



Original Article

The Acute Effect of Static Stretch Alone and in Combination with Dynamic Exercise on Some Functional Indices in Athletes with and without Hamstring Tightness

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ABSTRACT

Background: The aim of this study was to investigate the acute effects of static stretch alone and in combination with plyometric exercises on some functional indices in athletes with and without hamstring tightness.

Methods: For this controlled laboratory study, 20 female athletes with hamstring tightness and 15 female athletes with normal hamstring participated voluntarily in static stretching exercises or stretching in combination with plyometric exercises in two consecutive days after warm up, with a random stretching order. The maximum voluntary hamstring isometric strength, maximal vertical jump, and Y balance test were also measured.

Results: The results indicated that both static stretching and stretching in combination with plyometric exercises may affect balance more adversely in athletes with hamstring tightness. Both types of stretching programs may also cause adverse effects on balance, muscle strength, and maximal vertical jump ($P < 0.05$).

Conclusion: According to the results, the level of balance of individuals with hamstring tightness may be affected more adversely through static stretching exercises. Thus, we suggest that the static stretch should not be prescribed for athletes with hamstring tightness at the warm up of training sessions.

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Introduction

In the past, it was thought that regular stretching improves flexibility and thus it can reduce the risk of injury and lead to recovery [1]. Accordingly, regular stretch was suggested as a principal component of the training program such as warm up and cool down [2]. However, a recent study has indicated that pre-workout stretch may adversely affect the muscle strength and probably does not decrease the risk of injury [3]. Nevertheless, the physiological basis of these findings has not been well understood [3].

In addition, the general theory states that some types of stretching exercises can affect muscle structural and

nervous components and may decrease muscle ability to generate force [4-6]. Based on previous studies, performing static stretching is not recommended during warm-up before exercise [7]. Static stretching for at least 30 seconds seems to reduce muscle power and strength, while the ballistic or proprioceptive neuromuscular facilitation stretching does not have the same effect [8-10]. It has also been shown that static stretching exercises alone or in combination with dynamic exercises are not efficient to improve strength, jumping, and sprinting performance [11].

However, as mentioned above, performing static stretching is not recommended immediately before performing strength and power exercise [7-10]. Thus, use or non-use of stretch training in athlete with hamstring tightness remains controversial. On the other hand, it has been suggested that static stretch training can be replaced with dynamic stretch training. Thus, we hypothesize that

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static stretch in combination with plyometric exercises can be used as part of warm up before strength and power exercises in subjects with hamstring tightness.

Considering the results obtained from the effects of stretching as outlined above, and given that most studies have been conducted on subjects who appeared to be free from limited range of motion, the effects of pre-workout stretching exercises should be tested on the performance of athletes with tightened muscle groups. Accordingly, this study was designed to investigate the effect of stretching exercises on the maximum isometric strength, power, and balance in subjects with and without hamstring tightness.

Methods

The present research is a controlled laboratory study including 35 volunteer female students between 19 and 25 years old, from Allameh Tabataba'i University who had at least 3 sessions of exercise training per week from all sports, and at least from 3 years ago. The research method was approved in terms of ethical considerations in the department of corrective exercises and sport injuries, Allameh Tabataba'i University, Tehran, Iran. Prior to the start of the research, general information about the research methods was presented to the subjects during a briefing session both verbally and in a written form. The subjects were assured that they could leave the research any time they wished. All subjects underwent hamstring length measurement before starting the study; based on the findings they were divided into two groups: athletes with and without hamstring tightness. The subjects fulfilled and signed informed consent form before the study.

The following cases were excluded from the test procedure: women who were in the menstrual period, those with obvious musculoskeletal abnormalities (including kyphosis, scoliosis, genu valgum, genu varum, etc.) based on the New York assessment tool [12], presence of a lower limb injury interfering with exercising, history of fracture or surgery of the spine, pelvis or lower extremities and any other conditions which disturbed the test process. Tightness of hamstring muscles was investigated through an Active Straight Leg Raise Test (ASLR) based on a previous study [13], where subjects with more than 20 degrees of ROM limitation were considered as hamstring tightness [14].

The test was performed on two consecutive days and a kind of stretching protocol was established every day based on a random order. In order to study the effects of static stretching alone and in combination with plyometric exercises, after a 10-minute general warm-up, the maximum voluntary isometric strength of hamstring muscles, the Y balance test and maximum vertical jump height were recorded in a random sequence. The subjects then performed the stretching protocol and immediately after that, measurements were repeated with the same pre-test sequence. Arrangements of stretching on the desired muscle groups as well as the order of the stretching implementation of the protocols specified here for each day were randomly determined for each

individual. Subjects were asked not to participate in intense activities 24 hours before the test.

Stretching was performed for only 20 seconds to the threshold of person's discomfort on the quadriceps, hamstrings, as well as the right and left calves. The muscles in the non-dominant side were always stretched [11].

Stretch Programs

Static stretching alone: a 20 second of static stretching exercises with 50 seconds of time interval between each stretching was prescribed for rectus femoris, hamstrings, and *gastrosoleus* muscles based on previous studies [11].

Static stretching combined with plyometric exercises: In this state, the subjects performed the same stretching exercises as before (both sides, randomly and up to the pain threshold) at the same time for each muscle group. However, for performing plyometric exercises with stretching, a shorter stretch (5 seconds) with 4 repeats was performed.

The exercises involved the muscles of the right and left sides and immediately after that, dynamic plyometric exercises were performed at a distance of 15 meters. The dynamic exercises involved the same muscle groups (fast knee pulling, fast kickback from the knee joint, fast up and down movements of ankle joint for quadriceps, hamstrings and calf). The participants stayed in a fixed position for 20 seconds between involvements of each muscle group [11].

The Maximum Hamstring Isometric Strength Test

A tensiometer cable with high reliability (Intra Class Correlation (ICC)=0.99-0.88) [15] was used to measure the maximum isometric strength of hamstring muscles. To run the test, the individual laid in the prone position while the hip joint was in a normal state with the knee situated in 90 degrees of flexion.

The tensiometer cable was fixated to a wall from one side. Further, it was positioned on the lower posterior side of the leg to the ankle on the other side while being covered with a pad to protect the foot. The subject was asked to apply a maximum contraction for 4 seconds. The test was repeated twice with 10-second intervals. Finally, the best record in kilograms was considered as the performance of the individual [16].

Vertical Sargent Jump Test

Bosco et al reported the reliability coefficient $r=0.95$ for this test [17], and in this study the test procedure was performed based on the previous study [18]. The test was repeated twice and the best performance was calculated as the score of the subject.

Y Balance Test

Plisky et al reported a high reliability (the inter-rater reliability of the test was about 0.85-0.91 and the interrater reliability was about 0.99 to 0.001) for this test [19]. Prior to the beginning of the test, the subject's dominant foot was determined. The subject was asked to kick a ball in front of her on the ground to determine her dominant foot. The person repeated this activity 3 times. The foot used at least 2 times to shoot the ball was considered as

the dominant leg [20]. If the right leg was the dominant foot, the test was performed counterclockwise, while it was done clockwise for the left. The test procedure was performed based on previous studies [19, 21]. The test procedures and data extraction were performed again based on previous studies [19, 21].

Statistical Methods

The Shapiro Wilk test was utilized to evaluate the normal distribution of data. In order to compare the post-test results by eliminating the possible effects of pretest measures in each session, one-way ANCOVA was employed. The dependent t-test was run to compare within subject's effect of stretching exercises. All statistical analyses were done at a significance level of 95% ($P \leq 0.05$).

Results

The anthropometric data of the two groups are summarized in Table 1. It was observed that there was no significant difference between the two groups in terms of age, height, and weight. A significant difference was only observed in the length of hamstring (≤ 0.05).

To compare the effect of static and combined stretching exercises on variables of the study in the two groups, one-way ANCOVA was run by considering the pre-test scores as covariate. The results revealed that the effect of static stretching exercises ($P=0.004$) and combined exercises ($P=0.031$) differed on the balance of the two groups. However, there was no significant difference between them in terms of the effect of these on the maximum isometric strength and maximum vertical jump height ($P > 0.05$). Further details are shown in Table 2.

To examine the difference in the balance variable, plots were drawn for both groups over time. The results revealed that the scores of balance after static stretching exercises in hamstring tightness group were reduced while it improved in the normal group. On the other hand, the results of the balance test were associated with improvement in both groups after combined stretching. The improvement of the line slope in the normal group was greater than in the hamstring tightness group (Figures 1, 2).

Discussion

The results of this study revealed that the mean changes in the maximum isometric strength and maximum vertical jump in both experimental and normal groups were not significantly different after performing the two stretching protocols. There was, however, a significant difference in the balance response following the two stretching protocols.

The results indicated that static stretching had adverse effects on Maximal Voluntary contraction (MVC), vertical jump height, and balance in subjects with tightened and normal hamstring. Also, the study demonstrated that combined stretching had no adverse effects on balance, the vertical jump height of both groups, and MVC of subjects with hamstring tightness.

Further, based on the comparison of post-test measures, there was no significant difference between the two protocols for vertical jump and hamstring strength. It seems that the results obtained from the muscle strength and vertical jump in line with the results of a previous study which found they are significantly inter-correlated [22]. Note that the researchers found no study directly

Table 1: Individual characteristics of the subjects in the experimental and normal groups (20 cases in experimental group, 15 individuals in normal group, *: significant differences were observed)

Group	Normal group	Tight hamstring	P value	t
Variable	Mean±standard deviation	Mean±standard deviation		
Age (year)	23.37±1.58	23.30±1.75	0.810	-0.58
Height (centimeters)	162.86±3.833	161.67±4.878	0.776	0.781
Weight (kg)	55.25±7.534	56.34±6.128	0.463	-0.472
BMI	20.788±2.212	21.54±2.151	0.312	-1.028
Hamstring length (degree)	15.00±2.00	25.750±3.058	*0.000	-11.825

Table 2: The within-subject and between-subject analysis for comparing the effect of static and combined stretching exercises in the two groups (20 subjects in experimental group, 15 subjects in normal group, *: significant differences were observed)

Variable	Type of Stretch	Group	Mean±standard deviation		Within subjects effect		Between group effect			
			Pre test	Post test	t	P value	F	P value	Power of test	Effect size
Maximum isometric strength (newton/Kg of body weight)	Static	Tightened	9.05±1.57	8.51±1.60	4.91	*0.001	0.046	0.832	0.055	0.001
		Normal	9.82±1.62	9.33±1.85	2.26	*0.040				
	Combined	Tightened	8.75±1.62	8.48±1.51	1.82	0.084	0.843	0.366	0.145	0.026
		Normal	10.03±1.81	9.35±2.12	2.36	*0.034				
Balance (percent)	Static	Tightened	104.31±7.58	103.62±5.55	0.76	0.460	9.44	*0.004	0.846	0.228
		Normal	104.33±7.06	108.53±09.62	-2.91	*0.011				
	Combined	Tightened	102.39±7.79	103.16±5.02	-0.85	0.409	5.08	*0.031	0.590	0.137
		Normal	106.71±7.95	109.51±9.23	-2.58	*0.022				
Maximum vertical jump (cm)	Static	Tightened	28.55±5.31	27.23±4.96	2.92	*0.009	0.022	0.884	0.052	0.001
		Normal	30.43±2.73	29.13±3.33	2.41	*0.030				
	Combined	Tightened	28.60±5.08	27.78±4.83	1.87	0.076	0.251	0.620	0.077	0.008
		Normal	30.17±3.39	29.50±3.67	1.31	0.213				

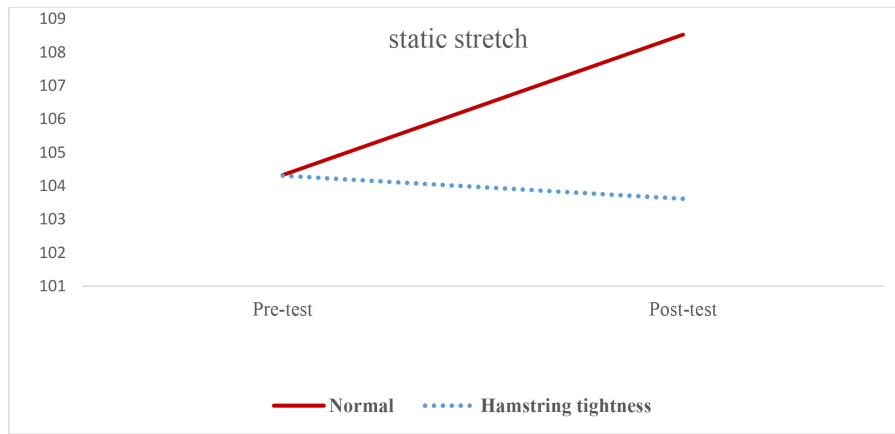


Figure 1: Changes over time for the balance test scores in the two groups following the static stretching training (20 subjects in experimental group, 15 cases in normal group)

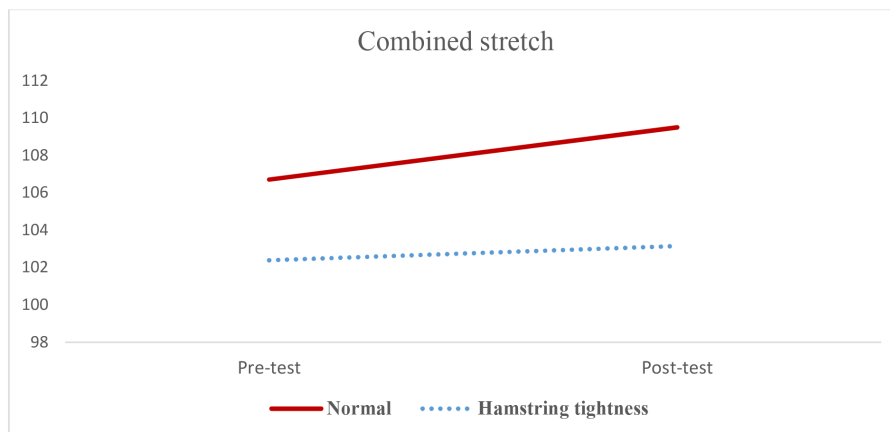


Figure 2: Changes over time for balance test scores in the two groups following the combined stretch training (20 cases in experimental group, 15 subjects in normal group)

focusing on this issue, so these results are not comparable with others in the field.

According to Robinie et al, stretching has a negative effect on power, even when its duration is limited [23]. Ogura et al stated that a 30 second static stretch did not lead to a subsequent decline in isometric strength of the hamstring muscle, but 60 seconds of stretching led to a significant reduction [24]. The results of our study are consistent with the results of the research by Fortier et al. (2013), Stafilidis & Tilp (2015), and Kendall (2017) on healthy subjects. Based on the study of Fortier et al, it was shown that 20 seconds of static stretching alone and in combination with dynamic exercises did not affect the performance of the maximum force and sprint, while the vertical jump height was significantly reduced ($P < 0.5$) [11]. Stafilidis & Tilp found that the static stretch stimulus (15 or 60 seconds) was insufficient to make adaptation in the mechanical morphological properties of the lower limb musculotendinous unit. Thus, it affects neither the jump performance nor the MVC [7]. Also, having compared the acute effects of static and dynamic stretching with and without active warm-up on anaerobic performance, Kendall observed no significant difference either between these methods [25].

Based on our findings, it can be suggested that static stretching as well as stretching in combination with plyometric exercises with duration of 20 seconds does not affect the performance of the maximum strength in healthy people and people with hamstring tightness

before exercising. In a certain muscle, maximal intrinsic contraction force depends on the length of the muscle [26]. Structures that are affected by stretching may include tendons and connective tissues, cytoskeleton elements, actomyosin cross bridges, and central nervous system pathways [27]. Muscle length affects the muscle force production capacity as excessive stretching and inadequate length reduce the interaction (overlapping) of actin and myosin [26]. Also, the stretching of the muscle tendon unit reduces the reflexive-spinal excitability. In acute conditions, the reduced irritability may lower inactive stress and increase the range of motion of the joint. Stretching programs in the long run reduce the tonic reflex activity, which greatly increases the flexibility [28].

However, it seems that the maximal voluntary isometric force is not affected much by the muscle length alone. On the other hand, the short duration of stretching (20 seconds) seems to be insufficient to cause physiological changes in the muscle tissue. One explanation for this finding may be the fact that the acute response to the stretching exercise of humans with hamstring tightness does not differ from that healthy ones. No study has been conducted up to now on the effect of stretching on the function of people with muscle tightness.

According to the results of comparing intra-group mean of vertical jump performance in the pre-test and post-test of normal and hamstring tightness groups, a slight decrease was observed. The results obtained for the relationship between power performance and vertical

jump may suggest that these two variables confirm each other. The findings of this study were inconsistent with the findings of Christopher Murphy (2008). Murphy conducted a study to determine the effects of static and dynamic stretching on the maximal muscular strength and the range of motion of the knee and thigh in university-age men. They reported that static and dynamic stretching movements with a duration of 20 seconds before a vertical jump could enhance the mean height of vertical jump, maximum power, and range of movement of knee as well as thigh in male athletes participating in this study who did exercise for recreational purposes [29].

The results of this study revealed that static stretching exercises alone caused an instantaneous increase in the dynamic balance performance in the healthy group and a slight reduction in the performance of the hamstring tightness group. Also, combined exercises led to a rapid significant improvement in the balance performance of both groups including healthy cases and those with hamstring tightness, though the rate of improvement was small in the hamstring tightness. Elsewhere, researchers reported that static stretching with 45-second duration did not have much effect on the balance, and the stretching protocol lasting 15 seconds can improve the balance performance, reduce postural instability, and boost strength [30]. In a study by Chatzopoulos et al to compare the acute effects of three different stretch protocols on balance, agility, reaction time, and upper limb movement time, significant improvements were reported in both static and dynamic stretch types for all variables except the reaction time, where this improvement was greater after dynamic stretch [31]. Erkut et al also found that both static and dynamic protocols improve balance performance after examining the effect of static and dynamic warm-up protocols on balance performance [32].

Studies which were conducted on healthy subjects, are partly consistent with the results of this study on the normal group. However, the results of present research are in line with the outcomes of a study by Behm et al. (2004). They investigated the short-term effects of static stretching on power parameters, balance, reaction time, and movement time on 14 healthy male students. It was reported in their study that the balance was reduced after applying static stretch. One explanation for these controversies may be that these studies prescribed different stretching time in their exercise protocols [6]. Few studies were found on the effects of stretching on balance. Further, the effect of stretching exercise has not been investigated in any studies on the balance of individuals with hamstring tightness.

One of the limitations of this research was examining only the short-term effects of stretching exercises. Since the samples with hamstring tightness seem to have some adaptations to compensate for this shortcoming in the body, it is better to pay special attention in future research to long-term effects. This research was only conducted on female athletes and thus, its data may not be generalized to all athletes. In the current study, the maximum isometric strength of the hamstring muscle was measured while the main function of hamstring muscles seemed to be eccentric contractions [33]. Thus,

examination of eccentric muscle strength following the stretching training may provide more valuable findings.

Conclusion

The present study indicated that the effect of stretching protocols was different among female athletes with hamstring tightness and healthy subjects. Further, the level of balance of individuals with hamstring tightness may be affected adversely by static stretching exercises.

Conflict of Interests: None declared.

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