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Immediate Effect of Hip Hinge Exercise Stretching on Flexibility of Lower Limb, Pelvic Tilting Angle, Proprioception and Dynamic Balance in Individual with Hamstring Tightness

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Objective: The purpose of this study was to measure the immediate effect of hip hinge exercise stretching on hamstring flexibility, pelvic tilting angle, proprioception, and dynamic balance in individual with tightness of the hamstring.

Design: A randomized controlled trial.

Methods: A total of 35 healthy young adults (27 males, 8 females) volunteered for this study and randomly divided into three groups (Hip hinge exercise stretching group, passive stretching group, and PNF stretching group). The hamstring flexibility, pelvic tilting angle, knee joint proprioception, dynamic balance was conducted for 3 times. In order to evaluate the hamstring flexibility, the active knee extension test was performed. Forward bending test was performed to examine pelvic tilting angle.The proprioception was tested by the joint position sense test and dynamic balance was evaluated by Y balance test.

Results: The hamstring flexibility, pelvic tilting angle and dynamic balance were significantly improved between three groups before and after intervention ($p < 0.05$). Dynamic balance was significantly difference between the three groups in the posterolateral direction ($p < 0.05$).

Conclusions: This study result showed that hip hinge exercise stretching was the most effective method for increasing hamstring flexibility, pelvic tilting angle and dynamic balance. In addition, it is necessary to study whether hamstring stretching is effective in low back pain patient with hamstrings tightness.

Key Words: Muscle stretching exercise, Low back pain, Flexibility, Hamstring muscle

Introduction

About 23% of the world's population is affected by chronic low back pain, of which 24% to 80% recur within 1 year [1]. Back pain is caused by a variety of factors, including previous back pain, repeated bending and twisting, persistent static posture, anxiety, depression, and somatization [2]. Low back pain arising from the spine, intervertebral disks, or surrounding soft tissues is called mechanical low back pain. This includes lumbosacral muscle strain, lumbar spondylosis, vertebral compression fractures, spondylolisthesis, spondylolysis, and traumatic injury [1].

The underlying mechanism of tissue damage that causes LBP may include the accumulation of mechanical loads in specific tissues due to repetitive stresses resulting from repetitive movements or sustained postures in specific directions [3, 4]. Therefore, the abnormal flexibility of the muscles acting on the lumbar spine can reduce the change in the direction of the load applied to the lumbar spine, which can be a factor in the onset of low back pain [5].

van Wingerden and Vleeming [6] proposed that hamstring tightness in individuals with LBP could be a compensatory mechanism for weak gluteal muscles and

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decreased sacroiliac joint stability in patients with sacroiliac disorders. They indicated that gluteus maximus muscle, due to its attachments to sacrum, iliac bones, and sacrotuberous ligament, plays a significant role in stability of the SI joint [7].

The lumbar-pelvic rhythm is a coupled movement caused by lumbar flexion and pelvic rotation, and is caused by the coordinated activity of the extensors of the lower back and the extensors of the hip joint when bent forward in daily life [8]. It reported that a 110-degree movement of the lumbopelvic complex is produced by a 40-degree movement of the waist and 70-degree movement of the hip joint [9]. Esola and McClure [10] measured lumbo-pelvic rhythm in healthy subjects and subjects with a history of back pain. In the low back pain group, when the lumbar segment is bent forward, the lumbar segment moves more then the pelvis, suggesting that greater lumbar motion may overload the lumbar spine and consequently cause low back pain. Based on these biomechanical concepts, forward bending has been implicated as a possible cause of LBP, thus suggesting that a relationship exists between hamstring muscle length and pelvic tilt range [7].

Altered knee kinematics, impaired knee joint proprioception, and poor hamstring flexibility along with inadequate hamstring strength may serve as major risk factors for hamstring strain. [11]. However, static stretching before exercise was found to negatively affect muscle strength, strength, maximum reps, and vertical jump performance [12]. On the other hand, dynamic stretching that moves the extremities in an active range of motion by contracting the muscle group antagonist without bouncing to the target muscle group is reported to improve muscle strength, muscle strength, sprint time, and vertical jump performance. The stretched or lengthened muscle causes changes in the force generated by muscle contraction and changes in the ideal joint angle [11]. The hip hinge exercise is an eccentric contraction while simultaneously contracting the prime mover (quadriceps) and antagonist (hamstring) muscles. Muscle stiffness can have a significant impact on muscle performance and injury, and active contractions to prevent this can help when stretching. Consequently, dynamic warm-up interventions such as dynamic stretching, unlike static or PNF stretching, may serve as an effective technique not only to improve flexibility, but also to improve lower extremity muscle performance [11]. Although the effect of these various stretching methods has been reported, there is still a lack of research on stretching, which can improve knee joint proprioception, dynamic balance, pelvic movement, forward bending to effect lumbar pelvic rhythm.

The aim of this study was to investigate the immediate effects of hip hinge excise stretching on flexibility, pelvic tilting angle, knee joint proprioception, dynamic balance.

Method

Participants

Subjects were recruited for 3 weeks through the post at Sahmyook University. The subjects provided their informed consent and voluntarily agreed to participate. This study recruited 36 healthy young adults with hamstring tightness in their 20s who were living in Seoul city of Korea, excluding one person who met the exclusion criteria. This study used G*Power (version 3.1.9.4, Heinrich-Heine-University Düseldorf, Düseldorf, Germany) to report statistical power of subject number. Su and Chang [13] study of 30 people to find out the flexibility and muscle strength of knee flexion and extension was calculated the effect size 0.60. The sample size was obtained using One-way ANOVA of the g-power program with effect size = 0.60, power = 0.80, and group number = 3. The total number of sample size was calculated as 30. Therefore, a total of 35 participants who had hamstring tightness during Active Knee Extension (AKE) test were selected for final analysis. Study eligibility criteria included healthy young men and women who have tightness of the hamstring muscles. In the active knee extension test, there was stiffness of the hamstrings when the hip joint was flexed to 90° and the knee extension was limited to 20° [14]. The exclusion criteria were: First, with neurological problems in lumbar within 6 months, Second, with history of injury to the knee, hip, or back, Third, surgery of the lower extremity, Fourth, history of hamstring or other muscle damage in the lower extremity [14]. Research proceeds with approval of the Institutional Review Committee of Sahmyook University (2-1040781-A-N-012021017HR).

Procedure

In order to randomly divided the subjects, lots were drawn. Twelve sheets of paper with "A" or "B" or "C" were placed in the box and classified into hip hinge exercise stretching (A), passive stretching (B), and PNF stretching (C).

All testing was performed on the leg with more hamstring tightness. Hip hinge exercise stretching performed a total of 36 repetitions (3 sets × 12 repetitions per set), passive stretching group performed 20 seconds and rested for 15 seconds after stretching repeated three times, PNF stretching group performed 20% strength isometric contractions of the hamstrings for 10 seconds and passive stretching for 5 seconds. Before and after the stretching intervention, the hamstring flexibility, pelvic tilting angle, knee joint proprioception and dynamic balance wereimmediately measured (Figure 1).

Intervention

The Hip hinge exercise is dynamic active stretching. First, the subject was instructed in bare feet with their feet shoulder width apart. Bend knees slightly, about 10-15 degrees. Knee should not be pulled forward or collapsed inward. Then, with the pelvis tilted forward,

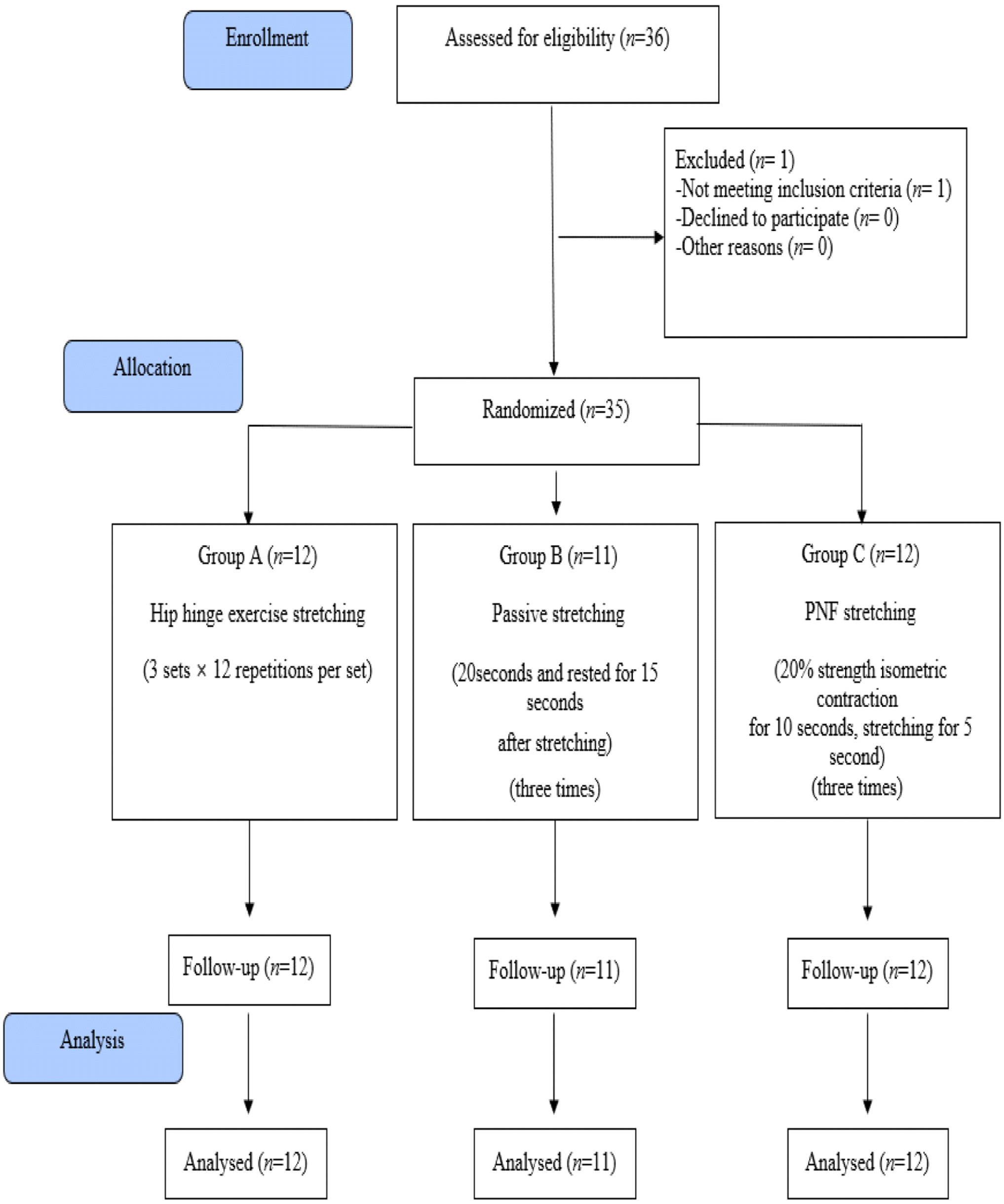

Figure 1. Flow diagram of the experimental procedure

the participant slowly bends the trunk forward until the end of the hip flexion. From the pose, raise your arms above your head and return to the starting position by extending your arms back and forth. In this exercise, the hamstring muscles were stretched by slightly extending the knee joint, the upper body was emphasized to always be in a straight line, and a 15 second break was given between interventions. Accordingly, a total of 36 hip hinge exercises were performed.

For passive stretching, subjects were placed in a supine position with the leg with less hamstring tension secured to the bed with a belt. The researcher flexed the leg with the hip joint with more hamstrings tightened until a normal lumbar curve was maintained and the thigh was stabilized with a belt. A leg with tighter hamstrings rested on the researcher's shoulder. The researcher held the participant's knee and performed knee extension until the subject felt discomfort in posterior thigh or restriction to the hamstring. The researcher passively stretched the knee joint to the extent that the subject felt discomfort, held for 20 seconds, and rested for 15 seconds after stretch. This process was repeated three times [12].

The PNF condition involved stretching the lower extremity using the hold-relax technique.Thesubjects were placed in a supine position with the less tight hamstring side leg secured to the bed with a belt. The researcher flexed the leg with the hip joint with more tight hamstring side until a normal lumbar curve was maintained and the thigh was stabilized with a belt. The more restricted hamstring side of leg was put on the researcher's shoulder. The researcher supported the subject's knee joint and lifted the body to extend knee. The researcher passively stretched the participant’s fully extended leg. Subjects pushed the researcher's shoulder for 10 seconds while performing isometric contractions at 20% intensity. After the contraction, the subjects take 5 seconds rests. The researchers passively stretched for 5 seconds until the subject felt discomfort. The hold-relax PNF Stretching was performed 3 times, with resting for 15 seconds between stretching [15].

Assessment tool and Data Collection

A flexibility test was performed to measure hamstring flexibility before and after the experiment. The participant lay down with the hip and knee bent 90 degrees on the side of the tighter hamstring. The less tight hamstring leg was secured to the bed with a belt to prevent movement. With 90 degrees of hip flexion, the subject extended the knee until the subject felt discomfort in the posterior thigh. The examiner supported and supervised the subject to keep the hip joint in 90 degree flexion. The ROM of the knee joint was measured using the smartphone bubble level clinometer application (Spirit Level, NixGame Developer, Russian). To measure the knee extension angle, a smartphone was placed on the lower surface of the tibial tuberosity. The ROM of the knee joint was measured through the AKE test, and the average value was recorded after repeating it 3 times. The AKE test interrater reliability was excellent, with ICC values of 0.87 and the test-retest reliability values ranging from 0.78 to 0.92 [16]. The smartphone (SM-G950N, Samsung, Republic of Korea) used in this study has a built-in tilt sensor, so it can function as an inclinometer. The smartphone ICC between the sets of measurements was 0.81 [17]. The flexibility of the knee joint was measured using a smartphone application.

The forward bending test was used to measure the pelvic tilting angle before and after intervention. The subject was in the upright position, with stood in bare feet with their feet shoulder width apart. The pelvic tilting rage was measured using the smartphone clinometer application. The smartphone clinometer application was placed over the subject’s sacrum with its upper edge aligned with the subject’s posterior superior iliac spines. The top of the goniometer was positioned horizontally with the ASIS, and it was firmly fixed in order to adhere to the skin.In the starting position, the goniometer was set to zero and instructed to bend forward without changing the knee joint angle. The end position was maintained for 2~3s, during which time the reading stabilized and a recorded as the angle of anterior pelvic tilt and the mean value of three repeats was recorded. Forward bending test ICC values of 0.09 [18].

The joint position sense test was used to measure the proprioception senses before and after intervention. Participants sat with their buttocks on the bed so that their legs did not touch the ground. The proprioception sense was measured using the smart phone clinometer application. In order to block the subject's field of vision, the researcher closed his eyes, restricted the knee angle from 0 to 90 degrees, and instructed to reproduce the pre-recognized angle of 45 degrees for the knee extension angle. The starting position was with the knee joint flexed 90 degrees. After blocking the visual information, the subject reproduces the target angle by repeating the target angle 3 times, and measures the error between the target angle and the measured angle to obtain an average value. The joint position sense test ICC values of 0.716 with eyes open and ICC 0.404 with eyes closed [19].

Y balance test was used to measure dynamic balance before and after intervention. The Y balance test is designed to increase the repeatability of the star excursion balance test commonly used to measure leg strength, flexibility, and proprioception [20]. Analyze the maximum reach in each direction for each limb and normalize to the lower extremity length. Leg length was measured on each limb while the participant was lying down. The length of each lower extremity was measured from the lower side of the ASIS to the distal aspect of the medial malleolus. Participants extended their free limbs as far as possible in the anterior, posterior medial, posterior lateral directions sequentially three times, in two posterior directions at a 135-degree position from the anterior direction. A break of 15 seconds was allowed between each trial and the average of three measurements was used for analysis to minimize the learning effect. Retests were performed when the participant lost balance, the supporting foot fell off the floor, kicked the reach indicator, released the moving foot on the indicator, the moving foot failed to return to the starting position, or released the hand. Normalization was performed by dividing each distance by the participant's leg length and then multiplying by 100 [21] (see Figure 2).

The Y balance test anterior reach intra-rater reliability ICC values of 0.88, Posteromedial reach intra-rater reliability ICC values of 0.88, Posterolateral reach intra-rater reliability ICC values of 0.90 [20].

Data Analysis

SPSS statistical software (version 22.0, IBM Corp, USA) was using in analysis of all statistical values. The Shapiro–Wilk test was used to testfor the normality of the participants' general characteristics. One-way ANOVA and chi-square test were used to test the homogeneity of the dependent variables between the three groups.

One-way ANOVA was performed to compare the pre and post hamstring muscle flexibility, pelvic tilt angle, proprioception and dynamic balance of the three groups. A paired t-test was used to compare hamstring muscle flexibility, pelvic tilt angle, proprioception, and dynamic balance in each group between pre and post. Scheffe's method was used for post-hoc testing. The statistical significance level was set to 0.05.

Results

General characteristics of subjects were no significant difference between the three groups and there were no significant difference terms of the homogeneity between the three groups (Table 1).

$$\text{Normalized Reach Distance} = \frac{\text{Raw Reach Distance (cm)}}{\text{Leg Length (cm)}} * 100$$

Figure 2. Normalized Reach Distance

Table 1. General Characteristics of Participants (n = 35)

	Hiphinge exercise stretching group (n = 12)	Passive stretching group (n = 11)	PNF stretching group (n = 12)	χ^2/F(p)
Sex (male/female)	10 / 2	9 / 2	8 / 4	1.144[b] (0.564)
Intervention leg (Right/left)	8 / 4	5 / 6	5 / 7	1.512[b] (0.470)
Age (years)	26.25±6.69[a]	23.82±4.21	24.17±3.51	0.807 (0.455)
Heigh (cm)	173.24±8.22	171.41±7.22	170.08±12.21	0.332 (0.720)
Weight (kg)	66.06±10.13	65.54±10.29	65.33±14.71	0.012 (0.988)
BMI (kg/m²)	22.01±3.08	22.24±2.65	22.35±2.80	0.046 (0.955)

Note. a = Mean ± standard deviation (SD); b = Chi-square test.

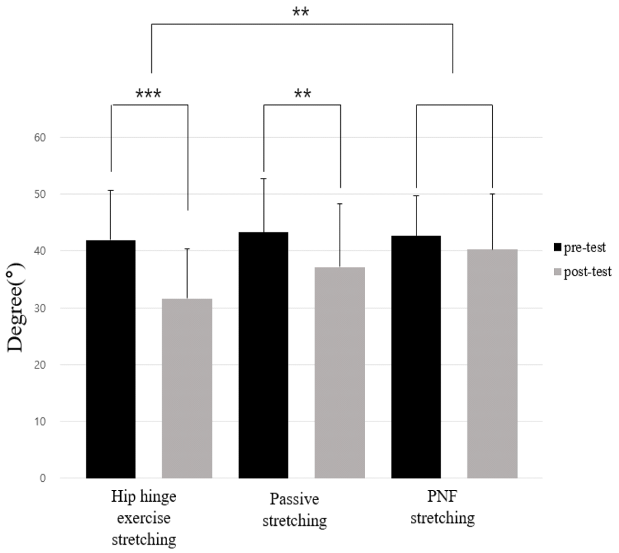

Figure 3. Comparison of active knee extension before and after intervention.

Significant difference within group ($p<0.05$, **$p<0.01$, ***$p<0.001$).

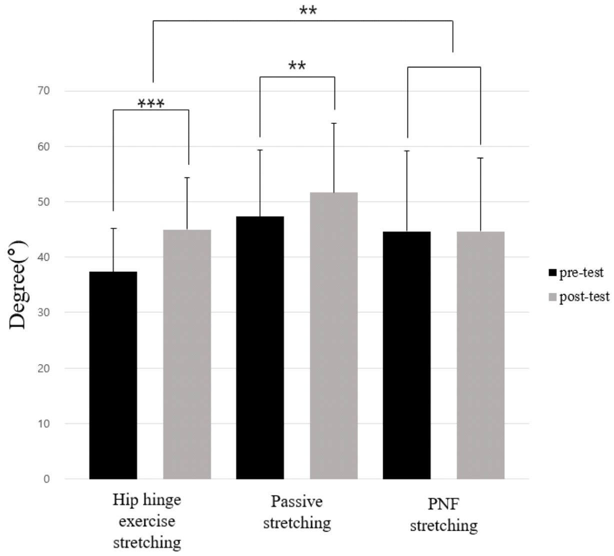

Figure 4. Comparison of pelvic tilting angle before and after intervention.

Significant difference within group ($p<0.05$, **$p<0.01$, ***$p<0.001$)

Comparison of active knee extension before and after intervention

Comparison among pre-test and post-test difference of hip hinge exercise stretching group, passive stretching group and PNF stretching group are shown is Figure 3. There was statistically significant difference before and after intervention between the three groups ($p<0.05$). No significant difference on active knee extension was shown between passive stretching group and PNF stretching group. Significant difference on active knee extension was shown between PNF stretching group and hip hinge exercise stretching group ($p<0.05$). Active knee extension of passive stretching group was significantly reduced from 43.22±9.43° to 37.13±11.14° ($p<0.05$), active knee extension reduction of PNF stretching group was 42.61±7.12° to 40.22±9.83° which is not statistically significant, hip hinge exercise stretching was 41.93±5.68° to 31.62±8.67° which is statistically significant ($p<0.05$).

Comparison of pelvic tilting angle before and after intervention

Comparison among pre-test and post-test difference of passive stretching group, PNF stretching group, and hip hinge exercise stretching group are shown in Figure 4. There was statistically significant difference before and after intervention between the three groups ($p<0.05$). No significant difference on pelvic tilting angle was shown between passive stretching group and PNF stretching group. Significant difference on pelvic tilting angle was shown between PNF stretching group and hip hinge exercise stretching group ($p<0.05$). Pelvic tilting angle of passive stretching group was significantly improved from 47.26±12.09° to 51.61±12.56° ($p<0.05$), pelvic tilting angle improvement of PNF stretching group was 63±14.51° to 44.67±13.18° which is not statistically significant, hip hinge exercise stretching was 37.33±7.86° to 44.95±9.38° which is statistically significant ($p<0.05$).

Comparison of proprioception before and after intervention

Comparison among pre-test and post-test difference of passive stretching group, PNF stretching group, and hip hinge exercise stretching group are shown in Figure 5. There were no statistically significant differences between three groups before and after the intervention.

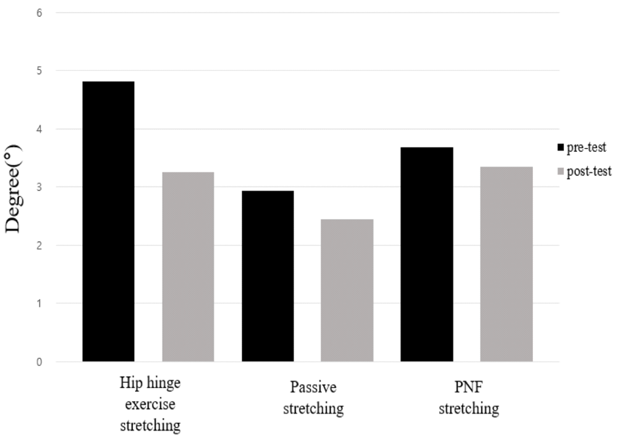

Figure 5. Comparison of proprioception before and after intervention

No significant difference before and after intervention on proprioception was shown within each group. Proprioception reduction of passive stretching group was 2.94±3.41° to 2.44±1.44°and PNF stretching group was 3.68±4.36° to 3.34±3.31° and hip hinge exercise stretching was 4.81±5.43° to 3.25±3.97° which is not statistically significant.

Comparison of dynamic balance before and after intervention

Comparison among pre-test and post-test difference of passive stretching group, PNF stretching group, and hip hinge exercise stretching group are shown in Figure 6 and 7. There was no statistically significant difference before and after intervention between the three in the anterior, posteromedial direction. Significant difference on dynamic balance was shown between the three group in the posterolateral direction ($p < 0.05$).

Dynamic balance in the anterior direction improvement of passive stretching group was 74.21±7.43% to 75.56 ±6.79% which is not statistically significant and the posteromedial direction of passive stretching group was significantly improved from 108.43±9.38% to 113.82 ±9.12% ($p < 0.05$) and the posterolateral direction of passive stretching group was significantly improved from 105.27±6.05% to 110.42±6.14% ($p < 0.05$). Dynamic balance in the anterior direction improvement of PNF stretching group was 71.42±5.89% to 71.50±5.89% which is not statistically significant and the posteromedial direction of PNF stretching group was significantly

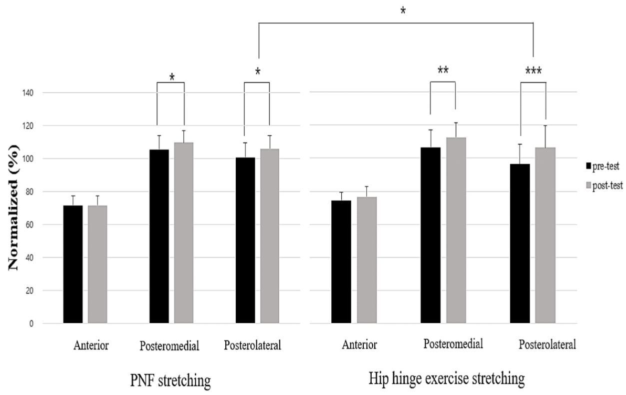

Figure 6. Comparison of dynamic balance before and after intervention.

*Significant difference between group ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$).

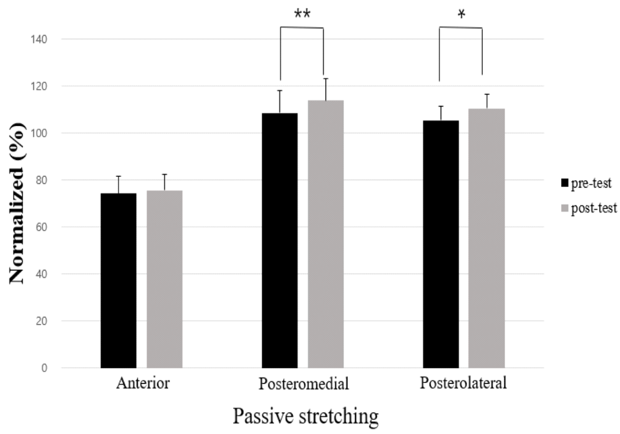

Figure 7. Comparison of dynamic balance before and after intervention.

*Significant difference within group ($^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$).

improved from 105.41±8.42% to 109.49±7.15% ($p < 0.05$) and the posterolateral direction of PNF stretching group was significantly improved from 100.55±8.96% to 105.90±7.89% ($p < 0.05$). Dynamic balance in the anterior direction improvement of hip hinge exercise stretching group was 74.49±4.84% to 76.64±6.13% which is not statistically significant and the posteromedial direction of passive stretching group was significantly improved from 106.63±10.60% to 112.74±8.84% ($p < 0.05$) and the posterolateral direction of hip hinge exercise stretching group was significantly improved from 96.37±11.95% to 106.41±13.29% ($p < 0.05$).

Discussion

In this study, we tried to find out the immediate effects of hip hinge excise stretching on hamstring flexibility, pelvic tilting angle, knee joint proprioception, dynamic balance.

In the results of this study, there was statistically significant difference on hamstring flexibility between the three groups ($p<0.05$). Hip hinge exercise stretching was shown to be statistically the most efficient compared to passive stretching and PNF stretching for improvement of hamstring flexibility ($p<0.05$). Iwata and Yamamoto [22] found that dynamic stretching immediately increased passive knee extension ROM and decreased passive stiffness of the hamstrings. Ozmen and Yagmur Gunes [23] found that static stretching and PNF stretching increased hamstring flexibility but there was not statistically significant difference on flexibility between the groups ($p>0.05$). Therefore, in the study, our findings showed that hip hinge exercise stretching can improve hamstring flexibility and passive stretching, PNF stretching were not statistically significant difference on flexibility between the groups ($p>0.05$).

In the results of this study, there was statistically significant difference on pelvic tilting angle between the three groups ($p<0.05$). Hip hinge exercise stretching was shown to be statistically the most efficient compared to passive stretching and PNF stretching for improvement of pelvic tilting angle. In a previous study, Jandre Reis and Macedo [24] found that LBP group had a decreased range of pelvic motion compared to non-LBP group and evaluated the effect of reduced hamstring flexibility on trunk and pelvic movement strategies during manual processing tasks. It was found that subjects with reduced flexibility exhibited higher trunk movement amplitudes and pelvic movement restrictions while processing tasks. As a result, hamstring stiffness showed a moderate correlation with pelvic tilt movement, which could be explained by the thought that the hamstring muscle pulls the pelvis to posterior rotation. This study suggests that hamstring stretching may be useful to restore pelvic movement. Similarly, our finding showed that hip hinge exercise stretching, passive stretching can improve pelvic tilting angle during forward bending.

In the results of this study, there was no statistic significant difference on proprioception between the three groups ($p>0.05$). In a previous study, Chen and Xin [11] found that knee joint proprioception did not change after stretching, found no improvement in proprioception in LEC (eccentric hamstring windmill lunges), and decreased proprioception of knee movements. As a result of this study, hamstring stretching increased knee joint motion error and there was no significant difference in proprioception.

In the results of this study, there was statistically significant difference on dynamic balance in the posterolateral direction between the three groups ($p<0.05$). Lee and Jang [25] indicated that muscle activation time were significantly improved in the affected knees of the dynamic stretching group compared with those of the static stretching group, which could be attributed to a neural inhibitory mechanism. Hamstring tightness showed a moderate correlation with pelvic tilting movement and this finding can be explained because it is thought that hamstring muscles draw the pelvis into posterior rotation. This study suggests that hamstring stretching may be useful to restore pelvic movement. Inhibition of neural factors, such as altered motor control and reflex sensitivity, may affect muscle activation. Similarly, our findings showed that hip hinge exercise stretching can improve dynamic balance in the posterolateral direction.

However, this study had limitations. First, it is difficult to generalize the results of this study because the sample size is small and the experiment is conducted on healthy adults. Second, there is a limitation maintenance or the long-term effects by comparing the immediate effect before and after intervention. In future studies, it is necessary to supplement these limitations and evaluate long-term effects of hamstring flexibility, pelvic tilting angle, proprioception, dynamic balance.

Conclusion

Through this study, it was found that hip hinge exercise stretching was the most immediate effective for hamstring flexibility, pelvic tilting angle, dynamic balance. Therefore, it is suggested that hip hinge exercise stretching is effective stretching method for chronic low back pain with hamstring tightness.

Conflicts of interest

The authors of this study declare that there are no potential conflicts of interest regarding research, author rights, and publication.

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