Investigation of Gluteus Medius and Biceps Femoris Activity in Three Plyometric Exercises

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ABSTRACT

Purpose: This study was accomplished to investigate the electromyographic activity of 3 plyometric exercises (tuck jump and single leg hop in sagittal and frontal planes) to find out the appropriate procedures for strengthening biceps femoris and gluteus medius muscles.

Methods: The kind of study is applied and data were collected from the supervised exercises of 15 male athletes without injury of lower extremity from Tehran University, which participated voluntarily in this research. It was assumed that subjects expend the extreme potential during their activities. Statistical analysis was made using repeated measures ANOVA to investigate the muscle activity in feedforward and feedback phases of landing with SPSS 20.

Results: Significant differences ($P \leq 0.05$) were found between treatments in relation to feedforward and feedback phases of muscles activities. Single leg hop in sagittal and frontal planes showed the highest activity of biceps femoris and gluteus medius in feedforward phase, respectively. Nevertheless, tuck jump demonstrated the lowest activity of these muscles in both phases.

Conclusion: According to the results, single leg hop in sagittal and frontal planes could be the most appropriate exercises for improving strength and neuromuscular system of gluteus medius and biceps femoris. We should take special attention to these 2 plyometric exercises in exercise programs. However, tuck jump in comparison with 2 other exercises show less effectiveness.

Keywords:

Knee joint, Plyometric exercise, Electromyography, Anterior cruciate ligament

1. Introduction

Various studies show that anterior cruciate ligament (ACL) injury is one of the most common injuries among athletes [1] and different mechanisms are proposed for that [2,4]. Approximately, 70% of ACL injuries are related to doing exercise, and about 70% of ACL injuries are non-contact type [4,5]. The association between neuromuscular impairments and risk of non-contact ACL injury leads to design neuromuscular exercise programs for its prevention [6,7]. Changing pattern of muscular activity in some neuromuscular exercises can reduce the ground reaction force and balance in landing, which will reduce ACL injury [8]. These neuromuscular exercises mostly include plyometric, balance, and agility exercises [9,10].

Plyometric exercises are one of the main parts of neuromuscular exercises in prevention and rehabilitation exercises [9,11,12]. These exercises also can reduce of maximum ground reaction force, knee valgus and hip joint adduction in landing [11,13], which play a critical role in preventing of injury [11].

Renstrom et al (1986) reported that hamstring muscles have a protective effect on ACL [14] and these muscles generate dynamic stability for knee through resistance

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against tibia's anterior shear forces [15]. Hewett et al (2005) reported increasing knee valgus angle in jump-landing predict the danger of ACL injury in adult women. Therefore, restriction of knee valgus movement in practice and competition may reduce risk of ACL injury [16]. In closed kinetic chain (such as cutting, pivoting, and landing) knee valgus motion is generated through combination of adduction and internal rotation of femur. Because the gluteal muscles, particularly gluteus medius, make an eccentric resistance for these movements [17], more activity of these muscles will restrict knee valgus movement [17-19]. Plyometric exercises improve strength and power of hamstring and gluteal muscles. These muscles, however in some plyometric exercises, may not be strengthened to the same extent. Unfortunately a little information is available about the activity of hamstring and gluteal muscles through these exercises [20-24]. Thus, focusing on the activity of the hamstring and gluteal muscles in plyometric exercises helps prepare an appropriate training program.

Previous studies have been mostly focused on the study of plyometric exercises and activity of knee muscles through jump landing with changing height [20], or examining gender differences [24]. Thus, there are few studies examined activity of muscles around hip and knee in more than 2 exercises [21,22]. The purpose of this study was to investigate the gluteus medius and biceps femoris activity of male collegiate athletes in 3 plyometric exercises to determine the appropriate plyometric exercise that strengthen hamstring and gluteus medius to support ACL and limit knee valgus motion.

2. Materials and Methods

The kind of this research is applied and after filing the informed consent form, 15 collegiate male athletes from Tehran University participated voluntarily. Volunteers played basketball and handball for three sessions in a week and in each session they had at least half an hour exercise. They had no history of knee injury or knee surgery, no knee pain at the time of the study, and no lower extremity injury in the 6 months before the study. They had average 174 ± 6 cm height, 65.1 ± 4.4 kg weight, and 23 ± 1.6 years old. The study was approved by the Tehran University research ethics committee and was carried out in Physical Education College of Tehran University.

To investigate the activity of muscles, we used a ME6000 surface electromyography device (Mega Company–Finland) with bipolar silver-silver chloride surface electrodes (diameter 2 cm, SKINTACT, Australia) with input impedance= 1012 Ω, common mode rejection ratio= 110 dB, gain range= 1000 dB, and cut off frequency of 8-600 Hz. We also shaved the hairs and cleaned the areas with alcohol to make the skin ready and reduce the resistance.

To locate the position of electrodes, palpation of bony land marks and isometric contraction have been used. Electrodes were located in the direction of muscle fibers. Location of gluteus medius electrodes is in the middle of the distance between great trochanter and external side of iliac crest, 5 cm posterior to anterior superior iliac spine and 3-4 cm lower than iliac crest [25] and the reference electrode was placed on anterior superior iliac spine [26]. Biceps femoris electrodes located right between ischial tuberosity and fibula's head [25] with reference electrode on tibia tuberosity [26]. All electromyographic data were collected from dominant foot and with sampling frequency of 1000 Hz.

The plyometric exercises used in this study are the most common ones that were used in previous studies [9,11-13]. After complete description of each exercise (Table 1), each subject did these exercises 5 times (to be insured that subjects learned these exercises adequately). Then subjects performed each exercise 3 times with maximum effort to jump. The mean electromyographic activity in 3 jumps was considered for calculations (3 repetitions is selected in order to have more valid data because more than 3 replicates ensue fatigue that have effect on muscle activity). The order of doing these exercises for each subject was in random (so that exhaustion would not have a persistent effect on the exercise). After doing each exercise, subjects rested for one minute.

Electromyographic activity of each muscle was calculated in 2 phases of feedforward and feedback. Feedforward phase in a time span of 200 ms (from 160 ms before foot contact until 40 ms after foot contact) [27] and feedback phase in a time span of 100 ms (from 40 ms before foot contact until 140 ms after foot contact) [27] was considered. Electromyography data were analyzed by root of mean square (RMS) in 15 ms windows. Maximum voluntary isometric contraction (MVIC) of muscles was collected during knee flexion and hip abduction (respectively for biceps femoris and gluteus medius) [28]. To allow comparison among subjects, EMG values obtained by RMS were normalized to the MVIC of each muscle; and muscle activity was considered as a percentage of MVIC (%MVIC). Each MVIC was repeated twice and each time for 3 seconds and their average was used.

Table 1. Plyometric exercise descriptions.

Exercise	Description
Tuck jump	From standing position, The subject jumps upward, then bring both knees up as high as possible at the highest point of the jump.
Single leg hop in sagittal plane	The subject stands on the dominant foot then jump forward in the sagittal plane to make a maximum displacement and landing with the dominant foot.
Single leg hop in frontal plane	The subject stands on the dominant foot then jump toward the non-dominant leg in the frontal plane to make a maximum displacement and landing with the dominant foot.

SPSS Base 20.0 for Windows (SPSS Inc. Chicago, IL) computer program was used for data analysis. Repeated measures analysis of variance was applied for each muscle. When a significant main effect was found, post-hoc analysis for pairwise comparisons would be carried out. Significance level was established at the 0.05 level.

3. Results

Table 2 and figures 1 and 2 show the %MVIC of muscles in each exercise.

Results of one way repeated measures showed there is only significant difference in the feed forward activity of biceps femoris ($F(2,42)=6.741$, $P=0.013$) (Figure 1 and Table 2). Upon post-hoc analysis, feed forward activity of tuck jump is significantly lower than two other exercises.

Significant differences between exercises were found for gluteus medius activation during both the feed forward ($F(2,42)=4.21$, $P=0.027$) and feedback ($F(2,42)=5.041$, $P=0.019$) phases (Figure 2, Table 2). Post-hoc analysis determined that single leg hop in frontal plane demonstrated a significantly greater gluteus medius activity than two other exercises in the feed forward phase. Tuck jump, also, demonstrated a significantly lower gluteus medius activity than two other exercises in feedback phase.

4. Discussion

In this research we tried to investigate the gluteus medius and biceps femoris activity of male athlete's during 3 plyometric exercises. Based on the results of this study, more effective exercises on the activation of hamstring and gluteus medius could be determined. Preliminary findings of this study showed that single leg hop in frontal plane has the highest activity of gluteus medius in both phases. Furthermore, single leg hop in sagittal plane has the highest activity of biceps femoris in both phases. Tuck jump has the lowest activity of these muscles.

In this research, because feedforward activity is more important than feedback activity [29], we did not compare feedforward phase to feedback phase. Also, as the types of these exercises are different, we overlooked the relation between jumping height and muscle activity.

Krosshaug et al (2007) reported that ACL injury would take place about 17 to 50 ms after foot contact [29]. Seegmiller and McCaw (2003) stated that the first maximum ground reaction force would occur in the range of 10 to 18 ms after the first contact. According to the findings of these researchers, we tried to determine the most important time frame to investigate the feedforward and feedback activity of gluteus medius and biceps femoris muscles.

As it was mentioned in the results, feedforward activity of gluteus medius in single leg hop in frontal plane has a significant difference compared to other 2 exercises. Gluteus medius, which is the most effective abductor muscle of femur for controlling its movements on pelvic and pelvic on femur [30,31], has the highest activity in

Table 2. Mean EMG values of plyometric exercises for the feed forward and feedback phase (mean±SD).

		Tuck jump	Single leg hop in frontal plane	Single leg hop in sagittal plane
Feed forward	Gluteus medius	0.31±0.09	0.59±0.14 *	0.43±0.14
	Biceps femoris	0.13±0.07 α	0.22±0.07	0.33±0.17
Feedback	Gluteus medius	0.46±0.2 α	0.92±0.26	0.83±0.27
	Biceps femoris	0.18±0.12	0.24±0.11	0.27±0.12

*: is significantly more than the other two exercises.
α: is significantly fewer than the other two exercises.

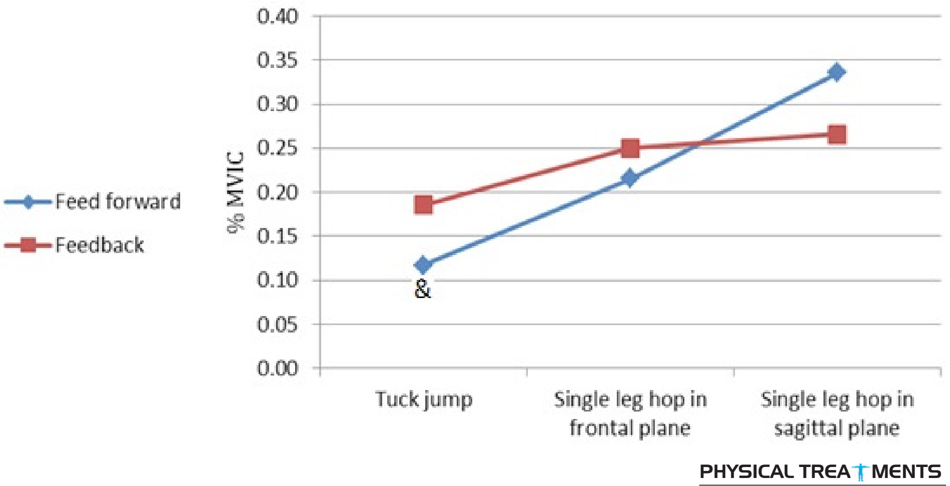

Figure 1. Feedforward and feedback activation of biceps femoris. &: Feedforward activity of biceps femoris in tuck jump is significantly lower than the other two exercises.

single leg hop in frontal plane to control pelvic stability and prevent internal rotation and adduction of femur.

Lawrence et al (2008) investigated the strength of abductor and external rotator muscles of females' lower extremity during single leg landing. They reported that stronger females showed lower ground reaction force and valgus compared to weaker females [32]. Also Hewett et al (2005) declared that asymmetrical activation of proximal muscles like gluteus medius during landing and cutting maneuvers will increase the risk of ACL injury [8]. The findings of this research show that gluteus medius in single leg hop in frontal plane has the most activity and, it could be the most effective exercise to strengthen this muscle.

Biceps femoris is ACL-antagonist and strength of this muscle is important for injury prevention [14,15]. The results of this study indicate that biceps femoris activity in different plyometric exercises is various. Single leg hop in sagittal plane demands the highest activity of this muscle that is in contrast with the findings of Ebben et al (2006). They reported that hamstring has a different activity in plyometric exercises [22].

However, they did not mention the method of doing plyometric exercises, so we cannot discuss about the reason of this contrast between these two results. These results are in line with the results obtained by Struminger et al (2013) [21], although our findings show greater amounts of muscle activity. Likewise, Rezaimanesh et al (2011) and Chimera et al (2004) observed increase in electromyographic activity of biceps femoris after doing

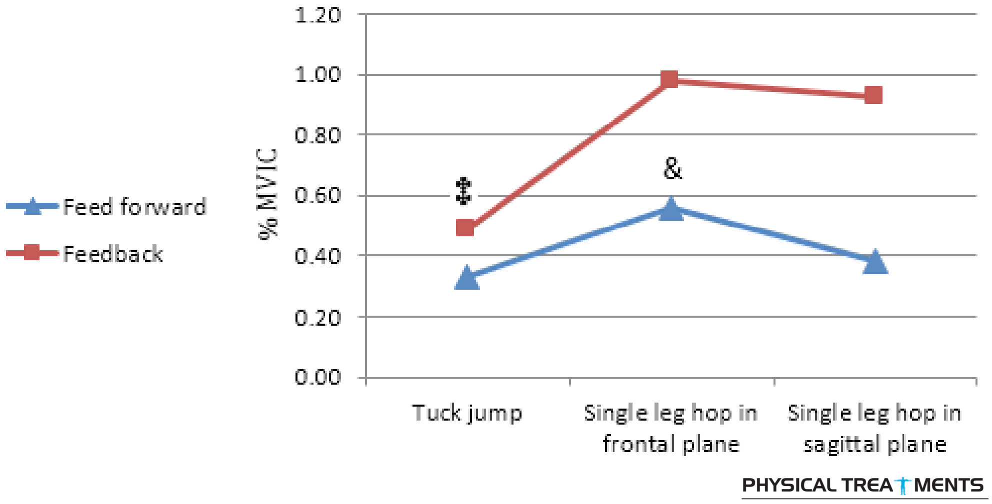

Figure 2. Feedforward and feedback activation of gluteus medius. & : Feedforward activity of gluteus medius in single leg hop in frontal plane is significantly higher than the other two exercises. ‡: Feedback activity of gluteus medius in tuck jump is significantly lower than the other two exercises.

plyometric exercises [12, 33], and this activity increase can reduce anterior displacement of tibia [34]. According to these discussions and obtained results, single leg hop in sagittal plane could be a good exercise for reinforcement and improving activity pattern of this muscle.

We expected to observe more hamstring activity in tuck jump due to increased distance of foot from the ground in landing. But, in line with the findings of Peng et al (2011) no significant difference was observed in hamstring activity with increasing height [20]. In this study, also, gluteus medius in feedback phase has a significantly less activity compared to other 2 exercises that will increase the risk of injury. Basketball, volleyball, and handball disciplines have the most risk of ACL injury [1] and one of the most important moments to take place injury in these sports is landing time [2, 4].

The results of this research and the findings of Peng et al (2011) demonstrate that hamstring activity is approximately fixed when landing height increases, quadriceps activity increases and gluteus medius activity is low. Thus, this muscle imbalance will increase the risk of injury. Finally, tuck jump in comparison with other two exercises has less benefit.

Based on these results, single leg hop in frontal plane and single leg hop in sagittal plane could be the most appropriate exercises for improving strength and neuromuscular system of gluteus medius and biceps femoris.

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