Effects of Different Soccer Stud Configurations on Knee Kinematics and Shoe-Surface Traction of Sidestep Cutting Movement on Natural Grass

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The purpose of this study was to investigate the effect of different stud configuration on knee joint kinematics of sidestep cutting movement on natural grass. A total of 14 amateur soccer players participated in the tests. Participants were asked to complete tasks of 45° sidestep cutting at the speed of 5.0±0.2m/s on natural grass. They selected soccer shoes with firm ground design (FG), artificial ground design (AG) and turf cleats (TF) randomly. During 45° cut, peak knee flexion ($p<0.001$) and abduction angles ($p<0.001$) of firm ground design (FG) were significantly greater than turf cleats (TF). FG also showed significant greater average required traction ratio compared with AG ($p<0.001$) and TF ($p<0.001$). Decreased knee flexion angles and increased knee abduction angles of firm ground design (FG) during cutting movements may increase risk of anterior cruciate ligament (ACL) injury. Higher utilized traction of FG could produce more grip which allows athletes to cutting and turning rapidly without skidding. However, higher utilized traction might lead to risk of slip resistance and foot fixation which might increase the load of lower limbs.

KEY WORDS: stud, cutting, knee, traction.

INTRODUCTION: The biomechanical factors relevant to success in the game of soccer are those which relate to the technical performance of skills, to the equipment used and to the causative mechanisms of injury (Lees & Nolan, 1998). Cutting movements are characterized by substantial changes in speed, thus requiring large horizontal impulses exerted by the feet on the surface (Driscoll et al., 2012). The ability to perform fast cutting maneuvers is essential in soccer. However, cutting movements in soccer may induce high loads on anterior cruciate ligament (ACL) in the knee joint (Smith et al., 2004). During athletic movements, shoes are considered to play a vital role in the transmission of forces from surface to athlete, soccer players greatly rely on the design of their footwear to enable optimum performance (Hennig 2011). The purpose of this study was to investigate the knee joint kinematics and shoe-surface traction with different studded soccer shoes on natural turf during 45°cut. This could lead to a more comprehensive knowledge of player-surface interaction and provide further understanding of the mechanism of athletic performance and injury risk.

METHODS: Fourteen male soccer players (mean ± SD: age, 19.7 ± 1.2 y; height, 1.73 ± 0.04 m and body mass, 66.7 ± 4.4kg; soccer experience, 12.1 ± 2.2 y) from university soccer team were recruited for this study. Different studded soccer shoes were sponsored by ANTA Sports Science Laboratory, stud design were firm ground design (FG) with 11 studs, artificial ground design (AG) with 23 studs, turf cleats shoes (TF) with 71 short cleats covering the entire sole. All running tests and experiments were conducted at the Sports Biomechanics Laboratory of Ningbo University. The 8-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK) was used to capture participant's lower limb kinematics at a frequency of 200 Hz. All subjects ran with the right foot step onto the force plate (Kistler, Switzerland). Natural grass in this study was approved for national competition, a separate piece of natural grass was cut to 60 cm×90 cm to fit the dimension of force platform. Cutting movement was performed at the speed of 5.0±0.2m/s. The SPSS 17.0 software (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. The one-way ANOVA (analysis of variance) were taken for analysis. The significance level was set at 0.05.

RESULTS: Knee kinematic variables due to different stud configurations during stance phase of 45° cut. The peak flexion angles of FG, AG and TF were 44.1°±3.2, 40.5°±2.7 and 40.1°±2.5, FG showed a greater knee flexion angle compared with AG ($p=0.007 < 0.05$) and TF ($p < 0.001$). The peak abduction angles of FG, AG and TF were -8.09°±1.21, -6.94°±1.03, and -6.45°±1.14, FG showed a greater knee abduction angle compared with AG ($p < 0.001$) and TF ($p < 0.001$).

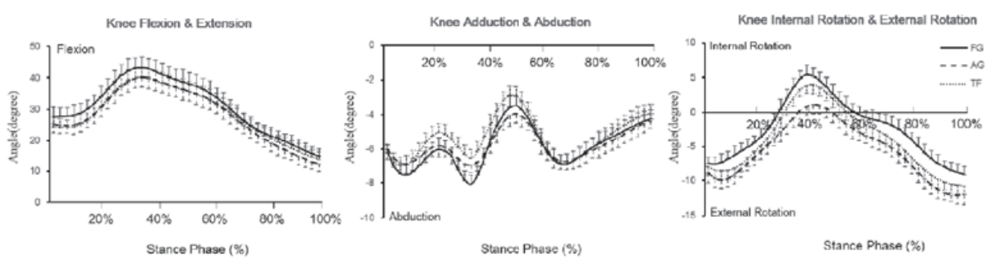

Figure 1: The knee angle curves in the stance phase of cutting movement.

The required (or utilized) traction was quantified using the time dependent traction ratio, dividing the horizontal by the vertical component of the ground reaction force. Define δ represent traction ratio between shoe and surface of cutting movement, the equation of traction ratio as follows：

$$\delta = \frac{hGRF}{vGRF}$$

The traction ratio shows large variability at initial and end of stance phase during cutting movement. Therefore, the average traction value was calculated in the interval where the traction ratio is rather constant, starting at 10% of stance phase and ending when the vertical ground reaction force dropped under body weight towards the end of stance phase (Clercq et al., 2014), as shown in the gray area of figure 2.

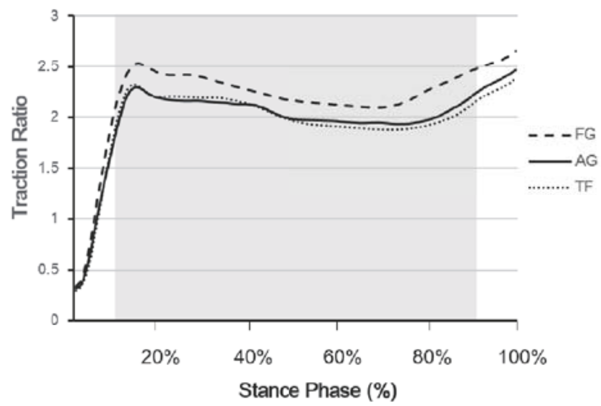

Figure 2: Traction ratio of three stud conditions during stance phase of cutting movement. Notes. The grey area indicates the interval during which the mean traction was calculated; FG, AG, TF represent firm ground design, artificial ground design, and turf cleats shoes.

The average required traction ratio of firm ground design (FG), artificial ground design (AG) and turf cleats (TF) shoes were 2.18±0.12, 1.98±0.09 and 1.96±0.13. FG showed significant greater average required traction ratio compared with AG ($p<0.001$) and TF ($p<0.001$) during stance phase of 45° left sidestep cutting.

DISCUSSION: Dynamic changes of direction have been determined as a risk factor for non-contact injuries in soccer, and these injuries normally occurred in ankle joint, knee joint and some plantar regions (Fong et al., 2007). Decreased knee flexion angle of AG and TF reduce the ability of lower extremity to absorb compressive loads placed on the knee, putting it at risk for injury, increased knee flexion may reduce impact and load on knee joint (Boden et al., 2000), speculated smaller knee load of TF during cutting movement. Some studies also had suggested an increased risk of anterior cruciate ligament (ACL) injury with decreased knee flexion angles and increased knee abduction angles during movements involving rapid changes of direction (McLean et al., 2004).

Sufficient traction between footwear and turf is extremely important for sport performance. It allows an athlete to cutting or turning sharply without skidding (Schrier et al., 2014). The grey area of figure 2 indicates the interval during which the mean traction ratio was calculated, mean utilized traction ratio of FG was significantly higher than AG and TF. Higher utilized traction could produce more grip which allows athletes to cutting and turning rapidly without skidding. However, the shortcoming of higher utilized traction of FG has also been proposed to be associated with athlete injury. It has been proposed that higher utilized traction might lead to risk of slip resistance and foot fixation which might increase the load of lower limbs. Slip resistance and foot fixation are two potential factors of non-contact injuries. Foot fixation has been related to the knee injuries (Torg 1982). In the direction phase of cutting movement, to prevent slipping injuries an adequate level of traction ratio is necessary, speculated that traction ratio should be as low as possible and able to provide adequate slip resistance.

CONCLUSION: Decreased knee flexion angles of firm ground design (FG) reduce the ability of lower extremity to absorb compressive loads placed on the knee, putting it at risk for injury, and increased knee abduction angles of FG during cutting movement involving rapid changes of direction also suggested an increased risk of anterior cruciate ligament (ACL) injury. Higher utilized traction of FG could produce more grip which allows athletes to cutting rapidly without skidding. However, higher utilized traction might lead to risk of slip resistance and foot fixation which might also increase knee joint loads, speculated that traction ratio should be as low as possible and able to provide adequate slip resistance.

REFERENCES:

Boden, B.P., Feagin Jr, J. A., & Garrett Jr, W. E. (2000). Mechanisms of anterior cruciate ligament injury. *Orthopedics*, 23(6), 573-578.

De Clercq, D., Debuyck, G., Gerlo, J., Rambour, S., Segers, V., & Van Caekenberghe, I. (2014). Cutting performance wearing different studded soccer shoes on dry and wet artificial turf. *Footwear Science*, 6(2), 81-87.

Driscoll, H., Kirk, B., Koerger, H., & Haake, S. (2012). Influence of outsole design on centre of rotation during turning movements. *Procedia Engineering*, 34, 301-306.

Fong, D.T.P., Hong, Y., Chan, L.K., Yung, P.S.H., & Chan, K.M. (2007). A systematic review on ankle injury and ankle sprain in sports. *Sports medicine*, 37(1), 73-94.

Hennig, E.M. (2011). The influence of soccer shoe design on player performance and injuries. *Research in Sports Medicine*, 19(3), 186-201.

Lees, A., & Nolan, L. (1998). The biomechanics of soccer: a review. *Journal of sports sciences*, 16(3), 211-234.

McLean, S.G., Lipfert, S.W., & van den Bogert, A.J. (2004). Effect of gender and defensive opponent on the biomechanics of sidestep cutting. *Medicine and Science in Sports and Exercise*, 36(6), 1008-1016.

Müller, C., Sterzing, T., Lange, J., & Milani, T.L. (2010). Comprehensive evaluation of player-surface interaction on artificial soccer turf. *Sports Biomechanics*, 9(3), 193-205.

Schrier, N.M., Wannop, J.W., Lewinson, R.T., Worobets, J., & Stefanyshyn, D. (2014). Shoe traction and surface compliance affect performance of soccer-related movements. *Footwear Science*, 6(2), 69-80.

Smith, N., Dyson, R., & Janaway, L. (2004). Ground reaction force measures when running in soccer boots and soccer training shoes on a natural turf surface. *Sports Engineering*, 7(3), 159-167.

Torg, J.S. (1982). Athletic footwear and orthotic appliances. *Clinics in sports medicine*, 1(1), 157-175.