT (cm)			0.763	**0.035**	0.068			
Pre	19.6 (4.9)	21.2 (6.8)						
Post	22.5 (4.6)	24.2 (6.83)				0.58 (0.3, 0.86) *	0.44 (0.17, 0.71) *	−0.05 (−0.93, 0.83)
Follow-up	23.6 (5.48)	22.4 (6.56)				0.89 (0.58, 1.19) **	0.14 (−0.12, 0.39)	0.93 (0.01, 1.84)
TUG (seconds)			0.96	0.853	**0.001**			
Pre	13.1 (3.1)	11.6 (3.6)						
Post	10.5 (3.18)	11.4 (2.87)				0.87 (0.57, 1.17) ***	0.06 (−0.2, 0.32)	1.56 (0.68, 2.44)
Follow-up	10.8 (3.34)	11.3 (3.23)				0.82 (0.52, 1.11) ***	0.07 (−0.18, 0.33)	1.43 (0.51, 2.34)
6MWT (m)			0.934	0.084	0.40			
Pre	327.0 (89.2)	343.0 (63.1)						
Post	372.0 (94.7)	375.0 (61.8)				0.49 (0.22, 0.76) **	0.51 (0.24, 0.78)	0.26 (−0.62, 1.14)
Follow-up	364.0 (65.6)	352.0 (59.2)				0.47 (0.19, 0.74) *	0.21 (−0.05, 0.47)	0.62 (−0.29, 1.54)
STS−30 (reps)			0.984	**0.018**	0.09			
Pre	10.0 (3.61)	11.0 (3.77)						
Post	12.4 (3.75)	12.2 (3.42)				0.63 (0.34, 0.91) ***	0.33 (0.06, 0.59)	0.57 (−0.31, 1.45)
Follow-up	11.3 (4.2)	10.6 (3.24)				0.4 (0.13, 0.67) *	−0.1 (−0.37, 0.15)	1.01 (0.1, 1.93)
HGS (kg)			0.968	0.075	0.121			
Pre	22.5 (4.79)	22.1 (4.12)						
Post	22.4 (4.86)	23.6 (4.77)				−0.02 (−0.27, 0.24)	0.36 (0.09, 0.62)	−0.75 (−1.63, 0.13)
Follow-up	22.7 (3.86)	22.1 (3.54)				0.13 (−0.13, 0.39)	0.09 (−0.17, 0.35)	0.11 (−0.8, 1.03)

Note. Data expressed as mean (SD); CI, Confidence Interval; Effect sizes (Cohen's d) determined from the coefficient for the slope divided by the baseline standard deviation, with Hedges' g corrections. A positive within-group effect size indicates improvement, while a positive between-group effect size favors the ACT+Ex group. Edu+Ex, patient education plus exercises group; ACT+Ex, ACT plus exercises group; Pre, baseline; Post, immediate post-treatment; Follow-up, 6-month follow-up; FRT, function reach test; TUG, time up to go test; STS-30, 30 s sit-to-stand test; 6MWT, 6-min walking test; HGS, hand-grip-strength; reps, repetitions;
Bold indicates a statistically significant time, group, or interaction effects.
* indicates $p < 0.05$; **indicates $p < 0.01$; ***indicates $p < 0.001$.

Most participants expressed satisfaction with their overall health improvements and reported positive perceptions of the study procedures during focus group interviews. It was observed that participants who had previously undergone multiple ineffective treatments for CLBP found ACT beneficial, which was not observed in the Edu+Ex group. However, both the one-hour ACT and one-hour education sessions presented cognitive challenges to participants in terms of attention and memory, indicating a need to either shorten session durations or lengthen breaks. Moreover, feedback from the Edu+Ex group participants suggested that education should emphasize practical steps for managing CLBP while addressing potential dangers in a balanced manner. Despite verbal reminders given by a research assistant following the weekly sessions, most participants did not complete their exercise log books, complicating adherence assessment. It was reported

Table 4
Subordinate and super-ordinate themes emerged from the cross-case analysis.

Superordinate and Subordinate Themes	Description
'Previous healthcare experience affecting pain beliefs' **Subordinate themes** • Multiple failed attempts • Disclosure of diagnosis with inappropriate explanation	When queried about their experience with CLBP, some participants reported feeling discouraged because of previous multiple unsuccessful attempts to manage their pain, leading to concerns about the ongoing negative consequences of the chronic pain. Among those with multiple failed treatment-seeking efforts, only ACT recipients found our program effective. In contrast, the control group merely noted that our program was more detailed than that they had previously received.In contrast to the control group, a few ACT recipients mentioned that their previous healthcare-seeking experience including receiving a clinical diagnosis with inappropriate explanations (e.g., "back pain is incurable", "changes in lumbar structure led to the CLBP") continued to cause them anxiety.
'Acceptance strategies guiding behavioral changes' **Subordinate themes** • Experiencing pain without judgment or struggle • Defusing from pain-related thoughts • Existing values clarification • Health-oriented behaviors	ACT recipients used mindfulness meditation as both an acceptance and distraction strategy during the flare-ups of CLBP, allowing them to experience pain without judgment or struggle. The powerful metaphors during meditation enhance their willpower to cope with pain. Metaphors (e.g., leaves on a stream) helped them view pain-related thoughts as transient mental events and detach from them. Moreover, after the intervention, ACT recipients proactively engaged in values-oriented activities (e.g., exercises, hiking, gathering with friends) by focusing on the values that truly matter to them like health and social relationships. after the intervention. This approach continued through the 6-month follow-up. Overall, the ACT recipients adopted a more positive outlook on coping with their LBP.
'Facilitators and barriers of treatment compliance' **Subordinate themes** • Convenience of practice • Peer supports • Trust in therapists • Resorting to quick fixes during severe pain	One of the reasons for being willing to adhere to the treatment programs (both ACT and the education groups) was that the exercise and/or meditation were easy to implement in various settings (e.g., at home or in the park) with the help of take-home materials. In both groups, the group settings offered a communal platform for individuals to articulate and share their age-specific challenges and pain-related emotions with peers. Participants in both groups expressed trust and gratitude toward the therapists, which facilitated their participation in the program. However, over-reliance on therapists may be associated with a lack of confidence in their self-ability, such as concerns about getting injured due to incorrect movement control during exercise without professional instruction. This situation was more common in some participants in the ACT group who expressed concerns about the association between lumbar structure changes and pain.At the 6-month follow-up, ACT recipients expressed that they tended to prefer quick-acting pain relief approaches (i.e., painkillers, hot application, and acupuncture) over ACT strategies (such as mindfulness meditation) during severe pain episodes. During the 6-month period, they expressed a strong desire to 'control the pain' and found it difficult to maintain regular mindfulness meditation practice independently, due to the loss of the supportive environment and forgetting course content.

Note. ACT, Acceptance and Commitment Therapy; CLBP, chronic low back pain.

that older adults are more willing to document their adherence if they know what and how they can improve by adhering to exercise.[58] Thus, future studies can use a more convenient digital recording method (e.g., regular online forms), and provide enhanced motivation and timely feedback to improve adherence assessment.[58]

The study was conducted in low-income communities, where individuals with CLBP often encounter barriers to healthcare access, treatment program engagement, and adherence to prescribed interventions due to limited resources or poor health literacy.[59] The high recruitment and class adherence rates, low attrition rate, and promising self-reported improvements in both groups demonstrated the feasibility and acceptability of the interventions. Additionally, the improvements in physical functioning observed in the ACT+Ex group suggest its potential to reduce health disparities in underserved populations. Our results may be ascribed to the fact that group-based interventions enhance engagement and satisfaction in patients with chronic pain by fostering a sense of community and shared purpose.[6,16]

A larger proportion of older adults in the ACT+Ex group achieved clinically meaningful pain improvement immediately post-treatment. Compared with the findings of Casy et al. that adding ACT to a supervised exercise program in young adults with CLBP did not result in additional benefits, the significant improvements in pain intensity, disability, psychological inflexibility, and HRQoL after ACT+Ex were maintained during the 6-month follow-up in the older adults, albeit with rebound.[9] Our favorable findings may be due to the fact that older adults have a greater response to ACT than younger adults.[15] Specifically, participants in the ACT processes reported experiencing pain without judgment or struggle, defusing pain-related thoughts, existing values clarification, and health-oriented behaviors. These novel coping perspectives help them deal with pain in the context of daily life and navigate the transition to a more positive lifestyle. Concurrently, the supervised exercise incorporated within the ACT intervention guided participants to elucidate health-oriented values and catalyze concrete actions, which appears to be a unique benefit for older adults who may not have to balance a greater number of life domains, resulting in sustained physical improvement.

Current guidelines for managing CLBP emphasize the importance of functional improvements.[1,7,20] The ACT model for chronic pain supports this by promoting improved functioning despite ongoing pain.[12,60] However, existing evidence on ACT's effects on enhancing physical function showed mixed results.[61–63] To address this gap, our study used objective outcome measures and found moderate-to-large effects of ACT+Ex on enhancing mobility in older adults with CLBP. These improvements were sustained at the 6-month follow-up, unlike the Edu+Ex group. Participants in focus group interviews noted that ACT provided them with acceptance strategies to modulate their physical activity levels, helping them coexist with CLBP and create psychological distance from the pain. This approach encouraged engagement in value-driven activities (e.g., staying physically active by doing more exercise, hiking, and/or gathering with friends) that positively impacted their lives.

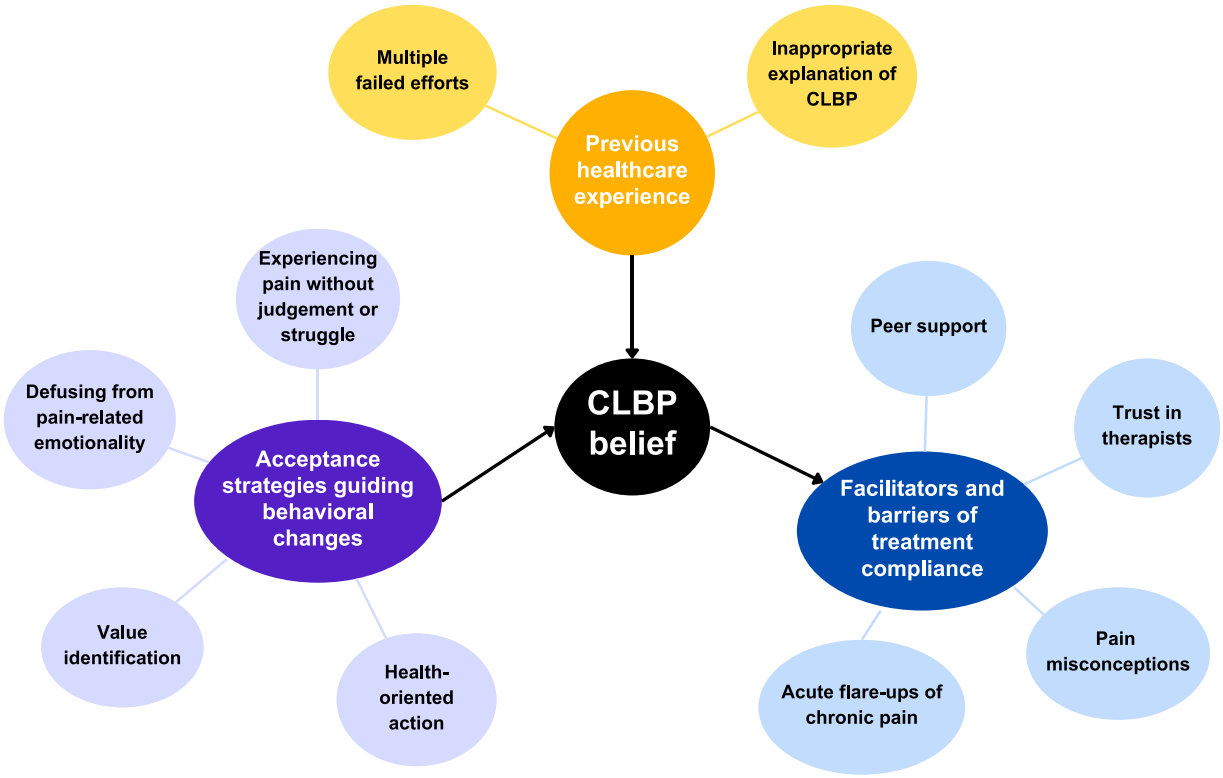

Fig. 4. Visual representation of themes.

Significant immediate post-treatment improvements in DASS depression and anxiety subscale scores in the ACT+Ex group were consistent with the observed reduction in psychological inflexibility and participants' reported changes in coping strategies for back pain flare-ups (e.g., adopting mindfulness meditation to cope with unexpected back pain, noticing interfering thoughts, emotions, and body sensations without unnecessary judgements or struggles, focusing on value-based actions).[12] However, these improvements in depression and anxiety were not sustained at the 6-month follow-up, aligning with findings from Martinez-Calderon et al.[61] Although ACT promotes openness to emotions, thoughts, and bodily sensations to encourage positive behavioral changes, age-related declines in cognitive flexibility and emotional adaptability may challenge older adults in sustaining long-term improvements, particularly for emotional symptoms related to chronic health conditions.[64] This highlights the potential need for booster sessions to sustain these improvements.

There appear to be practical limitations to using ACT as an adjunctive therapy for CLBP. Some ACT recipients merely incorporated mindfulness meditation into their CLBP management, without making other life changes. As one of the most common pain-coping strategies, meditation has mixed evidence of effectiveness, possibly dependent on its active versus passive nature.[65,66] We noted that a few ACT recipients resorted to quick fixes (e.g., pain medication and acupuncture) as they found it difficult to adopt an accepting attitude during episodes of severe pain (descriptions from AP4 and AP8). Furthermore, a few participants did not achieve autonomy after completing the ACT+Ex treatment program. The dependence on peer support and trust in therapists may have served both as a motivator for them to practice and as a barrier to self-execution (elaboration of AP5 and EP1).

In addition, pain misconception influenced by the biomedical model (i.e., linking lumbar structure changes to CLBP) may be a factor that continues to affect patients' self-efficacy and contribute to increased fear avoidance beliefs during self-exercise (descriptions from AP5). Remarkably, none of the Edu+Ex group participants mentioned a pain belief about an inevitable relationship between the biomedical model and CLBP. A better understanding of CLBP pathophysiology and the correction of fear-avoidance beliefs in our education component may partly explain the above differences, as findings by King et al. that pain science education can positively affect chronic pain perception and self-management.[67] We found a significant decrease in stress levels in the Edu+Ex group. Since the current study did not assess participants' fear-avoidance beliefs, the association between stress levels and kinesiophobia remains unclear. In the future, advancing acceptance-based strategies within the framework of pain science education (e.g., integrating pain reconceptualization education) may enhance the clinical application of ACT for CLBP, leading to better cognitive defusion and helping break the cycle of fear-avoidance behaviors.

Several limitations warrant mention. First, the clinical results were based on a small sample size in this pilot study and should therefore be interpreted with caution. Second, the absence of mid-point assessments during the intervention limited our ability to track the trajectory of change, making it unclear whether improvements occurred gradually or at specific time points. Third, due to the challenges of implementing double-blinding in behavioral research, participants and therapists were aware of the treatment allocation. However, this study employed blinding for researchers, assessors, and statisticians to minimize bias. Finally, most participants recruited were predominantly female, which limits the generalization of the results to a broader elderly population. Further validation in future larger, well-defined RCT is required to confirm the observed findings.

Conclusions

This study provides important new insight regarding the potential long-term clinical effects and participant experiences of ACT+Ex for community-dwelling older adults with CLBP. Our data suggests that ACT+Ex offers benefits in improving pain intensity, disability, psychological inflexibility, HRQoL, and physical fitness over a 6-month period, based on findings from a predominantly female sample. However, some important questions remain: (1) Whether integrating pain reconceptualization education with ACT can promote the treatment effects for CLBP. (2) Is ACT equally effective in improving various health outcomes in older males with CLBP? (3) What are the key process factors or mediators influencing the long-term effects on physical fitness, especially regarding TUG speed? Although the results of this pilot trial are promising, a large-scale RCT is warranted to answer these questions and provide more conclusive evidence on the beneficial effects of ACT in older adults with CLBP.

Disclosures

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Author contributions

JQJL, WYM, CYK, and AYLW conceptualized the study; FAZ and AYLW provided expertise in methodology; ALYT, TKTW, GSHT, HCWK, SWTL, SPSS, and KTKH acquired the data; JQJL and AYLW developed the statistical protocol, and CKCC performed the statistical analyses; AYLW was responsible for funding acquisition and project supervision; JQJL drafted the original manuscript; AYLW, WYM, CYK, FAZ, DS, and KKSC edited the manuscript.

Appendix 1. Overview of the ACT Group Intervention's content

Session	Module	ACT Processes	Content	Exercise/ Homework
1	Introduction: Expectations for training	-	1. Set ground rules for group 2. Introduce the group agenda 3. Understand the intentions from group members 4. Normalize aging and psychoeducation on its relationship with back pain	E: Imagery exercise on the intentions of this groupD: Introducing self, intentions, and low back pain backgroundD: Myths on aging H: Elicit negative thoughts towards LBP labelling
2	Module 1: Thoughts and Emotions	Cognitive defusion	1. Introduce cognitive fusion with respect to low back pain 2. Learn to distant thoughts, reduce negative thoughts about stereotyping, and understanding that pain is common universal suffering 3. Learn thoughts are not facts	D: Elicit negative thoughts towards LBPM: Blocking vision with thoughtsE: Watching clouds in the sky
3 & 4	Module 2: Control and Acceptance	Present moment awareness	1. Concept of mindfulness 2. Be aware of body sensations and cultivate acceptance to own limitations	E: Observing with 5 sensesE: Sitting with difficultyE: Mindful stretchingH: Daily mindfulness exercise (with recordings)
		Acceptance, present moment awareness	1. Understand experiential avoidance and its negative effects 2. Learn acceptance and enhance willingness to not control/avoid the difficulties in life while flexibly respond	E: Pink elephant M: Stirring up the sandM: Ball in the seaE: Holding a penH: Daily mindfulness exercise (with recordings)
5	Module 3: You and yourself	Self-as-context, present moment awareness	1. Understand observing self 2. Learning the self with back pain is only part of the self; an individual has other roles and strengths in life	M: Watching a drama E: Different parts of meE: Floating leaves on riverH: Daily mindfulness exercise (with recordings)
6	Module 4: What I value in life	Values, present moment awareness	1. Feeling the importance of achieving progress towards values in the presence of negative life events and ruminations 2. Directing one's behavior to one's values	E: Comment from friendsD: Choice pointH: Exploring values-related action H: Daily mindfulness exercise (with recordings)
7	Module 5: Commitment	Committed action, present moment awareness	1. Prioritizing activities based on their perceived values and importance. 2. Develop an action plan to perform activities related to values that are with optimal difficulty. 3. Learn to break down a larger activity into a smaller one. 4. Learn techniques of problem-solving	D: Sharing of values and related committed actionsE: Prioritizing activities and formulating an action planM: Driving a busH: Action plan record
8	Module 6: Looking ahead	Values and committed action, present moment awareness	1. Summary of 6 core processes and strategies learnt. 2. Strengthening concepts and skills of autonomy and accepting their own functional limitations 3. Relapse prevention	E: Imagery exercise for intentions and future templatesE: Identifying useful strategies learnt and commit to practice

Note. ACT: Acceptance and Commitment Therapy; LBP=low back pain; D = Discussion; E = Exercise; H = Homework; M = Metaphor;

Appendix 2. Overview of the content of back care education

Session	Topic	Content	Discussion
1	Introduction: Expectations of the course	1. Set ground rules for group 2. Understand intentions from group members 3. Introduce the group agenda and course outline 4. Normalize the prevalence of LBP	Introducing self, intentions, and LBP background
2	Risk factors for worse back pain	1. Introduce the underlying concepts of LBP 2. Describe the mechanism of LBP based on spinal anatomy and kinetics 3. Causes of non-specific and specific LBP 4. Red-flag sign identification	Personal insights into the causes of LBP
3	Clarification of LBP misconceptions	1. No necessity of imaging findings to diagnose causes of LBP (e.g. spur hyperplasia is normal to happen) 2. Pain not being an accurate indicator of tissue damage 3. Surgery may not be the answer to LBP 4. Activities should not be avoided when in pain	Personal conceptions and doubts about LBP-management
4	Conservative treatments	1. Inappropriate movements (e.g. proper lifting posture to avoid excessive loading for the lumbar spine) 2. Non-surgical treatments for LBP 3. Pain-related stress management	1. The correct postures of sitting, standing, and lying 2. Stress induced by LBP and how to cope with
5	Back pain exercises for LBP	1. Importance of staying active and benefits of exercises 2. Types and purpose of back pain exercise (e.g. doing stretching to reduce back muscle tightness) 3. General principle of exercise prescription for the elderly	Precautions to be taken when exercising
6	Traditional Chinese medicine for LBP	1. Underlying concepts of LBP from TCM perspective 2. Acupuncture and acupressure for LBP 3. Life-styles changes (e.g. fitness Qigong and regimen)	Opinions and experience on choosing TCM for LBP
7	Diet and nutrition for LBP, social support resource	1. Fighting back pain with food (e.g. anti-inflammation diet) 2. Providing information about social support programs on the Hong Kong elderly with pain	Dietary habits that cause worse back pain
8	Closing and Summary	1. Summary of knowledge and strategies learnt 2. Strengthening concept that positively confronting LBP is important for pain control 3. Raising the importance of back pain exercises	Impressive learnings and future actions

Note. LBP=low back pain;

Appendix 3. Exercises program

1. Sitting posture

(1) Abdominal breathing
(2) Flexibility/muscle stretching

- Cat and camel
- Lumbar flexion stretch
- Lumbar side flexion stretch
- Spinal twist

(3) Core strengthening

- Isometric back extensor holds
- Lateral trunk flexion
- Leg lift

2. Standing posture

- Isometric half squat
- Single-leg stance
- Side walking

Appendix 4. Summary of the mixed effects models in outcomes changes

	NPRS	RMDQ	EQ-5D-5L	AAQ-II	DASS-21-D	DASS-21-A	DASS-21-S	FRT (cm)	TUG (sec)	6MWT (m)	STS-30 (repetitions)	HGS (kg)
Group	0.1 (0.57)	1.35 (1.50)	−0.092 (0.059)	3.0 (2.53)	−1.4 (2.59)	1.40 (2.08)	−1.6 (2.45)	−1.58 (1.87)	1.52 (1.0)	−15.18 (23.48)	−0.95 (1.2)	0.4 (1.4)
T2-T1 (Edu+Ex)	−0.58 (0.37)	−1.7 (0.10)	**0.102 (0.042)** *	−1.8 (1.6)	−2.6 (1.32)	−2.7 (1.72)	**−5.2 (1.65)** **	**3.04 (1.17)** *	−0.22 (0.5)	32.6 (14.45)	1.3 (0.6)	1.49 (0.66)
T3-T1 (Edu+Ex)	**−0.95 (0.38)** *	**−4.3 (1.03)** ***	**0.134 (0.044)** **	**−4.34 (1.67)** *	−1.3 (1.37)	−3.5 (1.77)	**−5.38 (1.71)** **	0.94 (1.22)	−0.27 (0.51)	13.43 (14.99)	−0.4 (0.6)	0.39 (0.69)
T2-T1 (ACT+Ex)	**−1.48 (0.37)** ***	**−5.25 (0.1)** ***	**0.27 (0.04)** ***	**−8.3 (1.61)** ***	**−4.3 (1.32)** **	**−5.1 (1.72)** *	−3.8 (1.64)	**2.86 (1.17)** *	**−2.68 (0.5)** ***	**44.42 (14.4)** **	**2.3 (0.6)** ***	−0.1 (0.66)
T3-T1 (ACT+Ex)	**−1.27 (0.38)** **	**−3.99 (1.0)** ***	**0.16 (0.04)** **	**−5.88 (1.67)** **	2.89 (1.37)	−1.28 (1.78)	−0.79 (1.71)	**4.4 (1.22)** **	**−2.52 (0.5)** ***	**42.08 (15.0)** *	**1.46 (0.6)** *	0.63 (0.69)
Group x (T2-T1)	−0.9 (0.52)	**−3.55 (1.41)** *	**0.165 (0.06)** **	**−6.5 (2.28)** **	−1.7 (1.87)	−2.4 (2.43)	1.4 (2.33)	−0.18 (1.66)	**−2.46 (0.7)** ***	11.83 (20.43)	1.1 (0.8)	−1.59 (0.94)
Group x (T3-T1)	−0.32 (0.54)	0.31 (1.46)	0.025 (0.062)	−1.54 (2.37)	−0.12 (1.94)	2.22 (2.51)	4.59 (2.41)	3.46 (1.72)	**−2.25 (0.73)** **	28.65 (21.2)	1.9 (0.8)	0.24 (0.97)
Constant	5.08 (0.41)	12.0 (1.06)	0.644 (0.042)	20.9 (1.79)	9.3 (1.83)	10.5 (1.47)	12.9 (1.73)	21.18 (1.32)	11.61 (0.71)	342.65 (16.6)	11.0 (0.8)	22.10 (0.99)
Observations	116	116	116	116	116	116	116	116	116	116	116	116
Log Likelihood	−212.698	−320.46	31.377	−375.5	−364.384	−367.361	−374.97	−341.18	−258.2	−618.51	−274.4	−291.691
Akaike Inf. Crit.	441.396	656.918	−46.754	766.996	744.769	750.721	765.947	698.36	532.4	1253.02	564.8	599.382
Bayesian Inf. Crit.	463.4247	678.946	−24.725	789.025	766.797	772.75	787.975	720.39	554.43	1275.05	586.83	621.411

Note. Type III Sum of Squares. Values indicate the estimated effect (β) and corresponding standard error (SE).
Group, the average difference between the two groups (ACT+Ex subtracted from Edu+Ex); Constant (fixed intercept), baseline outcome values for Edu+Ex group;
T, Time point; NPRS, Numeric Pain Rating Scale (0-10 points); RMDQ, the 24-item Roland Morris Disability Index; AAQ-II, Acceptance and Action Questionnaire-Version II; EQ-5D-5L, the 5-level EQ-5D version for assessing health-related quality of life; DASS-21, the Chinese version of the 21-item Depression (D), Anxiety (A), Stress (S) Scale; FRT, function reach test; TUG, time up to go test; STS-30, 30 s sit-to-stand test; 6MWT, 6-min walking test; HGS, hand-grip-strength.
* indicates $p < 0.05$; **indicates $p < 0.01$; ***indicates $p < 0.001$. **Bold** indicates a statistically significant difference.

Appendix 5. Developing emergent themes and illustrative quotes

Analysis	Exploratory Comments	Illustrative quotes examples	Emergent Themes
Conceptual comments	Misconception of an association between lumbar structure changes and pain; Pain beliefs affected trust in treatments;	"In the past, I had back pain, knee pain, and even headaches, and I felt so bad, but my doctor couldn't find any problems from my health checkups. I was even afraid of getting cancer." (AP2, T2)"I've had back pain for over 10 years, and a radiograph showed that My lumbar spine has degenerated. I am afraid of doing something wrong to make it worse." (AP5, T2)"Sometimes, having excessive knowledge may not be useful, it's helpful for prevention. My doctor told me that I could only take medication." (EP6, T2)	Disclosure of diagnosis with inappropriate explanation
Linguistic comments	Multiple failed efforts in healthcare made them feel discouraged and helpless.Somewhat expectation fulfillment was achieved during this study program;	"I had been receiving physiotherapies, Chinese traditional medicine, and even psychotherapy, but none of it was satisfactory. I did not know what else I could do, so I joined this course. Your course has really helped me a lot." (AP2, T2)"I had sought help from doctors many times before, but nothing seemed effective. I felt very sad. They (doctors) explained it (back pain education) very simply and not in as much detail as you did. I think that it must be explained clearly for us to be able to understand and implement it." (EP2, T2)	Multiple failed attempts
Conceptual comments	Acceptance or distraction strategy for coping with pain; Increased self-efficacy by powerful metaphor;	"Whenever I felt pain, I chose to remain still and practice meditation to help distract myself from the back pain. I would feel relaxed and calm during this process." (AP1, T2)"Doing a body scan has helped me calm my messy and tangled thoughts, letting me understand that the back pain is here, and I could coexist with it. I recall a metaphor from the meditation training: 'Imagine yourself as a mountain, so stable that you will not fall even amid a storm'. I always think of this metaphor, picturing myself as an unwavering mountain. I'm no longer afraid of anything." (AP2, T2)	Experiencing pain without judgment
Conceptual comments	Reduced pain catastrophizing;Distanced from negative thoughts;Mental burden relief facilitated health-related behaviors.	"Now, after completing your course, I feel a sense of relief from the mental burden about my pain. I no longer constantly worry about whether my condition will worsen or whether I'll develop cancer." (AP2, T2) "Be like a cup of muddy water and let yourself be still, or imagine yourself as a leaf drifting on a river. Don't let the pain haunt you, let it float by like a leaf. These approaches helped release me from the tangle of pain." (AP7, T2)"I sincerely feel that only reducing mental burden will make you more willing to do it (exercise)." (AP7, T3)	Defusing from pain-related thoughts
Descriptive and conceptual comments	Benefit from the ACT sessions 'Values & Committed Action I & II';Clarifying personal core values (e.g. health and social relationships) and developing concreted behaviors;	"If you don't exercise, you're going to take the gloomy path. In the past, when I hiked, even a short walk would trigger pain, and then I started to worry and didn't want to do it anymore. Now, I am motivated to keep hiking and have found that I feel more relaxed afterward." (AP2, T2) "I went hiking yesterday. I'm now exercising more, although I don't always follow the taught exercises." (AP2, T3) "My family and friends are important to me. I'm now going out to participate in activities with my friends more often than I used to, as I challenge myself." (AP5, T2)"(I'm) moving more than ever. I'm going out more than I used to and I'm getting more daily steps now." (AP5, T3)"All the knowledge gained was very practical, I was just worried about whether I wouldn't be able to remember it, after all, I am old. I enjoyed learning about posture correction, diet and nutrition, and acupressure. However, to be honest, so far, I don't know whether they are helpful." (EP3, T2)"Sitting posture is very important. If my pain suddenly increases, I pay attention to whether I am sitting incorrectly. When I go to a supermarket to buy something, I try to use a trolley instead of carrying items myself. I now rarely eat red meat and try to consume more white meat, partly because my digestion is not very good." (EP3, T3)	Existing values identification and health-oriented behaviors
Descriptive comments	Program fitting with usual practice facilitated proactive experience	"I listened to the audios you provided (meditation audios) before I went to bed and then slowly fell asleep. It's easy to do." (AP5, T2)"I will do it (the exercise) and follow the materials you provided. I can easily complete the exercise program in a confined space, either by simply sitting or standing. Your design is simple, a chair is all that's needed." (EP7, T2)	Convenience of practice
Descriptive comments	A sense of community and empowerment from fellow patients help to increase initiative.	"We'll insist on a regular schedule of group therapy. It's good to know someone's waiting for you. I can relieve my mental burden by sharing the pain with others. Also, exercising together and pushing through - I want to achieve what others can do!" (AP4, T2) "It's hard to stick to (back care exercise) and stay motivated without someone to push you. Especially, my husband doesn't like to exercise either, so I tend to be lazy. And, when it (my back pain) flares up, I just want to lie down." (AP4, T3)	Peer supports

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Analysis	Exploratory Comments	Illustrative quotes examples	Emergent Themes
Descriptive and linguistic comments	Trust and appreciation for the instructors in the course; Lack of motivation/confidence in self-practice;	"Your program is great. The courses delivered by Tang sir and Ms Liu (the instructors of the ACT and exercise sessions) were very professional and attentive." (AP5, T2) "I'm going to adhere to it (the treatment program) because they (the instructors) are so kind to teach us, I don't want to let them down so I will make an effort (to practice)." (EP1, T2) "When I do exercises at home, sometimes my back becomes more and more painful, and I worry that I might be doing something wrong and must stop. I still hope someone can correct me in real-time." (AP5, T3) "I often forget to do them (exercises) because no one reminds me, haha…I'm lazy. When I don't feel pain, I don't think of doing them, and when I feel pain, I don't want to do them." (EP1, T3)	Trust in therapists
Descriptive comments	Quick-acting pain relievers are preferred for episodes of severe back pain and reduced dependency on pain medication;	"I've had back pain for almost a decade and used to rely on pain relievers or acupuncture first. However, after the course, I now take fewer doses (of pain relievers) than before." (AP4, T2) "When I experience severe pain, I don't want to do anything. I can't sleep or eat properly. It needs a sufficient dose of painkillers to control it. I would love to try meditation, but it doesn't seem to work anymore, especially without someone's guidance. Once the pain gets worse, I get upset and disappointed because it seems that this method no longer works for me. I don't know what I should do next to help myself." (AP4, T3)"I should understand that it (LBP) is inevitable because it's common for older people to be ill, just like cabinets will wear out over time. However, when the severe pain strikes, I can't stay calm." (AP8, T2)"It's so hard to accept (the pain) and it's better to keep it under control. I tend to use acupuncture or take painkillers first." (AP8, T3)	Resorting to quick fixes during severe pain
Descriptive comments	Senior-friendly delivery of the intervention; Difficult to follow a regular exercises log;	"I'm not skilled in writing, but 'Ah sir' (the ACT instructor) suggested that I could either draw it or speak using a microphone, which is a good option for us old individuals." (AP3, T2) "I can easily complete the exercise program in a confined space, either by simply sitting or standing. Your design is simple, a chair is all that's needed. But I often forget to write it (home exercises) down on the logbook." (EP7, T2)	Age-specific requirements
Descriptive comments	Prefer a shorter ACT session;	"I just wonder if the psychological course must last such long. I find it difficult to concentrate for a long time and I tend to fall asleep." (AP1, T2)"The course duration was a bit too much, for a full hour, and I dozed off during the latter half of the sessions. I didn't necessarily absorb that much information, even though it might be helpful to me." (EP4, T2)	Course duration
Descriptive comments	Prefer practical and memorable educational components; Knowledge about lumbar differential diagnosis can potentially raise concerns;	"I could remember what is useful to me rather than what is not. Posture correction would be useful for me. But about the knowledge of traditional Chinese medicine, even if I have learned it, I may not be able to apply it myself. Moreover, the more knowledge you acquire, the more fear it can instill. I was unaware of 'cauda equina syndrome' before, but after learning about it, I now worry that I might have it."(EP6)"The posture correction, diet, and acupressure massage sections are practical to know. I can remember that tofu, cheese, and calcium supplements are needed. Limit red and processed meats and choose lean protein sources like fish. A tutorial paper on acupressure would be great for me!" (EP8)	Preference for education components

Note. AP, the participant in the ACT+Ex group; EP, the participant in the Edu+Ex group. T2 = immediate post-treatment; T3 = 6-month follow-up.

Appendix 6. Summary of participants' information in focus group interviews

ID	age	gender	Education level (years)	LBP duration years	Pain intensity at baseline (NPRS)	Pain intensity at immediate post-treatment (NPRS)	Pain intensity at 6-month follow-up (NPRS)
AP1	66	female	6.0	10.0	4.0	4.0	3.0
AP2	82	female	7.0	2.0	8.0	5.0	4.0
AP3	75	Male	6.0	40.0	4.0	1.0	4.0
AP4	74	female	6.0	3.0	8.0	5.0	8.0
AP5	74	female	9.0	10.0	8.0	6.0	8.0
AP6	72	female	6.0	15.0	4.5	4.0	4.0
AP7	67	female	2.0	10.0	6.0	3.0	5.0
AP8	75	male	6.0	20.0	6.0	4.0	4.0
EP1	75	female	6.0	2.0	6.0	6.0	6.0
EP2	80	female	0	8.0	5.0	5.0	5.0

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ID	age	gender	Education level (years)	LBP duration years	Pain intensity at baseline (NPRS)	Pain intensity at immediate post-treatment (NPRS)	Pain intensity at 6-month follow-up (NPRS)
EP3	75	female	4.0	20.0	6.0	4.0	4.0
EP4	69	female	1.0	3.0	4.0	5.0	2.0
EP5	69	female	12.0	3.0	5.0	5.0	4.0
EP6	74	male	8.0	30.0	9.5	7.0	5.0
EP7	74	female	6.0	20.0	6.0	5.0	8.0
EP8	69	female	6.0	4.0	4.0	4.0	3.5

Note: AP, the participant in the ACT+Ex group; EP, the participant in the Edu+Ex group; NPRS, Numeric Pain Rating Scale (0-10 points);

Data availability

The data used in the manuscript are available upon reasonable request to the corresponding author.

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