EFFECT OF LEG MUSCLE FATIGUE ON INSTEP SOCCER KICK

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The aim of this study was to examine the effect of muscle fatigue on the soccer instep kicking motion. The muscle fatigue was induced by repeated knee extension and flexion until exhaustion. The kicking motions of seven players were captured at 500 Hz using a three-dimensional cinematographic technique before and immediately after the fatigue protocol. We found the muscle fatigue declined the peak linear and angular velocity of the distal segment during kicking. This was most likely attributed to the reduced peak magnitudes of resultant moment and motion-depended interactive moment acting at the knee joint. These results indicated that the muscle fatigue not only declined the muscle force but also induced a worse inter-segmental coordination during kicking.

KEY WORDS: fatigue, kicking, soccer.

INTRODUCTION: Soccer instep kicking has been described and analyzed from a biomechanical perspective (Dörge et al, 2002; Luhtanen, 1988; Nunome et al, 2002). However, the previous investigation has been done with the subjects who kick the ball without fatigue. In the course of an actual soccer match, muscle fatigues will be induced to players toward the end of soccer match which might disturb to maximally perform many soccer actions include kicking. In common perception, the muscle fatigue has been considered to disturb the coordinated motion and decline of kicking performance. However, the effect fatigue on the kicking motion has never been examined properly. The purpose of this study was, therefore, to investigate the effects of the leg muscle fatigue on soccer instep kicking for its performance (ball velocity) and leg swing mechanics.

METHODS: Seven adult male soccer players (height = 169.6 + 4.3 cm; weight = 60.5 + 3.4 kg) from Nagoya University soccer team volunteered to participate in this study. Subjects were provided the written consent to participate after being well informed to the nature and demands of this study. To induce a specific leg muscle fatigue, the subjects were requested to repeat knee extension and flexion exercise using a weight-training machine until exhaustion.
To quantify the effect of the fatigue protocol on the leg muscle strength, the isokinetic peak torques of the right knee extension and flexion were measured before and immediately after the fatigue protocol. A Cybex II dynamometer was used to measure the isokinetic peak torques. The peak knee extension and flexion torques at three velocity conditions: 30, 180 and 300 deg/s, were measured without rest between each set.
After an adequate warm-up, the subjects were required to perform five instep kicks as hard as possible using the preferred leg (right). Immediately after the fatigue protocol and the isokinetic muscle strength measurement, the same kicking trials were repeated.
For three-dimensional movement analysis, two high-speed video cameras placed at the kicking leg side (right) and at the behind of the kicker (subject) were used to capture the kicking motion at 500 Hz (exposure time was 1/2000). A digitizing system (Frame DIAS II, DKH Inc., Japan) was used to manually digitize the anatomical body landmarks including: right and left shoulders and hips, right knee, right ankle, right heel and right toe. Each trail was digitized from ten frames before take-off of the right foot toe until fifteenth frames after the ball impact.
The resultant joint moment (muscle moment), motion-dependent interactive moment due to the joint reaction force (interactive moment) and angular velocities (thigh and shank) were computed from a two-link kinetic chain composed of the thigh and shank. To avoid a systematic distortion of the data caused by ball impact, the moments were computed from unsmoothed coordinates until three frames before ball impact and then extrapolated for fifteen points by a linear regression line. The regression line was defined for each change variable. To resemble the final change of the data, the final eight to twelve data points were fitted to the

linear regression line. For angular velocities, a quadric regression line was fitted to the unsmoothed data in the same manner. After these extrapolations, all parameters were digitally smoothed by a fourth-order Butterworth low-pass filter at 12.5 Hz, and then the extrapolated regions after ball impact were removed.
Student t-test was used for the comparison between the non-fatigue and fatigue conditions. The criterion for statistical significance was $P < 0.05$ for all analysis.

RESULTS: The fatigue protocol used in this study significantly reduced the average isokinetic peak torques measured by the Cybex II dynamometer for knee extension and flexion in all velocity conditions (30, 180 and 300 deg/s).
The initial ball velocities of all participants were consistently and significantly decreased after the muscle fatigue was induced (28.4 + 1.6 vs. 26.8 + 1.1 m/s).
The peak shank angular velocity and toe linear velocity at ball impact were also significantly decreased in the fatigue condition, while no substantial differences were observed for the peak thigh angular velocity.
The typical changes of the muscle moment and interactive moment at knee joint throughout the kicking motion are presented in Figures 1 & 2, respectively. As shown, similar changes were observed in both conditions. Significant differences were found, however, between the two conditions for the peak magnitude of the muscle moment and interactive moment for the knee extension motion during kicking.

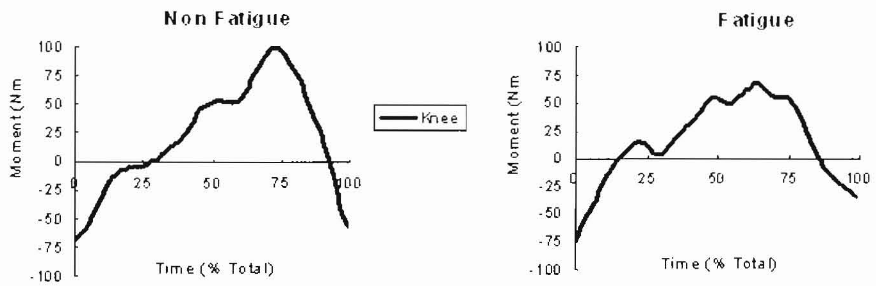

Figure 1: Typical changes of muscle moment at knee joint from toe-off until impact time for the non-fatigue (left side) and fatigue condition (right side).

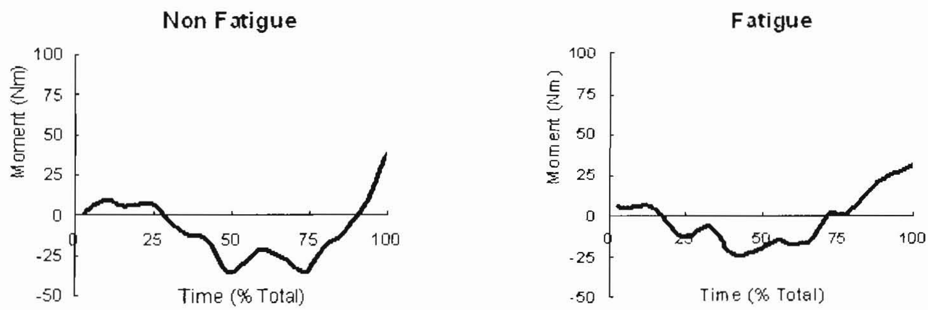

Figure 2: Typical changes of interaction moment at knee joint from toe-off until impact time for the non-fatigue (left side) and fatigue condition (right side).

DISCUSSION: It can be considered that the reduced ball speeds in the fatigue condition was due almost exclusively to the decreased leg swing speed represented as the toe linear velocity at ball impact and the peak shank angular velocity.

The result of the present study revealed several possible causes of the slower leg swing speed after a specific leg muscle fatigue was induced. The muscle fatigue significantly decreased the magnitude of the muscle moment for the knee extension during kicking. Moreover, the magnitude of the interactive moment was also significantly declined in the fatigue condition. The results of the present study indicated, that the leg muscle fatigue not only declined the muscle moment but also lead a worse inter-segmental coordination during kicking.

CONCLUSION: In the present study, the slower leg swing observed in the fatigue condition was not only due to the declined muscle effort, but also due to a worse coordination during kicking.

REFERENCES:

Dörge, H.C., Andersen, T.B., Sørensen, H., & Simonsen, E.B. (2002). Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. Journal of Sports Sciences, 20, 293-299.

Luhtanen, P. (1988). Kinematics and kinetics of maximal instep kicking in junior soccer players. In T. Reilly, A. Lees, K. Davids, W.J. Murphy (Eds.), Science and football (pp 441-448). London: E&FN Spon.

Nunome, H., Asai, T., Ikegami, Y., & Sakurai, S. (2002). Three-dimensional kinetic analysis of side-foot and instep soccer kicks. Medicine and Science in Sports Exercise, 34, 2028-2036.

Winter, D. A. (1990). In Biomechanics and Motor control of Human Movement. New York: John Wiley and Sons.