

EMG AND 3D KINEMATICS OF THE LOWER LIMB OF MALE AND FEMALE ELITE SOCCER PLAYERS PERFORMING AN UNANTICIPATED CUTTING TASK

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The purpose of this study is to compare the timing of recruitment and the amplitude of the EMG signal, as well as the three-dimensional kinematics, of the lower limb of female and male elite soccer players performing an unanticipated cutting manoeuvre. Results showed that women performed the cutting task with significantly higher knee valgus angles at initial ground contact (IC) and higher peak knee valgus angles than men. Furthermore, onset of the semitendinosus and peak biceps femoris activity occurred significantly sooner for the female athletes than for the male athletes, which may increase strain on the ACL. Women also executed the task with greater RF and BF activity. This increased hamstring activity may be a compensatory mechanism to offset increased knee joint laxity in order to achieve functional joint stability.

KEY WORDS: ACL, injury, gender differences, neuromuscular control, cutting, soccer.

INTRODUCTION: As demonstrated (Agel, Arendt, & Bershadsky, 2005; Arendt, Agel, & Dick, 1999), women injure their anterior cruciate ligament (ACL) more frequently than their male counterparts in noncontact situations, especially in sports involving many jumping/landing and planting/cutting tasks, such as soccer, basketball and volleyball.

Most noncontact ACL injuries seen in female athletes occur by means of two main injury mechanisms: a plant-and-cut movement and a one-legged landing (Hutchinson & Ireland, 1995; Olsen, Myklebust, Engebretsen, & Bahr, 2004). In such situations, the hip is most often internally rotated and adducted, the knee is in valgus and close to full extension, the foot is pronated, thus causing an external rotation of the tibia and a deceleration occurs (Hewett, Myer, & Ford, 2006; Ireland, 2000). This so-called position of no return puts the ACL at risk of injury due partly because in full knee extension all fibres of the ACL are under tension.

Although much attention has been given to uncovering the cause of such gender discrepancy with regards to noncontact ACL injuries, the exact origin of this divergence has yet to be determined. Three types of contributory factors have however been identified: (1) anatomical; (2) hormonal; (3) neuromuscular. Firstly, women's relatively smaller ACL and intercondylar notch and their greater Q-angle are anatomical factors that are thought to possibly predispose women to a higher risk of noncontact ACL injuries. Secondly, it has also been suggested that the menstrual cycle may play a role in women's increased susceptibility to ACL injuries. Lastly, women tend to display neuromuscular behaviours that predispose them to noncontact ACL injuries. The so-called "three-way neuromuscular imbalance" adequately summarizes the neuromuscular contributory factors (Hewett, Myer, & Ford, 2001): (1) Females tend to be *ligament-dominant*; (2) Women display a *quadriceps imbalance* in relation to their hamstrings; (3) Women also exhibit a *leg dominance*.

Of the three types of factors, neuromuscular factors seem to be more convincing to explain the gender discrepancy with regards to noncontact ACL injuries, as these have a possibility for modification to reduce a woman's risk of injury. Although, several studies have made lower limb electromyographical assessments, the researchers have performed the latter on the events following initial ground contact while their participants predominantly performed anticipated tasks, thus failing to acknowledge the importance of the preactivation of thigh muscles and the typical noncontact ACL injury environment (i.e. unanticipated). For this reason, additional research is needed to determine the exact cause of this increased risk experienced by women.

Consequently, the purpose of this study is to compare the timing of recruitment and the amplitude of the EMG signal, as well as the three-dimensional (3D) kinematics, of the lower limb of female and male elite soccer players performing an unanticipated cutting manoeuvre.

METHOD: Twelve healthy female (age: 20.8 ± 3.6 years; height: 1.68 ± 0.06 m; mass: 62.7 ± 5.0 kg; soccer experience: 13.83 ± 4.6 years) and nine healthy male (age: 22.1 ± 4.0 years; height: 1.79 ± 0.10 m; mass: 76.0 ± 7.8 kg; soccer experience: 15.22 ± 3.4 years) elite soccer players, volunteered to participate in the study, and informed consent was obtained. At the time of data collection, all participants were playing at the university, college or premier level and all female participants were tested between the first and eleventh day (i.e. follicular phase) of their menstrual cycle (5.3 ± 2.6 day).

Data Collection: Following skin preparation and surface electrode (Kendall Meditrace ® 133, Ag/AgCl) positioning on the targeted muscles (i.e. vastus lateralis (VL) and medialis (VM), rectus femoris (RF), biceps femoris (BF) and semitendinosus (ST)), the athletes performed three maximum voluntary isometric contractions (MVIC) against an external resistance for both knee flexion and extension. Thirty-nine reflective markers were then placed on the participants to measure knee flexion/extension, abduction/adduction and internal/external rotation by means of a modified Helen Hayes Marker Set. Subsequent to the recording of the athlete standing in a neutral position, as well as the execution of a number of warm-up/practice trials, the subject randomly performed several trials of each task: a 45° cutting manoeuvre, a straight ahead run and a stop. As the athlete approached an imbedded force platform, he/she triggered an illuminated target board, by means of a photoelectric cell located at 1.5 m from the force platform, indicating the nature of the movement to execute. As a result, the cutting task – consisting of an approach run, following by a plant of the right foot completely on the force platform and a cut at a 45° angle – became an unanticipated task. Data was acquired with a seven-camera (MX-13) high-speed motion analysis system (Vicon Peak, Oxford, UK), an eight-channel EMG system (Bortec Biomedical Ltd., AMT-8, Calgary, AB, Canada) and a force platform (AMTI, Model OR6-6-2000, Watertown, MA, USA) sampling at a speed of 200 Hz, 1000 Hz and 1000 Hz, respectively. Approach speed (4.0-5.0 m/s) was monitored by two photoelectric cells positioned 1 m apart and 0.5 m from the edge of the force platform.

Data Analysis: Three-dimensional coordinates of the markers by means of DLT was obtained from Workstation software (Vicon Peak, Oxford, UK) for quantification of knee flexion, abduction and internal rotation angles during the “cutting cycle”, which was defined as the time from peak right knee flexion angle (prior to initial ground contact) to right toe-off. The kinematic values at initial ground contact, as well as the peak and range values, were then obtained for each athlete. Using raw EMG data, the timing of the onset and peak value of muscle activation was obtained and reported as a percentage of the “cutting cycle” in relation to initial ground contact (IC). Furthermore, the integral for the pre-stance phase as well as muscle activity at IC were obtained from the linear envelop EMG (LEEMG) (critically damped filter, 6Hz) and MVIC-normalized EMG data. The pre-stance phase was defined as the time between the beginning of the “cutting cycle” and IC.

Statistics: Using SPSS statistical analysis software (SPSS for Windows, version 11.5, SPSS Science Inc. Chicago, IL), one-way ANOVAs were used to determine the presence of significant differences between genders with regards to the kinematic and EMG variables. An alpha level of 0.05 was used to determine statistical significance. The partial eta squared (η^2), an effect-size measure was also calculated. For ANOVAs, η^2 values of 0.01 represent small differences; 0.06 moderate differences; and 0.14 large differences.

RESULTS AND DISCUSSION: No significant differences between genders were found with regards to age and soccer experience. The male athletes had, however, a significantly larger height ($p=0.01$, $\eta^2=0.35$) and mass ($p=0.00$, $\eta^2=0.54$). Results from one-way ANOVAs showed that women displayed a significantly higher knee valgus angles at IC ($p=0.01$, $\eta^2=0.34$) and higher peak knee valgus angles than men ($p=0.02$, $\eta^2=0.25$) as shown in Fig. 1.

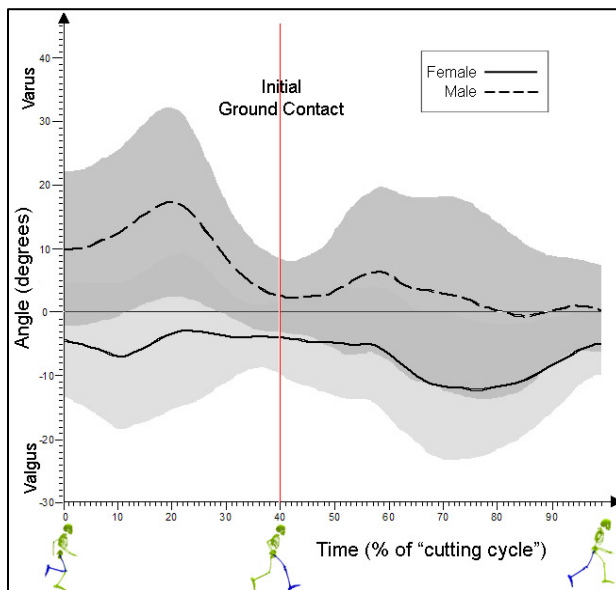


Figure 1: Average knee motion in the frontal plane normalized to the "cutting cycle" during an unanticipated cutting task for female and male elite soccer players.

both occurring prior to IC. Cowling and Steele (2001) found similar results during abrupt landings. As they explained, this delayed hamstrings onset provides a peak muscle activity that better coincides with the peak anterior tibio-femoral shear force that is generated immediately after IC, thus better protecting the ACL against such force given that the hamstrings are known to be agonists to the ACL. The delayed BF peak activity found among men in comparison with women ($p=0.05$, $\eta^2=0.18$), as illustrated in Figure 2, also validates this explanation. Women also displayed significantly greater BF activity prior to IC (Figure 2), as reflected by higher integrated LEEMG values (LEEMG normalized to %MVIC) in comparison with men ($p=0.04$, $\eta^2=0.21$). Hence, women contracted their hamstrings to a greater degree and for a longer period of time than their male counterparts, similarly to Rozzi and colleagues (1999). The latter group suggested that this might be a compensatory mechanism to offset increased knee joint laxity found in women, as the participants of the present study have successfully avoided injury while competing at an elite level. Hence, these athletes have achieved functional joint stability. There was also a difference found in the activity of RF, where women's RF was significantly more active prior to IC ($p=0.01$, $\eta^2=0.30$), as well as at IC ($p=0.00$, $\eta^2=0.41$) than men, as displayed in Figure 3. Sigward and Power (2006) reported similar findings among elite soccer players performing a cutting task. Since the quadriceps are known to be an antagonist to the ACL, this increased quadriceps activity displayed by the female participants may increase strain on the ACL. Additionally, no significant gender differences were found for the EMG variables with regards to VL and VM.

No significant gender differences were found, however, with regards to the knee flexion and knee internal rotation variables. These results are in accordance with the literature (Ford, Myer, Toms, & Hewett, 2005; McLean, Neal, Myers, & Walters, 1999), which demonstrates that women tend to perform a cutting manoeuvre with greater knee valgus angles, but with similar knee flexion and internal rotation angles than men. Conversely, McLean, Lipfert and van den Bogert (2004) found that women executed a cutting task with lower knee flexion and internal rotation angles than men. This discrepancy might be due to differences in the movement task and the subject population among studies.

Furthermore, results from one-way ANOVAs showed that the female soccer players ($-33.13 \pm 7.37\%$) exhibited a ST onset timing further to IC than the male players ($-24.53 \pm 7.50\%$), $p=0.02$, $\eta^2=0.27$,

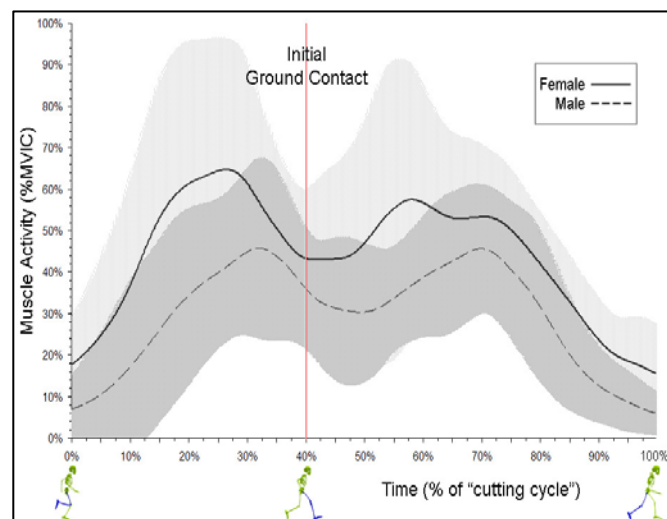


Figure 2: Average BF activity (%MVIC) normalized to the "cutting cycle" during an unanticipated cutting task for female and male elite soccer players.

CONCLUSION:

Consequently, the results of this study confirm that women execute a cutting task with greater knee valgus angles than men. Furthermore, these female elite soccer players displayed some neuromuscular control strategies that may be less protective to the ACL, such as timing of onset and peak hamstring activity and increased quadriceps activity. They also, however, displayed strategies that may assist in achieving functional joint stability given that these women have succeeded in avoiding ACL injury. As a result, further investigation is needed in order to make definite conclusions as to why women are more susceptible to ACL injuries than men.

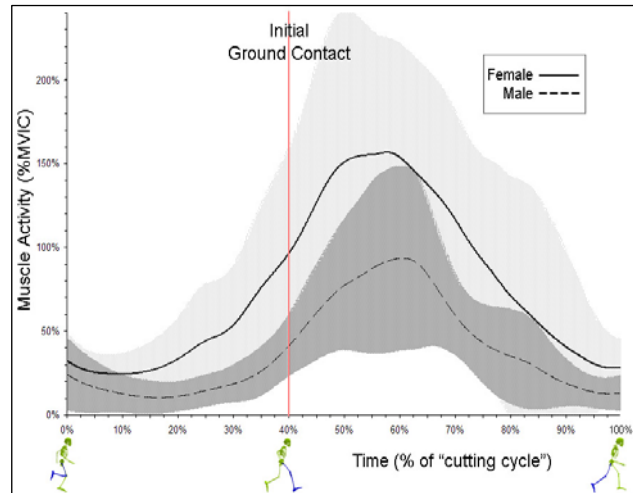


Figure 3: Average RF activity (%MVIC) normalized to the "cutting cycle" during an unanticipated cutting task for female and male elite soccer players.

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