EFFECT OF SHORT MEDIAL-SIDE STUDS ON FOOT BIOMECHANICS IN COLLEGIATE SOCCER PLAYERS

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The purpose of this study was to examine the effect of modified stud on ankle and foot kinematics, ground reaction force and forefoot force and pressure during sidestep cut (SC) and change direction (CD) movement. 6 male collegiate soccer players wore original and medial-side 2mm cut stud shoes and performed SC and CD on the artificial grass. Non-parametric Wilcoxon signed-rank test was used to compare differences between original and modified studs. The modified stud of non-dominant leg showed less inversion than the original stud in SC and CD. The modified stud of non-dominant leg showed more peak force and pressure and that of dominant legs showed more peak pressure than the original stud during SC and CD. The short medial-side modified studs with 2mm length can decrease the foot inversion of the non-dominant leg during SC and CD movement and increase the force production of the lower extremities in recreational soccer players.

KEY WORDS: kinematic, plantar pressure, soccer shoes.

INTRODUCTION: Many soccer players have lower extremity injuries such as ACL (McLean,S.G. et.at., 2004), ankle sprain (Kofotolis, N. D. 2007), stress fracture (Iwamoto, J., & Takeda, T., 2003) and so on. Elite soccer players sustain an average of two injuries per season and collegiate American football players have approximately five injuries per 1000 hours of playing/practice exposure to their lower limbs. There are immediate and long-term ramifications for the team and player (Thomson, A. et al., 2015). Internal or external factors cause lower extremity injury. One of the external factors is soccer shoes. The interaction between a player's foot and the playing surface is of critical importance in sports for both performance and injury risk (Kent, R. et al., 2015).
There are 4 types of soccer shoes outsole based on field condition: artificial ground (AG), hard ground (HG), firm ground (FG), soft ground (SG) (Park, S. B, et al., 2003). Soccer shoes outsole is most important for soccer's movement such as sprint, sidestep cut or change direction. Sidestep cut movement often occur in soccer game especially the defender. The cutting and shuffling generate larger horizontal ground reaction forces than the other tested movements. Excessive horizontal ground reaction forces place large joint torque or shear stress on the ligaments or other soft tissues of the lower limbs, and are thought to be the mechanical factors of non-contact anterior cruciate ligament tear and ankle sprain (Cong, Y. et al., 2014).
Taiwan is located subtropics and surrounded by the ocean in which the weather is hot and humid. The annual average temperature is a comfortable 22 degrees Celsius with the lowest temperatures on the lower altitude place generally ranging from 12 to 17 degrees Celsius (54-63 Fahrenheit). During the summer (June to August), typhoons often approach or hit the country (Tourism Bureau, M.O.T.C. Republic of China). Thus, ground condition of soccer field is very hard. Many of Taiwanese soccer players get foot injuries such as ankle sprain or stress fracture. So our hypothesis was that soccer shoes with medial-side modified stud can curtail metatarsal stress or foot inversion angle during change direction in soccer game situation.
The purpose of this study was to examine the effect of modified stud on ankle and foot kinematics, ground reaction force and forefoot force and pressure during sidestep cut and change direction in soccer players.

METHODS: 6 male Division III collegiate soccer players were participated in this study. Their mean age, mass, and height were 20.1 ± 2.6 years, 66.1 ± 5.3 kg, and 177.3 ± 1.3 cm, respectively.
They wore two different types of shoes; both of shoes are the same model (NIKE HYPERVENOM PHINISH HG-E) but one has original stud, another has be modified with 2mm length gradually cut in medial-side studs (Figure 1).

Figure 1: Medial-side part (left), original stud (right top), modified stud (right bottom)

Subject performed sidestep cut (SC) and change direction (CD) movement on 7m artificial grass (Artificialturf, Taiwan) which was fixed on a wooden platform track. For sidestep cut, the distance between 8 cones were 60cm and cutting angle was required 50-60 degree. For change direction, subjects dashed with 7m and change direction with 90 degree (Figure 2). Both movements were performed for left and right side. 3 trials were performed for each condition with their best performance. There was a 30sec rest between trials.

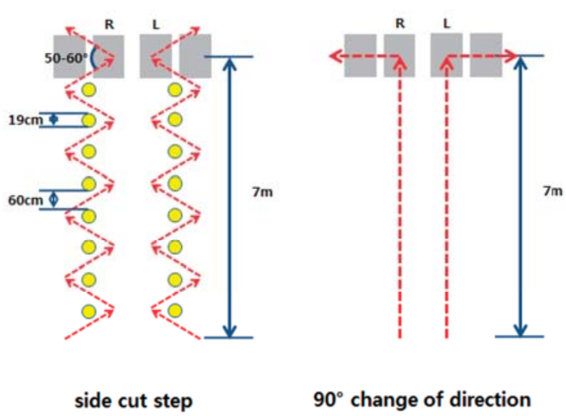

Figure 2: Experiment design
(R= right leg on the right force platform moving to the left side; L= left leg on the left force platform moving to the right side; dot line= moving direction)

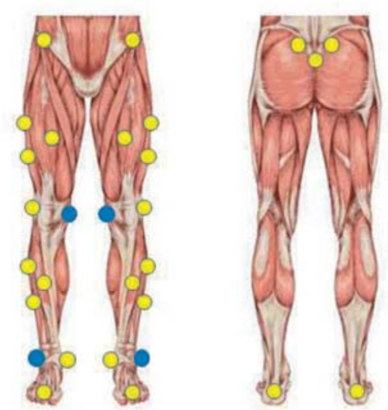

Figure 3: Marker locations

11 cameras (Motion Analysis Corporation, Santa Rosa, CA, USA), 2 force platform (AMTI Inc., Watertown, MA, USA), and F-Scan in-shoe system for measurement of plantar pressure (Tekscan Inc., Boston, MA) were used for data collection. 29 reflective markers were put on lower extremities (Figure 3). Medial knee and lateral ankle markers were removed after the static posture has been collected. Ankle flexion (AF), foot inversion (FI), foot abduction (FAb) and peak vertical ground reaction force (PVGRF) were analysed in the MotionMonitor software (Innovative Sports Training, Inc., USA). Peak force (PF) and peak pressure (PP) of forefoot were analysed in F-scan software (F-Scan Research 7.0, Tekscan, Boston, USA) during last step

of each trial. Both non-dominant (left) and dominant (right) legs were analysed from foot-contact to foot-off the force platform.

In kinematics, the following description defined each kinematic variable: positive AF indicated ankle dorsiflexion angle; negative AF indicated ankle plantarflexion angle; positive FI indicated foot inversion angle; negative FI indicated foot eversion angle; positive FAb indicated foot abduction angle; negative FAb indicated foot adduction angle.

Non-parametric Wilcoxon signed-rank test was used for statistics to compare differences between the original stud and modified stud in the observed variables during SC and CD movement. The significance level was set at α=0.05.

RESULTS: The modified stud of non-dominant leg showed less inversion than the original stud in SC and CD (Table 1 and Table 2).The modified stud of non-dominant leg showed greater foot abduction during CD (Table 2). The modified stud of non-dominant leg showed more peak force and pressure and that of dominant legs showed more peak pressure than the original stud during SC and CD.

Table 1

Joints angles, VGRF, and force and pressure of foot during SC (Mean±SD)

		Non-dominant leg (left leg)		Dominant leg (right leg)	
		Original stud	Modified stud	Original stud	Modified stud
AF	MAX (deg)	3.8±5.6	3.4±6.8	7.0±3.1	7.2±3.8
	MIN (deg)	-30.9±7.0	-30.1±10.9	-29.9±4.7	-29.8±7.8
FI	MAX (deg)	9.7±5.0 *	4.8±4.3 *	7.2±5.1	7.7±7.1
	MIN (deg)	1.8±6.6 *	-1.8±6.9 *	-1.6±4.6	-3.2±5.7
FAb	MAX (deg)	21.8±5.3	22.1±7.4	22.1±4.1	21.6±4
	MIN (deg)	9.8±7.1	11.5±8.2	9.7±5.5	11.1±6.7
PVGRF	(BW)	2.06±0.12	2.07±0.12	2.03±0.08	1.98±0.13
PF	(N)	589.8±100.6 *	730.0±269.1 *	620.1±193.6	594.3±229.4
PP	(KPa)	574.3±261.3 *	852.9±612.4 *	513.2±163.1 *	599.8±272.4 *

AF = ankle flex angle, FI = foot inversion angle, FAb = foot abduction angle, PVGRF = peak vertical ground reaction force, PF = peak force of forefoot, PP = peak pressure of forefoot, MAX = maximum value, MIN = minimum value. * Significant between original and modified studs (*p*<.05).

Table 2

Joints angles, VGRF, and force and pressure of foot during CD (Mean±SD)

		Non-dominant leg (left leg)		Dominant leg (right leg)	
		Original stud	Modified stud	Original stud	Modified stud
AF	MAX (deg)	-4.3±8.8	-3.9±6.0	-4.7±3.7	-4.7±4.6
	MIN (deg)	-35.1±7.4	-35.8±6.1	-36.3±4.8	-37.3±8.1
FI	MAX (deg)	10.0±5.8 *	5.1±5.1 *	7.5±4.1	5.7±3.5
	MIN (deg)	0.4±6.0 *	-3.7±6.0 *	-2.0±5.2	-5.7±3.3
FAb	MAX (deg)	21.6±4.9	23.0±5.8	21.4±4.5	23.3±4.4
	MIN (deg)	8.4±6.5 *	12.4±8.1 *	8.0±4.5	9.4±4.1
PVGRF	(BW)	2.20±0.17	2.24±0.30	2.49±0.35	2.36±0.53
PF	(N)	914.2±250.3 *	1016.2±319.3 *	824.0±196.8	875.5±291.8
PP	(KPa)	871.3±408.6 *	1019.9±493.8 *	687.4±298.7 *	827.1±406.5 *

AF = ankle flex angle, FI = foot inversion angle, FAb = foot abduction angle, PVGRF = peak vertical ground reaction force, PF = peak force of forefoot, PP = peak pressure of forefoot, MAX = maximum value, MIN = minimum value. * Significant between original and modified studs (*p*<.05).

DISCUSSION: The major findings of the study were that the medial-side modified stud demonstrated less foot inversion of the non-dominant leg and more forefoot force and foot pressure than the original stud during change direction and sidestep cut.

Knight and Weimar (2013) compared the ratio of evertor to invertor activity between the dominant and non-dominant legs and outer-sole conditions when the ankle is forced into inversion in their study. The result indicated that a greater evertor response was produced when the ankle was forced into inversion, and a greater response was produced for the non-dominant leg, which may function better during a postural-stabilizing task than the dominant leg (Knight and Weimar, 2013). It could be explained that the medial-side modified stud leading to the reduced foot inversion was only shown at the non-dominant leg in the present study.

Less foot inversion could decrease the risk of ankle sprain during the soccer movement of change direction or sidestep cut. Ankle sprain is the most common pathology accounting for up to 67% of all soccer related ankle injuries (Wong, P. L. et. al., 2007). In a typical sprain, forced ankle inversion-supination precipitates tearing of the anterior talofibular ligament to varying degrees. Video analysis of ankle injuries in professional soccer players has shown that direct contact with a laterally directed force on the medial aspect of the lower leg just before or at foot strike can causes the player to land with the ankle in this vulnerable inverted position of foot (Walls, R. J. et. al., 2016). In this study, the soccer shoes with the modified stud decreased foot inversion when subjects stepped with the non-dominant leg for change direction or sidestep cut movement.

In addition, the medial-side modified stud showed more peak force and peak pressure than the original stud during change direction and sidestep cut. It could be considered to correlate with less foot inversion angle which aligned the foot and shank to the right position. The contact area between the shoe and ground may be more evenly distributed. It may further help the lower extremities to increase the production of force.

If soccer players wear soccer shoes with the modified medial-side studs, the risk of ankle injury could be decreased in this study. But, in soccer games, it involves many directions of movement such as sprint, sidestep, back step, or even can be stepped up for kicking the ball. So if we consider about this fact, too large difference in length between medial and lateral studs, ironically, could increase risks of injuries. This was the reason of just modifying with 2mm length gradually cut in medial-side studs. Further studies can investigate the influence of different cut length in medial-side studs.

CONCLUSION: The short medial-side modified studs with 2mm length gradually cut can decrease the foot inversion of the non-dominant leg during sidestep cut and change direction movement and increase the force production of the lower extremities in recreational soccer players.

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