Title: Effects of an acute Mindfulness-based intervention on exercise tolerance, maximal strength, pain and effort-related experiences in individuals with primary chronic low back pain: a pilot study

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Abstract

Introduction: This study investigated the effects of an acute mindfulness-based intervention on exercise tolerance, maximal voluntary contraction (MVC), pain and effort-related experiences in individuals with primary chronic low back pain.

Method: Participants were randomly assigned to an experimental group and a control group. Before and after the intervention, participants completed a MVC test, a modified Sorensen test and numerical rating scales about pain intensity, pain unpleasantness, perceived effort and use of coping strategies. Dispositional measures such as pain catastrophizing, trait anxiety, dispositional mindfulness and impulsivity were also assessed. T-tests and linear mixed models were performed.

Results: Participants from the control group significantly decreased their MVC across time and showed a trend towards a decrease in exercise tolerance over time, which was not the case for the experimental group. For both groups, pain unpleasantness and effort were perceived higher during the second modified Sorensen test. Analyses revealed no significant effect of time nor group on pain intensity and the use of coping strategies.

Discussion: The results highlight the value of involving individuals with primary chronic pain in mindfulness-based interventions to improve adaptations to effort while targeting referred pain. Larger samples and controlling for individuals' functional status appear necessary for further research.

Keywords : mind-body intervention ; physical activity ; biopsychosocial outcomes

Introduction : Cette étude examine les effets aigus d'une stratégie d'acceptation basée sur la pleine conscience sur la tolérance à l'effort, la force maximale, la perception de l'effort et de la douleur, chez des personnes souffrant de lombalgie chronique.

Méthode : Les participants ont été répartis aléatoirement en deux groupes. Avant et après l'intervention expérimentale ou contrôle, un test de force maximale, un test de Sorensen, et des évaluations relatives à l'effort perçu et aux douleurs ressenties ont été réalisés. La dramatisation de la douleur, l'anxiété trait, la pleine conscience dispositionnelle, et l'impulsivité ont été contrôlées. Des tests-t et modèles à effets mixtes ont été utilisés pour traiter les données.

Résultats : L'effort et le caractère désagréable de la douleur ont été significativement plus élevés après l'intervention. Contrairement aux participants du groupe expérimental, les participants du groupe contrôle ont réduit significativement leur force maximale et ont tendu vers une réduction de leur tolérance à l'effort au cours du temps.

Discussion : Les résultats soulignent l'intérêt d'interventions basées sur la pleine conscience dans les adaptations à l'effort chez un public souffrant de douleurs chroniques. Les résultats nécessitent d'être répliqués avec des échantillons conséquents et en contrôlant les capacités fonctionnelles des participants.

1. Introduction

Low back pain (LBP), which has been defined as pain, muscle tension or stiffness located below the costal margin and above the inferior gluteal folds, with or without sciatica, is recognized as one of the highest global burdens on individuals and social-care systems worldwide (GBD, 2017). Depending on the identification of the pathoanatomical cause, LBP can be classified as specific, when the specific nociceptive source can be identified, or non-specific, when the specific nociceptive source cannot be identified. Patients with non-specific LBP represent 85-95% of individuals consulting primary care providers (Finucane et al., 2020). According to the International Classification of Diseases 11th (ICD-11), chronic primary pain is defined as pain in at least one anatomical region that persists or recurs for at least 3 months, is associated with substantial emotional distress (e.g., anxiety, anger, depressed mood) and/or functional disability (i.e., interference in activities of daily life and participation in social roles), and that cannot be better explained by another chronic pain condition (Nicholas et al., 2019). Chronic primary pain classifies conditions that were formerly named “non-specific” musculoskeletal pain.

Primary chronic LBP (CLBP) has biopsychosocial determinants (Hartvigsen et al., 2018; Hodges & Smeets, 2015; Vlaeyen et al., 2021), including pain-processing mechanisms (e.g., recursive patterns of maladaptive thoughts, emotions, avoiding behaviors), psychological disposition (e.g., trait anxiety, pain catastrophizing), social (e.g., physical workload, work satisfaction, education), biophysical (e.g., changes at multiple levels of the sensorimotor system and in mechanical behaviors), and lifestyle factors (e.g., low levels of physical activity, smoking).

Physical activity (PA) targeting aerobic fitness, strength, flexibility and skill/coordination exercises is recognized as a high evidence-based treatment for primary CLBP (Foster et al., 2018; Maher et al., 2017; Steffens et al. 2016). Nevertheless, it has been emphasized that exercise cannot be the only treatment by itself, and has to be included in a systemic approach (Foster et al., 2018; IASP, 2021). Mindfulness-Based Stress Reduction (MBSR) programs (Kabat-Zinn, 2013) are emerging as a relevant complementary treatment option, with short-term effects for individual with primary CLBP (Anheyer et al., 2017; Cherkin et al., 2016; Soundararajan, Prem, & Kishen, 2022). Mindfulness may be characterized as a trait/disposition underlying inter-individual differences in the ability of paying and maintaining attention to present-moment experiences with an open and non-judgmental attitude (Brown & Ryan, 2003); as a state of being attentive to and aware of what is taking place in the present (Brown & Ryan, 2003); as a way of life (Kabat-Zinn, 1994); but also as a practice rooted in several therapeutic programs such as MBSR (Stahl, Goldstein, & Kabat-Zinn, 2013), Mindfulness-Based Cognitive Therapy (MBCT; Segal, Williams, & Teasdale, 2013) or Acceptance and Commitment Therapy (ACT; Hayes, Strosahl, & Wilson, 1999). Although empirical evidence supports the benefits of mindfulness-based interventions in CLBP outcomes, such programs are intensive and time-consuming (e.g., individual daily practices besides eight group sessions for eight weeks for MBCT and MBSR).

Of particular interest, a few studies have shown that awareness, non-reactivity, non-judgment, and acceptance can be taught, or at least experienced, during a brief acute mindfulness session. For example, Ussher et al. (2014) showed that after a single 10-minute mindfulness-based intervention including a body scan, individuals with CLBP significantly reduced their level of pain-related distress in comparison with a control group. In individuals without CLBP, an acute mindfulness-based intervention improved perceived effort, perceived exercise-related enjoyment, and exercise tolerance/duration during a high-intensity cycling exercise in low activity-level women (Ivanova, Jensen, Cassoff, Gu, & Knäuper, 2015). In this experiment, a one-time 40-min intervention was designed to teach cognitive defusion (i.e., a skill or technique that is primarily used to detach, separate, or get some distance from thoughts and emotions) and acceptance techniques for coping with aversive physical discomfort, such as leg discomfort when walking on a treadmill, for example, and negative affect (e.g., boredom). Furthermore, in low-activity individuals, a single 10-minute mindful body scan intervention improved task absorption during a cycling task protocol and relationships between subjective (i.e., effort perception) and objective (i.e., heart rate) exercise-related measures (Meggs & Chen, 2021). Finally, in low-activity individuals with low intrinsic motivation to exercise, a single 10-minute audio mindfulness script dedicated to help participants be mindful to physical sensations during movement in a non-judgmental manner improved affective state, task enjoyment and body awareness during a treadmill walking task (Cox, Roberts, Cates, & McMahon, 2018).

To date, and to our knowledge, no previous study has yet examined the acute effect of a single mindfulness-based intervention applied to an active setting or a physical task on individuals with CLBP. On the basis of the aforementioned results, acute mindfulness-based interventions linked with PA appear promising, and should be examined in a task targeting low back muscles (e.g., a low back muscular endurance test) on individuals with CLBP. The duration of a muscular endurance exercise task such as a Sorensen task (Biering-Sorensen, 1984) is often co-studied with a measure of maximal voluntary contraction (MVC), as performance until failure is related to exhaustion, i.e., when individuals are no longer able to generate the power output required by the task, despite their maximal voluntary effort (Marcora & Staiano, 2010). In order to control for the potential reduction in the ability of trunk extensor muscles to generate maximal forces throughout the intervention (Demoulin et al., 2016), MVC therefore seems relevant to assess. Finally, in order to prevent task-learning bias, the use of an active control group, which has not been systematic in previous studies (Cox et al., 2018; Meggs & Chen, 2021), also appears to be necessary.

The first objective of this pilot study was therefore to compare the effects of an acute mindfulness-based intervention with those of an active control intervention on exercise tolerance and MVC in individuals with primary CLBP. The second objective was to compare the effects of the acute mindfulness-based intervention with those of an active control one on pain-related experiences (i.e., pain-related intensity and unpleasantness), perceived effort and the use of pain-related coping strategies (i.e., pain acceptance versus pain ignorance) in individuals with CLBP. Based on previous studies showing no significant effect of time in individuals performing two Sorensen tests 15 minutes apart under similar experimental conditions, it was expected that exercise tolerance in participants from the control group would not significantly change over time (Alahmari et al., 2020; Latimer, Maher, Refshauge, & Colaco, 1999). Consistent with Ivanova et al. (2015), it was hypothesized that only participants undergoing the mindfulness-based intervention would increase their tolerance to exercise over time, but that both groups would show a similar MVC evolution over time. Following Ivanova et al. (2015) and Cox et al. (2018), it was also hypothesized that only participants from the mindfulness-based intervention would decrease their levels of pain unpleasantness and perceived efforts, and increase their level of acceptance over time, while both groups of participants would maintain their level of pain intensity over time.

Furthermore, to ensure that the effects of the mindfulness-based intervention would not be related to dispositional psychological measures already known to be meaningful determinants of pain experience such as trait anxiety and pain catastrophizing (Hartvigsen et al., 2018), or as negatively correlated ways of responding in the present such as dispositional mindfulness and impulsivity (Peters et al., 2011), it was necessary to test for between-group similarities on these variables.

2. Materials and Methods

2.1. Participants

Participants with primary CLBP were recruited and randomly assigned to an experimental group called “the mindfulness group” (N = 13; 4 men, 9 women; M_{age} = 24.31, SD = 6.11) or an active control group (N = 10; 2 men, 8 women; M_{age} = 29.70, SD = 11.22). Participants were included if they had experienced recurrent or persistent non-specific lower back pain for at least 12 weeks in the past year at the time of the experiment. Exclusion criteria included health problems such as cancer, tumors, uncontrolled hypertension, neuromuscular disease, or use of psychotropic medication, as well as specific LBP, including spinal stenosis, herniated disk, back surgery, or traumatic injury. Pregnant or breastfeeding women were also excluded. The study protocol received approval from the Université du Québec à Trois-Rivières ethics committee, and all participants provided their written informed consent (CER-21-283-07.03). Participants were recruited from the university community and from the university's outpatient chiropractic clinic.

2.2 Measures

2.2.1. Objective measures

MVC: The MVC assessment was conducted according to the procedure of Abboud et al. (2014). Participants were asked to perform one submaximal isometric contraction to familiarize themselves with the task, followed by two MVC. The contractions were performed against a leather belt installed over their shoulders before each modified Sorensen test. The belt was linked to a load cell (Model lSB350; Futek Advanced Sensor Technology Inc, Irvine, CA, USA) by a cable permanently fixed to the ground. Participants were instructed to slowly raise their trunk until they could feel a tension in the cable (the cable length was individually adjusted so that a fully extended cable ensured that participants' body remained upright), at which point they had to perform the maximal isometric trunk extension for 5 seconds. Verbal encouragement was provided during the MVC tests. MVC was expressed in Newton for each time measurement (i.e., before the first and second modified Sorensen tests).

Exercise tolerance: In accordance with the work of Abboud et al. (2014), a modified Sorensen test was chosen to involve participants in an endurance exercise that mobilized the lumbar region (especially the erectus spinae muscles). Straps were placed at the hips and ankles to minimize the contribution of gluteal muscles to extension during the test. Participants' head, arms and trunk were maintained unsupported for as long as they could keep a horizontal position relative to the ground. Participants were instructed to hold the position for as long as possible, without any encouragement. Maintained times were recorded in seconds.

2.2.2. Situational subjective measures

Low back pain intensity: LBP intensity was measured using numerical scales ranging from 0 (no pain at all) to 100 (a maximal pain). LBP intensity was measured for each participant before and after performing the two modified Sorensen tests. The first assessment measured the level of LBP experienced before the first modified Sorensen test while the second ones measured the levels of LBP (averaged and maximal) experienced during the modified Sorensen tests. The levels of LBP (averaged and maximal) experienced during the modified Sorensen tests were assessed following their completion to avoid any interference with the mindfulness-based intervention.

Low back pain unpleasantness: LBP unpleasantness was measured using numerical scales ranging from 0 (not unpleasant at all) to 100 (maximally unpleasant). LBP unpleasantness was measured for each participant after the completion of the two modified Sorensen tests and referred to the level of LBP unpleasantness felt during these tests. Numerical scales are validated (Haefeli & Elfering, 2006) and commonly used in clinical and research settings.

Effort perception: Participants' effort perception was measured using the Borg CR100 scale, a numerical scale ranging from 0 (nothing at all) to 100 (almost maximal), after each modified Sorensen test.

Pain-related coping strategies: Acceptance and ignorance pain-related coping strategies used during the two modified Sorensen tests were investigated using a 10-point bidirectional scale ranging from – 5 (*I tried to avoid the pain I felt during the test*) to + 5 (*I tried to accept the pain I felt during the test*). A score of 0 meant that participants did not use any coping strategy. A bidirectional scale was chosen in order to highlight a potential preferential way of coping between these two strategies. Prior to answering, participants were given examples of pain acceptance (e.g., you focused on the sensations, feelings, and thoughts you might have experienced during the task) and pain ignorance (e.g., you did not pay attention to the pain you felt during the task). Participants were told that no answer was better or more desirable than another, and that only their subjective experiences mattered.

Mindfulness intervention assessments: Self-efficacy in reusing the techniques learned during the intervention (from 0 "no efficacy" to 100 "extremely high efficacy") was assessed using a single item prior to the second modified Sorensen test for participants allocated to the mindfulness-based intervention. Following the second modified Sorensen test, perceived effectiveness of the intervention (from 0 "no efficacy" to 100 "extremely high efficacy") and the perceived difficulty in using the techniques learned during the intervention (from 0 "no difficult at all" to 100 "extremely difficult") were assessed using two different items. The uses of these items and 0-100 scales including an intermediate degree at 50 are based on Bandura's guidelines (2006) as well as on Meggs & Chen (2021).

2.2.3. Dispositional measures

Dispositional mindfulness: The validated French version of the Five Facet Mindfulness Questionnaire (FFMQ; Heeren, Douilliez, Peschard, Debrauwere, & Philippot,

2011) was used to assess the general tendency to be mindful in daily life. This self-reported scale consists of 39 items describing different thoughts and feelings that individuals may experience daily. Items belong to six sub-dimensions, namely observing (e.g., “I pay attention to sensations, such as the wind in my hair or sun on my face”), describing (e.g., “I’m good at finding words to describe my feelings”), acting with awareness (e.g., “I find it difficult to stay focused on what’s happening in the present”), non-judging of inner experience (e.g., “I tell myself I shouldn’t be feeling the way I’ m feeling”), non-reactivity to inner experience (e.g., “When I have distressing thoughts or images, I just notice them and let them go”). Participants were asked to indicate the degree to which they agreed in experiencing each of thoughts or feelings on a 5-point Likert scale ranging from 1 (never or very rarely true) to 5 (very often or always true). A total averaged score as well as sub-dimensions-related scores were calculated. Cronbach alpha ranged from good to excellent (i.e., *observing*’s $\alpha = .72$, *describing*’s $\alpha = .91$, *acting with awareness*’s $\alpha = .87$, *non-judging*’s $\alpha = .91$, *non-reactivity*’s $\alpha = .73$).

Pain catastrophizing: The validated French version of the Pain Catastrophizing Scale (Sullivan, Bishop, & Pivik, 1995) was used to assess catastrophic thinking associated with pain. This self-reported scale consists of 13 items describing different thoughts and feelings that individuals may experience when they are in pain (e.g., “I can’t stop thinking about how much it hurts”). Participants were asked to indicate the degree to which they experienced each of thoughts or feelings when experiencing LBP on a 5-point Likert scale ranging from 0 (not at all) to 4 (all the time). The Pain Catastrophizing Scale items were summed to obtain a total score. Cronbach alpha was excellent ($\alpha = .95$).

Impulsivity: The UPPS Questionnaire (Van der Linden et al., 2006) was used to assess impulsivity. This self-reported scale consists of 45 items describing different thoughts and behaviors that individuals may experience dividing into four sub-dimensions: urgency (e.g., "I have trouble controlling my impulses"), lack of premeditation (e.g., "I have a reserved and cautious attitude toward life"), lack of perseverance (e.g., "I generally like to see things through to the end"), sensation seeking (e.g., "I generally seek new and exciting experiences and sensations"). Participants were asked to indicate the degree to which they agreed in experiencing each of the described thoughts or behaviors on a 4-point Likert scale ranging from 1 ("I agree strongly") to 4 ("I disagree strongly"). Items were summed to obtain a total score, as well as sub-dimensions-related scores. Cronbach alpha ranged from good to excellent for three sub-dimensions (i.e., *urgency*'s α = .88, lack of premeditation's α = .78, *sensation seeking*'s α = .85), but was questionable for one of them (*lack of perseverance*'s α = .67).

Trait anxiety: The validated French version of the State-Trait Anxiety Inventory (STAI-Y; Bruchon-Schweizer & Paulhan, 1993) was used to assess trait anxiety. This self-reported scale consists in 20 items describing different thoughts and feelings that individuals may experience (e.g., "I worry too much over something that really doesn't matter"). Participants were asked to indicate the extent to which they experienced each of these thoughts or feelings on a 5-point Likert scale ranging from 0 (never) to 4 (almost always). Items were summed to obtain a total score. Cronbach alpha was excellent (α = .94).

2.3. Experimental procedure

See Figure 1 for a synthetic timeline figure that summarizes the entire protocol and the variables recorded.

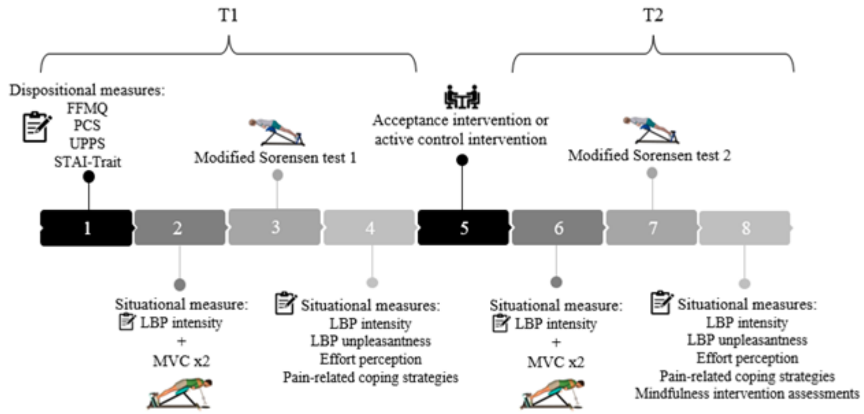

Figure 1. Synthetic timeline of the experimental procedure

Note. FFMQ: Five Facets Mindfulness; PCS: Pain Catastrophizing Scale; UPPS: Impulsive Behavior Scale; STAI-Trait: State Trait Anxiety Inventory Trait; LPB: Low Back Pain; MVC: Maximum Voluntary Contraction

Prior to the experimental session, participants were required to read and sign the letter of information as well as an informed consent form. The experimental procedure followed several phases. Participants first completed the questionnaires described in the previous section (see dispositional measures) and assessed their current level of LBP. Next, they were asked to perform MVC tests followed by a first modified Sorensen test. After the completion of the modified Sorensen test, situational measurements (see situational measures above) were performed. After a few minutes of rest during which participants were allowed to drink and sit, the experimental group completed the mindfulness-based intervention while the control group completed an active control intervention. Both interventions lasted approximately 45 minutes and were conducted by three of the authors, trained in physical activity interventions and experimental data collection.

The mindfulness-based intervention aimed to teach mindfulness strategies to be used when pain occurs, particularly during physical activity. It consisted of a psychoeducation session on pain, followed by explanations on the principles of mindfulness and acceptance, and physical activity exercises including non-judgmental body sensation observation, non-judgmental thought observation, and distancing from maladaptive thoughts or feelings. Each exercise was considered a relevant tool that could be reused to cope with LBP during the second Sorensen test. This intervention has been co-designed and validated by five of the seven authors, including expert practitioners in mindfulness-based interventions (e.g., Doron, Rouault, Jubeau, & Bernier, 2019; Fournier, 2019; Ruffault et al., 2016). See Appendix 1 for the detailed intervention.

The active control intervention consisted of a semi-structured interview about the participants' active and sedentary behaviors. Daily physical activity scheduling, enjoyment as well as difficulties experienced while engaging in physical activity were examined. The objective of this intervention was to allow participants to elaborate/share their sensations, emotions, and cognitions about physical activity in an empathetic context while having a control intervention not disconnected from the studied variables. No tips nor strategy to cope with LBP during PA practice were provided during this intervention.

Once the two respective interventions were completed, participants were all asked to perform two MVC tests, as well as a second modified Sorensen test. Finally, the situational measurements were reassessed, and participants were thanked.

2.4. Data analyses

Descriptive statistics across times and groups (i.e., means and standard deviations) were first performed for each measure. To ensure that participants did not differ between groups on dispositional measures as well as on their LBP intensity prior to start the experiment, *t*-test comparisons for independent samples were performed on these variables based on normality tests (i.e., Shapiro-Wilk tests). Since all dispositional measures as well as preintervention LBP intensity met normality assumptions, Student *t*- tests were used. Whenever Levene's test was significant, suggesting a violation of equal variance, the Student *t*-test was replaced by a Welch's test. This correction was only applied for the "non-judging" subscale of dispositional mindfulness.

Series of linear mixed models (LMMs) were then performed. These analyses, characterized as multilevel or hierarchical, are known to be relevant for within-participant psychology experiments due to repeated measurements (level 1) nested within each participant (level 2). LMMs enable the identification of the main effects and interaction terms between a response variable and other explanatory variables. LMMs require classifying explanatory variables as either "fixed factors" (i.e., factors where all levels of interest are included in the experiment; here "time" and "group") or "random factors" potentially varying in terms of intercepts or slopes (here "participant"). According to our study design (i.e., a single observation per subject per within-subject factor level), random effects were only allowed on intercepts. For all LMMs analyses, normality of the residuals had to be satisfied. A first set of LMMs was performed with the factors "group" (mindfulness group and control group) and "time" (with T1 referring to the first modified Sorensen test and T2 to the second modified Sorensen test) as independent variables on exercise tolerance and MVC as dependent variables. Based on our sample size, random effects were only allowed on intercepts. A second set of LMMs was finally performed with the same factors "group" and "time" as independent variables on pain-related experiences, perceived effort and the use of coping strategies as dependent variables. In addition, significant between-group dispositional measures were entered in each analysis as covariates. As for the potential effect of the time spent in the first modified Sorensen test on the following measures (i.e., MVC, pain-related experiences and perceived effort), the duration maintained at T1 was also controlled as a covariate in these analyses. Data were analyzed using the Jamovi® software, including the General Analyses for Linear Models in Jamovi (GAMLj) module.

3. Results

3.1. Descriptive statistics.

The participants in our study were predominantly female (n = 17), with an average age of 24.3 years (experimental) and 29.7 years (control). At inclusion, they had a pain score of 27.6/100 (experimental) and 34.2 (control). Table 1 presents the means and standard deviation of sociodemographic and dispositional variables. Participants' characteristics did not differ significantly prior to the experimental procedure, with the exception of trait anxiety, for which participants from the mindfulness group scored significantly higher ($t(15.4) = -2.30$, $p < .05$; $M_{\text{experimental group}} = 48.8$, $M_{\text{control group}} = 39$) and for non-judgementality, for which participants from the mindfulness group scored significantly lower ($t(21) = 2.11$, $p = .05$; $M_{\text{experimental group}} = 25.5$, $M_{\text{control group}} = 31.4$). Self-efficacy in reusing mindfulness techniques learned during the experiment, as well as perceived efficacy of the intervention were estimated to be above 50/100, while perceived difficulty in using them was below 50/100.

Table 2 shows the descriptive statistics for situational measures across groups and time of the experiment.

Table 1. Descriptive statistics and group differences for the sociodemographic and dispositional variables.

	Mindfulness group	Active control group	Group differences
	Mean (SD)	Mean (SD)	*p*
Sociodemographic measures			
Age (years)	24.31(6.11)	29.70(11.22)	*ns*
Height (cm)	170.30(8.16)	167.25(9.21)	*ns*
Weight (kg)	73.02(16.09)	69.06(10.78)	*ns*
Prior LBP intensity level (/100)	27.69(20.57)	34.20(24.78)	*ns*
Dispositional measures			
Dispositional mindfulness:			
Global score (/195)	120(26.1)	133(13.1)	*ns*
Observing (/40)	26.3(4.33)	25.8(6.94)	*ns*
Non-reactivity of inner experience (/35)	17.7(5.69)	20.5(2.72)	*ns*
Non-judging of inner experience (/40)	25.5(7.95)	31.4(4.14)	*
Acting with awareness (/40)	25.8(7.13)	27(3.97)	*ns*
Describing (/40)	24.2(8.45)	28(6.93)	*ns*
Pain catastrophizing (/52)	21.5(12.9)	20.3(9.41)	*ns*
Impulsivity:			
Urgency (/48)	27.7(8.80)	25.1(4.25)	*ns*
Lack of premeditation (/44)	21(5)	21.1(4.25)	*ns*
Lack of perseverance (/40)	17(3.57)	15(2.75)	*ns*
Sensation seeking (/48)	29.5(8.03)	32.2(7.05)	*ns*
Trait anxiety (/80)	48.8(14.1)	39(4.77)	*

Note. *$p \leq .05$; LBP: Low Back Pain; SD: standard deviation

Table 2. Descriptive statistics for situational variables between groups and times.

	Mindfulness group		Active control group	
	T1	T2	T1	T2
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Exercise tolerance (seconds)	139(76.9)	155(76.7)	214(104)	178(74.1)
MVC (Newton)	1009(425)	1008(424)	1015(339)	890(362)
Averaged LBP intensity during the test (/100)	48.1(20.2)	47.5(21)	47(16.5)	51(25.6)
Maximal LBP intensity during the test (/100)	62.1(26)	61.6(25.4)	70(22)	72(28.5)
Averaged LBP unpleasantness during the test (/100)	51.6(31.7)	56.6(23.7)	52.5(26.6)	65(18.4)
Effort perception (/100)	46(20.5)	52.2(24.5)	43(22.1)	52.5(23.7)
Use of acceptance/ignorance (-5; +5)	1.38(3.52)	2.46(2.50)	.90(3.6)	.60(3.37)
Experimental intervention assessment (before T2)				
Expected difficulty to re-use mindful exercises (/100)		43.8(24.3)		
Expected efficacy of mindful exercises (/100)		65.4(17.7)		
Self-efficacy to re-use mindful exercises (/100)		67.1(24.5)		

3.2. Effects of the mindfulness-based intervention on exercise tolerance and MVC.

All effects are detailed in Table 3.

Analyses did not reveal significant main effects of time or group on exercise tolerance while controlling for trait anxiety and nonjudging but revealed a significant time × group effect (B = 50.52, 95% CI [17.05, 83.99], $p < .01$). Although the time × group effect was less than $p < .01$, Bonferroni's post-hoc analyses showed only a trend, with participants in the control group tending to decrease their tolerance to exercise between T1 and T2 ($p = .07$), whereas the experimental group did not.

Analyses also revealed significant effects of time (B = -.63, 95% CI [-106.5, -19.57], $p = .01$) and time × group (B = 124.27, 95% CI [37.34, 211.20], $p = .01$) while controlling for the time spent in the first modified Sorensen test, trait anxiety and non-judging on MVC. Bonferroni post-hoc analyses showed that participants in the control group significantly decreased their MVC between T1 and T2 ($p < .01$), while the experimental group did not. The main effect of group on MVC was not significant.

3.3. Effects of the mindfulness-based intervention on pain-related measures, effort perception, and use of acceptance/ignorance strategies.

All effects are detailed in Table 3.

Analyses revealed significant main effects of time while controlling for the time spent in the first modified Sorensen test, trait anxiety and non-judging on perceived effort (B = 7.83, 95% CI [2.96, 12.70], $p = .01$) as well as on LBP unpleasantness (B = 8.75, 95% CI [1.35, 16.15], $p < .05$). Bonferroni post-hoc analyses showed that LBP unpleasantness was perceived significantly higher during the second modified Sorensen test ($M_{T1} = 52$; $M_{T2} = 60.3$, $p < .05$). Similarly, effort was perceived significantly higher during the second modified Sorensen test ($M_{T1} = 44.7$; $M_{T2} = 52.3$, $p < .01$). For these two respective variables, results did not reveal a main effect of group, nor a time × group effect.

Finally, analyses did not reveal any significant main or interaction effects of time and group while controlling for the time spent in the first modified Sorensen test, trait anxiety and non-judging on averaged LBP intensity, maximal LBP intensity, and the use of acceptance/ignorance pain-related coping strategies.

Table 3. Main and interaction effects for time and group on the studied variables

	Exercise tolerance	MVC	Averaged LBP intensity	Maximal LBP intensity	Averaged LBP unpleasantness	Effort perception	Coping strategies
Fixed effects - Estimates (Standard errors)							
Intercept	170.24***(17.20)	978.93***(86.72)	48.21***(4.49)	66.05***(5.26)	55.95*** (5.12)	48.47*** (4.68)	1.31* (.61)
Time	-10.11(8.54)	-63.03**(22.18)	1.73(2.56)	.77(2.71)	8.75* (3.77)	7.83** (2.48)	.39(.65)
Group	-30.68(38.24)	80.83(199.95)	1.72 (10.35)	-3.37(11.70)	2.77(11.81)	.41(10.80)	1.58(1.41)
Trait anxiety	-.10(2.29)	4.73(11.55)	.08(.59)	.14(.70)	.49 (.68)	.11(.62)	-.08(.08)
Non-judging	2.95(3.94)	.43(20.43)	.66(1.06)	1.22(1.21)	1.63(1.21)	-.86(1.10)	-.01(.14)
Time spent in the 1st Sorensen test	-	.93(1.06)	-.02(.05)	.05(.06)	.04(.06)	.07(.06)	-.01(.01)
Time*Group	50.52**(17.08)	124.27**(44.35)	-4.54(5.11)	-2.46(5.43)	-7.50(7.55)	-3.35(4.97)	1.38(1.29)
Random effects - Variance (Standard deviation)							
Intercept	6251(79.1)	166277(407.8)	416.3(20.40)	599(24.48)	509(22.6)	458.31(21.41)	6.10(2.47)
-2*log-likelihood	-230.03	-279.32	-180.66	-185.02	-191.20	-180.81	-115.99

Note. *$p \leq .05$, **$p \leq .01$, ***$p \leq .001$; MVC: maximal voluntary contraction; LBP: low back pain.

Discussion

The present pilot study had two objectives: first, to examine the effects of an acute mindfulness-based intervention versus an active control one on exercise tolerance and MVC in individuals with primary CLBP; and second, to compare their respective effects on pain-related experiences, perceived effort and use of pain-related coping strategies.

The results show that both groups performed differently after the experimental and the control groups interventions. Participants from the control group significantly decreased MVC across time and showed a trend towards a decrease in exercise tolerance, while participants from the experimental group did not significantly vary on these two variables. The results also showed that participants in both groups perceived greater pain unpleasantness and effort during the second modified Sorensen test, which is in contradiction with our second hypothesis. Furthermore, the use of acceptance as a coping strategy to deal with the pain occurring during the second modified Sorensen test did not significantly vary across time nor groups, which is also inconsistent our second hypothesis.

The results showing a decrease in exercise tolerance only for the control group during the second modified Sorensen task were unexpected in light of previous studies (Alahmari et al., 2020; Latimer et al., 1999) and can probably be discussed in terms of the content of both interventions. On the one hand, the content of the active control intervention may have emphasized or primed maladaptive thoughts, feelings or sensations typically encountered in physical activity (e.g., alarming thoughts, low self-efficacy in exercising), potentially altering exercise tolerance (Blanchfield, Hardy, & Marcora, 2014). As recently highlighted, active control interventions appear to be necessary when investigating the effect of mindfulness-based interventions (McClintock, McCarrick, Garland, Zeidan, & Zgierska, 2019). Regardless of the precautions taken to design an appropriate active control intervention, such a task appears to be challenging, and should be pre-tested. On the other hand, Jong et al.

(2016), found that mindfulness-based interventions improve participants' awareness of mind-body interrelations, as well as their ability to control psychological distress by consciously attending to body sensations, which may have occurred during the experimental task. In the present study, the mindfulness-based intervention allowed participants to at least maintain exercise tolerance, but not to improve it. As such, a third neutral intervention disconnected from PA could have been useful to clarify the psychophysiological effect respectively related to each intervention.

Nevertheless, the results partly replicate those of Ivanova et al. (2015), who found a trend towards decreased exercise tolerance for the control group, and showed significant improvements in exercise tolerance and perceived effort after a one-time mindfulness-based intervention associated with a cycling task. Both interventions were performed until volitional exhaustion, whether it was a high-intensity cycle exercise (Ivanova et al., 2015) or an isometric endurance task in the present study. The present findings are more consistent with results highlighting rather minimal improvements in perceived effort after a mindfulness-based intervention using submaximal (walking or cycling) tests (Cox et al., 2018; Meggs & Chen, 2021). Since the present study is the first to involve patients with primary CLBP in a task requiring low back muscle activation, the contrasting results could be task as well as sample dependent, and should be further examined. Similarly, but in individuals without primary CLBP, it has been shown that a one-time mindfulness-based intervention can improve pain tolerance and pain distress in an experimental induced pain setting (Liu, Wang, Chang, Chen, & Si, 2012), but that this acute effect may not be systematic, even after a five-session training (Esch et al., 2017). Such inconsistencies invite reflection about the nature of the intervention, as well as its duration. Indeed, it has been highlighted that cognitive defusion, which refers to "a state of mind wherein one achieves psychological distance from subjective experiences, seeing them merely as psychological events or states rather than as literal, truth-based interpretations of reality" (Masuda, Hayes, Sackett, & Twohig, 2004) is at the core of the pain sensory affective (un)coupling, and partly explains differences in pain responsiveness in novice versus experienced meditators (Zorn, Abdoun, Sonié, & Lutz, 2021). Cognitive defusion was at the core of Ivanova et al. (2015) study, whereas the intervention designed for the present study was not primarily dedicated to teaching this acceptance-based technique.

Participants in the experimental group rated the mindfulness-based intervention rather effective, and expressed more self-efficacy than difficulty in reusing it during the second part of the experiment. These descriptive results suggest that the mindfulness-based intervention is quite relevant and easy to use for individuals with primary CLBP in an active setting.

Beyond these results, the study has general limitations that must be considered. First, one third of individuals with chronic non-specific LBP have a high-impact LBP characterized by a substantial restriction of participation in work, social activities, and self-care activities for 6 months or longer (Pitcher, Von Korff, Bushnell, & Porter, 2019; Walker, Muller, & Grant, 2004). Not controlled for in the present study, participants' functional status might have accounted for rather large interindividual differences found in exercise tolerance and MVC and should be considered in further studies. Second, physical activity levels were not measured for study participants. Considering the risks associated with physical activity in individuals with low back pain, future studies should assess physical activity and sedentary levels in patients with low back pain (Heneweer, Vanhees, & Picavet, 2009). Regarding measures, the use of the CR-100 typically involves memory recall and/or experiential anchoring (see Pageaux, 2016 for a review). In the current study, there was no such standardized familiarization, but a verbal anchor-based familiarization as proposed and used by Foster et al. (2010; reviewed by Haddad et al., 2017), using the CR10. Although participants were given time and explanations to become familiar with the scale, we recognize that a memory recall and/or experiential anchoring with the scale might have been provided. In addition, although verbal encouragement is recognized to improve performance on endurance tasks (e.g., Bickers, 1993; Puce et al., 2022), as well as on the production of isometric force (Belkhiria, De Marco, & Driss, 2017), verbal encouragement was not provided during the Sorensen tests, as our goal was to rely on an active task that allowed the participants in the experimental group to practice the acceptance techniques taught, which required a calm and supportive environment. In order to standardize all experimental conditions, we therefore chose to suppress verbal encouragement from all the Sorensen tasks. The choice of using a bidirectional scale in order to assess a potential preferential coping mode between pain-related acceptance and ignorance could have been more accurate in highlighting participants' use of pain-related coping strategies. Although correlated, acceptance and ignorance are two distinctive constructs (McCracken & Eccleston, 2006), whose assessment might have been refined by the use of respective scales. Furthermore, it should be noted that the scale used only assessed the nature of the preferred coping strategy used in the modified Sorensen tests, not its level (or amount) of use as it is usually expected in coping strategies inventories (e.g., Rosenstiel & Keefe, 1983). Moreover, only pain-related acceptance and ignorance were assessed as LBP-related coping strategies, as both are contrasting aspects of the direct and complete connection with private experiences (Fernández-Rodríguez, Paz-Caballero, González-Fernández, & Pérez-Álvarez, 2018). Nevertheless, it is well recognized that experimental pain experiences involve several coping strategies, such as distraction, that occur naturally and fluctuate over time (e.g., Nouwen, Cloutier, Kappas, Warbrick, & Sheffield, 2006). The assessment of various coping strategies might have been insightful in explaining group differences in MVC and exercise tolerance. Another limitation of our study is the rather small sample size (i.e., 23 participants). However, pilot studies should be considered as small-scale versions of subsequent large-scale studies, allowing for evaluation of the outcomes and feasibility (Eldridge et al. 2014; Moore, Carter, Nietert, & Stewart, 2011).

This pilot study is one of the first to examine, in an exercise-related setting, the effect of an acute mindfulness-based intervention in individuals with primary CLBP. In light of the results, short mindfulness-based interventions targeting active situations could be relevant in daily active living as well as in clinical settings (e.g., physical therapy, kinesiology, adapted physical activity), in order to help and/or self-help individuals to engage in first-line treatments such as remaining active and practicing PA, despite their pain level.

Although the aforementioned limitations should be overcome in further studies, acute mindfulness-based interventions appear promising when seeking to optimize the benefits of PA session in patients with primary CLBP.

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