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PILOT, SINGLE-BLIND, RANDOMIZED STUDY

Changes in co-contraction during stair descent after manual therapy protocol in knee osteoarthritis: A pilot, single-blind, randomized study

Carlos Cruz-Montecinos, PT, MSc [a,b],
Rodrigo Flores-Cartes, PT [a], Agustín Montt-Rodriguez, PT [a],
Esteban Pozo, BS [a], Alvaro Besoaín-Saldaña, PT [a],
Giselle Horment-Lara, PT, MSc [a,b,*]

[a] *Department of Physical Therapy, Faculty of Medicine, University of Chile, Santiago, Chile*
[b] *Laboratory of Biomechanics, San José Hospital, Santiago, Chile*

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KEYWORDS
Knee osteoarthritis;
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Summary *Introduction:* Manual therapy has shown clinical results in patients with knee osteoarthritis. However, the biomechanical aspects during functional tasks have not been explored in depth.
Methods: Through surface electromyography, the medial and lateral co-contractions of the knee were measured while descending stairs, prior and posterior to applying a manual therapy protocol in the knee, with emphasis on techniques of joint mobilization and soft-tissue management.
Results: Sixteen females with slight or moderate knee osteoarthritis were recruited (eight experimental, eight control). It was observed that the lateral co-contraction index of the experimental group, posterior to intervention, increased by 11.7% ($p = 0.014$).
Conclusions: The application of a manual therapy protocol with emphasis on techniques of joint mobilization and soft-tissue management modified lateral co-contraction, which would have a protective effect on the joint.

* Corresponding author. Department of Physical Therapy, Faculty of Medicine, University of Chile, Avenida Independencia N-1027, Independencia, Santiago, Chile. Tel.: +56 2 29786514.
E-mail address: ghorment@med.uchile.cl (G. Horment-Lara).

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Introduction

Osteoarthritis (OA) is one of the most common forms of arthritis (Felson, 1990), with one of the most affected weight-bearing joints being the knee (Muraki et al., 2012). In individuals older than 55, severity tends to be greater in females (Srikanth et al., 2005). Osteoarthritis is characterized by pain and decreased range and strength, affecting the activities of daily life (Bedson et al., 2007; van Dijk et al., 2010). Among functional tasks, one of the most demanding is the ascent and descent of stairs, which generates a peak knee adduction moment (KAM), with subsequent medial overload in the knee (Hall et al., 2013). For these types of demanding tasks, co-contraction, the expression of simultaneous activities from opposing muscle groups, provides greater stability at the expense of placing greater joint overload on the knee (Hodges et al., 2015; Lloyd and Buchanan, 2001). In this regard, lateral co-contraction contributes towards better load distribution, translating into a protector effect of the medial cartilages, whereas increased medial co-contraction contributes towards greater overload and less volume of the joint cartilage in the medial compartment of the knee (Hodges et al., 2015; Maly et al., 2015). Likewise, alignment, both valgus or varus, influences the pattern of muscular activation, where varus alignment would have greater medial musculature activation (Lloyd and Buchanan, 2001). Therefore, due to the role that co-contraction play in joint load, it is relevant to determine the biomechanical effects of therapeutic interventions on the adaptive muscular pattern.

Among the types of interventions, manual therapy has been shown to have clinical effects in patients with OA (Courtney et al., 2016; Moss et al., 2007). Diverse studies have explored the analgesic effects of techniques for joint mobilization as compared to placebos (Courtney et al., 2016). Likewise, previous studies have reported clinical improvements in the mid-term through protocols of manual therapy and exercises in patients with reported knee OA, as determined by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (Deyle et al., 2005). Nevertheless, the biomechanical changes associated with these effects remain unknown. Furthermore, knee OA is determined by multifactorial variables, where not only local biomechanical aspects, such as patellar congruence, femorotibial alignment, and quadriceps weakness, would be involved; other biomechanical variables of the trunk, hip, and ankle would also be associated with the severity of OA (Astephen et al., 2008a, 2008b; Chang et al., 2005; Maly et al., 2015; Mundermann et al., 2005). Moreover, the observed presence of myofascial trigger points in the periarticular musculature of the knee could induce early fatigue (Alburquerque-Garcia et al., 2015).

Previous studies have reported on the favorable clinical effects of manual therapy protocols based on the mobilization and treatment of soft-tissues, such as through stretches and the release of tense bands, together with exercises (Abbott et al., 2015; Deyle et al., 2005). While these manual therapy protocols have been reported to have significant clinical effects, the neurophysiological and biomechanical effects are inconclusive.

The objective of the present study was to determine changes in the co-contraction index (CCI) while descending stairs posterior to a physical therapy protocol.

Our hypothesis was that manual therapy would favorably modify co-contraction, reducing pain and improving functionality.

Methods

Study participants

Ethical approval was obtained from the Northern Metropolitan Health Service of Santiago, Chile, and informed consent from each participant was required.

The inclusion criteria were a diagnosis of slight or moderate knee OA, confirmed through clinical and radiography examinations; radiographic signs of OA in the medial compartment; female; older than 50; a body mass index <35; did not require assistance to descend stairs; and did not have prior experience with joint mobilization or soft-tissue management as treatments.

For this study, subjects were excluded if they presented other forms of arthritis, non-arthritic disease, intra-articular therapies, previous knee surgeries, or acute or chronic injuries of the spine, hip, or ankle. The incapacity to alternately descend stairs was also considered an exclusion criterion. Likewise, patients were required to have sufficient language skills to understand and respond to the WOMAC survey regarding pain, stiffness, and functionality.

Participant selection

From a sample universe of 74 subjects recruited from the Hospital San José (Santiago, Chile), 36 subjects met inclusion criteria. Twenty-four subjects agreed to participate in the study. Of these, four patients decided to abandon the study for personal reasons, and four patients could not perform the task according to inclusion criterion. Therefore, 16 subjects were finally evaluated (Fig. 1). The participants were randomly allocated to the intervention group or the control group using randomization software (www.randomization.com).

Measurement protocol

The subjects from both groups were measured and weighed on arrival to the Motion Analysis Laboratory of the Department of Physical Therapy at the University of Chile. Pain was quantified using the Numerical Rating Scale (NRS). In a standing position, electrodes (Ag/AgCl) with a surface recording area of 3.8 cm^2 were positioned according to Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) (Hermens et al., 1999) on the Vastus Lateralis (VL), Vastus Medialis (VM), Biceps femoral (BF), and Semitendinosus (ST) muscles. To ensure good contact and low electrical interference, skin preparation included shaving and rubbing and cleaning with alcohol.

All participants were asked to descend stairs five times to practice task execution. If the subjects were unable to

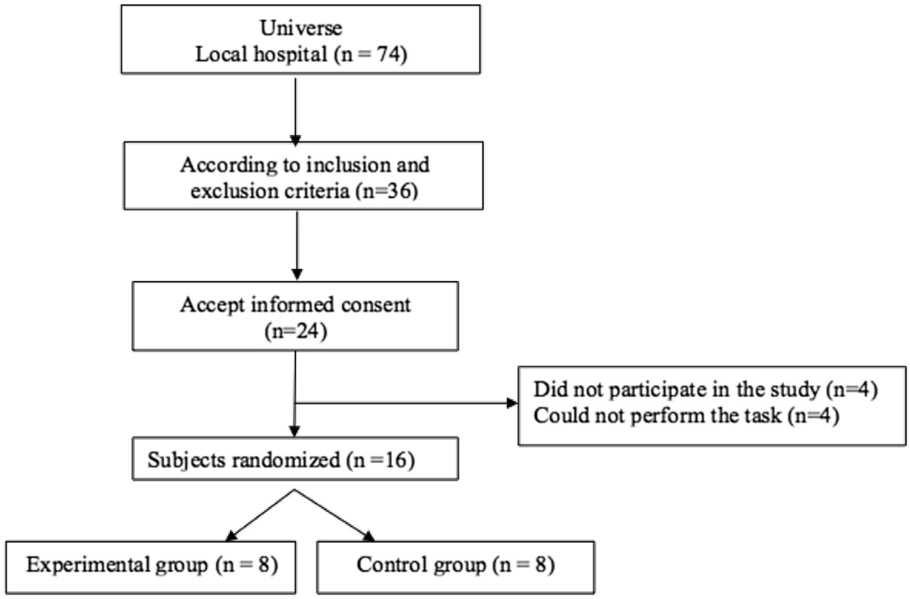

Figure 1 Sampling flowchart for participants.

alternately perform the task as indicated, they were excluded from the study. Prior and posterior to intervention, each subject descended the stairs three times, with a 2 min rest between each test.

The stair task consisted in three stairs (height: 17 cm, depth: 28 cm, and width: 90 cm). To evaluate the contact time, a pressure sensor was placed on the heel of the affected extremity, with readings synchronized to the electromyography (EMG) equipment. The task began with descending the first stair with the affected extremity, with the contralateral extremity used on the next step, and with the cycle ending with the affected extremity making floor contact (Fig. 2).

Evaluation of pain and time cycle for stairs descent

Pain intensity was quantified using the NRS. The stairs descent time was defined as the time the subject took to descend the three stairs from the point of first contact with the second stair until contact with the floor. This time was determined from the average of the three repetitions.

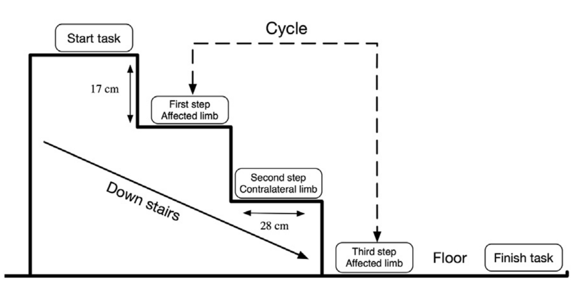

Figure 2 Illustration of the stairs descent task. The task began by descending the first step with the affected extremity, followed by the second step with the contralateral extremity, and finalizing the cycle through floor contact with the affected extremity. The task cycle was considered between the first and third steps.

Surface EMG (SEMG) processing

Surface EMG (SEMG) values were measured with an 8-channel BTS FREEEMG (BTS Bioengineering, Milan, Italy). Signal processing was performed using Matlab software (2013a, MathWorks Inc, Natick, Massachusetts). Skin cleaning and electrode positioning were performed according to SENIAM recommendations (Hermens et al., 1999). A pass-band (20—450 Hz; Butterworth fourth order) and band-stop filter (50 Hz; Butterworth fourth order) were applied to the obtained signal. Then, the root mean square was applied with a 250 ms window. Signal amplitude was normalized based on the maximum voluntary isometric contraction (MVIC) for the knee extensors (VM, VL) and flexors (ST, BF). For the CCI of the medialis muscles (VM/ST) and lateral muscles (VL/BF), normalized signals were used on the basis of a 100 ms window according to Formula (1) (Rudolph et al., 2001). For the analysis of both amplitude and CCI, the integrated signal was used in function of the normalized cycle time. The final value was determined from the average of three executions.

$$CCI = \int \frac{\left(\frac{\text{lower } EMG}{\text{higher } EMG}\right) \times (\text{lower } EMG + \text{higher } EMG)}{100} \quad (1)$$

Control group

Eight females were placed in a supine position on a bed. The placebo intervention consisted in placing both hands on the knee in a static position, near the patella, without exercising pressure or movement on the tissue for ten continuous minutes.

Table 1 Direction of arthrokinematic mobilization according to restriction perceived by therapist. External rotation (Ext. R), Internal rotation (Int. R), and patellar mobilization (Pat. M).

Subject	Varus/Valgus	Ext. R/Int. R	Pat. M
1	Valgus	Ext. R	Inferior
2	Valgus	Int. R	Inferior
3	Valgus	Int. R	Inferior
4	Valgus	Ext. R	Medial
5	Valgus	Ext. R	Medial
6	Valgus	Int. R	Inferior
7	Valgus	Int. R	Inferior
8	Valgus	Int. R	Inferior
Total	100% Valgus	50% Ext. R	75% Inferior

Intervention group protocol

The manual therapy protocol was based on a previous study (Deyle et al., 2005), which consisted in mobilization techniques and soft-tissue management lasting between 35 and 40 min for the patient. The protocol was performed by a Physical Therapist with post-graduate studies in manual therapy and ten years of experience. Regarding the joint techniques used, these were performed using Grade II Maitland Mobilizations, with emphasis on restoring joint mobility, or arthrokinematics. The mobilization was performed at the same direction that the therapist assessed for each patient (Table 1). First, mobilization was made towards knee extension, then towards the valgus or varus. Then, the joint was mobilized towards flexion, and patellar mobilization was performed at 5–10° of knee flexion.

Following these techniques, soft-tissue management techniques were used. These involved muscular stretching of the quadriceps, hamstring, gastrocnemius, adductors, psoas iliacus, and tensor fascia lata. In addition to soft-tissue management, periarticular band tensing was performed for the popliteal fossa, the peripatellar region, and suprapatellar, in addition to the lateral and medial joint capsules.

Statistical analysis

All data were analyzed using the statistical program IMB SPSS Statistics 20®. A significance level of <0.05 was used for the entire study. The type of distribution was determined by a Shapiro–Wilk's test. Only pain, determined by the NRS, did not present normal distribution.

For comparisons between groups, the non-parametric U Mann–Whitney test was used, while independent samples were evaluated with the parametric Student's t-test. For comparisons prior and posterior to interventions, the Student's t and Wilcoxon tests were used. All of the analyses were performed according to data normality.

Results

Participant characteristics

Sixteen subjects were evaluated (8 experimental, 8 control). No significant differences were observed between groups for age, weight, height, initial pain, and in the WOMAC survey. Table 2 presents a description of the two groups.

Signal amplitude

Prior to intervention, only differences in the VL were observed ($p = 0.032$), with higher values obtained in the control group. In the experimental group, posterior to intervention, the only muscle that changed its activation was the VL, which decreased by 12% ($p = 0.034$). No significant changes were observed in the control group (Table 3).

Co-contraction

Prior to intervention, no significant differences were observed between groups. The experimental group showed significant changes, specifically in lateral co-contraction, which increased by 11.7% ($p = 0.014$) (Fig. 3). No changes were observed for medial co-contraction ($p = 0.0147$). In the control group, no significant changes were presented for either medial ($p = 0.813$) or lateral ($p = 0.119$) co-contraction (Table 4). In relation to OA severity and co-contraction in the experimental group, a high correlation was found between pain (WOMAC items) and the change in lateral co-contraction $r = 0.804$ ($p = 0.008$).

Table 2 Characteristics and descriptive statistics of subjects.

	Control (n = 8)	Experimental (n = 8)	p
Age (years)	61 (1.9)	64.37 (2.9)	0.351
Weight	68.9 (2.2)	70.62 (2.9)	0.370
Height	155 (2)	155 (1)	0.972
Initial Pain NRS	4.50 (0.9)	3.80 (0.8)	0.501
Pain (WOMAC 0–20)	7.12 (1.2)	6.62 (1.1)	0.770
Stiffness (WOMAC 0–8)	3.80 (0.6)	2.80 (0.7)	0.243
Functionality (WOMAC 0–68)	25.5 [4 31][a]	21 [3 21][a]	0.220

Parametric distribution: Mean (Standard deviation).
[a] Nonparametric distribution: Median [Range].

Table 3 Integrated muscular activity normalized during the cycle (iEMG). Mean (Standard deviation). Vastus lateralis (VL), Vastus medialis (VM), Biceps femoral (BF), and Semitendinosus (ST).†$p < 0.05$ for comparisons between pre-treatment groups. *$p < 0.05$ for comparisons between post-treatment groups.

iEMG	Control n = 8			Experimental n = 8		
Muscle	Pre	Post	p	Pre	Post	p
VL	2971.90 (737.18)†	2815.55 (799.79)	0.101	2195.14 (543.31)†	2041.49 (568.08)	*0.034
VM	1498.23 (710.53)	1464.80 (723.04)	0.380	981.98 (300.05)	964.06 (313.27)	0.346
BF	1663.84 (466.88)	1632.00 (483.30)	0.425	1751.65 (1164.59)	1638.23 (949.00)	0.387
ST	1407.73 (716.98)	1394.25 (719.27)	0.593	1004.99 (674.80)	1051.42 (598.08)	0.710

Changes in the numerical rating scale

No differences were observed between the groups prior to intervention ($p = 0.505$). Both groups presented statistically significant changes posterior to intervention. The experimental group decreased an average of 3 points on the NRS ($p = 0.018$). In turn, the control group presented an average decrease of 1.8 points ($p = 0.027$). No significant differences between the groups were observed posterior to intervention ($p = 0.065$) (Table 5).

Time cycle of stairs descent

No differences were observed between groups in regards to descent time prior to intervention ($p = 0.172$). Post-intervention, the experimental group significantly reduced descent time by 0.39 s ($p = 0.019$). For the control group, no significant differences were observed ($p = 0.515$) (Table 5). A tendency was observed in relation to decreased time and increased lateral co-contraction $r = 0.54$; however, this was not significant ($p = 0.080$).

Discussion

The results of our investigation demonstrate that the application of one session of manual therapy, with emphasis on joint mobilization and soft-tissue management, is a useful tool in modifying the pattern of muscular activation in females with knee OA.

These results have clinical as well as biomechanical implications. Among the clinical implications, there was a significant decrease in pain and improvement in the average time of stair descent. From a biomechanical point of view, there was a decrease in the activity of the vastus lateralis and an increase in lateral co-contraction. The decrease of the VL could be related to better alignment of the patella through decreased patellar tilt, which would be intimately associated with the tension of the lateral retinaculum and iliotibial band (Merican and Amis, 2009; Pal et al., 2012). In turn, the increase in lateral co-contraction would generate a lower KAM during the support phase, thus permitting a better distribution of joint loads (Hodges et al., 2015).

It is fundamental to associate biomechanical changes with functional variables. In this regard, a significant decrease in stair descent time was observed, which showed a certain tendency to be associated with an increase in lateral co-contraction, with the p value very close to being significant ($p = 0.080$). The same phenomenon occurred in relation to pain, where both groups experienced a significant decrease; however, only the experimental group evidenced functional and activation pattern changes. Diverse studies have reported on the analgesic effect of manual therapy in subjects with OA (Courtney et al., 2016; Moss et al., 2007).

On the other hand, the placebo effect plays a role in all types of pain interventions, including in manual therapy,

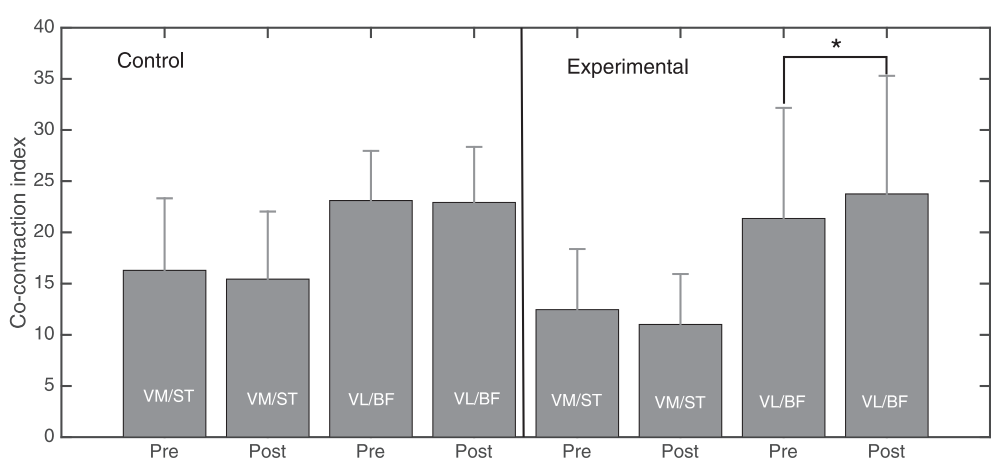

Figure 3 Integrated differences on the basis of CCI amplitude and the normalized cycle (VM/ST) and lateral co-contraction (VL/BF) pre- and post-intervention in the control and experimental groups (*$p < 0.05$).

Table 4 Co-contraction in function of integration between the intensity and normalized time cycle. Mean (Standard deviation). Vastus lateralis (VL), Vastus medialis (VM), Biceps femoral (BF), and Semitendinosus (ST). Lateral co-contraction (VL/BF), Medial co-contraction (VM/ST), Ratio between the medial and lateral co-contraction (M/L). *$p < 0.05$.

Co-contraction	Control n = 8			Experimental n = 8		
Muscle	Pre	Post	p	Pre	Post	p
VL/BF	23.10 (4.88)	22.95 (5.41)	0.813	21.38 (10.78)	23.76 (11.54)	*0.014
VM/ST	16.31 (7.02)	15.44 (6.60)	0.119	12.45 (5.91)	11.02 (4.92)	0.147
Ratio (M/L)	0.72 (0,31)	0.69 (0.29)	0.240	0.67 (0.41)	0.501 (0.21)	0.069

Table 5 Clinical variables. Pain NRS during execution of stair descent. Duration of the task cycle in seconds (s). Mean (Standard deviation). Median [Range]. *$p < 0.05$.

Clinical variables	Control n = 8			Experimental n = 8		
Muscle	Pre	Post	p	Pre	Post	p
NRS	4.50 [0 9]	2.64 [0 5]	0.027*	3.50 [0 7]	0 [0 2]	*0.018
Time cycle (s)	3.02 (0.4)	2.92 (0.30)	0.515	3.43 (0.72)	3.04 (0.07)	*0.019

where the placebo effect is not only considered to be a comparative intervention, but a potential mechanism for explaining part of the effects associated with manual therapy (Bialosky et al., 2011). This study, in contrast to previous research (Courtney et al., 2016), did not find that the analgesic effect of the experimental group was greater than the placebo group. Nevertheless, the effect was very close to significance ($p = 0.065$) and could be biased by the sample size.

Regarding the effect of the joint mobilization techniques, the mechanisms associated with biomechanical changes can be explained by models observed in the spine (Bialosky et al., 2009; Maigne and Vautravers, 2003), where stretching of the joint capsule as a product of manipulation would generate changes in muscular activation through reflex mechanisms. However, other studies propose that manual therapy of the knee would not result in changes in spinal reflex excitability (Grindstaff et al., 2014). Nonetheless, this has only been examined through patellar mobilization techniques and not combined with techniques focused at reestablishing joint movement of the knee based on arthrokinematic mobilization, which could result in a greater spatial and temporal summation of stimuli from different tissues (e.g. skin, fascia, muscle, tendon, joint capsule) (Riemann and Lephart, 2002).

Another aspect to consider is that in the present study, the joint mobilization was performed at the same direction that the therapist assessed for each patient. Stretching the joint capsule during mobilization in a restrictive way (valgus) could be a mechanism associated with the changes observed in the present study, as previous studies have reported changes in the patterns of activation depending on the varus or valgus alignment of the knee (Lloyd and Buchanan, 2001). Likewise, a previous study used the videofluoroscopy radiographic technique to quantify the effect of a single session of knee joint mobilization on OA by capturing motion at the end range of extension, observing an increased knee extension angle (Taylor et al., 2014). In regards to the present study, the points mentioned above reinforce the principal difference found between the control and experimental groups, particularly since the mechanical forces during joint mobilization could explain the changes in muscle activation patterns.

Another factor worth mentioning is that the muscular shortening of the rectus femoris would have an association with the lateral tilt even greater than that of the iliotibial band (Pourahmadi et al., 2016), and the present study included stretching poses of both muscles.

The co-contraction, as an adaptive mechanism to knee OA, provides short-term benefits as a motor strategy (Hodges, 2011; Lewek et al., 2004), due to which, therapeutic strategies that favorably modify co-contraction could be of great use for decreasing joint overload. Interestingly, the present results showed a high correlation between pain (WOMAC items) and increased lateral co-contraction; however, this point should be considered with caution as this study only examined patients with a diagnosis of mild or moderate knee OA.

On the other hand, studies on manual therapy should specify the applied techniques or at least provide a methodological framework instead of generically referring to manual therapy. It is also important to mention that OA, from a biomechanical standpoint, is multifactorial, where the focus of manual therapy would not only be on a local level, but also on recovering the normal function of contiguous segments. Due to this, considering a manual therapy protocol is relevant considering the multiple biomechanical factors associated with OA (Astephen et al., 2008a, 2008b; Chang et al., 2005; Weidow et al., 2006). The present study used mobilization and soft-tissue management techniques based on a protocol with demonstrated clinical results in the mid-term (Deyle et al., 2005). Although a manual therapy protocol is rigid in its execution by definition, the present study provides certain flexibility to the therapist in selecting the direction of joint mobilization techniques based on the perception of restriction for each patient (Table 1). While focus on a protocol for joint mobilization and soft-tissue management would make it difficult to define which particular technique most influences biomechanical and clinical results, in daily practice, manual therapy in patients with knee OA does not only involve manual intervention, but a number of complementary manual techniques due to the multifactorial biomechanical aspects of OA. It is due to this that the present protocol included stretching of musculature at the level of the hip (psoas iliacus, quadriceps, adductors, and tensor fascia lata) and ankle (medial gastrocnemius), in addition to joint mobilizations (Deyle et al., 2005). It is also important to consider in clinical practice that manual therapy is normally combined with therapeutic exercises, with reports that the combination of these increases treatment effectivity as compared to only exercises (Abbott et al., 2015).

Regarding the methodological aspects of measuring the CCI, prior studies have used the duration of the CCI during the walk cycle (Hodges et al., 2015). In the present study, the co-contraction area was integrated into the function of the normalized cycle for time and amplitude. This provided the advantage of incorporating temporal aspects as well as co-contraction magnitude.

To our knowledge, this is one of the first studies reporting on the effects to co-contraction of manual therapy in patients with knee OA, thus contributing to a better understanding of the clinical effects observed in the short term.

One of the principal limitations of this study was the small sample size and homogeneity of the subjects included according to OA severity, which could bias some of our results, particularly that of pain. It is due to this that our results cannot be extrapolated to the general population of patients with knee OA. Future studies should consider patients with severe OA and compare groups with different stages of OA to determine clinical and biomechanical outcomes. Another limitation of this study was that it did not evaluate variables associated with KAM, which would help to establish an association between changes in pattern activity and mechanical loads in the knee. Moreover, based on the methodology used, it remains unknown what type of intervention presents a greater effect on the patterns of activation and grade of valgocity generated through joint mobilization. Finally, to improve understandings of the mechanical effect on knee joint mobilization, future studies should consider assessing techniques through videofluoroscopy. However, minimum radiation exposure must be guaranteed for the subject.

Conclusions

A manual therapy session based on a protocol with emphasis on joint mobilization and soft-tissue management techniques favorably modified co-contraction in patients with knee OA, which would be beneficial in decreasing joint overload. Future studies should consider evaluating different manual therapy techniques, in addition to evaluating the duration of the biomechanical effects.

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