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The Effects of Static and Ballistic Stretching on ACL Shear Forces

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Abstract: The anterior cruciate ligament (ACL) injury is a common occurrence in sports requiring stop-jump task. In an attempt to reduce ACL injury rates during stop-jump tasks, neuromuscular and proprioceptive training programs have been developed to reduce an athlete's risk of injury. The purpose of this study was to determine the effects of static and ballistic stretching techniques on the anterior knee shear force during forward stop-jump in trained men. The study samples consisted of 15 healthy trained men who attended to the laboratory 3 times in 3 other days (the effects of previous stretching to be completely faded). All kinetics and kinematics data from Force Plate and Motion Analysis System were used in Matlab for inverse dynamic analysis. One-way analysis of variance test and Paired Samples T-Test were used to analyze the data. Paired Samples T-Test showed a significant effect of static stretching technique on anterior shear force. One-way analysis of variance test showed the interaction of the anterior knee shear force of all groups. This study revealed that the anterior knee shear force was significantly decreased. Moreover, Tukey test showed a significant effect in acute static stretching technique ($P \leq 0.05$), whereas there was no significant difference in Ballistic stretching. The results of this study suggested that applying static stretching technique before forward stop-jump task can decrease the peak anterior shear force. This means ACL injuries can be prevented after this stretching technique. Collectively, it is suggested that athletes, coaches and physiotherapists can use static stretching technique for preventing the ACL injuries.

Key words: Anterior Cruciate Ligament · Kinematics · Kinetics · Static Stretching Technique · Ballistic Stretching Technique · Stop-Jump Task

INTRODUCTION

The biomechanics of santerior cruciate ligament (ACL) has been studied from different perspectives such as anatomical observation, mathematical modeling, ACL force measurement and ACL displacement measurement [1-5]. Although landing and/or deceleration before a change in direction (what happens in sports such as basketball, handball and volleyball) are cited when discussing non-contact ACL injury mechanisms [3, 5], studying these mechanisms and identifying their various dimensions are still of interest of researchers. One of the joint forces that can increase ACL strain and lead to ligament rupture is tibia anterior shear force [6]. It has been shown that over 70% of ACL ruptures occur in a non-contact situation, specifically during closed chain movements requiring rapid decelerations of the body's center of mass [7] such as; cutting, pivoting, stopping, or landing.

In an attempt to reduce ACL injury rates during stop-jump tasks, neuromuscular and proprioceptive training programs have been developed to reduce an athlete's risk of injury. Decreases in ACL injury rates associated with these intervention programs have been attributed to a number of biomechanical changes during stop-jump [8]. The altered lower extremity position has been suggested to decrease ACL injury risk.

Also there have been many research studies regarding the role of leg muscles in the anterior translation of the tibia relative to the femur and loading on the ACL.

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Most studies carried out on the role of lower extremity muscles in the amount of loading on ACL have come to the conclusion that during landing, the hamstring pulls the proximal tibia posteriorly through its contraction and takes the load off the ACL and it has been referred to as the antagonist to ACL [1, 9-11]. In addition, most studies carried out in this field suggested that during landing, since the quadriceps decelerates the body due to its eccentric contraction, it produces an anterior shearing force on the proximal tibia via the patellar tendon and thus places a strain on the ACL and it has been suggested to act as the antagonist to the ACL [1, 9, 10, 12].

Exercises that stretch the muscle fibers with the aim to increase muscle-tendon flexibility, improve range of motion or musculoskeletal function and prevent injuries. Stretching is often used in sports and daily life. Several researchers have studied various stretching techniques to determine which stretching technique is most effective for changing biomechanics parameters [1]. The movement and flexibility of soft tissues around joints is an important factor to prevent injuries [13, 14]. Different ways have been used for increasing flexibility of ACL muscles group [13]. There is moderate to strong evidence that routine application of static stretching may reduce musculotendinous injuries [15]. Static and ballistic stretch techniques change biomechanics parameters of knee. Extortionate costs are paid for recovery or rehabilitation from ACL injuries [1, 16] and in addition the possibility of suffering joint diseases (e.g. osteoarthritis) remains even after the recovery and rehabilitation of the knee [17, 18]. Considering the extant literature, it seems that during landing the soleus, in concert with the hamstring, can play an important role in reducing loading on the ACL and a higher soleus-to-quadriceps peak torque ratio can be effective for reducing the possibility of ACL injuries. Thus, in this study, the stretching techniques are on these muscles.

It is totally unknown whether these stretching techniques decrease knee shear forces or not. Therefore, the purpose of this study was to determine the effects of static and ballistic stretching techniques on the knee shear forces. These items provide practical applications for the sports medicine and performance team that help athletes to have a safe act.

MATERIALS AND METHODS

Subjects: Fifteen healthy students with mean and standard deviation of (age 24.07±1.81 years, mass 70.27±6.16 Kg and height of 177.51±5.56 Cm) from department of physical education and sport sciences volunteered in this study. This study was a quasi-experimental research with pre-test and post-test.

All subjects performed the conditions in a randomized order on different days, interspersed by a minimum of 72 hours of rest. Subjects' performance was for 10 minutes under one of the following conditions: (a) no stretching, (b) static stretching and (c) ballistic stretching. Each subject provided written informed consent prior to participation in this study.

The present study was designed to investigate the effects of 2 types of stretching techniques on the anterior shear force. Before testing, we provided all subjects with identical instructions on the stop-jump protocol. We allowed each subject sufficient practice trials to become comfortable with the stop-jump procedure and to determine the preferred performance. Subjects landed on a force plate after 3 steps and then jump forward. We asked them to do this task with their highest potency (Fig. 1).

Materials: Kinematic data during the stop-jump task were recorded at a rate of 50 Hz using a 3-camera motion analysis system (Kinematrix, MIE, UK). Ground reaction forces (GRF) were collected at a rate of 200 Hz using one force plates (MIE, UK). Seven reflective markers were attached to the following bony landmarks: 1.Iliac crest, 2.Major trochanter, 3.L4.Lateral malleolus, 5.Lateral aspect of distal head of the fifth metatarsus, 6. The middle of major trochanter and lateral epicondyle of femur and 7. The middle of lateral epicondyle of femur.

Procedures: Subjects were reported to the laboratory on 4 separate occasions. The first session familiarized subjects with test procedures and equipment. In the remaining sessions, the subjects warmed up for 5 minutes and then performed the stop-jump before and immediately after stretching technique. The order of the type of stretching technique was randomized. Data collection occurred during sessions 2–4 and tests were performed at the same time of day to minimize the effect of circadian variation on performance. In each condition, the quadriceps, hamstrings and plantar flexor muscle groups were stretched, as these are prime movers in the stop-jump [19, 20]; the exception was the control group, in which no stretching was performed. Stretches included the supine gastrocnemius stretch, butterfly stretch, supine hamstring stretch, prone quadriceps stretch and kneeling quadriceps stretch [20]. To ensure consistency in the exercises, an experienced practitioner passively stretched the muscles to assist the subject in reaching his maximal range of motion. The stretches were repeated 4 times in each leg in an alternating manner so that the lower limbs were stretched for a total of 10 minutes. During the static stretching condition, the researcher passively stretched the muscle(s) to a point of mild discomfort for 30 seconds. Thirty seconds was selected because this duration is typically used by athletes [21] and has been found to increase the compliance of the musculotendinous unit [22, 23]. The ballistic condition was similar to the static stretching protocol, except that at the end range of motion, the researcher passively stretched the muscle(s) by moving forward and backward at a rate of approximately 1 bob every second for 30 seconds [24]. In all stretching conditions, each stretch was interspersed with a 30-second recovery period. During the control condition, subjects performed the standard cycle warm-up and then rested for 10 minutes so that the time between pre- and post- testing periods was consistent in all conditions.

Statistical Analyses: Joint kinematic data, joint kinetic data and ground reaction force data were exported to Matlab (2012, The MathWorks, Int.) for identification of the variables of interest. The ground reaction force data were used to calculate the maximum posterior ground reaction force (maximum deceleration force) during the initial stance phase of the stop-jump task. This point was then identified in the joint kinetic and kinematic data to determine proximal tibia anterior shear force at the point of maximum deceleration. Data were averaged across three trials. SPSS 16.0 (SPSS, Inc., Chicago, IL, USA) was used for all statistical procedures. Paired Samples T-Test was determined to compare the pre-test and post-test data. Next, a one-way ANOVA was calculated across the post-test scores of the three groups to assess if any difference existed in the post-test scores. This analysis was performed to assess whether any difference existed between the three groups (including the control group). Significance for all statistical tests and all follow-up tests was accepted at the 0.05 level of probability.

RESULTS

Table 1 presents the means and standard deviations of knee shear force in post-test of all 3 groups. Both static and ballistic stretching techniques decreased anterior shear force, but as it was seen in Table 2, paired- sample t-test showed that there is a significant reduction in post-stretch anterior shear force in the static stretching technique (P=0.016). The results of post-hoc tukey test showed no significant difference between control group and ballistic stretching technique on the anterior shear force and also it showed no significant difference between ballistic stretching technique and static stretching technique on the anterior shear force (p=0.304, p=0.043), however there is a significant difference between control group and static stretching technique group (p=0.010) (Table 3). The difference of pre-test and post-test of the three groups was shown in Figure 1.

DISCUSSION

The study hypothesis was that static and ballistic stretching would alter anterior shear force to reduce ACL loading during the stop-jump task. The results of this study demonstrated a significant decrease in anterior shear force after static stretching technique but did not

Table 1: Mean and standard deviation of knee shear force.

	Statistical Parameters		
Variable	Group	Mean	Standard deviation
Anterior shear force	Control	0.74	0.19
	Static stretching	0.49	0.26
	Ballistic stretching	0.61	0.19

Table 2: T-test analysis results of anterior shear forces of pre-test and post-test.

	Statistical Parameters				
Variable	Group	Mean Difference of Pretest and Posttest	SD	T	Sig.
Anterior shear force	Control	0.02	0.08	0.73	0.477
	Static stretching	0.26	0.38	2.73	0.016
	Ballistic stretching	0.16	0.31	2.05	0.06

* Statistical significance at $P < 0.05$

Table 3: Tukey Post Hoc (Post-test) results of the three groups

Group		Mean Difference	Std. Error	Sig.
Control	Static	0.25	0.07	0.010*
	Ballistic	0.13	0.07	0.304
Static	Control	-0.25	0.07	0.01*
	Ballistic	-0.11	0.07	0.437
Ballistic	Control	-0.13	0.07	0.304
	Static	0.11	0.07	0.437

* Statistical significance at P < 0.05

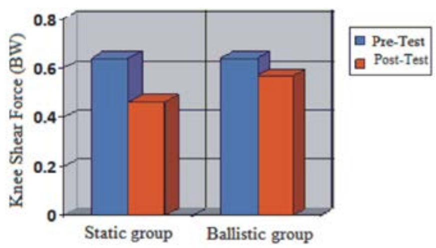

Fig. 1: Pre-test and post-test results of two stretching techniques

show any significant ballistic stretching technique effect. Hence this result does not support our hypothesis. Some studies believed that the reason of more effect of static stretching technique is the increase in metabolic processes [13]. This increases the body temperature and decreases viscosity of the muscles constrict gradually. Previous studies have demonstrated that the warm up before exercises significantly affect ACL loading in athletic tasks such as the stop-jump. The warmed- up muscles in corporate with energies and increase the tensely of the muscles and tendons [13]. Some have argued that warm-up is more important than stretching in the prevention of injuries in sports. Warm-up increases blood flow to muscles, speed of nerve impulses, oxygen and energy substrate delivery to working muscle while removing waste products and oxygen release from hemoglobin and myoglobin; warm-up decreases both the activation energy for cellular reactions and muscle viscosity. These changes prepare the body for vigorous exercise by accelerating metabolism in muscle fibers and decreasing intramuscular resistance, thus increasing both mechanical efficiency and range of motion (i.e., flexibility), as well as the speed and force of muscle contraction. And also some other research showed that in spite of increase in the range of motion in a group which ballistic stretching technique had been used, electromyography activities of muscles are more than the group which used static stretching technique [25]. On the other hand, because some researchers showed that static stretching technique increase range of motion two times more than ballistic stretching technique, therapists prefer to use static stretching technique more [26]. Some other research showed that ballistic stretching technique is effective in fast lengthening of the short muscles. But review of the literature shows that there is a threat of stimulation and this is not a reliable method [27]. It is believed that the difference in results of different studies is due to differences in research method and data analysis. Other factors like stretch during, stretch frequency, participants' age have an important role in the result of study. Our findings provide further evidence that ballistic stretching does not significantly reduce the anterior shear force. But static stretching significantly decreases the anterior shear force.

Thus, according to the results of this study, it is suggested that the athletes, coaches and therapists use static stretching technique which decrease the anterior shear forces and prevent an ACL injury.

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