Journal of Bodywork & Movement Therapies 24 (2020) 15–20

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

Prevention and Rehabilitation

A randomized clinical trial for the effect of static stretching and strengthening exercise on pelvic tilt angle in LBP patients

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Keywords:
Low back pain
Pelvic tilt
Hamstring

A B S T R A C T

Background: Stretching and strengthening exercises are commonly used to improve muscle shortness of the hamstring as any tension in this muscle can have an effect on the pelvic posture. Thus, the aim of this study was to evaluate the effects of two methods of improving short hamstring on the angle of pelvic tilt in LBP sufferers.
Methods: Forty-five low back pain patients aged 19–59 years with hamstring tightness participated in this clinical trial. The patients were categorized randomly into three groups: 1- static stretching, 2-strengthening exercise and 3-control group. The two intervention groups received physical therapy and special exercise program thrice a week in a total of 12 sessions, while the control group received only conventional physical therapy. Before and after the treatment implementation, the pelvic tilt and straight leg raising (SLR) degree were assessed for each group.
Result: After 12 sessions of treatment, the ANCOVA models indicated non-significant differences in pelvic tilt angle and SLR score changes ($p > 0.05$), among the three groups. In addition, no statistically significant correlation was observed between the pelvic tilt and SLR test [except for the strengthening exercise group (Pearson correlation coefficient $= -0.54$, $P < 0.05$)].
Conclusions: In LBP sufferers, both static stretching and strengthening of hamstring muscle in its lengthened position caused elongation and extensibility in the hamstring muscle and increased SLR test score, but did not change pelvic tilt angle.

1. Introduction

Four muscle groups including erector spinae, hamstrings, abdominals and hip flexors, support and hold the pelvis in its natural alignment. Their forces on the pelvis are balanced (Kendall et al., 2005; Narouei et al., 2018; Rockey, 2008). Any imbalance in these muscles or change in posture can make the pelvis tilt anteriorly or posteriorly, and the anterior tilting is mostly due to weakened and lengthened hamstring muscles (Ghare et al., 2018; Kendall et al., 2005; Nguyen and Shultz, 2007).

The angle between the horizontal plane and line which passes through the midpoint of the posterior superior iliac spine and midpoint of the anterior superior iliac spine is the pelvic tilt angle (Marques et al., 2018; Walker et al., 1987). Excessive anterior pelvic tilt has been regarded as undesirable because this change in movement pattern may cause excessive loading on back tissues and lead to low back pain (LBP) (Norris and Matthews, 2006).Therefore, it is thought that either bad static posture (change in body alignment) or impaired dynamic posture (alteration of back motor control) is a common risk factor for LBP (Norris and Matthews, 2006). The origin of hamstring is ischial tuberosity of the pelvis; thus, any tension in this muscle can have an effect on the pelvic posture (Congdon et al., 2005). The pelvis is regarded as the base for the vertebral column, and any deviation in it can cause a change in pelvis alignment (Delisle et al., 1997; Iyer et al., 2018).

In forward trunk bending, there is coordination between back

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https://doi.org/10.1016/j.jbmt.2020.02.001
1360-8592/

extensor muscles (erector spinae) and the hip extensor muscles (glutei and hamstrings). This coordination causes a combined movement of lumbar flexion and pelvic rotation which is called the lumbopelvic rhythm (Norris and Matthews, 2006). Because hamstring originates from the ischial tuberosity of the pelvis, poor flexibility of this muscle can restrict anterior pelvic tilt and, therefore, restrict forward bending, too. In this case, hamstring restriction may be compensated for by an increase in lumbar flexion and consequently predispose LBP (Deguzman et al., 2018; Esola et al., 1996; Norris and Matthews, 2006). Based on these biomechanical concepts, there is a relevance between hamstring muscle length and pelvic tilt range (Kendall et al., 2005; Mohamed et al., 2002).

Stretching is commonly used to improve muscle shortness. Static stretching, which is based on a slight stretch in the muscles while maintaining the joint in its end-range of position is well accepted for treatment (Deguzman et al., 2018; Walker et al., 1987).

In response to strengthening exercise, the length in which the muscle is contracted is important. Some authors also believe that stimulating a muscle to be contracted in such a joint position, while, the muscle is in its lengthened position can be effective in making structural changes in the muscle, and unlike stretching, changes developed by this method are long lasting (Norris and Matthews, 2006). Thus, the aim of this study is to define how these two methods of improving short hamstring (static stretching (SS) and strengthening of hamstring muscle in its lengthened position (SLP)) in chronic non-specific LBP sufferers can affect the pelvic tilt, and assess the relationship between hamstring length (assessed by straight leg raising test) and the angle of pelvic tilt. These two interventions (SS and SLP) were selected because static stretching is a common treatment used by strength and conditioning specialists and athletes to increase muscle length (Lopez-Minarro et al., 2012), wherase SLP is a new proposed method that should be evalutaed (Aquino et al., 2010). Pelvic tilt and straight leg raising test (SLR) changes were evaluated at baseline and at the end of the trial as the primary outcomes.

2. Materials and methods

2.1. Design

The sample size was computed based on the data from the previous study. With a 95% confidence level, 80% statistical power and angle of pelvic tilt as a key factor, at least 15 patients per group were chosen and recruited into this randomized clinical trial (Borman et al., 2011).

As a following step, after receiving the ethical approval of the study protocol (code: kums.rec.1394.26) from the ethics committee of Kermanshah University of Medical Sciences and registering it in the Iranian Registry of Clinical Trials (IRCT) (ID:IRCT201507258035N2), the selected patients were randomly allocated to either the control or intervention groups, including: (1) SS: n = 15 patients, (2) SLP: n = 15 patients and (3) Control with no specific intervention: n = 15 patients, through random blocks strategy (Fig. 1). Moreover, to conceal treatment assignment, the randomized allocation and assignment of patients to the groups was conducted by an expert statistician not involved in the trail (blinding).

2.2. Participants

Through a convenience sampling schedule at a physiotherapy clinic of Kermanshah University of Medical Sciences, Iran, 45 eligible patients who had chronic non-specific LBP (LBP without definite cause for more than three months), were enrolled in this trial from April 2016 to August 2017. The eligibility criteria were as follows: 1. Subjects with LBP for more than 3 months; 2. pain intensity from 3 to 6 according to the visual analogue scale (VAS); 3. Subjects with hamstring muscle shortness in SLR test; 4. Age between 18 and 60 years. History, imaging and clinical tests (pain provocation tests) were used to define participants as chronic LBP. Subjects were excluded if they had any pathology or anomaly in the lower limbs such as neuropathic pain, malignancy, inflammatory diseases, severe osteoporosis, arthritis and/or bone diseases.

At the beginning of the study, participants signed a written informed consent. Additionally, both participants and the therapist were not aware of the group assignment during the experimental period. The therapists were different from the main researcher.

2.3. Outcome measures

At the baseline and end of the study, pelvic tilt angle and passive SLR degree were measured.

2.4. Pelvic tilt angle

Pelvic tilt angle was measured using an inclinometer (INSIZE.CO.LTD) that was placed over the patient's sacrum. While the patients were in the relaxed standing position, the upper edge of the inclinometer was aligned with the line joining the patient's posterior superior iliac spines (Fig. 2). To make and maintain the junction, an inclinometer was pressed tightly against the body.

2.5. Passive SLR score

Participants were positioned in a supine position with the hip joint in 0° of flexion. The thigh was secured to the table by a Velcro strap. An inclinometer (INSIZE.CO.LTD) was placed over the distal tibia and the subject's leg was elevated passively, making the hip more flexed. While the leg was being raised, the knee was kept straight. The pelvis was fixed using a Velcro strap. At the point of maximum hip flexion, the maximum angle (degree) read from the inclinometer was defined as the SLR score (Fig. 3).

All testing procedures for both Pelvic tilt and SLR were repeated three times and the mean of the three repetitions was used for data analysis. The intra-rater reliability of the recorded data was assessed using the Intra-class Correlation Coefficient (ICC) for each test.

The ICC (95% CI) was 0.78 (0.65–0.86) and 0.91 (0.90–0.97) for pelvic tilt and SLR test, respectively.

2.6. Intervention

Forty-five subjects (31 men and 14 women; mean age 38.80 ± 11.14) in all the groups received common interventions including 15 min of heat therapy (hot pack), 15 min application of transcutaneous electrical nerve stimulation (TENS) to low back area, and the common use of exercises for back pain for 12 sessions, three times per week; however, the intervention groups (SS and SLP) received extra specific treatments.

In the SS group, while the participants were in a lying position with the knee fully extended, a passive stretch was applied on the hamstring by a spring (Fig. 4).

In the SLP group, participants were seated on a chair with their thighs being supported on a surface which kept the hip joint in 120° of flexion as well as the knee joint in full extension. They tried to

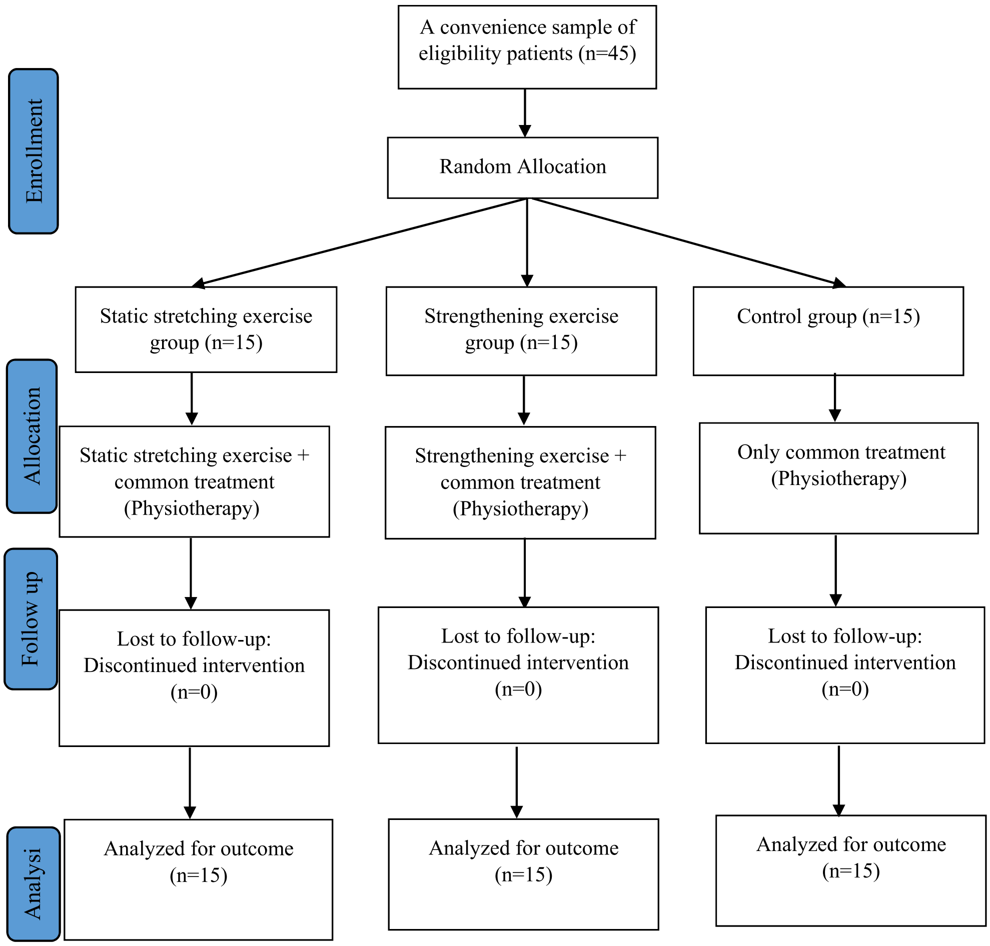

Fig. 1. Flow diagram of the study.

Fig. 2. Pelvic tilt angle measurement.

Fig. 3. Passive straight leg raise score measurement.

extend their hip against a spring and contract the hamstring muscle. The other hip and knee joint was kept flexed at 90° (Fig. 5).

2.7. Data analysis

Statistical analyses were performed using SPSS software, version 21.0 (SPSS Inc., Chicago, IL, USA), and all of the p-values smaller than 0.05 were considered statistically significant.

Possible differences in baseline measurements among the three groups were assessed using the Chi-square test and one-way analysis of variance (ANOVA) for categorical and continuous variables, respectively.

Analysis of covariance (ANCOVA) was used to compare the three groups for the measures at the end of the study, adjusting for the baseline measures.

Moreover, a paired *t*-test was performed to evaluate within-group changes in baseline and end of measurements.

In order to investigate the correlation between pelvic tilt and SLR score, the Pearson correlation test was performed (after checking normality of data distribution by Kolmogorov-Simrnov test).

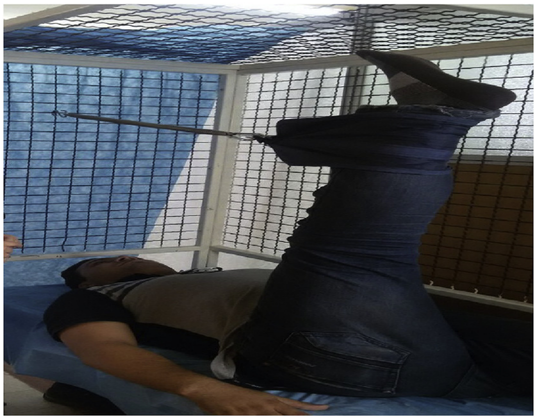

Fig. 4. Static stretching exercise.

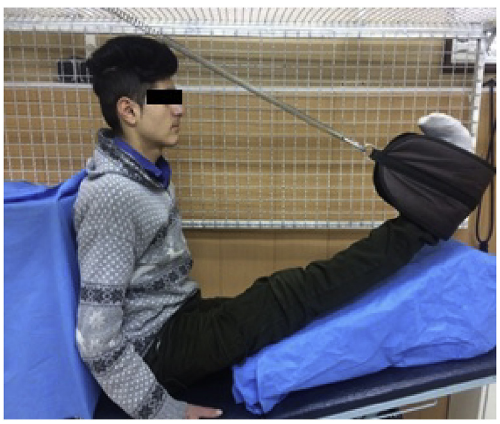

Fig. 5. Hamstring strengthening exercises in lengthened position.

3. Results

Characteristics of the patients are shown in Table 1. As observed, there were no significant differences between the characteristics of the groups with regards to age, body mass index, weight, height and gender (all $p > 0.05$). The mean values of the SLR test and pelvic tilt score in the pre and post-interventions for each group are shown in Table 2. In this study, baseline measurement of the study variables (pelvic tilt and SLR scores) was adjusted, and the results of the ANCOVA showed that changes in these variables were accompanied by no statistically significant difference among the three groups ($p > 0.05$ for all of them).

Moreover, the mean difference in the study variables between the baseline and end of the intervention for each group, is presented in Table 2. Mean differences (95% CI) of the SLR test scores for SS, SLP, and control group were 7.79 (2.90–12.67), 7.45(3.19–11.70) and 11.33 (4.10–18.56), respectively.

Within group analysis using paired *t*-test revealed that in the three groups, changes in the mean values of the SLR scores after the intervention were statistically significant ($P < 0.001$ for all groups).

In contrast, the within group comparison showed no significant change in pelvic tilt at the end of the study ($p > 0.05$- paired *t*-test).

The results showed a weak negative correlation between SLR score and pelvic tilt angle in the three groups (Table 3), and this correlation is significant only for SLP group in the post-intervention step (Pearson correlation coefficient = −0.54, $P < 0.05$).

4. Discussion

The main aim of the present study was to evaluate the effects of two types of intervention for elongating short hamstring muscle on pelvic tilt angle and SLR test score (both using an inclinometer) in patients with LBP, and to investigate the correlation between these two measures.

After 12 sessions of treatment, only SLR test score improved in all three groups. The changes made in pelvic tilt angle and SLR score after the intervention were not different among the three groups. There was a correlation between SLR score and pelvic tilt angle in the post-intervention step only for SLP group.

According to the literature, reliability of the SLR test is higher than 0.9, and this test is commonly used to evaluate hamstring flexibility (Boyd, 2012).

The results obtained from several studies on the effects of static stretching and strengthening exercise on improvement in shortness of hamstring muscle are consistent with the current study. Czaprowski observed that after 6 weeks of exercise program, the two different physiotherapy techniques (post-isometric relaxation and static stretching combined with stabilizing exercises) both led to improvement in the SLR result (Czaprowski et al., 2013). Ramesh showed that muscle energy technique (post-isometric relaxation technique- PIR) made hamstring muscle more significantly flexible than ultrasound therapy with active static stretching and passive static stretching in patients with hamstring tightness (Ramesh and Sivasankar, 2014). The intervention of PIR in this study is somehow like SLP in our study, but PIR caused more improvement than static stretch unlike our results showing no difference which may be due to more effects of PIR (passive muscle lengthening after submaximal contraction).

Many studies have investigated the relationship between hamstring extensibility and pelvic tilt. Bellew showed a strong correlation between hamstring extensibility and pelvic rotation during trunk flexion with knees extended (Bellew et al., 2010). However, Norris and Matthews in their study on a student population, reported no association between hamstring muscles extensibility and pelvic tilt, but in this study the angle of pelvic tilt

Table 1
Baseline characteristics of the LBP patients in each group.

Groups	Static Stretch (n = 15)	Strengthening Exercise (n = 15)	Control (n = 15)	p-value
Age(year)	37.67 (8.96)	37.07 (13.39)	39.12 (11.61)	0.823[a]
Height (cm)	171.93 (13.21)	172.64 (10.14)	172.31 (10.14)	0.995[a]
Weight (kg)	76.57 (13.05)	81.54 (16.59)	80.91 (14.1)	0.883[a]
BMI (kg/m^2)	25.90 (3.15)	26.82 (4.21)	27.47 (3.17)	0.535[a]
Sex				
Female	5 (33.3)	4 (26.7)	5 (33.3)	0.726[b]
Male	10 (66.7)	11 (73.3)	10 (66.7)	

BMI: Body Mass Index/Data are means (SD) except sex that presented as number (percent)/.
[a] Based on on-way ANOVA test/.
[b] Based on chi-square test.

Table 2
Results of variables measurements (pelvic tilt and SLR test) of low back pain patient before and after intervention and between three groups.

Variables	Measurement period	Static Stretch (n = 15)	Strengthening Exercise (n = 15)	Control (n = 15)	[a]P value
Pelvic tilt	Before	71.73 (5.43)	70.88 (6.59)	70.78 (4.56)	0.519
	After	71.67 (5.85)	71.54 (6.87)	69.77 (5.5)	
	MD (95% CI)	−0.12 (-2.46 to 2.23)	0.67 (-2.09 to 3.42)	−1.17 (-3.75 to 1.41)	
	[b]*P* value	0.061	0.087	0.151	
SLR test	Before	73.76 (8.25)	74.76 (8.25)	69.28 (13.77)	0.920
	After	80.87 (9.71)	80.86 (9.72)	79.24 (10.09)	
	MD (95% CI)	7.79 (2.90–12.67)	7.45 (3.19–11.70)	11.33 (4.10–18.56)	
	[b]*P* value	0.004	0.002	0.005	

Mean (SD) was reported/MD (95% CI): mean difference and 95% confidence interval/SLR: straight leg raising/
[a] P value is reported based on the analysis of covariance (ANCOVA/between-group changes) and adjusted for baseline values/
[b] P value is reported based on the paired *t*-test (within-group changes).

Table 3
Correlation between Pelvic tilt and SLR test.

Group	r (before)	p-value[a]	r (after)	p-value[a]
Static Stretch (n = 15)	−0.27	0.296	−0.32	0.253
Strengthening Exercise (n = 15)	−0.21	0.489	−0.54	**0.041**
Control (n = 15)	−0.18	0.505	−0.10	0.740

Pearson correlation coefficient (r) was reported/.
[a] Based on the Pearson correlation test.

was measured during trunk forward bending (Norris and Matthews, 2006). There is a belief that in those with greater hamstring extensibility, during doing trunk flexion with knees extended, there is a tendency towards greater anterior pelvic tilt. However, studies supporting this idea are cross-sectional type in design and do not include an intervention (Lopez-Minarro et al., 2012). Borman reported that 4 weeks of hamstring stretching in either sitting or standing position increased muscle length but, it did not cause a change in lumbar curvature. (Borman et al., 2011). Therefore, his results are in line with our study in that the intervention only changed the muscle length and not the pelvic tilt. López-Miñarro in his study found that, improvement of extensibility of hamstring had no effect on pelvic tilt, neither in the standing nor in maximal trunk flexion in sitting position and keeping knees flexed at 90°. He concluded that static stretching of the hamstring muscle caused only immediate changes in lumbar lordosis and pelvic tilt angle (Lopez-Minarro et al., 2012). This study is in agreement with ours that static stretching of hamstring had no effect on pelvic tilt (in our study the improvement of extensibility of hamstring was not correlated to pelvic tilt angle in SS group). This study only investigated acute effects of stretching in one session, unlike the current study that was conducted in a period.

There is a controversy regarding the relationship between hamstring muscle length (and extensibility) and pelvic tilt angle. Some researchers believe that since this muscle has an attachment on ischial tuberosity, any change in its length can affect pelvic tilt, whereas others doubt such kind of direct relationship. Indeed, the posterior tilting force is not limited to the hamstring as there are many other muscles that act in a similar way. In fact, changes in the hamstring length may only have a specified effect on pelvic rotation, i.e. it is not the only determinative factor.

Anyway, the hamstring is one of the most important muscles in this regard. In the current study, only in the SLP group and especially for post-intervention step, the correlations between SLR and pelvic tilt angle was significant. Because the strengthening exercise for hamstring muscle was applied only in this group, it may be concluded that increased strength of this muscle has had an effect on pelvic tilt. The matter that a correlations between SLR and pelvic tilt angle was not significant in other groups can be attributed to the lack of strengthening interventions in them. It may make sense that strengthening this muscle causes an increase in correlation between SLR and pelvic tilt. More studies investigating the effects of different kinds of hamstring exercises on pelvic tilt are recommended.

Limitations of the study: We should take human error with the minimal changes/results pre and post study into consideration. Also, hamstring muscle length is not measured directly and indirect methods such as angular measurements of unilateral hip flexion with the knee extended [straight leg raise (SLR)] or unilateral knee flexion after knee extension with the hip flexed to 90 (active knee extension test) are used (Gajdosik et al., 1993). SLR is a nerve root test and active knee extension test is a specific hamstring muscle length test. Though, active knee extension test may be better for assessment, difficulty to do this test increases the tendency to do SLR test.

5. Conclusions

For LBP sufferers, both static stretching and strengthening of hamstring muscle in its lengthened position caused elongation and extensibility in hamstring muscle and increased SLR test score, but did not change pelvic tilt angle. So, both of these interventions can be used for clinical purposes on the tightened hamstring muscles.

Declaration of competing interest

The authors have no conflict of interests.

Acknowledgments

The authors thank the Kermanshah University of Medical Sciences for grants to support this research. They also thank the participants of the study for their time and dedication.

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