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The Effect of Stretching on Lumbar Muscle Flexibility, Isokinetic Parameters and Lower Extremity Function

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Purpose: This study aimed to investigate the correlation of the flexibility of lumbar muscle fibers with the speed of the broad four-pronged muscle in healthy adult men and women.
Methods: This study selected 36 healthy male and female college students. The subjects were randomly assigned to two groups (Group A; performing three stretches, and Group B; not engaging in any stretching) and measured for flexibility, functional evaluation, and biomechanical parameters (CSMI) as pre-experimental evaluation items. Flexibility was evaluated using 2 types of sit and reach tests and Schober's test, while functional evaluation was assessed through the 3-hop test and the Sargent test. The knee extension angular velocities of the biomechanical parameters were measured at 60°, 120°, 180°, and 240° to determine peak torque, work per repetition, and peak power.
Results: Group A exhibited statistically significant improvements in both the before and after comparison of the sit and reach test and the difference in the quantum of change. There was a statistically significant improvement in the before and after comparison of the 3-hop jump test and the difference in the quantum of change. As for the isokinetic parameters, the peak torque of 60°, 120°, 180°, and 240° were only all significant in the experimental group.
Conclusion: This study focused on assessing the role of the lower extremities with respect to lumbar flexibility. The results suggest that lumbar flexibility has a statistically significant and positive effect on lower extremity flexibility and its function.

Keywords: Lumbar flexibility, Self-stretching, Sit and reach test, Sargent jump, 3-hop test

INTRODUCTION

According to previous research, sitting for long periods of time can cause work-related musculoskeletal disorders.[1] Back pain has a variety of causes, including poor posture, obesity, lack of exercise, multiparity, or even a tumor in the spine, but most back pain is caused by abnormalities in the muscles and ligaments that support the spine and trunk.[2,3] The most common causes can be broadly divided into three categories. The first category includes spinal back pain caused by direct spinal lesions, such as herniated discs and lumbosacral sprains, the second consists of back pain due to various diseases, such as systemic diseases of pelvic organs and the third is psychogenic back pain resulting from mental tension and stress.[4] Furthermore, if back pain persists for several months, physical activity may be limited. This can lead to a vicious cycle due to the lack of frequent movements related to maintaining spinal health.[5]

Back pain is a health treatment priority among musculoskeletal disorders, and almost everyone experiences back pain at least once in their lifetime.[6] The rise in chronic back pain in modern society results in asymmetrical gait pattern disorders, rigid posture, and various spine-related diseases, perpetuating a vicious cycle of further increase in pain.[7-9] In addition, the lumbar region is an important area for people who walk upright, and if pain in this area persists, movement of the pelvis, spine, and lower extremities may be impaired while walking.[10] Moreover, in a patient's gait, compensatory postural adjustments are employed to avoid pain, resulting in reduced gait flexibility and reciprocity, and a rigid, asymmetrical gait pattern appears.[8] In this way, because the trunk is stiffened and the

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body weight is supported using the lower extremities, walking speed decreases and pelvic rotation is also reduced, thereby consistently demonstrating an abnormal pattern of walking aimed at reducing pain.[11] Research has shown that patients with chronic low back pain may experience problems with a variety of lower extremity functions, including decreased walking speed and stability, and increased knee flexion range compared to individuals without chronic low back pain.[8]

Limited flexibility in muscles occurs especially in the hamstring muscles.[12] Shortening of the hamstrings increases the risk of leg muscle damage and can cause back pain.[13] Lower back flexibility plays an essential role in injury prevention and motor skill development, while overall flexibility is thought to be limited by muscles.[14] In particular, modern people who lead a sedentary lifestyle are prone to losing flexibility in their lower back. Injuries to the lower back can affect hamstring length, leading to problems in maintaining posture or causing functional abnormalities in the lower extremities.[12,15] Flexibility of the lower back is a key factor in controlling the smooth movement of the lumbar muscles, which has a significant impact on lower extremity function.[16]

Accordingly, this study is based on the need for research on the influence of increased lumbar flexibility on lower extremity function. Computer Sports Medicine Inc. (CSMI, Stoughton, USA, 2010), an isokinetic parameter measurement device, will be used to accurately compute the constant speed and performance ability of lower extremity functions. Objective functions such as peak torque, work per repetition, and average power per repetition of the lower extremities will be measured. Additionally, maximum muscle strength evaluation using peak torque has a high correlation with height and weight.[17] To increase reliability, if work per repetition is divided by body weight, functional aspects can be expressed more efficiently than peak torque.[18] In the case of average power per repetition, the repetition period measurement shows the highest value among the power per unit time obtained by dividing by the actual muscle contraction time and has been reported to be used as a highly reliable indicator for measuring muscle power in isokinetic evaluation.[19] This isokinetic exercise generates a constant speed while the resistance changes according to the rotational speed of the joint, enabling maximum expression of muscle strength throughout the range of motion.[20]

Previous studies on lower extremity function have been related to strength and pain. Therefore, this study aimed to measure changes in lumbar muscle flexibility, isokinetic parameters, and lower extremity functions following stretching of the lumbar muscles.

METHODS

1. Participants

This study was conducted on 36 healthy adults at S University in Asan, South Chungcheong Province. The purpose and methods of the study were explained to all subjects before participating in the study, and then written informed consent was obtained. The participants in this experiment were 36 healthy people who had no pain and diseases in the lumbar spine or lower extremities and had never been diagnosed with intervertebral disc herniation. Additional criteria include those who have no history of intervertebral disc herniation or surgery within 3 months, have worn a static brace within 3 months, have not had recent orthopedic problems, and have not suffered neurological damage to the lumbar spine. Thirty-six participants who met the criteria and voluntarily agreed to participate were selected as subjects after receiving sufficient explanations from the participants, their families, and guardians about the study content and purpose, experimental procedures, protection of human rights of subjects, and safety of the study. This study fully complied with the principles outlined in the Helsinki Declaration.

2. Measurement equipment

The sit and reach test and Schober's test (for back flexibility), and the 3-hop jump test (for functional ability), were measured using a tape measure. Sargent jumps were also recorded using a tape measure. Isokinetic exercise parameters were computed using angular velocities of 60°, 120°, 180°, and 240° from CSMI (Stoughton, USA, 2010). Previous studies on the reliability of isokinetic dynamometers have shown good to excellent reliability, with ICC values ranging from 0.74 to 0.89 for all tests.[21]

1) Lumbar flexibility measurement

Lumbar flexibility was measured using the sit and reach test and Schober's test (Figure 1). The sit and reach test was performed to measure the overall mobility of the lower back and hamstrings. Under supervision, subjects kept their knees straight, actively reached for their toes, and held this position. During the test, the facilitator ensured that

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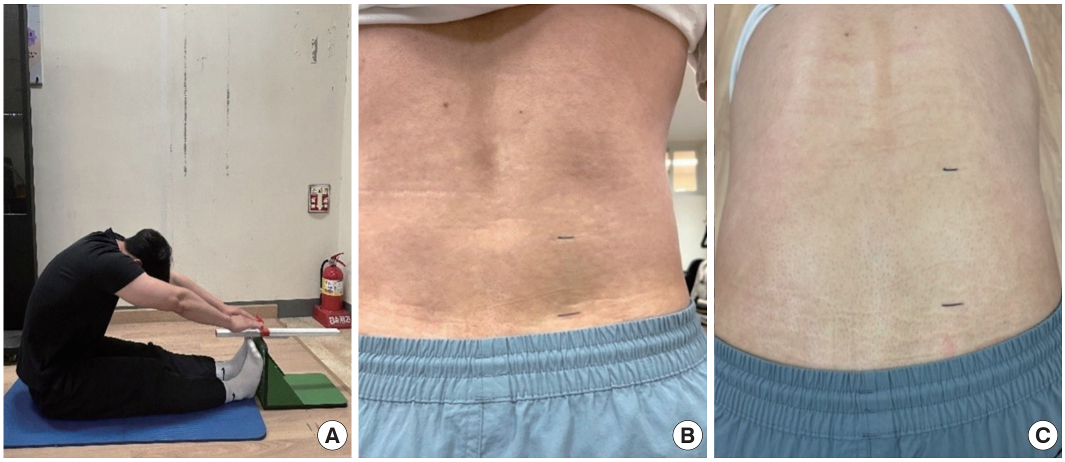

Figure 1. The picture shows how to measure lumbar flexibility. (A) is the sit and reach test, (B) is the preparation posture of Schober's test, and (C) is the measurement posture of Schober's test.

there was no excessive knee bending and corrected any compensatory actions. If the subject reached below their toes, the result was recorded as +(cm), and if above, it was recorded as -(cm) (Figure 1A).

Schober's test identified the subject's Posterior Superior Iliac Spine (PSIS), which was then measured and marked 5cm below and 10cm above this point. Next, the participant bent forward at the lumbar region, and the distance between the highest and lowest points was measured. In people with normal lumbar and pelvic rhythm, this distance increased by more than 5cm (Figure 1B, C).

2) Functional ability

The functional ability measurement included the 3-hop jump and Sargent jump. The 3-hop jump measures the distance traveled by jumping from a standing position and the agility and elasticity of the lower extremities. In this event, the subject jumped three times with the same leg from a starting point, and the final distance was measured. Before implementing the stretching intervention, the performance of the 3-hop jump was first measured. Afterward, stretching was performed to increase the flexibility of the lumbar region, followed by another measurement. Simultaneously, close attention was paid to the subject lands on the opposite foot.

The Sargent jump test measures muscle contraction by producing an instantaneous force. A board was installed 20cm away from the wall, and the point where the subject jumped with paint on their fingertip was recorded. Approaches and closings were not permitted. This test was conducted twice, and the higher results were recorded in centimeters. The height from the standing position before jumping was subtracted from the highest point height.

3) Peak torque, work per repetition, peak power

Peak torque, work per repetition, and peak power were measured using CSMI equipment, and knee joint extension was also measured. All measurements are performed with the dominant foot. The subject's isokinetic parameters were evaluated at angular velocities of 60°, 120°, 180°, and 240°. Angular velocity was performed 6 times per set, with 30 seconds of rest between sets to reduce measurement errors. It was conducted under the same conditions before and after the intervention. The four values, excluding the lowest and highest scores, were compared as averages. If there was an error in the measured value, only the relevant angular velocity was measured again.

3. Experimental procedures

In this study, subjects in each group visited the laboratory once and performed measurements. Subjects assessed lower extremity function in three ways. First, the 3 hop jump is a method of measuring the final distance by jumping 3 times with the dominant foot from a standing position. this is to measure the agility and elasticity of the lower extremities. The Sargent test measures muscle contraction force by generating momentary force. Additionally, a board was set up 20cm away from the wall. The height from the standing position was subtracted before jumping from the highest point height. This process was repeated twice and adequate results were recorded in centimeters. Using CSMI (Stoughton, USA, 2010), isokinetic knee extension exercises were performed at angular velocities of 90°, 120°, and 180°, and was measured as the maximum force the subject could produce. Flexibility was measured through the sit and reach test and schober's test. The above 3 functional tests are performed before and after stretching. the subjects performed three types of stretching. After intentionally creating a forward tilt of the pelvis in a sitting position, the pelvic bending motion was performed with the knees straight.[7] Furthermore, a study demonstrated that a stretching time of 60 seconds was most effective in increasing flexibility, therefore this study also used a stretching time of 60 seconds per movement (Figure 2).[22]

All stretches were performed at maximum intensity for 1 minute. After performing all stretching exercises, the previously performed lower extremity function evaluation was conducted to measure lower extremity function as the flexibility of the lower back increases.

Three high-intensity stretches for back flexibility were performed. In previous studies, high-intensity stretching demonstrated better flexibility maintenance than medium-intensity stretching. First, active knee extension is performed by sitting on a chair with an anterior tilt, with one knee straight and the toes pointed upward (Figure 2A). The second quadratus lumborum stretch was performed while lying on your side, supporting your upper body with your forearms, with your pelvis on the floor and your upper body bent to the side, holding for 1-2 minutes (Figure 2B). The third stretch was child's pose. Participants knelt and placed their buttocks close between their calves while straightening their backs. As they exhaled, they bent their body forward so that their forehead touched the floor, placing their hands on the floor. After maintaining the high-intensity stretch for about 1 to 3 minutes, they exhaled and raised their upper body to return to the initial position (Figure 2C).

4. Data analysis

All statistical analyses in this study used the mean and standard deviation for each measurement using the SPSS 29.0 statistical software program (IBM Inc., Chicago, IL, USA). After performing normality verification, an independent samples t-test was performed to determine the difference in change between the experimental and control groups, and a paired-sample t-test was performed to compare before and after the experiment within the experimental and control groups. The statistical significance level for all data was set at $p < 0.05$.

RESULTS

The subjects in this experiment were adult men and women aged 18 years or older who passed the selection criteria. They were randomly divided into two groups, each consisting of 9 men and 9 women. No dropouts occurred. Among the general characteristics of the test subjects, the mean age was 19.5 years in the experimental group and 19.4 years in the control group. Additionally, the mean height was 167.6cm in the experimental group and 170.1cm in the control group. In the mean body weight between groups: 63.6kg in the experimental group and 66.7kg in the control group ($p > 0.05$)(Table 1).

In the experimental group, the sit and reach test recording was statistically significant and improved from 9.34 ± 10.11/cm before stretching to 12.54 ± 9.94 after stretching ($p < 0.05$). Similarly, the 3-hop test was 469.39 ± 108.26/cm before stretching and 485.06 ± 117.3/cm after stretching, which was significant ($p < 0.05$). In the ex-

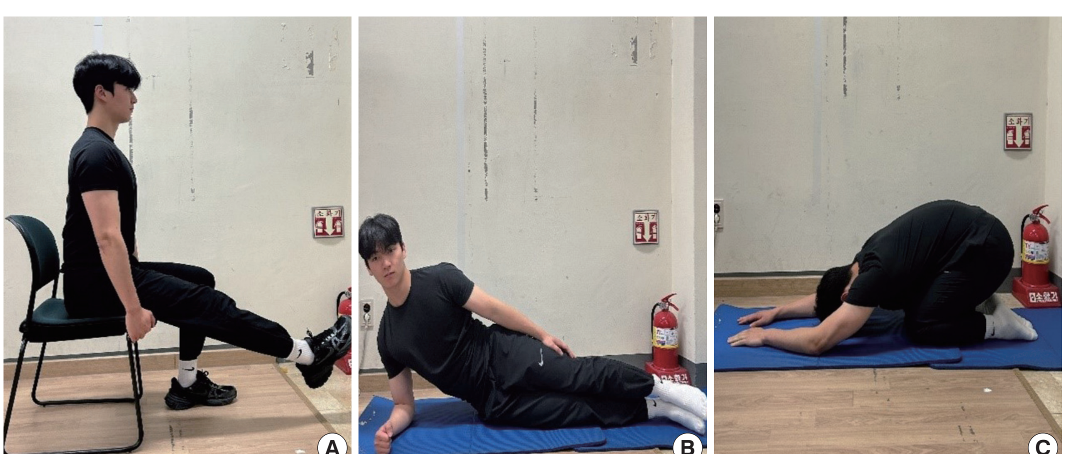

Figure 2. The picture shows high-intensity self-stretching. (A) is active knee extension, (B) is quadratus lumborum stretch, and (C) is child's pose.

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perimental group, the peak torque of 60°/sec recorded was statistically significant and improved from 124.32±46.73Nm before stretching to 132.81±48.43Nm after stretching ($p<0.05$)(Table 2). 120°/sec recorded was also statistically significant, increasing from 108.97±45.39Nm before stretching to 116.78±49.72Nm after stretching ($p<0.05$). 180°/sec recorded before stretching was 90.78±3 and after stretching, it showed a statistically significant improvement to 97.03±36.63 ($p<0.05$). Moreover, the peak torque of 240°/sec measured was statistically significant and rose from 73.61±30.88Nm before stretching to 79.18±34.61Nm after stretching ($p<0.05$). In the control group, after stretching, there was a statistically significant improvement 97.03±36.63 ($p<0.05$). The experimental group's work per repetition at 120°/sec record was 109.68±42.73/cm before stretching and 116.43±43.36 after stretching, exhibiting a statistically significant increase ($p<0.05$). Similarly, 180°/sec record was 94.14±36.60/cm before stretching and 99.69±37.94 after stretching, which was also statistically significant ($p<0.05$). The experimental group demonstrated a statistically significant improvement ($p<0.05$) in peak power at 60°/sec (140.75±59.96/cm before stretching and 149.03±55.88/cm after stretching), and at 120°/sec (216.75±79.94/cm before stretching and 231.17±86.75/cm after stretching). According to the sit and reach test records, the change was statistically significant at 3.19±3.25 for the experimental group and 0.89±1.17 for the control group ($p<0.05$). Regarding the 3-hop jump test records, the experimental group showed a statistically significant change of 15.67±27.08 and the control group exhibited a change of 1.28±3.16 ($p<0.05$)(Table 3).

Table 1. General characteristics of subjects (n=36)

Variable		Mean
Age (year)	Group A	19.6±1.3
	Group B	19.4±1.3
Height (cm)	Group A	168.9±8.4
	Group B	170.1±7.6
Weight (kg)	Group A	65.3±12.2
	Group B	66.7±14.3

Values indicate mean. Group A: performing three stretches, Group B: not engaging in any stretching.

DISCUSSION

The purpose of this study was to investigate changes in lower limb flexibility, lower extremity function, and isokinetic parameters after applying three types of back stretching to randomly selected adults. In

Table 3. Independent t-test results for differences in flexibility and functional assessment changes between the experimental and control groups (n=36)

Division		Average±standard deviation
Sit and reach* (cm)	Group A	3.19±3.25
	Group B	0.89±1.17
Schober's test (cm)	Group A	0.08±0.55
	Group B	0.16±1.33
3 hop jump test* (cm)	Group A	15.67±27.08
	Group B	1.28±3.16
Sargent jump (cm)	Group A	1.03±3.71
	Group B	2.81±3.74

Group A: performing three stretches, Group B: not engaging in any stretching. *$p<0.05$.

Table 2. Comparison before and after the experimental group and the control group in the torque, work, and power measurement values (n=36)

			Average±standard deviation			
			60°	120°	180°	240°
Torque (Nm)	Group A	Pre	124.32±46.73*	108.97±45.39*	90.78±35.09*	73.61±30.88*
		Post	132.81±48.43*	116.78±49.72*	97.03±36.63*	79.18±34.61*
	Group B	Pre	146.49±56.13	119.36±47.83	99.17±40.26	81.07±31.95
		Post	149.08±50.06	123.50±42.34	104.03±37.13	90.53±27.09
Work (J)	Group A	Pre	127.14±50.14	109.68±40.73*	94.14±36.60*	78.61±33.60
		Post	133.67±51.13	116.43±43.36*	99.69±37.94*	84.39±35.86
	Group B	Pre	129.61±43.67	114.31±40.17	99.25±38.59	83.72±31.72
		Post	138.36±44.78	117.92±40.34	105.67±33.61	89.31±27.26
Power (Nm)	Group A	Pre	140.75±59.96*	216.75±79.94*	281.36±106.71	295.92±126.01
		Post	149.03±55.88*	231.17±86.75*	281.14±101.65	304.19±126.60
	Group B	Pre	155.31±59.88	242.67±96.80	307.25±125.40	324.50±130.18
		Post	155.69±52.65	256.42±88.16	322.92±115.21	353.56±120.11

Group A: performing three stretches, Group B: not engaging in any stretching. *$p<0.05$.

this study, back flexibility was measured through the sit and reach test. As a result, the experimental group showed statistically significant improvement in the before and after comparison of the sit and reach test and the difference in change amount.

In the 3-hop jump test, there was a statistically significant improvement in the before and after comparison and the change amount. Correspondingly, the peak torque angular velocities at 60°, 120°, 180°, and 240° were all found to be statistically significant in isokinetic parameters. Significant values were found only at work per repetition values of 120° and 180°, and at peak power values of 60° and 120°. In the control group, significant values were found in sit and reach, 3-hop jump test, and sudden jump, but no significant values were found in isokinetic parameters. Furthermore, as a result of performing three self-stretching exercises, the sit and reach, which shows the degree of back flexibility in the group that applied stretching, showed statistically significant results ($p < 0.05$). However, the Schober test did not show a statistically significant difference. This is a method frequently used clinically to measure the range of motion of the lumbar spine and has high reliability compared to radiological measurements. Therefore, as it is specifically used to check muscle contraction and stiffness, it is thought that there are limits to the effectiveness of short-term stretching.[23] The muscles around the lumbar mainly work on both sides simultaneously to extend the lumbar spine, and when they work on one side, they bend the trunk. In particular, the importance of the quadratus lumborum muscle is emphasized because it works in cooperation with several muscles around the Lumbar when flexing or extending the trunk.[24]

Accordingly, in this study, child's pose, a yoga movement that can stretch both the quadratus lumborum muscle and the muscles around the lumbar, was performed. Additionally, Kana's stretching exercise method, AKES, was applied to the adult men and women subjects. Consequently, the results showed that the flexibility between the lower back and the posterior thigh muscles improved. These findings are consistent with the research conducted by Kana[25], further validating the meaningful results of this study. As a result of this study, both the control and experimental groups showed significant results in the dynamic lower limb functional evaluation 3-hop jump test ($p < 0.05$). However, no significant results were obtained in the Sargent jump of the experimental group. The 3-hop jump test is a test that is performed using several rounds of moderate power rather than explosive force. On the other hand, the Sargent jump is a representative measurement item of agility. It requires explosive agility during the test and can evaluate the power of the leg region, especially the gastrocnemius muscle.[26] In this study, the height of the surgent jump was measured immediately after stretching, and significant values were obtained for the control group, but no significant results were obtained for the experimental group. This decrease in muscle strength is explained by changes in muscle elasticity spastic force production and Golgi tendon reflex.[27-29] On the other hand, according to previous research, if the Sargent jump test is performed after 30 minutes of rest rather than immediately after stretching (as in this study), muscle strength increases. This is a result of epinephrine and norepinephrine secreted, over time, from the adrenal medulla, increasing the central mechanism and muscle contraction rate, thereby increasing energy availability.[30] Therefore, it is believed that effective results will be obtained when taking the time to evaluate again after stretching.

The isokinetic parameter results of the experimental group showed significant results at peak torque angular velocities of 60°, 120°, 180°, and 240° ($p < 0.05$). Increased flexibility resulting from stretching can reduce the occurrence of muscle and tendon injuries, minimize and relieve muscle pain, and improve exercise performance.[31] In addition, the experimental group's work per repetition angular velocities of 120° and 180° and peak power angular velocities of 60° and 120° showed significant results. Moreover, couple force refers to a force that causes rotation or movement of a joint in the same direction, although it is located at different positions.[32] Hence, it is considered that improved flexibility in the lower back not only enhances pelvic mobility but also has a flexible effect on the contraction of the quadriceps femoris, leading to positive changes in isokinetic parameters. According to previous studies, the significant results in work per repetition, peak power, and starting and middle angular velocities are that stretching does not have a positive effect at 240°, which requires instantaneous maximum power, but increases strength when exercising at low angular velocities. It was reported that muscle strength ultimately increases enhancing the length-tension relationship.[33] This improvement is thought to have a significant impact on the intermediate angular velocity at which lower extremity functions can be used efficiently because the alignment of the tendons that had been bunched up becomes parallel again and improves. Isokinetic exercises can generate

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maximum muscle contraction throughout the entire joint range of motion.[34] Therefore, in this study, we were able to show changes in the functional performance of the lower extremities based on normal mobility after a stretching intervention.

Previous research suggests that it is effective not only to relieve mechanical stress directly applied to the lumbar region by relaxing the tense or shortened muscles around it through stretching, but also to apply stabilization exercises that strengthen the muscles and ligaments.[35] In future studies, rather than comparing the amount of change through self-stretching alone, it may be more statistically significant to combine stretching with exercises that can increase additional back flexibility or to compare long-term changes over 6 weeks rather than immediate comparisons. Limitations of this study include the small number of subjects, making it difficult to generalize, and because it was applied as a single-shot stretch, the period was shorter than the typical experimental period. It is expected that the physical burden on subjects will be reduced if sufficient rest time is provided between each measurement experiment. Lastly, it seems necessary to lengthen the intervention period and investigate whether there are lasting changes after the end of the exercise. Even in the control group, significant differences were found in the sit and reach test, 3-hop jump test, and Sargent jump test when comparing pre-and post-evaluation. According to previous research, the same evaluation was conducted twice before and after, and the pre-assessment acts like a warm-up exercise, increasing isokinetic muscle strength and extensor power, thereby improving the muscle function of the lower extremities. In addition, it is performed as a high-intensity-low-repetition exercise and is thought to improve muscle nerve efficiency by increasing motor nerve conduction velocity and the Hmax-to-Mmax ratio.[36] Therefore, in future studies, if a post-evaluation is conducted with sufficient rest time after the pre-evaluation when evaluating the control group, it is believed that the effect of lower extremity function on lumbar flexibility will be clearly identified.

The purpose of this study was to investigate changes in lower limb flexibility and isokinetic parameters after applying back stretching to randomly selected adults. As a result, it was found that the experimental group that performed lumbar stretching was more effective in terms of flexibility, functional evaluation, and isokinetic parameters. The increased lumbar flexibility was achieved through stretching and the establishment of an appropriate force relationship. This led to significant improvements in the 3-hop jump test, primarily due to the viscoelastic properties of the hamstring muscles operating within their normal range of motion. In isokinetic parameters, peak torque, work per repetition, and peak power showed significant results at intermediate angular velocities. This was especially evident at 240°, which requires maximum instantaneous power during stretching. Although it did not have a positive effect, it is thought to have had a significant effect at intermediate angular velocities where lower extremity functions can be used efficiently because stretching aids in creating an appropriate length-tension relationship and balances and realigns the bundled tendons. Therefore, incorporating back stretching into the daily routines of modern people who sit for prolonged periods will contribute to smooth performance and the improvement of daily life.

CONCLUSION

The purpose of this study was to investigate changes in lower limb flexibility and isokinetic parameters after applying back stretching to randomly selected adults. As a result, it was found that the experimental group that performed lumbar stretching was more effective in terms of flexibility, functional evaluation, and isokinetic parameters. This increased lumbar flexibility through stretching, forming an appropriate pairing relationship, and as a result, significant results were seen in the 3-hop jump test due to the viscoelastic properties of the hamstring muscles within the normal range of motion. In isokinetic parameters, peak torque, work per repetition, and peak power showed significant results at intermediate angular velocities, specifically at 240°, which requires maximum instantaneous power when stretching, although it did not have a positive effect. This effect is attributed to the benefits of stretching, which helps to create an appropriate length-tension relationship and balances and realigns the bundled tendons. This is because, at these velocities, lower extremity functions can be used efficiently. Therefore, it is expected that applying daily back stretching to the lives of modern people who sit for long periods will contribute to smooth performance and enhancement of everyday life.

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