MUSCLE COORDINATION DURING SIDE-STEP CUTTING. CAN THE COORDINATION BE INFLUENCED BY PROPHYLACTIC TRAINING ?

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INTRODUCTION

The incidence of anterior cruciate ligament (ACL) injuries has been reported to be high during the popular team sports like soccer, basketball and team handball. The most highly risked movement in team handball has been reported to be the side-step cutting manoeuvre (Strand, 1990). Well-rehabilitated ACL-deficient athletes have been shown to have increased co-contraction about the knee joint (Walla, 1985).

Accordingly the aim of this study was to examine the effect of a prophylactic training program on the co-contraction of non-injured team handball players.

METHODS

Seventeen active male team handball players, with no history of knee joint pathology, participated in the study. The subjects were randomly assigned to a training group (n=10) and a control group (n=7). The mean age, body weight and body height for the two groups were 24.2 and 21.1 years, 84.8 and 80.5 kg and 184 and 185 cm respectively. All subjects gave informed consent to the experimental procedures.

The subjects performed the handball 'match-like' side-step cutting manoeuvre on a force platform. Prior to the recordings the subjects were allowed to get familiar with the set-up.

Electromyographic (EMG) recordings were made from the following six leg muscles all acting on the knee joint: m. vastus medialis (VM), m. vastus lateralis (VL), m. biceps femoris caput longum (BF), m. semitendinosus (ST), m. gastrocnemius medialis (GM) and gastrocnemius lateralis (GL).

An analogue-to-digital converter with a 1000 Hz sampling rate was used to collect the EMG and force plate data. 500 milliseconds before and after toe-down was sampled. Ten consecutive trials were recorded for each subject.

The subjects' maximal isometric moment of force was measured for the three muscle groups during a maximal voluntary contraction (MVC) in a Darcus dynamometer. Additionally maximal EMG amplitude for each of the six muscles were recorded. Each subject performed three consecutive MVC for each muscle group with a 2 min pause between trials.

Both the training group and the control group performed their weekly handball training sessions (2-3 times a week) and in addition the training group completed a training program designed in co-operation with a physiotherapist. The training group performed 5 different exercises under supervision, twice a week for 12 weeks. The post-training test procedure for the trained group was accomplished 2-3 days after the final special training session.

The exercises consisted of 1) maximal one-legged jumps to the side with fixed number of repetitions, 2) one-legged squats, 3) hamstring pulls, 4) hip abductions, 5) one-legged 'coordination jumps' for one minute. Exercise 2-4 were performed until exhaustion. The exercises were designed in a progressive manner by increasing the strain on the athletes twice during the training period.

The number of repetitions of exercises 2-5 was recorded during every training session and the mean of the repetitions in the second and third training session was used as pre-training values and compared with the number of repetitions at a test with the same relative load as at the start of training, 15 min. after the post-training test.

The force platform data were converted to Newton and the vertical ground reaction force (VGRF) was used for analysis. The peak forces and the duration of the ground contact phase were recorded. Due to the special shape of the VGRF it was possible to divide the ground contact phase into two sections. Gollhofer (1991) has shown, that the highest amplitude of the second top can be used as the instant at which the eccentric landing phase is changed into the concentric push-off phase. The duration of the landing phase and push-off phase were recorded, and the landing impulse and push-off impulse were calculated by time integration of the VGRF. The centre of pressure (COP) was calculated and the variation of COP during the landing phase was analysed.

All the EMG-recordings were highpass filtered at 25 Hz, rectified and lowpass filtered at 32 Hz. The highest amplitude found after filtering of the MVC EMG's was selected for normalisation. The EMG-signals of the ten trials of each subject recorded during the side-step cutting were averaged and normalised to the MVC EMG's. The onset of EMG relative to toe-down, instant of peak EMG amplitude relative to toe-down and peak ground reaction force, amount of EMG before toe-down (pre-activity IEMG) and HAM/QUA ratio of pre-activity IEMG were dertermined

RESULTS

An initial steep increase of VGRF was evident and resulted in a peak with a mean of 2500 N (± 600 N). This peak appeand about 40 ms. after toe-down. A second peak with a mean of 2200 N (± 230 N) was also evident after 100 ms.

Mean duration of the stance phase was 298 ms in the training group. The first part, the landing phase, lasted 100 ms.

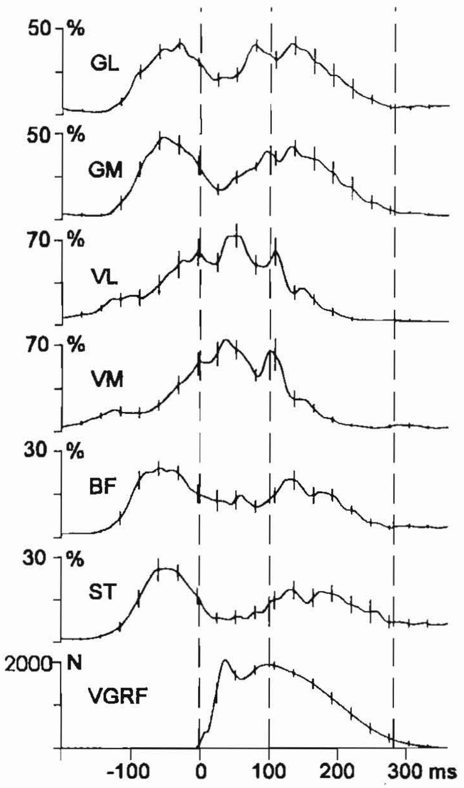
The force platform results showed that the training group had a significantly shorter stance phase after the training period. The shorter stance phase was found to be due to a shorter push-off phase. There was no change in the duration of the landing phase. This reduction in push-off phase may be due to a better neuromuscular coordination producing a more forceful knee extension in the beginning of the push-off phase. Even though the duration of the push-off phase was shorter there was no change in the push-off impulse. This may be explained by an insignificant (p=0.09) increase of the amplitude of the second peak of the vertical ground reaction force. Yet, no changes were observed in the EMG-signals of the knee extensors or the gastrocnemius muscles. The reason could be, that the EMG-analysis was not adequately sensitive to register these probably very small changes in muscle activation. No changes were observed in the magnitude of the first peak.

In an attempt to measure the overall stability of the joints during the landing phase, the centre of pressure (COP) was calculated during the landing phase. Tropp (1985) found a correlation between the variation in COP during a standardised test and the frequency of ankle sprains in soccer. In the present study no changes was found after the training period. The improvement in balance recorded in exercise 5 did apparently not affect the balance during the side-step cutting.

The overall EMG-pattern during side-step cutting was quite similar among the subjects. There was a characteristic difference in the shape of the EMG patterns between the knee extensor muscle group and the two knee flexor muscle groups, showing an alternating activity between the two groups. See figure 1.

One of the main features of EMG-pattern during the side step cutting manoeuvre was the early onset of the EMG-activity. This pre-activity EMG indicated that the central nervous system was prepared for the impact that followed. The pre-activity period of the semitendinosus muscle of the training group was significantly shorter ($p<0.05$) after the training period, while the m. biceps femoris showed an insignificantly shorter pre-activity period ($p=0.051$) after the training period. Dyhre-Poulsen (1987) has showed, that in very talented gymnasts, the periods of activity were more precisely timed to the landings during a split leap. This indicated that the technical quality of the jump was higher in the gymnasts with shorter periods of activity. A shorter pre-activity period does not necessarily mean less force development, since Gollhofer (1987) showed, that it is the rise in EMG-amplitude, and thereby the increase in IEMG, correlates with the impact to come. In the present study, there was no changes in IEMG, in spite of the later onset of EMG-activity in the hamstring muscles.

The hamstring muscles and the gastrocnemius muscles showed a peak activity about 45 ms. before toe-down while the activity of the VM and VL was rising during the same period. The peak relative activity of the hamstring muscles was about 30 % and no changes were observed after training. The EMG-activity of the knee extensors was at the same time only about 35 % of maximum activity. Considering an electro-mechanical delay of 50 ms, the peak force development of the ACL-protective hamstring and gastrocnemius muscle groups occured at toe-down. The HAM/QUA-ratio (amount of co-contraction) was maximal at toe-down. Since especially the hamstring muscles, due to the anatomical position, have a great influence on knee rotations and anterior shear forces during knee flexion, this must be an important feature of the muscle coordination in order to prevent injuries caused by incorrect knee angles or knee rotations during the impact.



Figur 1 shows a representative EMG pattern from the pre-training test together with the corresponding vertical force component.

The HAM/QUA-ratio did not change after the training period. The reason may be, that the proprioceptive feed-back, which is thought to modulate the motor programmes controlling the movements, was not strong enough in non-injured subjects. The coordination of the side step cutting manoeuvre seems to be optimal in non-injured subjects with a long history of performing the movement.

The VM and VL reached peak activity at about 45 ms. after toe-down and considering the EMD the peak knee extensor activity correlates with the time at which the eccentric landing phase is changed to the concentric push-off phase.

There was a significant increase in the number of performed training repetitions in all exercises except exercise 1, where the number of repetitions was fixed. This indicates an improvement of endurance in exercises 2-4 (65 %, 105% and 45 %, respectively) and an improved ability to repeatedly catch the balance during one-legged jumping in exercise 5 (115 %). As discussed earlier this improved balance did not show in the measurement of COP during the side step cutting. The reason may be that the exercise was too different from the actual side step cutting, and thus no transfer of neural learning could be detected.

The increase in endurance may influence the ability to perform the cutting manoeuvres with smaller risks later in a match.

CONCLUSION

The present study showed that it is possible to alter the timing of the hamstring muscles with respect to ground contact during a side-step cutting manoeuvre. The pre-activity period was shorter after 12 weeks of training twice a week with a specially designed training program. Yet, the amount of pre-activity IEMG was not altered, neither was the HAM/QUA-ratio. It is concluded, that the co-contraction of the knee muscle groups during a side-step cutting manoeuvre is optimal in athletes with no previous history of knee pathology. The training did improve the endurance of the involved muscle groups, and it is possible that this will have an influence on the ability to perform the side-step cutting manoeuvre with optimal coordination later in the match.

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