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Original article

Comparison of high, medium and low mobilization forces for reducing pain and improving physical function in patients with hip osteoarthritis: Secondary analysis of a randomized controlled trial

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A B S T R A C T

Background: Long-axis distraction mobilization (LADM) of the hip has been shown to reduce pain and improve physical function in hip osteoarthritis (OA). The optimal intensity of mobilization force necessary to reduce pain and improve physical function is unknown.

Objective: To compare the effects on pain and physical function of three different intensities of LADM mobilization force in hip OA patients.

Design: Randomized controlled trial.

Methods: Sixty patients with unilateral hip OA were randomized to three groups: low, medium or high force mobilization group. Participants received three treatment sessions of LADM. Pressure pain thresholds (PPT) at hip, knee and heel, physical function (Western Ontario and McMaster Universities physical function subscale, timed up and go and 40 m self-placed walk test) and pain after the physical function tests (visual analogic scale) were assessed before and after the intervention.

Results: The three treatment groups showed significant improvements in pain and in physical function ($p < 0.05$). The low-force group showed the largest effects size for pain ($d = 2.0$) and the greatest mean percentage increase in PPTs (hip = 30.3%, knee = 34.6%, heel = 25.6%). The high-force group showed the largest effects size for physical function ($d = 0.5–0.7$).

Conclusion: A low-force LADM produced the largest reduction in pain and a high-force LADM the largest improvement in physical function in hip OA patients. The improvements in pain and physical function after LADM in hip OA patients appear to be modulated by the intensity of the mobilization force.

1. Introduction

Manual therapy has demonstrated its effectiveness to reduce pain and improve physical function in patients with mild to moderate hip osteoarthritis (OA) (Brantingham et al., 2012; Beselga et al., 2016; Cibulka et al., 2017). Long-axis distraction mobilization (LADM) is one of the most reported manual therapy techniques in studies with hip OA patients (Hoeksma et al., 2004; MacDonald et al., 2006; Vaarbakken and Ljunggren, 2007; de Luca et al., 2010; Strunk and Hanses, 2011; Hando et al., 2012; Estébanez-de-Miguel et al., 2018). These preliminary studies have shown that LADM reduces pain, increases hip ROM and improves physical function in hip OA patients (Hoeksma et al., 2004; MacDonald et al., 2006; Vaarbakken and Ljunggren, 2007; Estébanez-de-Miguel et al., 2018).

McLean et al. (2002) and Jull and Moore (2002) suggested that a specific intensity of force mobilization appears to be necessary to achieve a specific therapeutic result. According to this, Estébanez-de-Miguel et al. (2018) demonstrated that a high force LADM in open packed position significantly increased hip range of motion (ROM) compared to a medium or low force mobilization in patients with hip OA. Several studies have shown that the magnitude of the manual force applied affects the degree of analgesia during active movement (McLean et al., 2002; Nougarou et al., 2013) and muscular response (McLean et al., 2002; Colloca et al., 2003; Nougarou et al., 2013). According to this, Bishop et al. (2015) suggested that the neurophysiological response of manual therapy depends on the magnitude of the mechanical force applied in manual therapy techniques. However, there is a lack of evidence on the different intensities of force which could be necessary to reduce pain and improve physical function in hip OA patients.

Local, segmental and central inhibitory mechanisms have been proposed to explain the hypoalgesic effects of passive joint

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mobilizations in OA patients. Local mechanisms would be related to the changes in the concentrations of inflammatory mediators, known to sensitize peripheral nociceptors (Sambajon et al., 2003). Segmental pain inhibitory mechanisms would be related to the inhibition of small diameter afferents because of the activation of large diameter joint afferent fibres (gate control theory of pain) during joint mobilization (Schaible and Grubb, 1993). Finally, central inhibitory mechanisms would be related to the decrease in central excitability of nociceptive pathways that produces a more generalized hypoalgesic response.

Several studies have demonstrated a decrease in central excitability of nociceptive pathways and pain measures following a treatment of knee joint mobilization in knee OA patients (Moss et al., 2007; Courtney et al., 2010, 2016). However, in these studies the amount of force applied during the mobilization is unknown. The grades of mobilization determine the intensity of the forces applied during a distraction mobilization and are related to the resistance of the tissue. Kaltenborn's grading system states 3 grades of distraction mobilization in relation to the slack of the joint and the first stop (Kaltenborn et al., 2014). We hypothesize that the hypoalgesic response is related to the intensity of the force applied during the passive joint mobilization.

Passive joint mobilization could enhance motor activity by hypoalgesic and sympatho-excitatory responses (Moss et al., 2007). We also hypothesize that the improvement in motor activity and physical function may be a response mediated by the intensity of the mobilization force.

The purpose of this study is to compare the effects on pain and physical function of three different intensities of LADM mobilization force (low, medium and high) in patients with hip OA.

2. Methods

2.1. Study design and ethics

The data presented in this article (pain, pressure pain threshold and physical function) represent a secondary analysis of a randomized double blind controlled clinical trial. The recruitment methods and a description of the trial have been published (Estébanez-de-Miguel et al., 2018). Three intervention groups were stablished: low-force mobilization group, medium-force mobilization group and high-force mobilization group.

Ethical approval was obtained from The Ethics Committee of Clinical Research of Aragon (CEICA). The study was registered in ClinicalTrials.gov (NCT02498314) and was designed according to CONSORT recommendations.

2.2. Participants

Sixty patients with hip OA (mean age 63 ± 9.7 years; 35 male) were enrolled in the study. Participants were recruited from private practice physiotherapy clinics or referred by general practitioners and orthopedic surgeons.

To be eligible, participants were required to be over 50 years of age, with unilateral primary hip OA according to the clinical criteria of the American College of Rheumathology (Altman et al., 1991), a grade III Kellgren & Lawrence (K-L) classification in their most recent hip X-rays and a score range of 1–6 in WOMAC pain subscale. Patients were excluded if they reported any neurological, vascular or other lower extremity musculoskeletal conditions that affected sensation, gait or functional performance; previous knee or hip joint replacement surgery of the affected extremity; contraindications for manual therapy; previous physiotherapy treatment to the hip and inability to complete the assessment or attend to all the sessions of the study. Participants were also excluded if they presented an insufficient understanding of the Spanish language.

2.3. Randomization and blinding

After signing the informed consent, participants were randomly allocated to one of three treatment groups: low-force mobilization group, medium-force mobilization group and high-force mobilization group. A random-number generator (Research Randomizer. Version 4.0) was used for randomization. Only the first author was aware of patients group allocation. Both the examiner and the patients were blinded to the assigned group.

2.4. Interventions

Interventions were carried out by an experienced physiotherapist with more than 15 years of clinical experience and a masters degree in manual therapy. This physiotherapist was blinded to the measurements.

LADM with different intensity of forces was applied to all patients according to the assigned group. The intervention was delivered in 3 sessions on alternate days. LADM was carried out with the patient lying supine with the hip in open packed position (30° of flexion, 30° of abduction and slight external rotation) (Wise, 2015). The open packed position of the hip was kept with a wedge cushion.

The intensity of the forces of the different treatment groups was applied according to Kaltenborn's grades of joint mobilization (Kaltenborn et al., 2014). In the low-force mobilization group, a force in the slack zone, before the slack is taken up (slack taken up) was applied. A force until the examiner felt a marked resistance (first stop) was applied in the medium-force mobilization group. A force that exceeded the first stop stretching the soft tissue surrounding joint was applied in the high-force mobilization group. The mean forces used in low-force mobilization group, medium-force mobilization group and high-force mobilization group were 26.4 ± 6.8 N, 50.7 ± 7.8 N and 68.6 ± 2.9 N, respectively (Estébanez-de-Miguel et al., 2018). To determine the magnitude of force exerted during LADM, a dynamometer was placed between the joint distraction cuff and the mobilization belt.

In all intervention groups LADM was applied for 10 min. In the low-force mobilization group, gentle and repetitive distraction movements were applied continuously. In the medium-force and high-force groups, mobilizations were applied periodically and each mobilization lasted 45 and 30 s respectively followed by 15 s rest period. If a patient experienced pain during LADM it was also recorded.

2.5. Outcome measures

Outcome measures were evaluated by a blinded examiner. Physical function, pain and pressure pain threshold were evaluated at baseline and after the last treatment session. Patients were instructed to maintain their usual activity levels and to avoid analgesic or anti-inflammatory medications 24 h prior the testing.

2.5.1. Physical function

Physical function was evaluated with the self-administered Western Ontario and McMaster Universities physical function subscale (WOMAC-PF), the Timed Up & Go test (TUG) and the 40-m self-paced walk test (40-m SPWT). Prior to performance of physical function tests, patients were explained the tests procedure and purpose. Adequate pauses between tests were allowed in order to avoid fatigue and similar verbal encouragement was provided to do their best.

The WOMAC-PF asks about the degree of difficulty in doing 17 daily activities involving the lower extremities/the reference joint. Answers are provided on a 5-point scale ranging from 0 (no difficulty at all) to 4 (very much difficulty). Total possible scores range from 0 to 68, with a higher score indicating greater disability. In OA populations, the WOMAC-PF has shown excellent psychometric properties (Gandek, 2015).

In the TUG, using a chair with arm rests, patients were asked to stand up from the chair, walk 3 m, turn, walk back to the chair, and sit

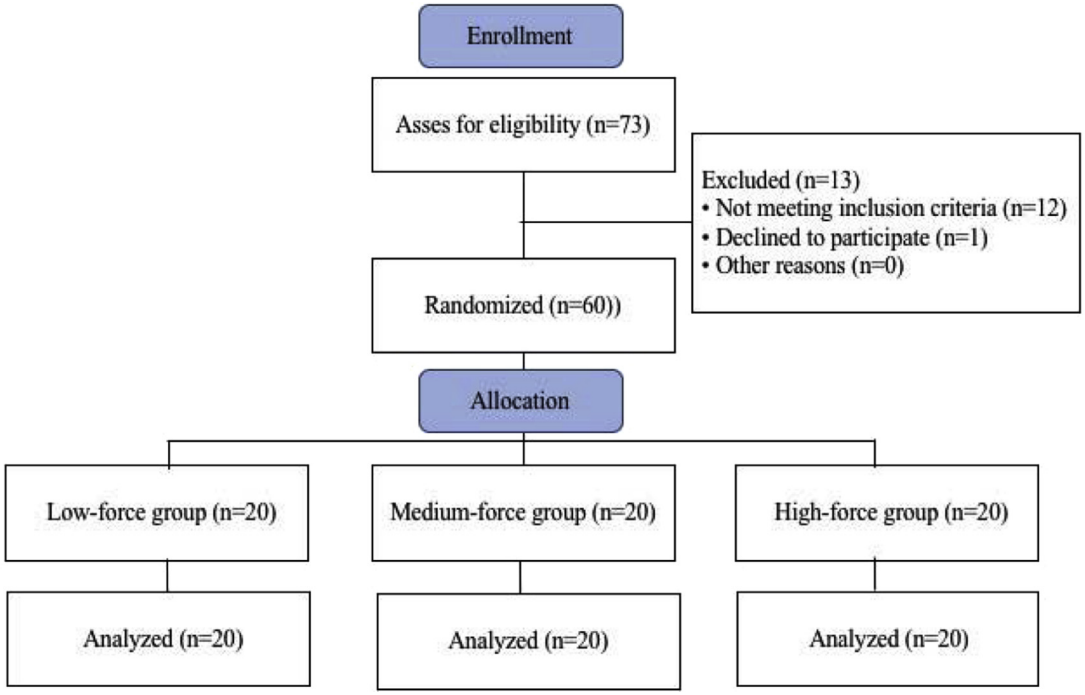

Fig. 1. Flow chart of the study.

down quickly and safely (Bennell et al., 2011). In the 40-m SPWT, all subjects were asked to walk as far as possible 2 lengths (turn excluded) of a 20-m indoor course (Kennedy et al., 2005). In both, the time (in seconds) required to complete the test was recorded and an average score of 2 trials was registered.

2.5.2. Pain

Hip pain intensity was assessed using a horizontal 10 cm visual analogue scale (VAS), immediately after the physical functions tests. The reliability of VAS in osteoarthritic patients is excellent (Alghadir et al., 2018).

2.5.3. Pressure pain threshold

Pressure pain threshold (PPT) was measured using a digital pressure algometer (Somedic AB, Farsta, Sweden). The tip of the algometer was applied perpendicular to the most painful site at the hip region on the affected limb, at a rate 50 kPa/s until the subject reported a change from pressure to a painful sensation (Kavchak et al., 2012). According to Moss et al. (2007) protocol, PPT was also registered at the medial knee and the medial heel on the affected limb. Tender points were marked and photographed to ensure standardization between assessment sessions. The procedure was performed 3 times at 20 s intervals and the mean of the 3 measurements was recorded (Rolke et al., 2006). Change in mean PPT was calculated for analysis.

To avoid bias, pain data (VAS and PPT) before treatment were evaluated after 10 min rest period on the treatment table. This was the same time spent to apply the intervention in the three treatments groups.

2.6. Sample size

The sample size was calculated using Minitab® 13.0 program. The differences in mean values between groups and standard deviation for primary outcomes were based on pilot data. Finally, the sample size was determined by VAS. Assuming a standard deviation of 1.57 and a between mean difference of 1.85, with 90% power and an alpha level of 0.05, a total sample size of 60 patients was estimated.

2.7. Statistical analyses

Data were analysed using SPSS Statistics Version 22.0. A p-value < 0.05 was considered statistically significant.

Descriptive statistics (frequency, mean and standard deviations) were calculated to describe the sample.

Normal distribution of the sample was analysed using the Shapiro-Wilk test ($p > 0.05$). Differences in VAS, the WOMAC-PF and physical function tests between the three conditions were tested with repeated measurements ANOVA with 2 factors (group and time) or Friedman test. The Bonferroni test or Wilcoxon test were used for multiple comparisons.

Percentage change between pre- and post-condition values was used in PPT variable (CPMP, 2003). Repeated measures analysis of covariance (ANCOVA) was used to analyse differences between percentage change in PPT measures, using pre-condition mean as the covariate.

The effect size was calculated to estimate the magnitude of the differences within and between groups with Cohen coefficients (d). Cohen coefficients were interpreted as follows: large effect sizes, $d > 0.8$; moderate effect sizes, $d = 0.5–0.79$; and small effect sizes, $d = 0.2–0.49$ (Cohen, 1988).

3. Results

Seventy-three consecutive patients with hip OA were initially recruited. Thirteen patients were excluded; twelve of them did not fulfill the inclusion criteria (11: extremity musculoskeletal conditions, 1: previous physiotherapy treatment) and one declined to participate for personal reasons. Finally, sixty patients satisfied the selection criteria and were randomized: low-force mobilization (n = 20), medium-force mobilization (n = 20) and high-force mobilization (n = 20) (Fig. 1). Demographic data were similar for all variables between groups (Table 1).

Table 2 provides before and after treatment session data, within and between groups differences as well as the effect sizes for VAS, WOMAC-PF, the TUG and the 40-m SPWT. There were statistically significant improvements in VAS and physical function variables in the three treatment groups ($p < 0.05$). However, there were no differences

Table 1
Demographic characteristics for the three groups.

Characteristics	Low Force (n = 20)	Medium Force (n = 20)	High Force (n = 20)	Significance
Gender (male/female)	12/8	8/12	15/5	$X^2 = 5.07$; p = 0.079
Age (years)	61.8 ± 9.6	66 ± 9.5	61.1 ± 9.5	F = 1.4; p = 0.240
Time since diagnosis (months)	26.1 ± 17.1	33.1 ± 21.3	31.6 ± 20.8	K = 3.9; p = 0.138
BMI (kg/cm^2)	26.7 ± 3.3	27.2 ± 4.7	26.7 ± 4.2	F = 2.1; p = 0.919
Pain (WOMAC pain subscale)	1.6 ± 0.4	1.2 ± 0.5	1.4 ± 0.4	K = 4.5; p = 0.102

BMI: Body Mass Index, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.
Values are expressed as mean ± SD, except where otherwise indicated.

between the groups either at baseline nor at the end of intervention (p > 0.05). The three intensity of forces applied in the study showed a large effect size for pain reduction (VAS) after the functional tests although the low-force mobilization group showed the largest effect size (d = 2.0). Effect sizes for physical function variables were small or moderate in the three treatment groups. However, the high-force mobilization group showed a moderate effect size for all physical function measures (TUG, d = 0.7, 20 m test, d = 0.6; WOMAC-PF, d = 0.5).

As illustrated in Table 3, a generalized hypoalgesic effect was shown in the three treatment groups. However, after the intervention, the mean change in PPT measures was greater in low-force mobilization group compared to the medium-force or high-force mobilization groups. The mean change in hip PPT was greater than 20% in the three treatment groups. There were significant differences in hip PPT between the low-force and the medium-force mobilization groups (low-force group: mean change = 30.3 ± 9.0%, medium-force group: mean change = 21.7 ± 10.1%, p = 0.045). The low-force LADM also significantly increased knee PPT over and above the medium-force or the high-force conditions, when adjusting for pre-condition values (p = 0.002). The mean changes in knee PPT in low-force mobilization group, medium-force mobilization group and high-force mobilization group were 34.6 ± 18.4%, 15.5 ± 11.4% and 20.8 ± 16.5%, respectively. There was a significant difference between the low-force and the medium-force mobilization groups in heel PPT (low-force group: mean change = 25.6 ± 12.2%, medium-force group: mean change = 16.5 ± 8.0%, p = 0.009), but not between the low-force and the high-force mobilization groups (p = 0.333).

Table 3
Baseline, final values, change scores and effect size for pain pressure threshold outcomes.

Outcome group	% difference pre- to post-			Between-groups P values	Between-group Effect sizes
	Mean	SD	95%CI		
Hip PPT					
Low Force	30.3[2]	9.0	26.1–34.5	0.036	0.6
Medium Force	21.7[1]	10.1	16.8–26.6		
High Force	25.8	8.0	22.4–29.5		
Knee PPT					
Low Force	34.6[2,3]	18.4	26.2–43.3	0.002	1.2
Medium Force	15.5[1]	11.4	8.9–20.0		
High Force	20.8[1]	16.5	12.8–28.8		
Heel PPT					
Low Force	25.6[2]	12.2	19.9–31.4	0.008	0.9
Medium Force	16.5[1]	8.0	12.6–20.4		
High Force	21.4	6.4	18.3–24.5		

PPT: pressure pain threshold.
Superscripts denote significant differences among groups (low force group = 1, medium force group = 2, high force group = 3).
P < 0.05, significant difference.

4. Discussion

This is the first study to investigate the effects of differences in applied LADM force on pain and physical function in patients with hip OA. The low-force, medium-force and high-force LADM showed significant improvements in pain and physical function in hip OA patients.

Table 2
Baseline, final values, change scores and effect size for pain and physical function outcomes.

Outcome group	Baseline	End of treatment	Within-group changes	Within-group Effect sizes	Between groups P values	Between-group Effect sizes
VAS (0–10)						
Low Force	4.1 ± 1.5	1.0 ± 1.5	−3.0 (−2.5,-3.6)	2.0	0.512	0.2
Medium Force	3.5 ± 1.6	1.1 ± 1.3	−2.4 (−1.6,-3.2)	1.6		
High Force	3.9 ± 1.5	1.2 ± 1.3	−2.6 (−1.8,-3.3)	1.9		
TUG test (seconds)						
Low Force	13.8 ± 6.1	11.2 ± 3.2[3]	−2.12 (−0.4,-3.7)	0.5	0.026	0.6
Medium Force	11.6 ± 3.6	9.9 ± 3.0	−1.6 (−0.7,-2.6)	0.5		
High Force	10.4 ± 2.8	8.6 ± 1.6[1]	−1.8 (−0.7,-2.8)	0.7		
SPW test (seconds)						
Low Force	55.2 ± 20.8	48.6 ± 12.2	−6.6 (-11.8,-1.4)	0.3	0.080	0.4
Medium Force	51.8 ± 15.0	45.2 ± 13.4	−6.4 (-8.8,-4.0)	0.4		
High Force	44.8 ± 7.2	40.0 ± 8.4	−4.4 (-6.6,-0.4)	0.6		
WOMAC-PF (0–68)						
Low Force	33.2 ± 11.8	27.2 ± 12.1	−6.0 (-8.7,-3,2)	0.5	0.071	0.4
Medium Force	25.6 ± 14.1	19.3 ± 11.8	−6.2 (-11.6,-0.95)	0.4		
High Force	26.9 ± 12.0	20.9 ± 9.4	−5.9 (-9.7,-2.2)	0.5		

VAS: Visual Analogue Scale; TUG: Time Up & Go; SPW: 40 m Self Placed Walk; WOMAC-PF: Western Ontario & McMaster Universities Osteoarthritis Index function scale.
Superscripts denote significant differences among groups (low force group = 1, medium force group = 2, high force group = 3).
Values are expressed as mean ± SD for baseline and final means and as mean (95% confidence interval) for within-group change scores. P < 0.05, significant difference.

However, the effect size for pain was larger in the low-force mobilization group than in the medium and high-force mobilization groups and the effect size for physical function was larger in the high-force mobilization group than in the low and medium-force mobilization groups. These results show that the hypoalgesic response and the improvements in physical function could be modulated by the intensity of the force applied during the passive joint mobilization.

4.1. Effects on pain-related measures

The three treatment groups showed a significant decrease in hip pain intensity after the physical function tests (VAS). The decrease in VAS was superior to the minimal clinically important difference (MCID) for hip OA patients (Tubach et al., 2005). Therefore, the three intensity of forces produced a clinically significant effect on pain reduction. Although there were no significant differences between groups, the low-force mobilization group showed the largest effect size for VAS ($d = 2.0$).

In relation to the PPT measures, LADM increased hip PPT more than 20% in the three treatment groups. An increase of > 15% in PPT is considered a clinically important change (Sterling et al., 2010), indicating a reduction in sensitivity to mechanical pain. In the present study, low-force LADM increased hip PPT by 30.3% compared to 21.7% resulting from medium-force LADM or 25.8% from high-force LADM, showing significant differences in hip PPT between the low and medium forces. Previous studies reported an increase in knee PTT of approximately 27% (Moss et al., 2007; Courtney et al., 2016) after oscillatory AP glide of the tibia on the femur mobilization (Maitland, 1991) in knee OA patients. In these studies, the intensity of force applied during the mobilization was determined by the resistance of the tissue. According to this criterion, the intensity of force was similar to the intensity applied in the low-force mobilization group in the present study. Therefore, the largest increases in PPT measures were produced by gentle oscillatory mobilization before the slack was taken up. Evidence suggests that a repeated oscillatory mobilization is an important mechanism to relieve pain (Moss et al., 2007; Bishop et al., 2015; Bialosky et al., 2018). Sambajon et al. (2003), in an invitro study, showed a reduction close to 70% in levels of the prostaglandin PGE2 after the repetitive mechanical deformation of healthy synovial fibroblasts. These changes in the local cellular environment would activate analgesic local mechanisms that would be very important for pathological joint changes of OA patients. The results of our study have showed that not only repeated oscillatory but also low-force mobilization is relevant to produce the largest analgesic effects in OA patients.

In relation to the high-mobilization group, the increase in hip PPT was similar to the increase in carpometacarpal (CMC) joint PPT after grade 3 distraction CMC mobilization in patients with thumb CMC OA (Villafañe et al., 2011). Therefore the force exceeding the first resistance by soft tissue surrounding the joint, increased the local PPT with approximately 25% in patients with hip OA. These results would confirm the hypothesis that the magnitude of the force applied during mobilization affects the reduction of the local sensitivity to mechanical pain in OA patients.

Changes in knee and heel PPT s in the three treatment groups presented a similar pattern of results, with low-force LADM resulting in the greatest knee (34.6%) and heel (25.6%) PPT increases. Low-force LADM differed significantly from both medium and high-force LADM in knee PPT and from medium-force LADM in heel PPT. Therefore, the hypoalgesic response produced by low-force LADM at the ipsilateral knee and foot was similar to that at the treated hip. Moss et al. (2007) demonstrated that the hypoalgesic response provoked by a knee mobilization is widespread and not just limited to the treated joint in knee OA patients. Villafañe et al. (2014) showed that the mobilization of the symptomatic hand reduces pressure pain sensitivity in the contralateral non-treated hand in CMC OA patients. Courtney et al. (2016) showed a generalized hypoalgesic effect to the hand after knee mobilization in knee OA patients. All these studies suggested that a mechanical force is required to produce a widespread pain modulation effect. However, the current study demonstrates for the first time that the generalized hypoalgesic response depends on the magnitude of the mechanical force applied during mobilization, showing that a low-intensity LADM in hip joint produced the largest generalized hypoalgesic effect in ipsilateral knee and heel in hip OA patients. To explain the generalized hypoalgesic response, it has been suggested that supraspinal pain inhibitory mechanisms are activated by joint mobilization (Bishop et al., 2015; Bialosky et al., 2018). The findings from the current study indicate that this activation could be modulated by the intensity of the mobilization force-that is, dose-dependent.

4.2. Effects on physical function-related measures

The three treatment groups showed a significant improvement in physical function after LADM. The improvements in the TUG, 40-m SPWT, WOMAC-PF were superior to the MCID for hip OA patients (Ehrich et al., 2000; Cibulka et al., 2009; Wright et al., 2011). Although only in the TUG test significant differences were found between the high and the low-mobilization groups, the high-mobilization group showed the largest effect sizes for physical function measures.

Previous studies have shown that joint mobilizations produce improvements in physical function in patients with lower-extremity OA (Moss et al., 2007; Courtney et al., 2010; Beselga et al., 2016). It has been suggested that joint mobilization would enhance motor activity alongside hypoalgesic and sympatho-excitatory responses to explain the improvements in physical function (Vicenzino et al., 1996, 2001; Moss et al., 2007; Courtney et al., 2010; Sterling et al., 2010). The improvements in physical function measures following application of high-force LADM could have resulted from the increases in hip ROM reported in the primary study (Estébanez-de-Miguel et al., 2018). For this, the mechanism that produced changes in physical function appears to be modulated by the intensity of mobilization forces. Future studies are required to determine the influence of the intensity of the forces applied during joint mobilization on the mechanisms related to the improvements in motor function.

4.3. Study limitations

This study had several limitations. First, the contraction of muscles around the hip joint during LADM was not controlled for. The reflex muscle activity could have varied the physical function and pain measures. If the reflex muscle activity appeared it was not because of pain, because no participants experienced pain during LADM. Second, PPT changes were observed after 3 treatment sessions on alternate days. PPT was assessed at baseline and after the third session. The changes in PPT were similar to the changes reported after one (Moss et al., 2007; Courtney et al., 2016) or six (Villafañe et al., 2011) sessions. For this reason, it would be interesting to determine how long these changes persist. Third, we cannot confirm the mechanisms associated to the hypoalgesic and motor changes observed in the current study. Future studies should analyse analgesic and motor changes to confirm local or central effects of LADM in hip OA patients. Finally, only one therapy was applied. Clinical practice guidelines recommend manual therapy combined with exercise as part of the management of patients with mild to moderate hip OA (Brantingham et al., 2012; National Institute for Clinical Excellence, 2014; Bialosky et al., 2018). Future studies should include multimodal therapeutic approaches in a long-term treatment.

5. Conclusions

Although the three intensity of forces applied reduced pain and improved physical function in hip OA patients, the changes depended on the magnitude of the force applied during LADM. According to the

findings, a repetitive gentle LADM before the slack is taken up (low-force), could be indicated to reduce pain during functional activities and in local and generalized sensitivity to mechanical pain. A force that exceeds the first stop stretching the soft tissue surrounding the joint (high-force) could be indicated to improve physical function. The improvements on pain and physical function after LADM in hip OA patients appear to be modulated by the intensity of the mobilization force.

Declaration of conflicting interests

The Authors declare that there is no conflict of interest.

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