Six-Week Progressive of Hip-Focused Exercises: An Alternative to Promote Dynamic Stability Following Anterior Cruciate Ligament Reconstruction

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(Received: *February 14, 2019*; Revised: *May 10, 2019*; Accepted: *May 23, 2019*)

ABSTRACT

Anterior Cruciate Ligament Reconstruction (ACLR) is a very successful method to restore mechanical stability of knee joint. However, significant instability can be found as a consequence of joint proprioception deficit and muscle weakness. The aim of the study was to determine the effects of progressive hip-focused exercises on dynamic postural control using the center of pressure (COP) variables. Recreationally active male who underwent ACLR were allocated into two groups (Exercise; n=13, control; n=10). The six-week progressive of hip-focused exercises were constantly performed on both legs, three times a week. A force platform was used to evaluate the changes in COP velocity after landing from a jump with the reconstructed leg. The subjective International Knee Documentation Committee (IKDC) was also used to evaluate the knee function. The results showed that, decreasing COP velocity has been detected for both mediolateral (ML) and anteroposterior (AP) direction ($p<0.05$). Participants in the exercise group has also showed greater changes for 36.38 and 42.73 percent from baseline of ML and AP direction, respectively. The IKDC score was also significantly increase (93.72±3.92; $p<0.01$) compared to the control. (77.92±9.19; $p<0.01$). Functional stability may have altered after returned to play following the ACLR. In order to attain the better performance, strengthen the hip muscles would benefit the dynamic stability in individuals with ACLR.

Keywords: Anterior cruciate ligament reconstruction, Hip-focused exercises, Dynamic postural control

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Introduction

The center of pressure (COP), normally, is calculated from ground reaction forces. To quantify postural control, various parameters, for example, mean sway amplitude, minimum-maximum sway amplitude, peak-to-peak amplitude, sway path, sway velocity, Root-mean-square (RMS) amplitude, and RMS velocity have been used deriving from the COP data. Previously studies, [1-2] both in research and clinical practice, have used COP velocity, which is represents the total distance traveled by the COP over time, [3] to evaluate changes in COP. Increasing of the velocity is thought to indicate a decrease of the ability to control body's position which related in both mediolateral (ML) and anteroposterior (AP) directions. Basically, the postural control system, involves multiple interactions including sensory input, motor control and biomechanical components. [4]

It has been reported that static postural control was impaired in the injured knee compared to the uninjured controls in patients with Anterior Cruciate Ligament Reconstruction (ACLR). Static postural control is valid measurement to determine the restoration of knee functions. Measuring the dynamic postural control may also provide important information to confirm the readiness to return to sport after ACLR. [5-8]

The study of biomechanics has become an important aspect of Anterior Cruciate Ligament (ACL) injury and rehabilitation. Paterno MV et al [9] have been suggested that a subsequent ACL injury more tend to occur in those who altering hip kinetics and knee kinematics, and decreasing single-leg stability. Moreover, a deficiency of proximal neuromuscular control in both frontal and transverse planes is one of the factors to incline the injury. The relationship between hip muscle strength and knee kinematics has been extensively studied. [10-11] Weakness in hip muscles, particularly hip abductors, extensors and external rotators, has been identified as a contributor to valgus knee motion which increases injury on the ACL. These findings suggested that hip strength may play a significant role in limiting faulty lower extremity mechanics. Thus, the development of hip-focused exercises has led to the hope that individuals who have ACL injury may have progressive in the rehabilitation. Furthermore, a systematic review study of Ford KR et al [12] has also suggested that strengthening hip exercises 2-3 times a week continue for at least 6-12 weeks may promote size and strength of the muscle.

Therefore, the purpose of this study was to determine whether the dynamic postural control, is improved following completed the progressive hip-focused exercises. And also to evaluate the knee functions in the patients with the history of ACLR.

Method

Participants

Twenty-three recreationally active male in ages between 18 and 35 years, had undergone ACLR between one and three years and be able to return to play volunteered for the study. The injured time more than three years prior to reconstruct, previous serious knee pain and/or surgery, positively in pivot shift testing, and limit knee range of motion

were excluded. The participants were allocated into two groups. (Exercise; n=13, control; n=10) All participants provided inform written consent approving by The Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

Hip-focused exercise

According to the Study by Kristen Boren et al [13] in 2011 , The six-week progressive of hip-focused exercises consists of five exercises; clam-shell exercise, side-lying hip abduction, single-leg squat, front plank with hip extension and side plank with hip abduction. These exercises has been shown to provide maximal electromyography of Gluteus muscles in healthy population. The exercise program were constantly performed on both legs. Participants in the exercise group were continuously met at the laboratory three times a week until completed the total six weeks. A warm-up and stretching were ensured for five minute before performing 10-12 times per set with two minute rest in between for overall three sets. Conversely, the control group were advised to maintain their regular activities and were engaged to complete the test at the sixth week as if the exercise group.

Figure 1 hip-focused exercises

Procedures

The single leg jump-landing test was perform at before (pretest) and after (posttest) the entire of the exercise program. The participants wore athletic shoes and were instructed to stand behind a 70 cm mark away from the center of a force platform (Bertec FP4060-07-1000, Sampling rate 1,000 Hz). They were asked to perform anteriorly jump with both feet, hit the target tab on Vertec setting at 50% of the maximal jump height [14] and firmly land on the force platform with the reconstructed leg, then hold the motionless position for 10 seconds. Any hopped-landing, target-missing or touching the other foot on the ground was rejected. All participants were asked to complete total five successful jump-landing with one minute rest between trials.

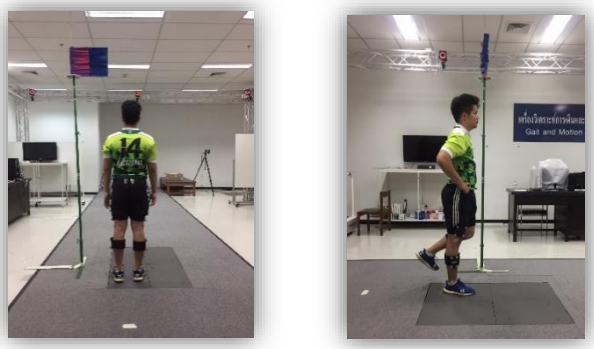

Figure 2 the single leg jump-landing test

The subjective International Knee Documentation Committee (IKDC), scoring from 0-100 with the higher scores represents the better function, was also used to evaluate the knee functions. All participants were asked to complete the evaluation form which is validated in Thai version [15], at the beginning and ending of the data collection.

Statistical analysis

Differences in demographic data between groups are showed in mean and standard deviation. To evaluate the COP velocity if there was difference, nonparametric statistics was completed. Independent sample t-test was used to compare the IKDC scores between the exercise and control group. Statistical analysis was performed using SPSS for windows (Version 23.0, IBM Corporation, NY). The statistical significant was considered at $p<0.05$.

Results

Participants' demographic characteristics are shown in Table 1. There were no significant difference between groups. Among all participants, they committed on running for 34.78 %, football for 30.43 %, and rugby for 13.04 %, and others (basketball, badminton and hockey) for 21.74 %.

Table 1 General characteristics (Mean±SD)

Variables	Control (n=10)	Exercise (n=13)
Age (y)	25.10±5.42	23.92±4.64
Weight (kg)	77.22±7.47	78.48±12.70
Height (m)	1.74±0.03	1.73±0.04
BMI (kg/m^2)	25.31±2.54	26.26±4.64
Time since surgery (y)	1.7±0.82	1.92±0.75

Table 2 COP velocity of the exercise and control group (Mean±SD)

Group		COP Velocity (mm/s)			
		Baseline standing		Jump-Landing	
		ML	AP	ML	AP
Exercise	Pretest	5.76±2.97	5.88±3.12	8.14±4.52	13.14±10.06
	Posttest	4.71±2.08	3.83±2.81	5.17±2.05	7.52±3.55
	% Changed	18.31	34.92	36.38	42.73
Control	Pretest	4.51±2.83	3.54±2.50	3.30±1.64	6.43±2.39
	Posttest	3.92±3.61	2.45±2.20	3.56±1.66	6.70±1.76
	% Changed	12.98	30.7	7.74	4.17
p-value		0.279	0.087	0.039*	0.046*

** Significant difference between groups (p<0.05)*

There was a significant difference of percent changing in COP velocity of jump-landing test, both in ML (p=0.039) and AP (p=0.046) between the exercise and control group. In addition, the participants in exercise group has also showed greater of percent changing in the COP velocity (ML=36.38%; AP=42.73%) compared to the control. (ML=7.74%; AP =4.17%) However, there was no significant difference of percent changing in COP velocity measuring at baseline standing between groups. (Table 2) Moreover, significantly increase IKDC scores were founded in the exercise group compared to the control (Table 3).

Table 3 The International Knee Documentation Committee scores between groups (Mean±SD)

IKDC (Score)	Control	Exercise	*p* value
Pretest	77.87±10.51	84.94±12.70	0.22
Posttest	77.92±9.19	93.72±3.92*	< 0.01

** Significant difference between group (p<0.05)*

Discussion and Conclusion

The current study demonstrates that the hip-focused exercises have benefits on the dynamic postural control in patients with ACLR. The results from this study show improvements to control the body's position following a single leg jump-landing. After six weeks of completing the exercise, decreasing in COP velocity was detected. This finding was interpreted as learning effect resulting in a better coordinate of neuromuscular system.

Previously prospective studies have provided the information that abnormality movement patterns of the trunk, hip, and knee are associated with an increasing of ACL injury. It is commonly known that quadriceps and hamstrings muscle group working together as a dynamic stabilizer, mainly, to control the sagittal plane movement of knee joint. However, functional activities particular in athletic skills need an appropriate cooperation of all motion plane. We founded that the COP velocity of participants in the exercise group was significantly decrease from baseline, for both ML and AP directions. Similarly, the study by Paterno MV et al [16] has also reported a significantly improved in AP single-leg postural control, but not in ML direction, after conducted the six-weeks neuromuscular training program which particularly to reduce the ACL injury risk factors. The hip-focused exercises in the current study extensively involve frontal, sagittal and transverse planes of lower extremity movements. Indeed, the exercise program was allowed the activation of hip abductors, hip extensors, hip external rotators, both knee extensors and flexors including core stabilizer muscle groups to control the stability.

The IKDC evaluation form widely used in orthopedic and sports medicine to assess the symptom, sport activities and knee functions. We also observed the significantly improvement of functional knee scores in the exercise group. Study of Han F et al [17] has supported that those who had supervised rehabilitation presents the satisfying functional knee scores with higher opportunities returning to previous level played compared to the control. Moreover, Garrison JC et al [18] has reported the significantly improved of the dynamic balance and functional knee scores after completed the early hip strengthening exercises in patients with ACLR. These may suggesting that controlling of proximal part promotes not only the stability but also the function of knee joint.

The study also has some limitations. We only analyzed data from the reconstructed leg. In fact, biomechanical studies have revealed the changes- after injury or even surgery of lower extremity mechanics – both in the injured and contralateral limb. Moreover, we have evaluated the subjective knee functioning score so it is also difficult to affirm that there was improvements in muscle performance. Accordingly, we may not directly compared these exercises position with others weight bearing activities. Additionally, trunk biomechanics would be the other important factor to control the stability of leg. Further research should investigate the kinematics as well as kinetic in order to ensure the advantages of the rehabilitation program.

In conclusion, the findings reveal that the functional stability may have altered following the ACLR. The hip-focused exercises help not only the stability of leg but also the functional knee scores. In order to attain the better performance, strengthen the hip muscles would benefits the dynamic stability in individuals with ACLR.

Acknowledgement

This study was supported by Ratchadapiseksompotch Fund, Faculty of Medicine, Chulalongkorn University, grant number RA61/034.

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