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Comparative effects of 12 weeks of equipment based and mat Pilates in patients with Chronic Low Back Pain on pain, function and transversus abdominis activation. A randomized controlled trial

David Cruz-Díaz[a,*], M. Bergamin[b], S. Gobbo[b], Antonio Martínez-Amat[a], Fidel Hita-Contreras[a]

[a] Department of Health Sciences, Faculty of Health Sciences, University of Jaén, E-23071 Jaén, Spain
[b] Sport and Exercise Medicine Division, Department of Medicine, University of Padova Palazzina ex Semeiotica Medica, Via Ospedale Civile, 105 - 35128 Padova, Italy

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ABSTRACT

Background: Pilates method has been recommended for patients with chronic low back pain (CLBP) and the activation of transversus abdominis has been deemed to play an important role in the improvement of these patients. Nevertheless, the evidence of the activation of TrA in Pilates practitioners remains unclear.
Objective: To assess the effectiveness of 12 weeks of Pilates practice in disability, pain, kinesiophobia and transversus abdominis activation in patients with chronic nonspecific Low Back Pain.
Design: A randomized controlled trial was carried out.
Methods: A single-blind randomized controlled trial with repeated measures at 6 and 12 weeks was carried out. A total of ninety eight patients with low back pain were included and randomly allocated to a Pilates Mat group (PMG) equipment based with apparatus Pilates (PAG) or control group (CG). Roland Morris Disability Questionnaire (RMDQ), visual analog scale (VAS) Tampa Scale of Kinesiophobia (TSK), and transversus abdominis (TrA) activation assessed by real time ultrasound measurement (US) were assessed as outcome measures.
Results: Improvement were observed in both intervention groups in all the included variables at 6 and 12 weeks ($p < 0.001$). Faster enhancement was observed in the equipment based Pilates group ($p = 0.007$).
Conclusions: Equipment based and mat Pilates modalities are both effective in the improvement of TaA activation in patients with CLBP with associate improvement on pain, function and kinesiophobia. Significant differences were observed after 12 weeks of intervention in PMG and PAG with faster improvement in PAG suggesting that, feedback provided by equipment could help in the interiorization of Pilates principles.

1. Background

Chronic nonspecific low back pain (CLBP) is defined as persistent low back pain of at least 12 weeks without any specific cause.[1] It is one of the most common musculoskeletal disorder and it has been stated that over 80% population worldwide will experience a low back pain episode.[2] This pathology is related to functional limitation, disability and pain in developed countries, which is associated with serious economic impact as a consequence of received health care and work absenteeism.[1,3]

Although CLBP etiology should be analyzed under a multifactorial approach, scientific literature highlight the role of deep trunk muscles coordination and coactivation in the management of this population group.[4] Taking into account this perspective, the number of studies addressing supervised exercise intervention in patients with CLBP have been raised in the last decade. The obtained results suggested that this kind of intervention, based on an active role of the patients in the recovery process, was superior to medication or conventional physiotherapy.[5] Among these exercises programs, Pilates intervention has become one of the most recommended activity due to the improvement in function, disability and pain in those with CLBP[6].

The Pilates method was developed originally by Joseph H Pilates and consisted in an array of exercises, which enhance physical capacities such as strength, flexibility or coordination and is based on 6 basic principles; centering, concentration, control, precision, breath and flow that could be performed on a mat on the floor or using apparatus.[7] The benefits of Pilates in differents populations group including CLBP patients have been reported in previous studies presenting better results than other physical activity programs.[5] These findings could be explained by the importance of motor control and lumbo-pelvic stabilization learning during Pilates exercises through deep trunk muscles activation, which is known as “powerhouse”[7]. Pilates promotes the

* Corresponding author.
E-mail address: dcruz@ujaen.es (D. Cruz-Díaz).

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activation of Transversus abdominis (TrA) as well as the pelvic floor muscles (PFM) and multifidus (MF) whose appropriate coordination and activation have been reported to play an important role in CLBP therapeutic approach.[8,9] However, there is no consensus on the effects of Pilates in muscle activation and its benefits among some studied populations with contradictories findings. The described disagreement could be related by some methodological issues with the existing Pilates studies such as heterogeneous population, inappropriate outcome measures and lack of intervention description.[10] Concerning the Pilates intervention, one of the biggest challenges lies in the difficulty of assessing the TrA activation during the performed exercises.[7] Surface electromyography has been employed during Pilates training monitoring the activation of superficial muscles with positive findings.[11] Nevertheless, deep trunk muscles activity has not been reported until recently.[11] Pilates does not consist on simple trunk, lower or upper limbs movement, the effectiveness of the method resides in the proper powerhouse activation and thus lumbo-pelvic stabilization during the Pilates tasks.

The purpose of the present study was to assess the effectiveness of two modalities of Pilates (mat and equipment based or apparatus pilates) on pain, function, TrA activation and kinesiophobia in patients with chronic non-specific low back pain.

2. Materials and methods

2.1. Design

The study is a randomized controlled trial with a blinded evaluator and a follow up of 12 weeks. The study (NCT02371837) was approved by the Human Ethics Committee of the University of Jaén and conducted in accordance with the Declaration of Helsinki, good clinical practices, and applicable laws and regulations and meets the CONSORT guidelines standards.[12] Informed consent was obtained from all participants and the rights of the participants were protected.

2.2. Participants

The study included patients with CLBP who responded to the recruitment advertisement launched through different health and sport centers. To be enrolled in the present study participants had to meet the following inclusion criteria: a history of at least twelve weeks of low back pain; age between 18 and 50; pain between 3 and 7 on a 10-cm visual analog scale; absence of radiculopathy or other damages to the spine such as fractures, stenosis, or tumors; not habitual Pilates practitioners; not receiving other physical therapy treatment during the trial or immediately prior thereto (previous 6 months); pregnancy and enough physical autonomy to participate in the physical activities required by the study. Data were collected in the physical therapy unit of Jaen.

Patients who met the inclusion criteria and accepted to be enrolled in the study were randomly allocated, using a computer-generated table of random numbers to a Pilates Mat group (PMG), equipment based Pilates with apparatus group (PAG) or no treatment control group (CG). Allocations were sealed in opaque and consecutively numbered envelopes kept in a locked location. These were to be opened in sequence by an independent administrator not involved in eligibility assessment, outcome assessment, or treatment. The intervention was carried out during 12 weeks with two sessions of approximately 50 min per week. In order to preserve the accuracy of the intervention effectiveness, participants who missed more than two sessions were excluded from the study. All subjects were assessed by a blinded evaluator at baseline prior to the beginning of the intervention and after 6 and 12 weeks of intervention. Both participants and evaluator were encourage not to discuss about the received intervention. Fig. 1.

2.3. Intervention

The Pilates intervention were divided into two groups, Pilates mat (PMG) and equipment based Pilates with apparatus (PAG). Both Pilates modalities follow the same principles and structure during the training session which was divided in warm up, main Pilates training activity and cool down. During the warm up, patients were instructed to consciously activate the power house with pelvic tilt movement and TrA activation with draw-in maneuver in combination with breathe exercises as well as joint mobility drills. Main Pilates training activity included a variety of strength, flexibility and coordination exercises with a progressive load depending of the patients' level and skills. The end of the session consisted on some exercises prescribed to alleviate the generated tensions during the Pilates training including some active stretching and myofascial release. The main difference between interventions consisted in the use of just a mat placed on the floor in the PMG and a reformer in PAG. The reformer is a multi-pulley based machine developed by Joshep H Pilates which provides the possibility of intensity regulation by the addition or removal of the spring system responsible of the exercise power.[7] Both interventions were performed in small group of 4 participants and monitored by a Pilates expert physiotherapist. The detailed protocol is explained on Table 1 and Fig. 2.

3. Outcome measures

3.1. Primary outcome

Patient level of pain was consider the main outcome measure for this intervention. Pain was assessed using a visual analog scale (VAS), a 10 cm line marked with the numbers 0–10 and divided in equal intervals, considered to be a valid and reliable tool to evaluate pain intensity. A score of 0 indicates no pain, while 10 represents the worst pain imaginable.[13]

3.2. Secondary outcome measures

Functional impairment and disability related to CLBP were assessed due to the negative influence in the quality of life of the patients, including not only health status but also the psychological and social aspects. Disability was evaluated using the Roland-Morris Disability Questionnaire (RMDQ), a short and simple measure with contrasted validity, reliability and responsiveness. The questionnaire is a 24-item scale which scores range from 0 (no disability) to 24 (high disability)[14].

The transversus abdominis activation is deemed to be altered in those with CLBP and thus the measurement of this variable has been included in this study.[15] Transversus abdominis (TrA) was assessed using a real time ultrasound scanning (US), MyLab™25 Gold (Esaote inc, Paris, France) with a 60- mm, 5-MHz curvilinear array in brightness mode at rest and during abdominal drawing-in maneuver (ADIM). The TrA was tested in the supine hook-lying position (subject lying supine, with feet placed on the table, hips flexed to visually approximated 45° and knees to 90°) as described in previous studies[16,17]. The thickness of TrA was defined as the distance between the upper and lower borders of the fascia of the TrA and the percentage change in thickness was calculated using the following formula[17,18]:

$$\%\Delta T = \left(\frac{\Delta T}{Tr}\right) \times 100$$

Fear avoidance beliefs towards movement is usually present in those with CLBP and is known as kinesiophobia. Fear of movement/injury or reinjury were assessed using the Tampa Scale of Kinesiophobia (TSK), a 17-item with scores ranged from 17 (absence of fear) to 68 (highest fear) whose items vary from 1 to 4 points, with 1 point for "total disagree," 2 points for "partial disagree," 3 points for "partial agree," and 4 points for "total agree"[19] TSK has been reported to correlate with the

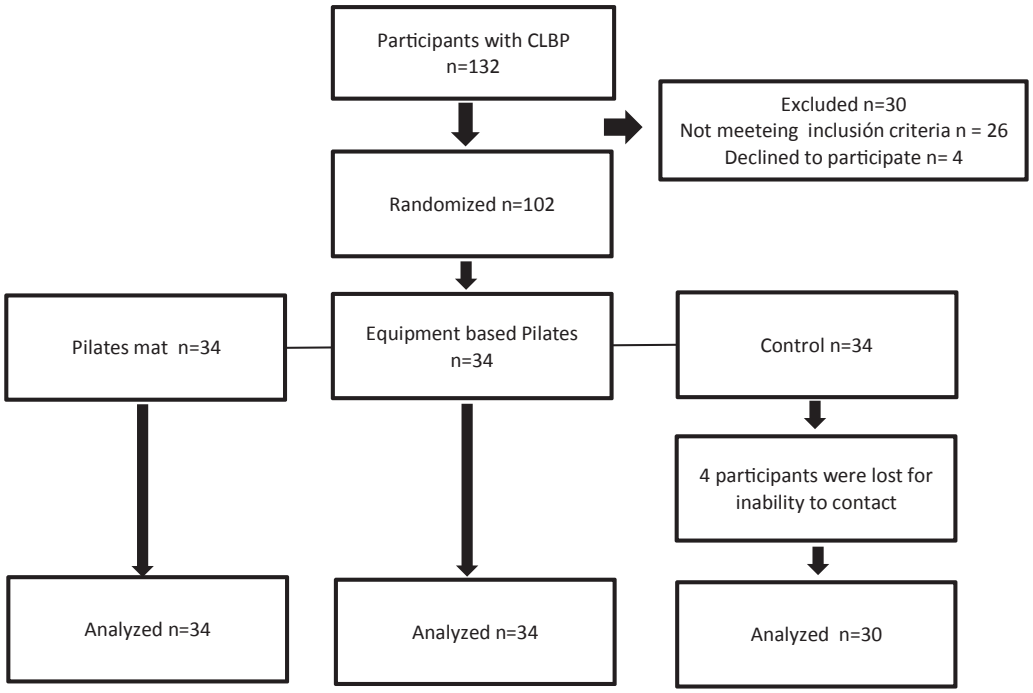

Fig. 1. Flow chart of the study design and participants follow up through the trial.

Table 1
Intervention program.

Pilates Mat	Equipment based Pilates
1. Warm-ups	1. Warm-up
2. Single leg stretch	2. Footwork Toes.
3. Double leg stretch	3. Leg series.
4. Criss cross	4. Shoulder bridge.
5. Single straight leg	5. Hundred.
6. Roll up	6. Arm Pull.
7. Rolling	7. Kneeling Pull Back.
8. Side kick: front/back	8. Seated rotations.
9. Side kick: small circles	9. Camel.
10. Spine twist	10. Elephant.
11. Rowing 3	11. Spine stretch.
12. Rowing 4	12. Back Extensions
13. Pull straps 1	13. Mermaid
14. Pull straps 2	14. Roll down
15. Swimming	15. Cool Down
16. Teaser 1	
17. Leg pull back	
18. Leg pull front	
19. Mermaid	
20. Rolling down	
21. Cool down	

RMDQ and presented a good reliability in patients with CLBP.[20,21]

3.3. Statistical analysis

Data were analyzed using the SPSS version 23.0 statistical package (SPSS, Inc., Chicago, IL). The normal distribution of continuous variables was verified using the Kolmogorov-Smirnov test ($p < 0.05$). Mean and standard deviations were calculated for each variable. Between-groups variables were compared using the Student *t*-test or non-parametric equivalent, Mann–Whitney *U* test. To determine differences in the outcomes between groups over time repeated-measures ANOVA were performed. Mauchly's test was used to test the assumption of sphericity. When sphericity was not assumed, the Greenhouse-Geisser adjustment was applied. When the F value was significant, the Bonferroni post hoc test was used to identify the differences. Sample size calculation was performed with ENE 3.0 (GlaxoSmithKline, Brentford, United Kingdom) based on related studies examining the effects of Pilates on back pain assuming a 20% improvement in the pain VAS score, with 80% power at the 0.05 level with an estimated drop out of 10% 36 subjects per group were required.[22,23]

3.4. Results

A total of 98 patients concluded the study and were analyzed. Characteristics of participants included in each group are presented in Table 2 and were homogenous for weight height and age at baseline.

Tests of within-subject effects indicated a group per time statistically significant changes in several variables such as weight (df 4; F 2.463; $p = 0.047$), TrAcont (df 4; F 17.413; $p < 0.001$) TrAact (df 4; F 23.435; $p < 0.001$), RMQ (df 4; F 29.495; $p < 0.001$), VAS (df 4; F 5.565; $p < 0.001$) and TSK (df 4; F 12.297; $p < 0.001$). Tests of within-subject contrasts indicated that a general improvement was found in the intervention groups and such improvement was increasing over time reporting statistical significant differences among the groups, for all the aforementioned outcomes, excepted for weight and VAS. Specifically, in these variable statistical differences were found only between PAG vs. PMG ($p = 0.007$) and between Results, 95% confidence interval and significance level are summarized in Table 3.

3.5. Adverse events

At baseline, medical history data of all patients were collected before enrollment. Ten patient were hypertensive and four were diabetic. All the cases were stables at baseline and were under medication. No adverse events or aggravation were observed in these patients. The physiotherapist who carried out the intervention was told to complete a list of attendance at the end of each session where adverse events were collected. There was no aggravation of Symptoms in the lumbar spine. Nevertheless some minor ailments were registered, six patients had a cold, one patient presented dysmenorrhea, three cases of diarrhea and one case of conjunctivitis.

3.6. Discussion

The purpose of the present study was to evaluate the effects of two

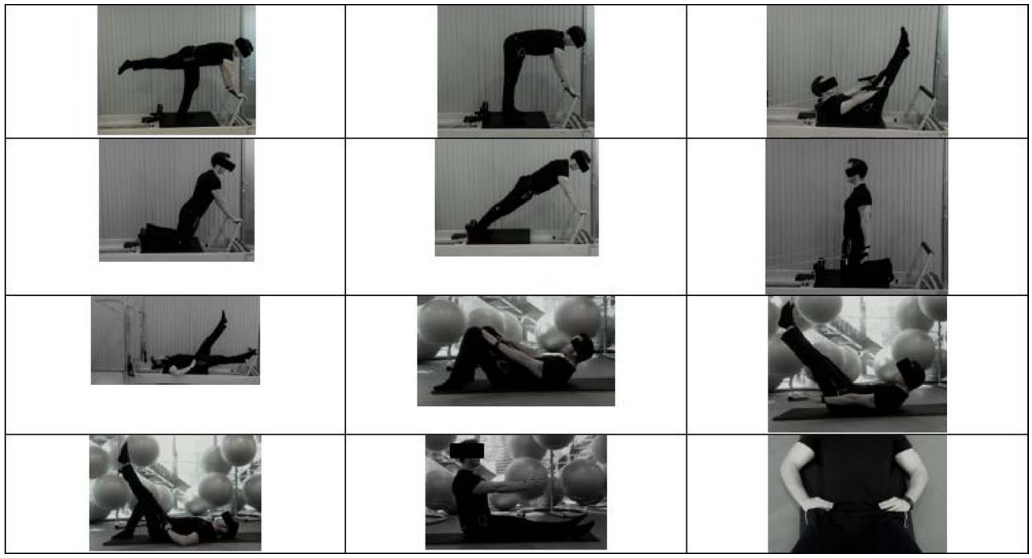

Fig. 2. Pilates mat and apparatus intervention.

modalities of Pilates practice in patients with CLBP. The results showed an improvement in both groups PAG and PMG in comparison with the control group at 6 and 12 weeks of treatment in all studied variables except for TrA thickness at rest. No adverse events were observed during the intervention, this could be related to the high adherence to treatment in both intervention groups. Pilates is widely extended and recommended among health care professionals for those with CLBP because it is a non-impact activity, that has been shown to improve the symptoms related with this pathology.[6,24] However, a recent systematic review conclude that there is a lack of high quality randomized controlled trials addressing Pilates effectiveness in patients with CLBP and the obtained results were inconclusive.[6]

Some studies have focused in the importance of deep trunk muscles strengthening and its relationship with CLBP management.[25,26] In contrast with the belief assuming that CLBP improvement is due to strengthening of core muscles,[22] our results suggested that appropriate activation of deep trunk muscles may play an important role in CLBP recovery. Therefore, muscle retraining and activation awareness could led to better results. TrA activation is one of the main principles of Pilates and Lee Harrington et al., [28] carried out a study evaluating the ability to contract the TrA in asymptomatic Pilates' practitioners. However, the measurement of TrA activation based on a biofeedback unit during the ADIM maneuver performed by Lee Harrington, has been reported to be a non-reliable instrument for TrA assessment.[29] Until recently our study is the first evaluating by US, the effects of Pilates on TrA activity in patients with CLBP. Our results support the importance of a proper activation of TrA in lumbo-pelvic stabilization and its relationship with CLBP[17,33]. There were not significant differences in TrA thickness at rest in the study population after Pilates intervention but it was observed an improvement in TrA activation ratio in PAG and PMG respect the CG where no change was observed from baseline to 6 and 12 weeks ($p = 0.007$). Our results concerning TrA activation ratio agree with those obtained in previous studies in CLBP patients with baseline values of; (mean 25.41 in the PMG), (mean 18.57 in PAG) and (mean 20.16 in CG).[20,30] The improvement in TrA activation ratio after 6 and 12 weeks were observed in both Pilates groups (mean 35.27% 6 w/ 41.87% 12 w) in the PMG and (37.29% 6 w/51,81% 12 w) in the PAG with no significant differences in CG (mean 20.85/6 w and 20.62/12w). Notwithstanding as has been presented in Fig. 3 and Table 3, the use of apparatus involved faster and greater TrA activation ($p < 0.001$) as

Table 2
Demografic charasteristics at baseline.

		Mat Pilates Group (n = 34)	Equipment based pilates (n = 34)	Control group (n = 30)	P value
Age		36,94 ± 12,46	35,5 ± 11,98	36.32 ± 10.67	0.72
Gender					0.521
	Male	11 (32,35%)	13 (38,23%)	11 (36,66%)	
	Female	23 (67,64%)	21 (61,76%)	19 (63,33%)	
Height (cm)		172 ± 8,5	171 ± 7.2	173 ± 6.7	0.144
Weight (Kg)		65.54 ± 7.08	66.02 ± 6.95	65.10 ± 7.24	0.521
Education					
	Primary	2 (5,88%)		3 (10%)	0.81
	Secondary	10 (29,41%)	14 (41,17%)	9 (30%)	
	University	16 (47,05%)	18 (52,94%)	15 (50%)	
	Not finished	6 (17,64%)	4 (11,76%)	3 (10%)	
Marital Status					
	Single	18 (52,94%)	14 (41,17%)	15 (50%)	0.651
	Married	14 (41,17%)	16 (47,05%)	12 (40%)	
	Divorced	2 (5,88%)	4 (11,76%)	3 (10%)	
Occupational status					
	Full-time Worker	26 (76,47%)	25 (73,52%)	24 (80%)	0.72
	Part-time worker	3 (8,82%)	5 (14,70%)	4 (13,33%)	
	Unemployed	5 (14,70%)	4 (11,76%)	2 (6,66%)	

One-way analysis of variance for continuous variables and $\chi 2$ test for categorical variables.

Table 3
The comparison of VAS, RMQDI, TrAR and TKS between groups.

		Mat Pilates Group (n = 34)	Equipment based pilates (n = 34)	Control group (n = 30)
VAS	Pre	4,64 ± 1.22	4.95 ± 1.12	4,84 ± 1.04
Mean	6 w	3,3 ± 1.61 a,b	2,1 ± 1.26 a,b,c	5,06 ± 1.02
	12 w	2,1 ± 1.36 a,b	1.70 ± 1.41 a,b	4,96 ± 1.31
RMQD	Pre	11,38 ± 5.02	11,23 ± 5.13	10,50 ± 4.89
Mean	6 w	7,94 ± 5.12 a,b	6,73 ± 5.08 a,b,c	10,33 ± 5.2
	12 w	6,35 ± 5.3 a,b	4,76 ± 4.9 a,b,c	10,41 ± 5.6
TrAR%	Pre	25,40 ± 11,85	18,57 ± 13,12	20,16 ± 10,65
Mean	6 w	35,27 ± 17,26 a,b	37,29 ± 14,10 a,b,c	20,85 ± 14.01
	12 w	41,87 ± 15,63 a,b	51,81 ± 15,38 a,b,c	20,62 ± 10,23
TSK	Pre	34,52 ± 4.14	36,50 ± 3.92	33,90 ± 4.23
Mean	6 w	32,23 ± 3.06 a,b	34,08 ± 4.1 a,b,c	34,26 ± 3.96
	12 w	31,73 ± 3.24 a,b	32,00 ± 3.56 a,b,c	34,10 ± 4.04

Visual Analogue Scale (VAS); Roland-Morris Disability Questionnaire (RMQD); Transversus Abdominis Activation Ratio (TrAR) expressed as percentage; Tampa Scale of Kinsiophobia.
a Denotes $p < 0.05$ in intragroup comparison before and after treatment.
b Denotes $p < 0.05$ when compared to control group.
c Denotes between group differences.

well as pain and disability ($p < 0.001$). These findings suggest that use of apparatus provides larger stimuli to sensory system which provides information about the status of lumbo-pelvic stability and contributes to elaborate a coordinated internal response in relation with environment interaction.[31] Until recently, only a few studies attempted to evaluate the effects of Equipment based Pilates in patient with CLBP with contradictories results[32,33]. Lee CW et al., evaluated the effectiveness of equipment based Pilates vs mat Pilates on pain and balance in business women with better results in mat Pilates group.[32] Furthermore, da Luz Jr et al,[32] developed a study with two allocated group, Pilates mat and Equipment based Pilates with no control group whose results on pain and disability agree with the reported results in the present study. Nevertheless, it was stated that there was no significant difference after 6 weeks of intervention in contrast with our results where PAG showed faster improvement than PMG. The activity of TrA in combination with thoracolumbar fascia tension contributes to increase lumbar spine stiffness which may perform a significant function in CLBP recurrence rate prevention.[34] Previous studies have shown delayed activation time as well as decreased contraction in those with CLBP, furthermore pain has been deemed to play an important role in this muscle activation pattern.[4] During the first sessions of the intervention, the exercises focusing on the TrA activation were strictly monitored by the Pilates instructor. The isolation of the TrA was practiced in different positions such as supine hook lying position, four point kneeling and prone. Participants were told to perform a smooth contraction of the TrA trying to avoid the activation of obliquus externus (OE) and internus (OI) instructing them in muscle palpation two centimeters inside the anterior superior iliac spine (ASIS). Patients who experimented difficulties in TrA activation with verbal and tactile cues were encouraged to feel the TrA activation by active contraction of the pelvic floor muscles.[9] Authors considered this motor control training as a key factor which could have a significant influence in the study results. The achievement of deep trunk muscles contraction could explain the contradictories findings obtained during Pilates intervention.[25]

Chronic non-specific low back pain is a complex pathology that should be managed under a multifactorial therapeutic approach. Pain could be related with musculoskeletal adaptations promoted by the nervous system in order to reduce the possibility of injury.[33] Treatment of CLBP should not be focused only on pain improvement by modification of nociceptive afferents on motoneurons, especially in a chronic phase. This statement is supported by scientific literature which demonstrate better results in Pilates practice compared with therapeutic analgesic approach.[6,27] Intervention groups showed improvement on pain at 6 and 12 weeks from baseline (mean PMG 3.3 and 2.1) and (mean PAG 2,1 and 170) with a $p < 0.001$, while no changes were observed in control group (mean CG 5.06 and 4.96) $p = 0.875$. These results agree with other studies addressing the effectiveness of Pilates on pain with similar scores obtained in Pilates mat and equipment based Pilates.[25,32]

Regarding disability and function, achieved results in the RMDQ were positive in PAG and PMG after 6 and 12 weeks with better results in the apparatus group ($p < 0.001$). These results are consistent with those provided by da Luz et al.,[32] who hypothesized that placebo effect could be enhanced as a consequence of apparatus utilization. Furthermore, equipment based Pilates provides larger feedback and proprioception stimuli because the perceived movement during the exercise execution may facilitate the understanding and internalization of the

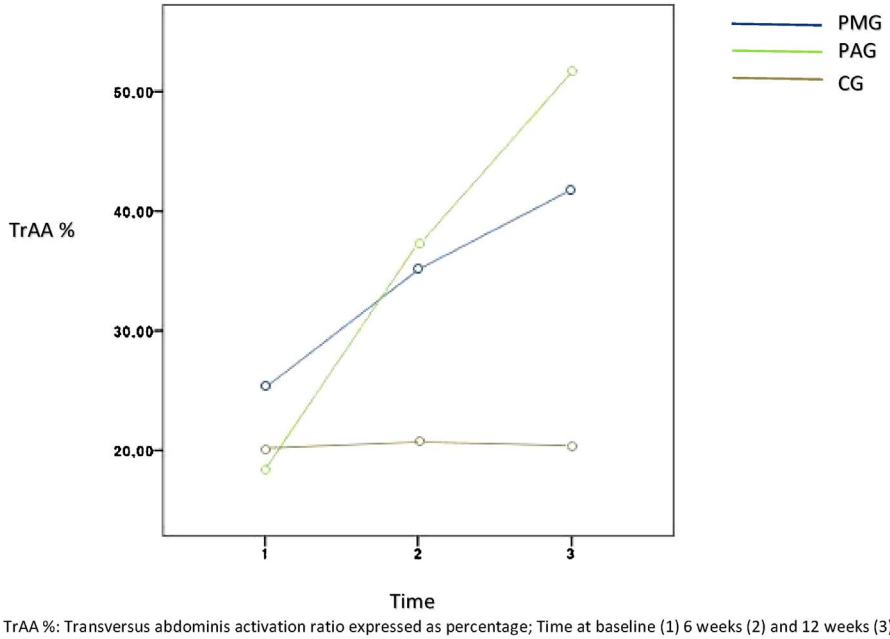

Fig. 3. TrA activation ratio.
TrAA%: Transversus abdominis activation ratio expressed as percentage; Time at baseline (1) 6 weeks (2) and 12 weeks (3); PMG, Pilates mat group; PAG, equipment based with apparatus Pilates; CG, control group

TrAA %: Transversus abdominis activation ratio expressed as percentage; Time at baseline (1) 6 weeks (2) and 12 weeks (3); PMG, Pilates mat group; PAG, equipment based with apparatus Pilates; CG, control group.

method principles. This theory could explain why PAG obtained faster improvement in measured variables. Previous studies have employed the same assessment measure but our patients showed larger improvement.[22,26] Many factors could be the responsible of these differences, such as the study population, instructor performance, patient motivation or accuracy of the given instructions during the TrA activation.

Another important variable whit a great influence on patient's quality of life, recurrence of pain and motor control impairment is fear of movement or kinesiophobia.[19] Pilates has been deemed to be an effective activity in daily functioning and kinesiophobia achievement.[22,27] Nevertheless, the target population of some Pilates studies consisted on elder patients and hence the results should not be extrapolated to CLBP. Kinesiophobia were assessed by the TKS[19] and it was showed improvement at 6 and 12 weeks in both intervention groups. Slightly superior scores were obtained in the PAG at the end of the intervention with mean scores of 32 vs 31.73 of the PMG, CG showed not significant differences with mean 34.10 in the TKS. These results suggest that both Pilates modalities are beneficial for fear of movement and movement avoidance beliefs. The Pilates method focused in precision and control in the performed exercise that are usually included in motor control learning/retraining programs[5]. Better knowledge of own body and movement possibilities may be acquired during Pilates intervention and together with the deep trunk muscles activation and coordination could result in better movement execution and confidence

3.7. Conclusion

Obtained results suggest that Pilates Mat and equipment based Pilates were both effective in CLBP management with observed improvement on pain, disability, deep trunk muscles activation and kinesiophobia. Equipment based Pilates seems to provide faster and better results in comparison with mat Pilates especially in the short term. Further studies focusing on real time ultrasound measurement of the superficial and deep trunk muscles in CLBP patients during Pilates practice with a follow up period should be performed. Regarding limitations in the present study, dropout rate of control group was a problem because adherence of patient who did not received any treatment is difficult and some of them missed the assessment sessions.

Conflict of interest

We certify that no party having a direct interest in the results of the research supporting this article has or will confer a benefit on us or on any organization with which we are associated AND, if applicable, we certify that all financial and material support for this research (eg, NIH or NHS grants) and work are clearly identified in the title page of the manuscript.

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