ORIGINAL

The effect of dynamic stretching on hamstrings flexibility with respect to the spino-pelvic rhythm

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Abstract : Objectives : To ascertain the dynamic stretch effects of flexibility of the hamstrings on lumbar spine and pelvic kinematics. Background : Tight hamstrings are positively correlated with low back pain. However, it is unclear how flexibility of the hamstrings affects spino-pelvic rhythm. Methods : Twelve healthy men participated in the study. The straight leg raising (SLR) angle, finger floor distance (FFD), and spino-pelvic rhythm was measured before and after the 6-week stretching protocol. The forward bending task was divided into 4 phases. The paired *t*-test was used to determine significant differences before and after the FFD, SLR angle, lumbar motion, and pelvic motion, and spino-pelvic rhythm in each phase ($p<0.05$). Results : After 6 weeks of stretching, significant improvements were seen in the FFD with maximum forward bending and in the SLR angle. Total pelvic rotation was also significantly increased in contrast to total lumbar flexion. A decreased spino-pelvic ratio was seen in the final phase. Conclusion : Dynamic stretching could change the spino-pelvic rhythm to a pelvis-dominant motion, indicating that flexible hamstrings are important for preventing low back pain. J. Med. Invest. 63 : 85-90, February, 2016

***Keywords* :** *FFD, SLR angle, spinal mouse, low back, lumbo-pelvic rhythm*

INTRODUCTION

Low back pain is one of the most common symptoms in the general population. In fact, more than 80% of people experience low back pain at least once in their life (1). Tight hamstrings correlate strongly with low back pain (2-5). Esola *et al.* reported that spino-pelvic rhythm (lumbar motion/pelvic motion) contributes to low back pain, and that the spino-pelvic rhythm is disturbed by tight hamstrings (2).

It is reported that the spino-pelvic complex has a range of motion of 110° : 40° in the lumbar spine and 70° in the hip joint (2). During forward bending of the trunk, lumbar spine movement is dominant during the initial phase ; lumbar spine movement and pelvic movement are similar during the middle phase ; and pelvic movement is dominant during the ending phase. Esola *et al.* measured spino-pelvic rhythm in healthy subjects and in subjects with a history of low back pain. In the back pain group, the lumbar segment moved more than the pelvis during forward bending of the trunk, suggesting that greater lumbar motion can induce overloading of the lumbar spine and consequently cause low back pain (2).

Tight hamstrings can restrict hip movement, thereby increasing lumbar spine motion (6, 7) and causing back pain due to their influence on spino-pelvic rhythm during forward bending (8). Recently, Hasebe *et al.* (9) measured spino-pelvic rhythm in healthy subjects with various grades of hamstrings tightness and found increase pelvic motion in subjects with flexible hamstrings than in those with tight hamstrings. They also stated that improving hamstrings flexibility is important for reducing lumbar loading during activities in daily life. Thus, it is reasonable to assume that decreased lumbar loading would decrease the incidence of such mechanical stress-induced lumbar disorders. Therefore, a possible means of reducing lumbar loading through physical therapy is improving the flexibility of the hamstrings.

Previous studies investigating the spino-pelvic rhythm after hamstrings stretching had mainly used static stretching (10). Dynamic stretching is another method that aims to improve the capacity of an individual's body to move instantaneously (11). It utilizes gentle momentum of limbs, or a bouncing motion to move limbs throughout the possible range of motion (12). It has been widely performed as a warm-up for athletes before the training or games (11). There are various studies regarding dynamic stretching that showed positive effects of the same on power (13), jump performance (14), and sprinting (15). In addition, recent articles have indicated that dynamic stretching improved not only maximal strength and power performance but also balance and agility. This indicates that dynamic stretching is more appropriate than static stretching for activities that require balance, rapid change of running direction (agility), and movement time of the upper extremities (16).

To the best of our knowledge, no report has yet investigated the effect of dynamic stretching on spino-pelvic rhythm. Investigating how the lumbo-pelvic rhythm changes when hamstring flexibility improves through dynamic stretching may help prevent the development of lower back pain. Therefore, the aim of this study is to clarify the influence of dynamic stretching of hamstrings on spino-pelvic rhythm. Our hypothesis is that improving the flexibility of the hamstrings would be beneficial for pelvic motion through reducing lumbar motion.

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SUBJECT AND METHODS

Subjects

In total, 14 healthy men were recruited in the study. Exclusion criteria included history of lumbar spine disorder, neurological disorder, spinal surgery, or lower extremity surgery. Subjects were excluded if they could touch their fingers to the floor in the finger floor distance (FFD) test. Two of the participants performed stretching exercises regularly during the intervention period, so they were excluded. Finally, we used the data of 12 participants for the data analysis. The age, height, and body mass of the participants were 20.5±1.1 years (mean±SD), 170.1±5.9 cm, and 62.3±5.3 kg, respectively.

The purpose and protocol of the study was explained to each participant, and a signed informed consent form was obtained prior to participation. The study was approved by the Ethics Committee of Saitama medical University. (approval number, 87)

Measurement Protocol & analysis

The straight leg raising (SLR) angle, FFD, and spino-pelvic rhythm was measured before and after the 6-week stretching protocol and the results were compared to elucidate the effects of stretching exercises on the spino-pelvic rhythm. To conduct image analysis, four passive reflective markers were attached to the right side of the participants at specific anatomical landmarks : the lateral epicondyle, greater trochanter, 7th rib, and 10th rib along the axillary line.

As a characteristic of hamstring flexibility, we measured the SLR angle. Flexibility of the hamstring muscles through the SLR test was measured at full hip flexion with the knee extended. The SLR motions were filmed with a digital video camera (DCR-TRV30 ; Sony Corporation, Tokyo, Japan). The camera was positioned at the same height as the bed and 3 m away from the right side of each subject. We analyzed the obtained images with the Image J software (National Institutes of Health, USA), calculated the angle between the line linking the 10th rib to the 7th rib and the line linking the greater trochanter to the lateral epicondyle. The SLR angle was measured twice, and the mean value was used.

We measured the FFD in both the upright standing position (x cm) and at the maximum forward bending posture with full extension of the knee joint (y cm), such that we measured the total finger movement with flexion (TFM ; x-y cm) by using a digital FFD meter (T.K.K.5403 : Takei Scientific Instruments Co., Ltd, Tokyo, Japan). If the finger was extended below the level of the table, the value was regarded as negative.

Spinal alignment was measured with a spinal mouse (Idiag AG, Voletswil, Switzerland) in the following five positions : (1) upright posture 0% TFM ; (2) forward bending 25% TFM ; (3) forward bending 50% TFM ; (4) forward bending 75% TFM ; and forward bending 100% TFM (Figure 1). The reliability of the spinal mouse has been well established (9, 17-19). A spinal mouse enables measurement of the entire thoracic angle, from T1 to T12, and likewise, the pelvic rotation motion (sacrum inclination angle) and the entire lumbar angle from L1 to L5. In each position, the average value obtained through three measurements was used following analysis.

Changes in the angle of the thoracic and lumbar spine as well as that of the pelvis were calculated for each step. The change from positions 0% TFM to 25% TFM was designated as phase I, from positions 25% TFM to 50% as phase II, from positions 50% to 75% TFM as phase III, and from positions 75% TFM to 100% TFM as phase IV. The kyphotic angles were positive and lordotic angles were negative. In each phase, the ratio of lumbar motion to pelvic motion (L/P) was measured to understand the lumbo-pelvic rhythm. When the L/P ratio was > 1.0, the motion was considered lumbar dominant ; when the L/P ratio was < 1.0, the motion was considered pelvis dominant.

Stretching exercise program

To stretch the hamstrings, we used a stretching machine (Never-Tight-Ham, Hogrel Inc., Tokyo, Japan) as shown in Figure 2. This machine has been reported to be effective for active stretching of tight hamstrings (20). Theoretically active stretching is efficient for gaining flexibility since the stretch utilizes reciprocal inhibition from contraction of the quadriceps muscle. The stretching machine is designed to perform active stretching while lying on a bench. Each subject performed 20 repetitions of knee extension every second for 5 sets, with 1-min rest intervals between the sets, 3 days per week for 6 weeks.

The seat angle of the machine can be adjusted to four positions based on the changing angle of the hip joint. (Figure 3). During the intervention period, the seat angle was changed by one stage every 1 week, which increased the strength of the stretch progressively.

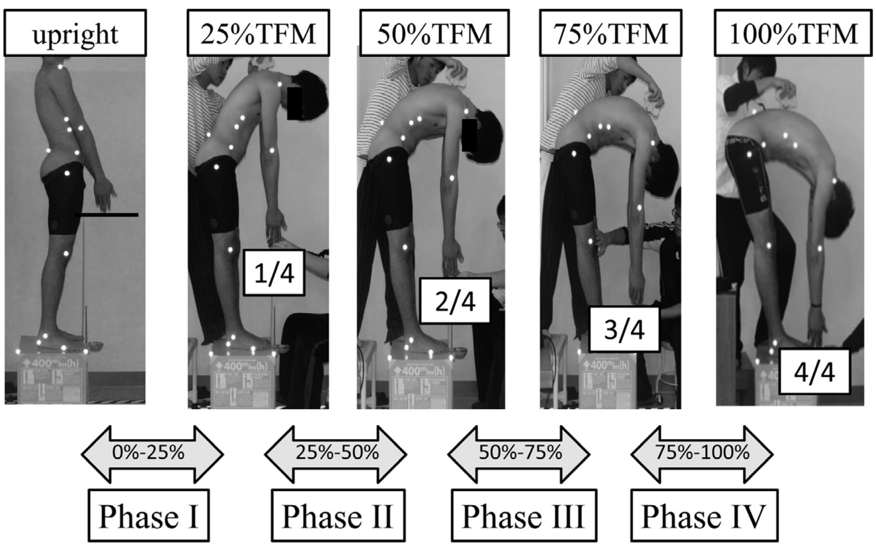

Figure 1 : Posture and position of the subjects during measurement of the spino-pelvic rhythm. Spinal alignment was measured with a spinal mouse in the following five positions : (1) upright posture 0% TFM ; (2) forward bending 25% TFM ; (3) forward bending 50% TFM ; (4) forward bending 75% TFM ; and forward bending 100% TFM. TFM : total finger movement with flexion.

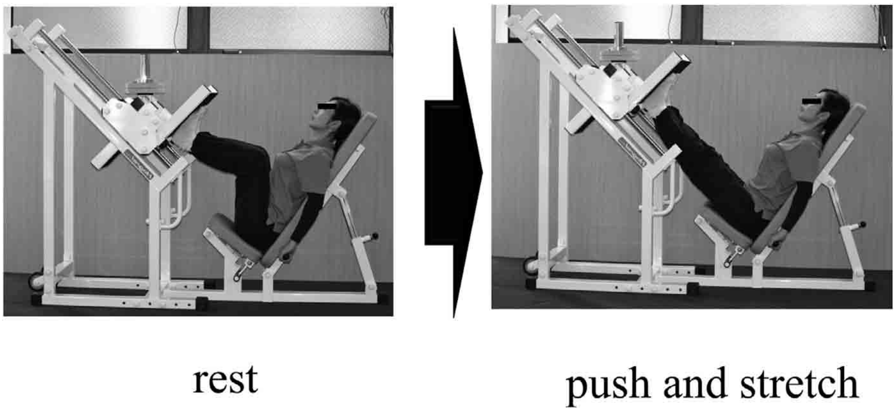

Figure 2 : Stretching on the “Never-Tight-Ham” machine designed to perform active stretch in the lying position on a bench. In the stretching position, subjects contract the quadriceps muscles against resistance, which simultaneously relaxes the hamstrings through reciprocal inhibition.

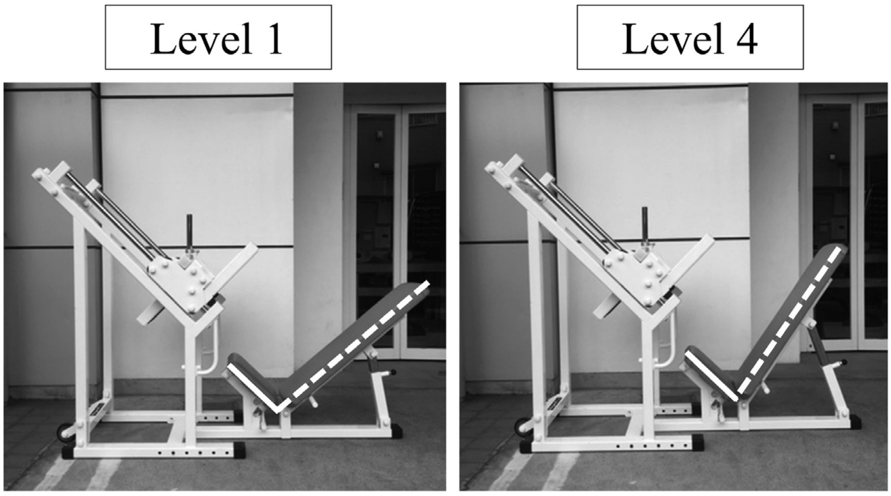

Figure 3 : Seat angle of the machine. The seat angle can be adjusted to four positions according to the flexibility of the hamstrings. The angle at position 4 is less than 90°. Simply sitting on the bench produces deep hip joint flexion, which stretches the hamstrings.

In the fifth and sixth weeks of the intervention, the stretch was performed at the maximum angle.

Statistical analysis

Statcel 2 (OMS publishing Inc., Tokyo, Japan) was used for statistical analysis. The paired *t*-test was used to determine significant differences before and after the FFD, SLR angle, the total lumbar motion and pelvic motion, thoracic spine motion and lumbar spine motion and pelvic rotation motion and L/P ratio in each phase. A p value < 0.05 was considered significant.

RESULTS

After the 6-week stretching protocol, all subjects showed increased flexibility in the hamstrings. The FFD and SLR were significantly ($p < 0.05$) improved, from 5.8±5.5 cm and 71.2±9.7° to -2.5±3.8 cm and 79.3±9.0°, respectively (Figure 4). During full flexion (upright position to maximum forward bending position), total pelvic motion was also significantly ($p < 0.01$) increased, from 31.9±6.9° to 42.3±8.3° (Figure 5). On the other hand, no significant differences were observed between measurements for the lumbar motion. Figure 6 shows the thoracic spine movement in each phase. In phase I, the thoracic spine showed the greatest flexion ; thereafter, it showed extension as trunk flexion progressed from phase II to phase IV. Movement of the lumbar spine in each phase is depicted in Figure 7. The lumbar spine moved to a greater extent in phases I and II, with significantly greater ($p < 0.05$) movement in phase I after stretching than before. In phases III and IV, the movement was small, and further decreased significantly ($p < 0.05$) after stretching.

Pelvic rotation is shown in Figure 8. The motion appeared to be increased in all phases after stretching, with significant ($p < 0.05$) differences seen in phases III and IV. To understand lumbo-pelvic rhythm, the lumbar movement to pelvic rotation (L/P) ratio was calculated (Figure 9). The L/P value decreased from phases I to IV both before and after the stretching protocol, indicating predominant use of the lumbar spine in the early stages and predominant use of the pelvis in the late stages. The ratio in phase IV was 0.5±0.3 and 0.3±0.2 before and after stretching, respectively. The values were less than 1.0, indicating that the motion was generated mainly from the pelvis in the final stage of bending the trunk forward. The values after stretching were significantly smaller ($p < 0.05$) than those before stretching, indicating that subjects had achieved efficient use of the pelvis in phase IV.

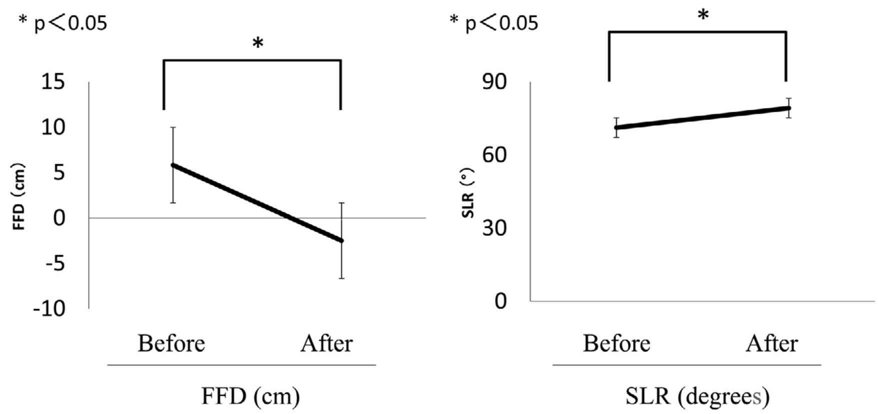

Figure 4 : Finger to floor distance and straight leg raising were significantly ($p < 0.01$) improved after stretching.

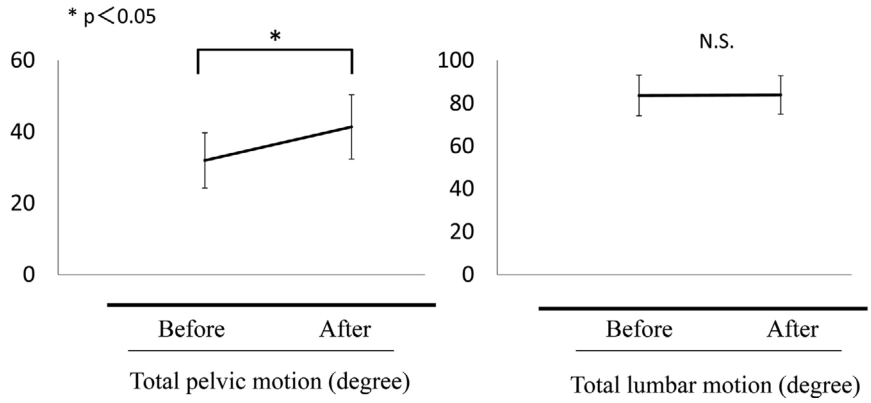

Figure 5 : Total pelvic and lumbar spine angles before and after stretching. Total pelvic motion was significantly ($p < 0.01$) increased, whereas total lumbar spine angle was largely unchanged.

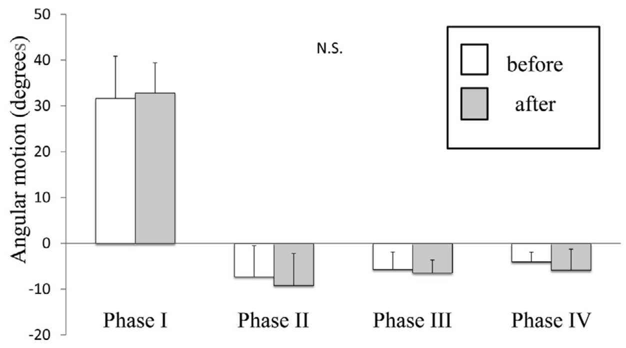

Figure 6 : Thoracic spine motion in each phase. Note the paradoxical extension motion during trunk forward bending in phases II, III, and IV.

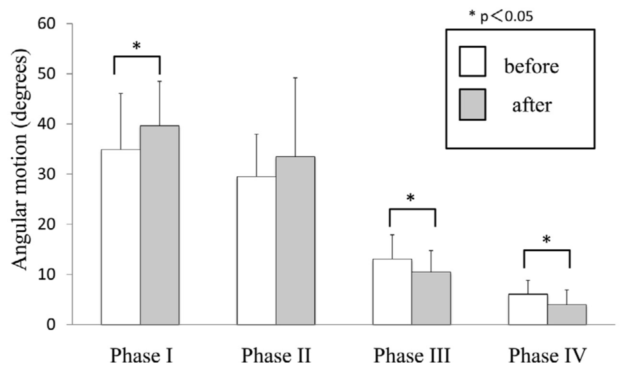

Figure 7 : Lumbar spine motion in each phase. In phase I, the movement was greater ($p < 0.05$) after stretching than before. In phases III and IV, the movement was small before stretching but decreased significantly ($p < 0.05$) after stretching.

DISCUSSION

After 6 weeks of dynamic stretching intervention in healthy men, the SLR angle increased significantly, while the FFD decreased significantly. After the intervention, FFD and SLR showed significant improvements, with a mean of approximately 7 cm and 8°, respectively, which indicates the improvement in hamstrings flexibility. In a previous study, the effect of active static stretching was investigated and FFD was seen to improve by 8.9 cm (21). The improvement in the SLR angle was the same in both studies (9°) (7), which suggests that this method is equally effective as the static stretch at improving flexibility. Ayala *et al.* reported that after active static stretching intervention in healthy men with normal hamstrings, the SLR angle increased to 10° (22). Therefore, we believe that this stretching method was as effective as previously studied methods at improving flexibility.

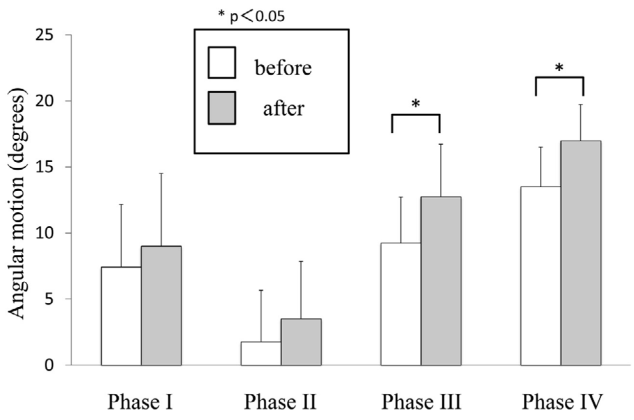

Figure 8 : Pelvic rotation motion in each phase. In all phases, the motion increased after stretching, and the difference was significant ($p < 0.05$) in phases III and IV.

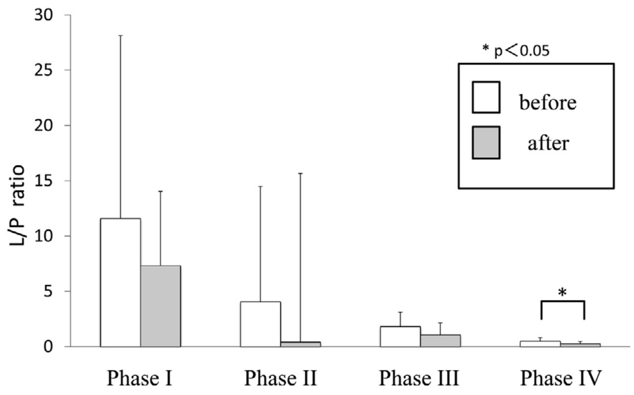

Figure 9 : Lumbo-pelvic ratio before and after stretching. In phase IV, the value after stretching was significantly smaller ($p < 0.05$) than before stretching, indicating that subjects gained efficient use of the pelvis.

The dynamic stretch on the hamstrings did not show significant difference in the total variation of the lumbar motion, and only the total variation of pelvic motion increased significantly. This result suggested that improvement of the hamstrings flexibility significantly increased the pelvic anterior motion. Some previous studies have investigated the effects of hamstrings stretching on the spino-pelvic rhythm (10). However, although some studies reported that stretching improved the flexibility of the hamstrings, and as a consequence, the pelvic anterior motion increased significantly (7), there was no report that the spino-pelvic rhythm significantly changed. In this study, as the result of separately indicating the variation in the lumbar spine angle in each phase, the pelvic angle variation significantly increased in phase III and IV, and the lumbar angle variation significantly decreased. Moreover, the L/P rate significantly decreased only in phase IV. Regarding the differing results of earlier studies with respect to no change in the spino-pelvic rhythm, the difference of the stretching methods was likely the reason (7). Also, it might be that earlier studies used the static stretch, which is the most used clinical method, but this study used the dynamic stretch. The dynamic stretch improves the specific flexibility of the movements, particularly when movements are simulating actual motions (23, 24). In this study, as the dynamic stretch was applied when the hip joint deep flexion posture was performed, it is possible that a change occurring in the spino-pelvic rhythm of the late phase of anterior forward bending involved the deep flexion position of the hip joint. Dynamic stretching elevates muscle temperature (25) and stimulates the nervous system (26) as well as improvement of the spino-pelvic rhythm in this study. Therefore, dynamic stretching is considered to be more useful for a warm-up before sports activity than static stretching.

Tightness in the hamstrings can restrict pelvic forward movement, thereby increasing compensatory lumbar flexion. The result of our study showed that the dynamic stretching intervention for hamstring muscles can possibly improve pelvic mobility in the late phase of trunk forward bending (phase III and IV), leading to a reduction in compensatory lumbar flexion movement. It is therefore logical that overcoming hamstrings tightness and improving flexibility will ensure greater mobility of the pelvis, leading to reduced lumbar motion and mechanical loading during trunk motion. These data indicate that flexible hamstrings are beneficial for preventing low back pain by reducing lumbar loading.

There are several limitations of the current study. First, it is unknown whether there will be reduction in low back pain prevalence or the vicious cycle of low back pain will be broken when lumbo-pelvic rhythm is improved by stretching the hamstrings. Second point, we used only male subjects, because no studies have reported sex differences in spino-pelvic rhythm. Future studies should include female subjects and examine the relationship between spino-pelvic rhythm and sexes.

CONCLUSION

Our results indicate that after 6 weeks of dynamic stretching intervention in healthy men, the SLR angle significantly increased and the FFD significantly decreased, which indicates improvement in hamstrings flexibility. In addition, the dynamic stretching intervention for hamstring muscles can possibly improve pelvic mobility at the late phase of trunk forward bending (phase III and IV), leading to a reduction in compensatory lumbar flexion movement and change in the spino-pelvic rhythm.

CONFLICT OF INTEREST

None of the authors have any conflicts of interest to declare

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