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The Effects of Nordic hamstring exercise on the different surface to muscle strength, proprioception and postural sway in healthy adult

Eun-Bi Bong[1], Ji-Soo Kwak[2], Hyun-Ji Jung[3], Jeong woo Jeon[4], Ji-Heon Hong[5], Jae-Ho Yu[6], Jin-Seop Kim[7], Dong-Yeop Lee*[8]

[1,2,3] Student, Dept. Physical Therapy, Sun Moon Univeresity, Asan-si, 31460, Republic of Korea

[4]PhD student, Dept. Physical Therapy, Sun Moon Univeresity, Asan-si, 31460, Republic of Korea

[5,6,7]Professor, Dept. Physical Therapy, Sun Moon Univeresity, Asan-si, 31460, Republic of Korea

*[*8] Professor, Dept. Physical Therapy, Sun Moon Univeresity, Asan-si, 31460, Republic of Korea*

qhddmsql@naver.com[1], xxxjisoo@naver.com[2], jhj0373@naver.com[3],
doublej_woo@naver.com[4], hgh1020@hanmail.net[5], naresa@sunmoon.ac.kr[6],
skylove3373@hanmail.net[7], kan717@hanmail.net*[8]

Corresponding author[*]: Dong-Yeop Lee, mobile Phone: +82-010-4421-7177

Abstract

Background/Objectives: The purpose of this study is to investigate the changes of postural sway and eccentric muscle strength and proprioception on an unstable surface during the Nordic Hamstring Exercise (NHE).

Methods/Statistical analysis: Forty male adults participated in this study. All subjects are randomized into groups of stable and unstable surfaces. NHE is administered three times a week for four weeks, with two measurements of muscle strength, proprioception, and postural sway before and after exercise. Paired t-tests were used to compare the differences before and after intervention in the group, and independent t-tests were used to compare the difference of effects between groups.

Findings: As a result of this study, there was a significant difference in the joint position sense of knee and hip in the comparison between groups($p<.05$). However, there was no significant difference in muscle strength and postural sway. In the comparison between the groups, the joint position sense of knee and hip was not significantly different in the control group, but in the experimental group. There were also significant differences in muscle strength in both the control and experimental groups, and postural sway was significant only in the experimental group.

Improvements/Applications: Considering these findings, this study may help to design a more effective exercise for athlete and elderly people

***Keywords*:** Nordic Hamstring exercise, Eccentric exercise, Proprioception, Muscle strength, Postural sway, Unstable surface

1. Introduction

These days people spend their free time exercising. However, exercise would be the most frequent cause of injury. So, preventing injuries is regarded as one of the important things in doing exercise [1,2]. For the recent years, a lot of studies have been conducted in an effort to identify risk factors for injury, develop preventive measures or optimize a way of exercising [3]. Nordic Hamstring Exercise (NHE) requires high level of muscle activity compared with other types of hamstring exercise [4] and is one of the eccentric exercises to prevent sports players from getting injured in sports rehabilitation [5]. NHE has reduced the incidence of primary hamstring injury by 60% and activating hamstring at knee and hip joints has increased eccentric strength of hamstring more effectively [6] than other types of exercise [7,8]. Hamstring injury can largely occur when hamstring contracts at maximum speed or rapidly accelerates, or in outdoor sports. Also hamstring damage accounts for 12% of lower limb injury and the causes are age, past injury experiences, abrupt muscle activity, lack of flexibility, muscular fatigue, etc. The long head of biceps femoris is one of the hamstring muscles where muscle injury occurs most frequently and accounts for 53~68% of all hamstring injuries. Hamstring plays an important role in daily life activity including walking, running, jump, etc. [9,10]. It also is used to stabilize knee joint in walking. Also, it is activated for a period of swing phase of short

distance running [11,12] and is important for posture adjustment when a person is standing still [13].

Postural stability is defined as an ability to maintain the center of gravity of a body within Base of Support (BOS) [14,16]. Postural sway means maintaining the center of gravity with minimal position sway on unstable surface and keeping posture within the range of stability [15,17]. When a person is standing still, tiny posture sway occurs even with minimal movement. In other words, sway of center of gravity in a human body occurs repeatedly in front and back, right and left direction and this sway takes irregular and complex forms [18]. The ability to adjust posture is maintained by input of signals of visual system, vestibular system and proprioception. And these sensory functions should be integrated to improve this ability [19,20]. Therefore, an increase in postural sway is related to muscular weakness and lack of proprioception [21].

Components of proprioception include joint position sense and the tension, strength, sense of muscle. The information of the proprioception is comprised of 5 receptors including vestibular system, joint receptors, muscle spindle, Golgi Tendon Organ (GTO), skin receptor. Vestibular organ is essential to the proprioception. And muscle spindle is important in detecting the location and movement of joints because a change in the length of muscle and the speed of muscle contraction is sensed by muscle spindle. Joint receptor is important in detecting the location of joints and is usually activated the most at end-range of motion. Golgi Tendon Organ is located within tendons of a body and contributes to regulating the strength and tension of muscle. Skin receptor detects the pressure, contact and transformation of skin. The proprioception is one of the important things to prevent injury because it senses such factors and controls them in a human body. So motion control ability and joint stability resulting from enhanced proprioceptive sense can reduce injuries such as hamstring damage, anterior cruciate ligament tear, etc [22].

Unstable support surface improves posture strategy to increase the ability to adjust and control posture by creating disturbance, compared with movement on stable support surface [16]. It is suggested that neuromuscular system can be stimulated on unstable support surface more than stable support surface. According to theoretical basis, unstable training environment enhances neuromuscular adaptation and training specificity and as a result it can provide various effective training stimulation [23]. Also, exercise on unstable support surface is believed to make significant impacts on the muscle strength and muscle endurance of teenagers and young adults, and improve the strength, postural adjustment ability and proprioception [23,24].

So far study results have been reported showing that hamstring exercise can be effective in proprioception of knee joints and postural control. Hamstring is composed of biceps femoris muscle the outside, and semimembranosus muscle and semitendinosus muscle the inside. And as two-joint muscles, it contributes to the movement of hip and knee joint [25,26]. Therefore, it is important to study these two joint changes [22]. And there is little research that investigates the difference in changes of the proprioception and posture sway on after the support surface-based Nordic Hamstring Exercise (NHE) among hamstring strengthening exercises. That is why this research will study the support surface-based Nordic Hamstring Exercise (NHE) can make impacts on the changes of strength of the extensor muscles of hip joints and the flexor muscles of knee joints, and the changes of joint position sense and postural sway among other proprioceptive senses of hip and knee joints and it is intended to be the basic data that can be used for further research.

2. Materials and Methods

2.1. Participants and design

Researchers in this study recruited 50 healthy male students of S university in A city who play sports such as basketball, football, baseball, tennis, running, etc. twice or 3 times a week. Subjects with severe damages or neurotic disorder and those who already participated in other exercise programs were excluded. And those who were recruited in the study program but had less than 90% of participation rates were also excluded from the final data analysis. After excluding 10 subjects who did not satisfy the selection criteria and were applicable to exclusion criteria, total 40 subjects were selected for the research. General characteristics of all subjects such as height, weight, age, were measured and the subjects were randomly assigned into an experiment group and a control group [Table 1]. Then, muscle strength, proprioception, and postural sway were measured in advance before intervention. And interventions for an experiment group and a control group were performed on unstable support surface and stable support surface for 4 weeks. After 4 weeks of intervention, the muscle strength, proprioception, and postural sway were measured in the same way they were measured prior to the intervention [Figure 1]. Researchers provided all subjects with the explanation of the purpose, content, process of the study. And subjects who agreed to the written consent form finally took part in the study. The study was conducted according to the process approved by Institutional Review Board (IRB) of Sunmoon University.

Table 1. General Characteristics of the study subjects (N=40)

	Experimental group	Control group
Age (years)	21.53±1.42	21.07±1.43
Height (cm)	169.30±7.10	170.40±7.80

Weight (kg)	67.83±4.50	68.15±5.60

Mean ± standard deviation

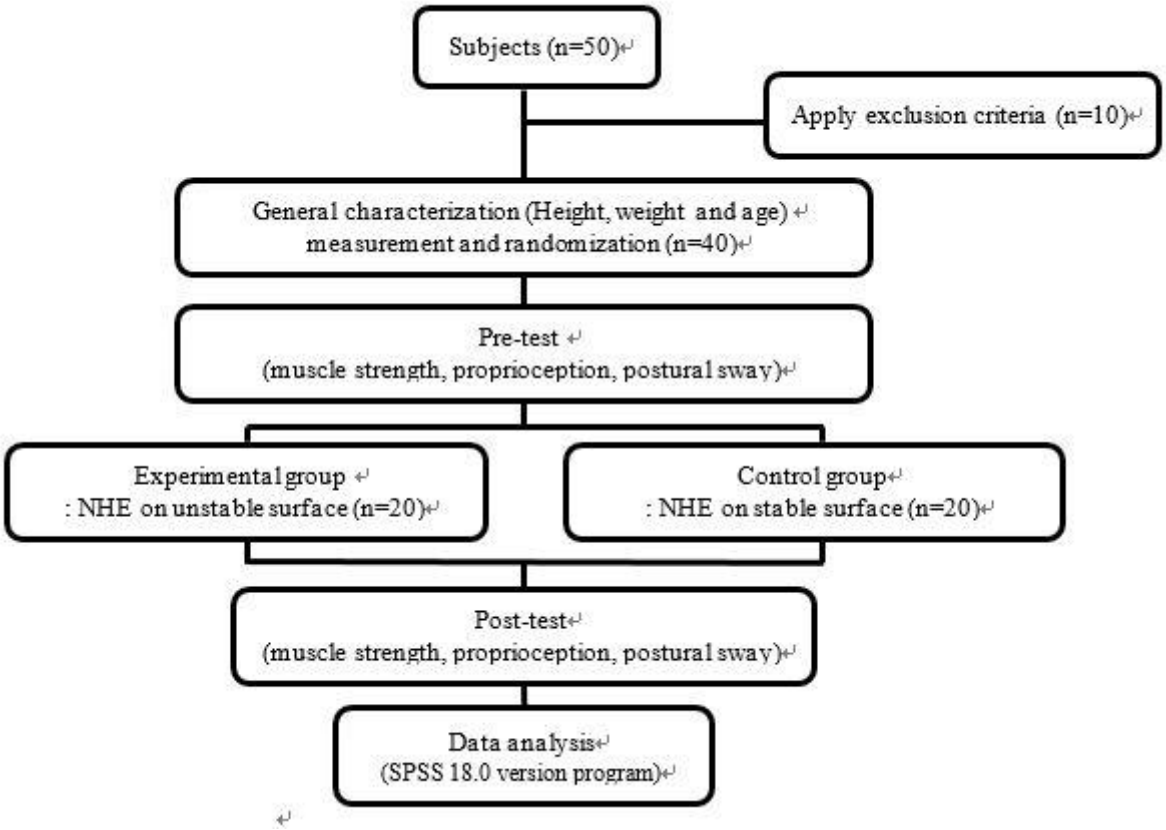

Figure 1. Experiment protocol flow chart

2.2. Experimental procedures

Subjects were asked to perform NHE for 4 weeks. NHE in an experiment group was conducted on unstable support surface, and NHE in a control group was conducted on stable support surface. The starting position of NHE was kneeling with upright state of trunk over a mat on the ground, knees flexed 90° and both arms placed in front of the body [Figure 2-A]. An examiner held the legs of the subjects. The participants slowly lowered whole of trunk toward the ground as far as possible and maintained the posture for 3 second. They were asked to incline the trunk with using the strength of hamstring until it was not able to resist gravity. And then they were asked to land by reaching out their arms when the trunk touched the ground [Figure 2-B]. Lastly, they were asked to return back to the starting point. This process was regarded as one-time. One-time of NHE was performed for 6 second. 1 set was comprised of three-times exercises and total 2 sets were performed. There was an interval of 2 minutes between each set. And interventions were undertaken three days a week (total 4 weeks).

A: Starting position B: End position

Figure 2. Nordic hamstring exercise

2.3. Measurement

Isokinetic dynamometer (CSMI, CSMI solutions, USA, 2010) was used to measure muscle strength and proprioception and Tetrax Balance System (Tetrax Ltd., Ramat Gan, Israel) was used to measure postural sway.

2.3.1. Muscle strength

To assess eccentric muscle strength of subjects, the extensor muscles of hip joints and the flexor muscles of knee joints of the dominant limb were measured. The dominant limb was the one to feel more comfortable when the subject kicked a ball. Peak torque was measured at 60 and 180 from degrees/sec. When the flexor muscles of knee joints were measured, the subjects were asked to sit a dynamometer chair. The chest and thigh were fixed with a strap. A resistance pad was placed approximately 2 cm above the lateral malleolus to prevent interference with dorsiflexion of the ankle [Figure 3-A]. When the extensor muscles of hip joints were measured by a dynamometer, the subjects were asked to be in a supine position. Their chests were fixed with a string, and the subjects were required to place non-dominant limbs on a scaffold. After that, a resistance pad was put approx. 7 cm above the knee [Figure 3-B]. To familiarize the subjects with the equipment and procedures, three practice trials of sub-maximal contraction and three practice trials of maximal contraction were performed and then 2 min of rest were allowed. During eccentric peak torque measurement, the researcher encouraged verbally the subjects. A set consisting of five repetitions was measured twice, with a 90-sec rest after each set.

2.3.2. Proprioception

The proprioception of dominant limb is regarded as joint position sense and it was evaluated by the passive positioning at target angle and the difference values of active repositioning performed by the subjects. To measure JPS of knee joints, the subjects were asked to sit in a dynamometer chair with hip joint flexed to 90 degrees. A tibial pad was placed 3 cm above the lateral malleolus [Fig. 3-A]. To measure hip joint, the subjects were asked to be in a supine position on a dynamometer chair with hip joint extended. The resistance pad was placed at 7 cm above knee joint [Figure 3-B]. In order to minimize the influence of other senses except the proprioception, eyes were closed, and the headphones were worn. The target angle was set at 45°. The subjects' knee joint and hip joint were passively extended at an angular velocity of 2°/sec. This angular velocity was selected to limit the reflexive muscle contraction of the muscles. When the knee joint reached the target angle, it was stopped for 10 s and the subject was asked to remember the angle. The knee joint was returned to the starting position and the target angle was actively reproduced by the subjects. Three measurements were repeated, and the evaluator did not provide any feedback to the subjects during the evaluation. After each test, the subjects were instructed to walk in the lab for 30 s to reduce the learning effect. To obtain the absolute error value, the difference between the target angle and the mean of the repositioning angle produced by the subject was calculated.

A: Knee joint B: Hip joint

Figure 3. Eccentric strength and joint position sense measurements in an isokinetic dynamometer

2.3.3. Postural sway

The posture stability was measured through standing with one dominant leg. Tetrax Balance System reflects the pressure changes of the plate and the movement of pressure center. And it is comprised of 4 force plates to locate the heels and front parts of both feet of the subject and it can be measured. This study placed a wooden plate 30 cm in length and 3.5 cm in height on center parts of 4 force plates precisely and attached 4 non-skid pads on them in order to measure in a standing position with one dominant leg and evenly distribute weight [Figure 4-B]. The center of the wooden plate was marked by a pen to locate one foot [27]. The subject put their dominant leg on the center of the plate. Then when the subject with eyes open was told to raise ‘a non-dominant leg’, they kept the non-dominant leg for each 30 secs with knee flexion 90° and hip flexion 45°[Fig.4-A]. At this time, the subjects were asked to place

the two fingers of both hands lightly on a horizontal bar in front of waistline to prevent the trunk in a standing position from moving toward one direction [28].

A: Tetrax Balance System B: Plate for one leg standing

Figure 4. Postural sway measurement

2.4. Statistical analysis

The values of all variables were calculated as mean and standard deviation. To compare the differences between pre and after intervention within a group, paired t-test was used. And to compare the differences in effects between groups, independent t-test was used. SPSS 18.0 version program was used for all statistics analysis and significance level of statistics was set less than .05.

3. Results and Discussion

The strength of muscles were 60°/sec and 180°/sec and measured at both hip and knee joints. As a result, when knee flexion and hip extension, the action of hamstrings, were measured as 60°/sec, 180°/sec, there were no significant differences between stable surface-based intervention group and unstable surface-based intervention group. But there were significant differences within the experiment group and control group respectively ($p<.05$) [Table 2]. When the position senses of hip joint and knee joint for each two intervention groups were compared, there were significant differences between the groups ($p<.05$). However, there were no significant differences in the position senses of hip joint and knee joint within the control group, and there were significant differences in the experiment group ($p<.05$) [Table 3]. As a result of comparing general stability index (GST) of stable and unstable surface-based intervention groups, there were no significant differences within the control group and there were significant differences within the experiences ($p<.05$). Also, there were no significant differences in comparison between the experiment group and control group [Table 4].

Table 2. Comparison of inter groups and between groups of knee flexor, hip extensor strength

Muscle	Angular velocity (°/s)	Experimental group				Control group				Between groups	
		pre	post	t	*p*	pre	post	t	*p*	*t*	*P*
Knee flexor (Nm)	60	78.35±11.79	97.85±18.54	-6.41	.00	81.60±9.42	94.50±13.34	-5.55	.00	-.66	.52
	180	62.65±12.70	77.90±11.79	-9.05	.00	61.40±9.95	81.45±8.79	-17.39	.00	1.08	.29
Hip extensor (Nm)	60	139.20±13.25	160.05±9.02	-8.68	.00	140.05±16.04	158.10±15.76	-10.00	.00	-.48	.63
	180	87.40±10.52	104.60±14.12	-7.20	.00	80.45±9.14	100.45±11.66	-11.36	.00	-1.01	.32

Mean ± standard deviation

Table 3. Comparison of inter groups and between groups of knee, hip proprioception

Joint	Experimental group				Control group				Between groups	
	pre	post	t	*p*	pre	post	*t*	*p*	*t*	*P*
Knee (Degree)	7.86±1.87	2.26±0.63	13.76	.00	7.29±6.59	4.89±5.39	1.97	.06	2.17	.04
Hip (Degree)	11.90±6.26	2.44±2.14	7.97	.00	10.49±7.47	7.31±4.15	2.15	.05	4.67	.00

Mean ± standard deviation

Table 4. Comparison of inter groups and between groups of postural sway

postural sway	Experimental group				Control group				Between groups	
	pre	post	t	*p*	pre	post	*t*	*p*	*t*	*P*
NST	43.24±1.20	39.08±1.77	8.67	.00	42.06±6.46	41.46±10.51	.24	.82	1.00	.33

Mean ± standard deviation

The strength of muscles were 60°/sec and 180°/sec and measured at both hip and knee joints. As a result, when knee flexion and hip extension, the action of hamstrings, were measured as 60°/sec, 180°/sec, there were no significant differences between stable surface-based intervention group and unstable surface-based intervention group. But there were significant differences within the experiment group and control group respectively ($p<.05$) [Table 2]. When the position senses of hip joint and knee joint for each two intervention groups were compared, there were significant differences between the groups ($p<.05$). However, there were no significant differences in the position senses of hip joint and knee joint within the control group, and there were significant differences in the experiment group ($p<.05$) [Table 3]. As a result of comparing general stability index (GST) of stable and unstable surface-based intervention groups, there were no significant differences within the control group and there were significant differences within the experiences ($p<.05$). Also, there were no significant differences in comparison between the experiment group and control group [Table 4].

The study recruited 40 healthy adult men and tried to figure out how Nordic hamstring exercises on stable support surface and unstable support surface would affect the muscle strength, proprioception, postural sway of knee joint and hip joint. The results of this study showed that muscle strength significant differences before and after the experimental and control groups. The proprioception showed significant differences between the two groups, and only the experimental group showed differences in the before and after intervention comparisons, and finally, the postural sway indicates significant differences in the comparison before and after the intervention in the experimental group.

NHE is widely used in injury prevention and rehabilitation exercise for sports players [5]. According to this study, both groups which performed NHE on unstable and stable support surface showed great muscle enhancement effects. But there were no differences in muscle enhancement between the stable support surface group and unstable support surface group without NHE. As NHE requires high level of hamstring muscle strength and muscle activity [4], both groups showed the improvement of muscle strength despite different support surface conditions used in this study. That is why any difference does not appear between two groups.

Douglas and et al. reported that eccentric contraction activated muscle cell activities and metabolic sign pathway unlike afferent or isometric contractions [29]. Also they said that eccentric resistance exercise enhanced the muscle strength and vertical jump performance more effectively than afferent resistance exercise [30]. In addition, eccentric muscle exercise was reported to effectively prevent injuries by affecting the form of muscle and inducing changes in neuromuscular regulating [31]. The Nordic hamstring exercise (NHE) using eccentric contraction of hamstring is well known as an exercise that can make positive impacts on muscle forms and muscle activity [32]. Leg curl is also an exercise that increases the muscle activity of hamstring, but The Nordic hamstring exercise (NHE)

is much more effective in inducing muscle activity, compared with leg curl exercise [33]. So the Nordic hamstring exercise (NHE) can increase the cross section areas of biceps femoris muscle and semitendinosus muscle comprising hamstring [34].

When support surface is becoming unstable more, ankle joint strategy is changed into hip joint strategy and the hip joint strategy is applied to postural adjustment. Actually, in difficult tasks such as posture adjustment in narrow support surface, hip joint strategy is used more [35]. Also Hansson and etc. reported that the proprioception sense affected the posture stability most [36]. These studies imply that exercises on unstable support surface increase stimulation in proprioception sense and posture stability. Therefore, this study measured posture stability such as one leg standing on a narrow support surface to compare the effects of the Nordic hamstring exercise (NHE) on unstable support surface. And proprioception sense of two joints (hip and knee) influenced by hamstring was measured. Motions used in sports, fitness, daily life are usually made on unstable support surface. So, an alternative usage of unstable support surface requires higher level of physical ability of a person and can be included in training program to stimulate muscle and postural adjustment. And training on unstable support surface is reported effective in improving muscle and postural adjustment even for the elderly who is vulnerable to outdoor exercise [23].

The Nordic hamstring exercise (NHE) is a high intensity eccentric muscle strengthening exercise [4]. The subjects of the study were in their 20s and had no difficulty in performing NHE. But it was believed that it would be difficult for seniors with decreased muscle strength to perform NHE. Therefore, it is expected that when seniors perform lower level of functional tasks on unstable support surface instead of NHE, these tasks will make positive impacts on postural sway and proprioception.

The study has several limitations. First, 40 of 50 subjects took part in the study due to injuries and withdrawing. 20 subjects were assigned into two groups (unstable support surface and stable support surface) and the number of subjects was small so it should be careful to generalize the study results. Second, the postural stability measuring equipment used in this study has a principle that uses the distributed measured weight on 4 force plates and assesses the postural stability. It means that when subjects stood and got their feet on the force plates, postural stability for posture adjustment and distribution of weight are measured. However, in this study, since separate plates were placed between the subject and the equipment to measure one leg standing, there was possibility that delicate measuring failed. Third, only static postural adjustment was used to measure the ability to maintain posture. To evaluate the ability to maintain posture, static and dynamic postural adjustment should be assessed. But this study didn't conduct the measurement of dynamic postural adjustment. Lastly, to evaluate proprioception sense, there are methods such as joint position sense, kinesthesia, force sense, etc. These measurement methods are to assess proprioception sense but each one reflects different factors. The problem is that this study only uses joint position sense as a way of measurement. In the future, other kinematic effects on unstable support surface as well as NHE should be investigated. Also, it is necessary to develop a new invention to clinically apply to unhealthy subjects with impaired ability to regulate muscle strength and to adjust posture.

4. Conclusion

This study targeted 40 health adult men and investigated effects of Nordic hamstring exercise on unstable support surface in muscle strength of knee joint and hip joint, proprioception, and postural sway. In conclusion, NHE on unstable support surface was more effective in increasing proprioception and maintaining postural sway than on stable support surface, but there was no difference in improving muscle strength. But NHE implemented on each surface is regarded as a way to enhance muscle strength. Therefore, NHE is considered as an effective exercise to improve muscle strength and prevent injury.

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