THE ACUTE EFFECTS OF KNEE ON DYNAMIC HAMSTRING STRETCH DURING SIDE-STEP CUTTING IN FEMALE ATHLETES

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The purpose of this study was to investigate the effects of dynamic hamstring stretch on knee joint biomechanical parameters during side-step cutting in female athletes. Methods: Ten participants performed 45-degree side-step cutting for the pre-test and post-test and then dynamic hamstring stretch included single-leg standing with straight leg raise and straight leg hip flexion intervened after pre-test, respectively. Data were collected synchronously by 8 VICON cameras (250 Hz), 1 Kistler force plate (1000 Hz), and 5 Delsys wireless EMG sensors (2000 Hz) during side-step cutting. Results: Participants showed significantly greater hamstrings activation and muscle co-contraction (H/Q ratio) on post-test during deceleration phase at the peak valgus moment. Vertical ground reaction force and knee varus moment decreased significantly on post-test during deceleration phase at the peak varus moment.. Conclusion: Dynamic stretch could increase the activation of the hamstring, and improved buffering impact of the knee joint.

KEYWORDS: prevention of knee injury, dynamic warm-up, neuromuscular control.

INTRODUCTION: The ACL injury was the most severe knee injury, and the occurrence of ACL injury of female athletes was 2 to 4 times higher than male athletes (Arendt & Dick, 1995). When occurred the ACL injury, these consequences of ACL injury could increase the cost for surgery, rehabilitation, and psychosocial costs, such as loss of time in sport participation (Bien, 2011). The previous study found that the ACL injury often occurs during a sudden stop or changing direction movements, such as stop-jump, jump landing and side-step cutting, and these maneuvres produced the knee valgus load when the knee extension which pushed tibia forward and internally rotated, causing ACL tear (Koga et al., 2010). Besides that, McLean, Borotikar, and Lucey (2010) found that medial hamstring preactivation time correlated with external peak knee abduction (valgus) moment during single leg landing. This result confirmed the increase of medial hamstring activation in dynamic knee stability motor strategies during single leg landing. Therefore, it is essential to clarify how is the knee moment changes with the increase of hamstrings activation during the landing phase. Bien (2011) organized that many of ACL injury prevention programs have been introduced in a warm-up format and successfully decreased ACL injury risk. Some of these programs included stretch condition, and the previous study proposed that dynamic stretch could increase muscle activation and strength by post-activation potentiation in the stretched muscle caused by voluntary contractions of the antagonist (Behm & Chaouachi, 2011). Although dynamic stretch could transiently enhance muscular strength for short-term intervention, the increase of hamstrings activation could stabilize the knee joint during side-step cutting is still unclear. Thus, the purpose of this study was to investigate the effects of dynamic hamstring stretch on knee joint biomechanical parameters during side-step cutting in female athletes, and we hypothesized that the dynamic stretch could increase female athletes' hamstring activation and decreased the knee joint moment, which could further reduce the risk of ACL injury.

METHODS: This study recruited ten voluntary female college students with sports experience, such as basketball, soccer, football or rugby (height: 166.1 ± 4.5 cm, mass: 59.1 ± 8.2 kg, age: 22.7 ± 2.4 years), and their body mass index was within the normal range (18.5 ≤ BMI ≤ 27).
The criteria of the experiment:

1. To avoid too many differences in maneuvers, the participants required experience with side-step cutting.
2. When the participants performed the dynamic hamstring stretch, it required to reach hip flexion angle 90 degrees with knee extension.

3. No lower limb injury, musculoskeletal injury, or surgery within six months.

For experiment setup, five wireless EMG sensors attached on rectus femoris (RF), vastus medialis (VM), vastus lateralis (VL), semitendinosus (ST), biceps femoris (BF) of participants' dominant leg and 26 reflective markers attached bilaterally on the participants' lower limbs which were collected by infrared cameras. Participants performed a static calibration trial with all markers presented. After the calibration trial, participants completed a 5-minute walk on a treadmill as a warm-up, followed by performing 3 countermovement vertical jumps, with the highest jump used for EMG normalization. After that, the dynamic stretch protocol conducted, followed by 3 successful 45° side-step cutting. For the 45° side-step cutting, participants started from 5-meter away from the force platform and ran forward with maximum effort, planted their dominant foot on the force platform perpendicular to their approach running direction, and then accelerated off the force platform 45° to their initial running direction until past a cone 3-meter away from the force platform. We used dynamic straight leg raise and straight leg hip flexion (Herda, Cramer, Ryan, McHugh & Stout, 2008) to stretch the participants' hamstrings. Two stretches were preformed 15 repetitions using 60 beats/min, and repeated 3 times with 30-second rest between the stretches. The procedure was performed first on the dominant leg and then on the non-dominant leg.
The EMG system (2000Hz, Trigno wireless; Delsys), 8-camera motion analysis system (250 Hz, Vicon Motion Analysis) and a force platform (1,000 Hz; Kistler Instruments) used to simultaneously record the EMG signals, the 3D kinematics, and ground reaction forces (GRF), respectively, during the testing. The data was analyzed and processed synchronously using Visual 3D (C-Motion) to compute the 3D kinematic and kinetic variables, as well as the EMG variables.
The data was intercepted from the point of initial contact (IC) to the point of toe-off from the force platform. The marker coordinates and GRF signals smoothed using a fourth-order Butterworth low-pass filter with cut-off frequencies of 10 and 100 Hz, respectively. The angular kinematics computed using a Cardan sequence (X-Y-Z), in which the order of rotation as flexion/extension, abduction/adduction (valgus/varus), and internal/external rotation. A right-hand rule used to determine the polarity of the angular variables. An inverse dynamics approach used to calculate the external joint moments (Winter, 2009). The GRF and joint moments normalized to the body mass. The raw EMG signals using band-pass 20-450 Hz and full-wave rectified and filtered using a moving root-mean-squared (RMS) filter with a window size of 50 ms. The maximum RMS values of the EMG signal of each of the 5 muscles in vertical jump used to normalize the EMG of the muscle during the side-step cutting trials. The vertical jump normalization was used because of its ability to provide reproducible reference EMG value for stretch-shortening cycle movements (Ball & Scurr, 2011).
The deceleration phase identified from IC to maximum knee flexion angle. Besides, the time of peak knee valgus moment (early deceleration phase) and peak varus moment (late deceleration phase) identified as a critical time point for knee loading, which used for evaluating the ACL injury risk (Wild, Steele, & Munro, 2013). The instantaneous horizontal velocity of the center of mass (COM) at the moment of initial contact during side-step cutting calculated to quantify approach speed. The H/Q ratio calculated by dividing the average activation of the hamstrings (BF and ST) by the average activation of the quadriceps (RF, VM, and VL). The data of this study were analyzed by SPSS 23.0, and one-way ANOVA with repeated measures used for statistical test to compare the effect of dynamic hamstrings stretch. The independent variables were pre- and post- stretch, and the dependent variables were the biomechanical parameters. The statistical significance level set to $\alpha = .05$.

RESULTS: We found that there was no significant difference in knee angle after dynamic stretch at the initial contact during side-step cutting, but the center of mass (COM) velocity tended to increase (Table 1). The peak value of the knee varus moment was decreased significantly after dynamic stretch. Still, the peak value of the knee valgus moment was increased significantly (Table 2). The vertical GRF increased significantly at PK_{val}, and it decreased significantly at PK_{var} (Figure 1). Finally, the muscle activation of the semitendinosus, biceps femoris, and H/Q values significantly increased after stretch (Table 3).

Table 1: Pre and post stretch knee joint angle and COM velocity at initial contact

variables	Prestretch	Poststretch	P value
Flexion (deg)	22.8±5.5	21.9±4.8	0.381
Varus (deg)	2.2±2.8	1.6±2.8	0.304
External rotation (deg)	12.3±8.2	-12.0±7.7	0.773
COM velocity (m/s)	3.8±0.6	4.0±0.5	0.056

Table 2: Pre and post stretch peak of knee joint moment (N·m/kg)

variables	Prestretch	Poststretch	P value
Peak valgus	-0.2±0.2	-0.3±0.2	0.015*
Peak varus	1.0±0.5	0.9±0.5	0.026*

Table 3: Pre and post stretch average muscle activation during three phases (%MVC)

variables	Prestretch	Poststretch	P value
semitendinosus	104.0±62.7	134.9±79.2	0.010*
biceps femoris	88.4±48.5	112.4±76.2	0.053
vastus medialis	18.9±9.1	21.1±15.5	0.401
Vastus lateralis	18.3±5.0	18.3±5.4	0.981
rectus femoris	16.0±8.7	12.6±6.1	0.117
H/Q ratio	7.0±6.9	8.8±6.8	0.008*

Note: Three phases included initial contact (IC), the peak of knee valgus moment (PKval) and the peak of knee varus moment (PKvar).

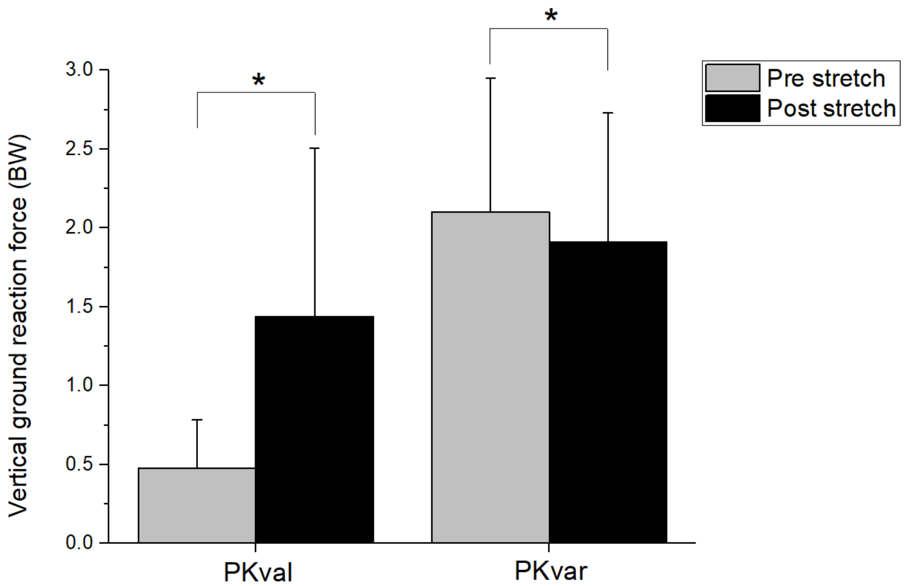

Figure 1: Different phase of pre and post stretch vertical ground reaction force

DISCUSSION: The purpose of this study, we hypothesized that more hamstrings activation after dynamic stretch during the landing phase, which could reduce the knee joint moment and decrease the risk of ACL injury. Although our data indicated no significant difference in knee joint angle, the knee frontal plane landing posture was more neutral after dynamic stretch, which can lower the knee joint moment. For the muscle activation, our study found that the semitendinosus activation and H/Q values increased after dynamic stretch, which might affect cushioning capacity and knee stability during landing.

However, our results contradicted Besier, Lloyd & Ackland (2003) conclusion that increasing semitendinosus activation could pull the tibia inward to adduction position which could reduce external knee valgus moment. We found that the knee valgus moment could not be effectively reduced at the knee peak valgus moment in the early stage of the deceleration phase after dynamic stretch because this phase was rapid and short. Due to this result, one controversial issue was found on the value of the peak knee valgus moment. Although there was no positive effect on the decreasing of the peak knee valgus moment, the peak knee valgus moment was much lower than the peak knee varus moment, so that it had a small effect on the knee joint. On the other hand, the peak knee varus moment significantly decreased after dynamic stretch, which could help reduce the knee torque. Our study indicated that dynamic stretch could indeed, by increasing hamstrings activation to increase landing buffer capacity which could reduce the GRF and the knee moment at the late deceleration phase. While this study demonstrated that the peak knee valgus moment did not decrease at the early deceleration phase, Fletcher (2010) proposed that rapid dynamic stretch (100 beats/minute) had a better effect on increasing muscle activation of fast-movements, such as counter-movement jump, squat jump, and drop jump. Therefore, the results might be different if using rapid dynamic stretch, but it still needs further study.

CONCLUSION: This study investigated the acute effects of the dynamic hamstring stretch on knee joint biomechanics during on side-step cutting in female athletes. Although no difference in peak knee valgus moment during side-step cutting were found following dynamic stretch, it found that dynamic stretch can increase the activation of hamstrings and co-contraction of the hamstrings and quadriceps, and reduce the peak knee varus moment. Therefore, we recommend that coaches, strength and conditioning trainers, or athletic trainers need to perform appropriate dynamic stretch to reduce the risk of knee injuries before training or competition.

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