# CAN LOW HAMSTRING ACTIVATION EXPLAIN ACL-INJURY? A CASE STUDY

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The neuromuscular coordination, and especially the activation of the hamstrings have been hypothesised as very important for knee stability during side-step cutting and other movements. The present study is a case study and presents data from a single subject, who participated in an experiment with EMG recordings quadriceps and hamstring activity during side-step cutting. Eight months after the original experiment the subject suffered an ACL-injury performing a side-step cutting maneuver during a team handball match. The study showed that prior to the injury the subject had much lower preactivity EMG in his lateral hamstring than the rest of the subjects. This may potentially result in lesser rotational stability, and may support the hypothesis that hamstring activity is important for ACL-protection during side-step cutting.

**INTRODUCTION:** Knee injuries are common and may account for up to 50% of all injuries in sports involving explosive movements and changes of direction like landings and cutting (de Loës, Dahlstedt & Thomée, 2000).
Injury of the anterior cruciate ligament is one of the most severe knee injuries and will keep the athlete out of competition for 5-12 months. Especially the ball games, soccer, basketball, ice hockey and team handball have a high incidence of ACL injuries (Arendt & Dick, 1995; Myklebust et al, 1997; de Loës, Dahlstedt & Thomée, 2000).
No single mechanical movement has been identified as the mechanism of ACL-injury. However, both pure anterior shear forces alone and anterior shear forces combined with internal or external rotation moments and/or valgus moments have been proposed as potential mechanisms of ACL-rupture (Emerson, 1993; Ebstrup & Bojsen-Møller, 2000). In team handball, a sport with a high occurrence of ACL-injuries, cutting maneuvers has been identified as the movevent with the greatest risk of ACL-rupture covering 55% of the registered ACL-injuries during a two-year prospective study following 3392 players (Myklebust et al, 1997).
Several anthropometric, biomechanical, and physiological factors have been proposed as risk factors for injury of the ACL. Intrinsic factors like Q-angle, femoral notch have been proposed as potential risk factors partly explaining the greater risk of ACL-injury in female athletes compared to male athletes. Extrinsic factors are also thought to contribute to the risk of ACL-injury. Smaller muscular strength of quadriceps and hamstrings, even when normalized for body mass, has also been proposed as a risk factor for female athletes when compared to male athletes. The lack of sufficient muscular strength may also explain the less knee flexion and greater knee valgus moments found in women during cutting maneuvers (Malinzak et al, 2001). However, more important than maximal muscle strength itself may be the neuromuscular coordination during loaded movements. Huston & Wojtys (1996) reported less hamstring activation and greater quadriceps activation in respons to anterior tibial translation, and also Malinzak et al. (2001) found lower hamstring activation and greater quadriceps activation in women compared to men during cutting maneuvers, and the authors suggested that this combination increased the anterior shear force for female subjects.
To our knowledge, no studies have reported neuromuscular coordination patterns during athletic tasks in healthy subjects who later suffered an ACL-injury. The purpose of this case-study was to report the specific neuromuscular coordination patterns during sidestep cutting of a single subject participating in an experimental study (Bencke et al, 2000). Eight months after the experiment the subject suffered an ACL-injury performing a side-step cutting maneuver during a team handball match.

**METHODS:** The present study will be presented as a case-study, describing the neuromuscular motor pattern characteristics of a single subject (JF) in comparison with the mean values of the remaining 16 subjects of the original study (Bencke et al, 2000). Eight months after the original study JF suffered an ACL-injury performing a side-step cutting

maneuver during a team handball match.
In the original study, 16 healthy male subjects mean age: 22.9 yrs, with no prior history of severe knee injuries participated in the study. Mean age, body mass and body height were 22.9 yrs, 83 kg, and 184.1 cm, respectively. All subjects played team handball at sub-elite level with 3-4 weekly practice sessions or matches, and have been playing team handball for an average of 12.6 yrs. Subject JF was 19.1 yrs old, weighed 73.4 kg and was 176.0 cm tall, and he participated in handball sessions with the same frequency as the rest of the subjects. JF had 9 years of active handball experience.
The test was performed as one-step approach before side-step cutting on a force platform with their normal side-step cutting technique. Due to the long time experience in handball, the subjects were very familiar with the side-step cutting maneuver. Ten consecutive trials were recorded for each subject with a 45-s pause between the trials. The subjects were allowed to perform a number of warm-up trials to get accustomed to the experimental conditions. In addition to force platform measurements, EMG-activity was obtained from 6 muscles simultaneous during the test: Medial hamstrings (MH), lateral hamstrings (LH), vastus medialis (VM), and vastus lateralis (VL).
After the side-step cutting test, the maximal isometric moments of force for the three muscle groups during a maximal voluntary contraction (MVC) were measured by a Darcus dynamometer. Additionally, maximal EMG for each of the 4 muscles was recorded during the MVC measurements. Each subject performed three consecutive MVCs for each muscle group with a 2-min pause between trials.
All EMG-recordings were highpass filtered at 25 Hz, and rectified and lowpass filtered at 32 Hz (fourth order Butterworth digital filters with zero phase lag). The highest amplitude found after rectification and filtering of the MVC EMGs was selected for normalisation. The EMG-signals from ten trials of each subject recorded during the side-step cutting were averaged and normalised to the MVC EMGs. The mean level of relative EMG during the last 50 ms before toe-down (pre-activity EMG) and first 50 ms after toe-down were calculated for JF and the other subjects separately for both hamstrings and quadriceps.
The level of cocontraction at toe-down was determined by dividing the sum the two hamstring levels by the sum of the two quadriceps muscles during the last 50 ms.

**RESULTS AND DISCUSSION:** The results for the hamstrings are shown in figure 1 and 2. The errorbars of the JF-bars indicate standard deviation of the 10 trials performed, while the errorbars of the Subj-bars indicate standard deviation of the mean values of the remaining 16 subjects. When interpreting EMG results, it is important to consider the electromechanical delay (EMD). The EMD has a duration of 50-100 ms and is generally regarded partly as a latency period due to the delay of contraction coupling (Bigland-Ritchie et al.,1983; Vos, Harlaar, & van Ingen Schenau, 1991), and partly as a period of preparatory force build-up before toedown (Gollhofer, 1987). As a consequence, the level of EMG seen during the last 50 ms before toe-down may reflect the force development during the first 50-100 ms after toe-down. However, caution must be observed in these interpretations, since EMG obtained during dynamic movement can not accurately be translated to specific force levels, due to different force levels during different contraction velocities. These limitations in interpretation of the EMG may, be considered equal for all subjects, since all subjects performed the same movement with the same intensity.
Hamstrings are considered agonists to the ACL and high activation during the first 100 ms of the landing, where the impact forces are largest, may be important for stabilization of the knee joint and protection of the ACL. Thus, the pre-activity EMG may be considered important for protection of the ACL.

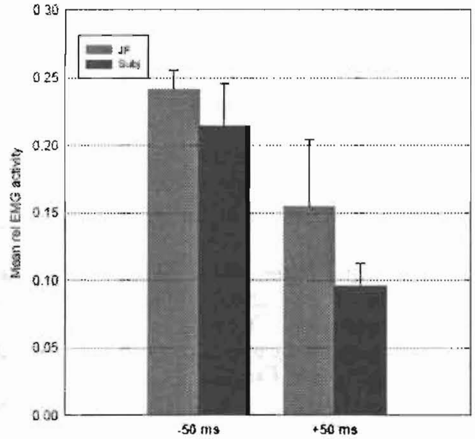


Figure 1: Medial hamstring activity 50 ms before and after toe-down. Errorbars indicate SD.

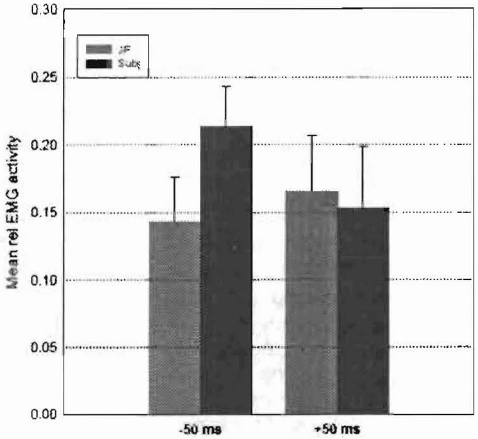


Figure 2: Lateral hamstring activity 50 ms before and after toe-down. Errorbars indicate SD.

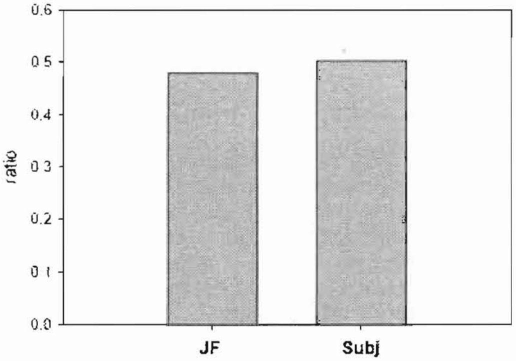


Figure 3: Mean co-contraction ratio during the last 50 ms prior to toe-down.

The major differences between JF and the rest of the subjects seem to be a lower lateral hamstring preactivation and a higher medial hamstring activity during the first 50 ms after toe-down. Despite the lower lateral hamstring activation, JF does not show any apparent deviation from the rest of the subjects in co-contraction during the last 50 ms prior to toe-down (figure 3). The level of co-contraction describes the ability of the hamstrings to counteract the anterior shear force created by the quadriceps contraction. But due to the anatomical insertion of the lateral and medial hamstrings, the hamstrings may better stabilize the knee joint in terms of rotation compared with the quadriceps. The low pre-activity EMG levels of the lateral hamstring may thus have reduced the ability to stabilize and counteract externally induced internal rotations of the knee joint, even though the co-contraction ratio was the same for JF as for the other subjects. Since these rotations are frequently occuring during side-step cutting (Cross, Gibbs & Bryant, 1989; Besier et al., 2001), the potential lack of adequate hamstring activation may have increased the risk of ACL-injury for subject JF.

**CONCLUSION:** Being a case study, firm conclusions may not be drawn from the results of this study. However, this study presented data of a subject with approximately one-third lesser activation of the lateral hamstring than his peers during a well-trained and through many years practised movement. When this subject subsequently suffers an ACL-injury, it may raise support for the thesis, that increased activation of the hamstrings prior to ground contact during side-step cutting may be beneficial for ACL-protection.

**REFERENCES:**

Arendt, E., & Dick, R., (1995). Knee injury patterns among men and women in collegiate basketball and soccer. American Journal of Sports Medicine, 6, 694-701.
Bencke J., Naesborg H., Simonsen E.B., & Klausen K. (2000). Motor pattern of the knee joint muscles during side-step cutting in European team handball. Influence on muscular co-ordination after an intervention study. Scandinavian Journal of Medicine and Science in Sports, 10, 68-77.
Besier, T.F., Lloyd, D.G., Ackland, T.R., & Cochrane, J.L., (2001). Anticipatory effects on knee joint loading during running and cutting maneuvers. Medicine and Science in Sports and Exercise, 33, 1176-1181.
Bigland-Ritchie, B., Johansson, R., Lippold, O.C., & Woods, J.J., (1983). Contractile speed and EMG changes during fatigue of sustained maximal voluntary contractions. Journal of Neurophysiology, 50, 313-324.
Cross, M.J., Gibbs, N.J., & Bryant, G.J. (1989). An analysis of the sidestep cutting manoeuvre. American Journal of Sports Medicine, 17, 363-366.
Ebstrup, J.F., & Bojsen-Moller, F., (2000). Anterior cruciate ligament injury in indoor ball games. Scandinavian Journal of Medicine and Science in Sports, 10, 114-116.
Emerson, R.J. (1993). Basketball knee injuries and the anterior cruciate ligament. Clinical Sports Medicine, 12, 317-28.
Gollhofer, A. (1987). Innervation characteristics of m. gastrocnemius during landing on different surfaces. Biomechanics X-b: 701 - 705.
Huston, L.J., & Wojtys E.M. (1996). Neuromuscular performance characteristics in elite female athletes. American Journal of Sports Medicine, 24, 427-436.
de Loës, M., Dahlstedt, L.J., & Thomée, R. (2000). A 7-year study on risks and costs of knee injuries in male and female youth participants in 12 sports. Scandinavian Journal of Medicine and Science in Sports, 10, 90-97.
Malinzak, R.A., Colby, S.M., Kirkendall, D.T., Yu, B., & Garrett, W.E. (2001). A comparison of knee joint motion patterns between men and women in selected athletic tasks. Clinical Biomechanics, 16, 438-45.
Myklebust, G., Mæhlum, S., Engebretsen, L., Strand, T., & Solheim, E. (1997). Registration of cruciate ligament injuries in Norwegian top level team handball. A prospective study covering two seasons. Scandinavian Journal of Medicine and Science in Sports, 7, 289-92.
Vos, E.J., Harlaar, J., & van Ingen Schenau, G.J. (1991). Electromechanical delay during knee extensor contractions. Medicine and Science in Sports and Exercise, 23, 1187 - 1193.