DISCREPANCIES BETWEEN MECHANICAL AND BIOMECHANICAL MEASUREMENTS OF SOCCER SHOE TRACTION ON ARTIFICIAL TURF

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This study analyzed mechanical and biomechanical traction properties of four different stud configurations on artificial soccer turf. Mechanical traction parameters showed statistical differences between the shoe conditions for the friction coefficient during acceleration and force rates during cutting and turning. Biomechanical force ratios statistically discriminated between the four stud configurations for cutting. It is concluded that stud configurations featuring more studs are better suited for playing on artificial turf compared to more aggressive stud configurations with only a small number of studs. It was shown that a combined approach of mechanical and biomechanical testing procedures is needed for traction testing as results differ. In contrast to mechanical testing biomechanical testing can detect movement adaptation of players.

KEY WORDS: footwear, stud configuration, shoe-surface interaction, movement adaptation

INTRODUCTION:

The roots of artificial turf go back to 1969 when the first generation of artificial turf, the Astroturf, was used at the Houston Astrodome for American football. In 2004 top level soccer game play on artificial turf was approved by the FIFA. Development processes have reached the third generation of artificial turf, characterized by an infill of sand and rubber. The response to artificial turf is controversial and differs between players, team managers, and soccer officials. These discussions involve performance criteria, injury prevention, game characteristics, and finances. FIFA claims that, in general, playing on artificial turf does not dramatically effect the nature of the soccer game (FIFA, 2007). Ekstrand et al. (2006) did not find a greater injury risk for players practicing and playing on artificial turf compared to natural grass. However, they noted an increased number of ankle sprains when playing on artificial turf but stated that further studies need to be done in order to confirm this finding. Müller et al. (2007) showed that players perception of surface performance criteria differs between artificial and natural surfaces. Players perceived artificial turf to allow higher accuracy of passes, to foster more short passes, to enhance the speed of the game and to give advantage to those players having better technical skills. They also perceived artificial turf to increase loads on the body and injuries.

When evaluating the quality of artificial soccer turf the interaction between the shoe and the ground is a key issue. Soccer players rated traction second among the most desirable soccer shoe properties after comfort, and prior to stability, weight, and ball sensing (Sterzing et al., 2007). Livesay et al. (2006) claimed with regard to clinical relevance that an improved understanding of shoe-surface interaction remains critical in order to address players' needs with respect to performance and also injury prevention. Currently, players use soccer footwear designed for natural grass, commonly firm ground or hard ground stud configurations when playing on artificial turf. However, it is unclear whether these stud configurations offer the best suited traction to players for performance and injury prevention.

Footwear evaluation in general should take into account mechanical, biomechanical, subjective-sensory, and performance testing (Lafortune, 2001; Sterzing et al., 2007). Milani and Hennig (2002) showed for impact measurements of running shoes that, due to adaptive movement behaviour of athletes, biomechanical measurements do not necessarily reflect mechanical measurements. Therefore, this investigation aims to examine the relationship between mechanical and biomechanical traction measurements of current soccer shoe stud configurations on artificial turf.

METHODS:
The following four stud configurations (Figure 1) were used in this study: hard ground (HG), firm ground (FG), soft ground (SG), and an innovative design (ID). The artificial turf type was Polytan Liga Turf 240 22/4 RPU brown (Polytan, Burgheim/Germany), certified according to FIFA 2-Star standards. For mechanical testing the sole plates were removed from the shoe uppers and glued on 36 mm wooden blocks for tighter attachment to the mechanical testing apparatus. With regard to biomechanical testing the shoe uppers were almost similar not giving any stud configuration an advantage over others. Straight acceleration, deceleration, cutting, and turning were chosen as soccer-specific movements.

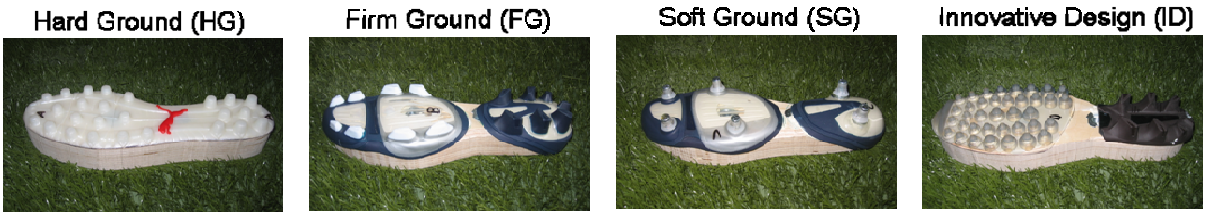

Figure 1: Stud configurations glued on wooden blocks (thickness: 36 mm)

Mechanical testing took place on a two-axial dynamic-servohydraulic testing machine (Zwick Roell Inc., Ulm, Germany) with a sledge system movable in horizontal direction. A wooden box containing the artificial turf was mounted on the sledge. The angle between traction plate and surface was 10° for all testing conditions, the vertical force applied to the system of shoe and surface was 750N. Three different movements were investigated mechanically by n=10 repetitive trials. For straight acceleration the forefoot traction plate was moved against the locked artificial turf box. For deceleration the box was moved against the resistance of the locked rearfoot traction plate at a constant speed of 0.3m/s producing anterior-posterior shear forces. For cutting the sledge was moved also at 0.3m/s against the resistance of the whole medial traction plate in medio-lateral direction (90°) producing sideward shear forces. For acceleration the friction coefficient max. ($\mu\_max.$) of horizontal divided by vertical force was calculated. For deceleration and cutting the horizontal force rates max. were calculated over a time interval of 50ms corresponding to 15mm of relative movement.
Biomechanical testing took place in a laboratory environment. A Kistler force plate (9287 BA, 60x90cm) was covered with a wooden box containing the artificial turf. The surrounding floor level was elevated in order to match the height of the box. Data collection was done at a frequency of 1kHz. 18 subjects (age: 24.1±3.2years, height: 178.4±3.8cm, weight: 71.7±4.8kg) participated in the study. They performed five repetitive trials of a straight acceleration, a cutting (45°), and a turning (180°) movement. Subjects had to perform these movements as fast as possible with no specific velocity set and controlled. It was assumed that five trials per shoe condition and type of movement are suited to account for natural movement variability and to keep testing time practicable. The predominant horizontal force component, vertical force, and the force ratio of horizontal divided by vertical force were calculated for the three different movements. The predominant horizontal force component of acceleration and turning was in anterior-posterior direction. For cutting the medio-lateral force component was considered to be most important.
Mean values and standard deviations for the parameters of mechanical and biomechanical testing were calculated. Furthermore, repeated measures ANOVA and Post-Hoc tests (Fisher's PLSD) were used. Since measured variables are potentially not independent, the common alpha level of significance ($p<0.05$) was adjusted according to the Bonferroni method to $p<0.017$ for mechanical measurements and to $p<0.008$ for biomechanical measurements (Bland and Altman, 1995).

RESULTS AND DISCUSSION:
Mechanical testing shows that the soft ground design exhibited the highest friction coefficient during straight acceleration as well as the highest horizontal force rates during the cutting and deceleration movements among the four stud designs (Figure 2). From a mechanical point of view traction intensity is highest for the soft ground stud configuration for all tested soccer-specific movements.

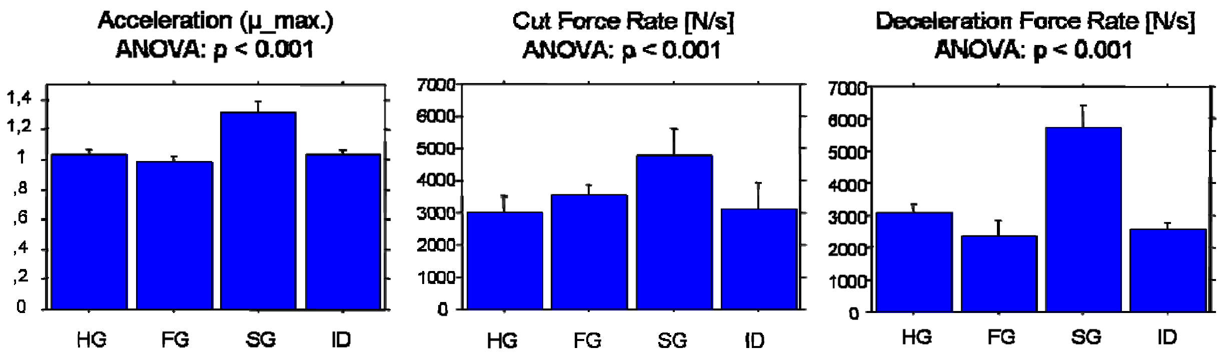

Figure 2: Mechanical testing parameters, mean and standard deviation

Biomechanical testing indicated no statistical differences for straight acceleration and turning with regard to force ratios (Figure 3). For cutting the force ratio is significantly decreased for the soft ground design compared to all other shoe conditions (Figure 3). This is due to a significantly decreased horizontal component of the ground reaction force in medio-lateral direction ($p<0.005$). The vertical component of the ground reaction force during cutting revealed no differences among the four stud configurations ($p=0.550$).

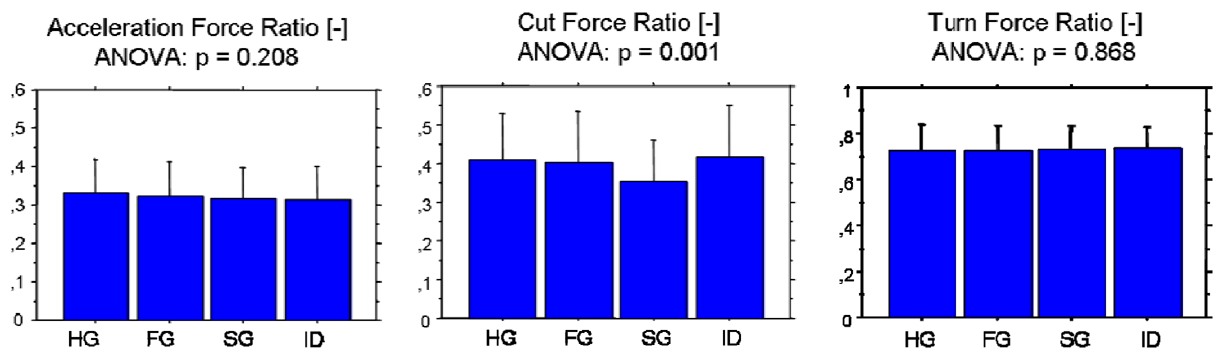

Figure 3: Biomechanical testing parameters, mean and standard deviation

The mechanical and the biomechanical testing procedures revealed discriminating force development of the four stud configurations. However, force development for the soft ground stud design is high in mechanical testing but low in biomechanical testing (cutting) compared to the other shoe designs. For straight acceleration a comprehensive view on mechanical and biomechanical data shows that the higher friction coefficient (μ_max.) of the soft ground design does not influence the biomechanical force ratio during subject testing. For the cutting movement the mechanically higher force rate of the soft ground design is reflected by a lower force ratio during subject testing. As this is due to lower medio-lateral horizontal forces it is likely that players perform the cutting movement in this shoe more cautiously compared to the other shoes. A potential reason for this is the perception of traction properties of the soft ground design to be too aggressive when interacting with artificial turf. With regard to injury prevention a strategy of avoidance of high horizontal shear forces seems reasonable for the subjects as ankle injuries may occur during rapid sideward movements. Obviously, these observations cannot be obtained by pure mechanical testing procedures.

CONCLUSION:

In this study mechanical and biomechanical data of traction properties did not reflect each other. As mechanical and biomechanical variables differed due to data collection procedures comparisons need to be made with caution. Whereas mechanical testing addresses solely the interaction between materials, biomechanical testing allows to evaluate the functionality of this interaction. Mechanical testing procedures produce highly reliable data with less variability, biomechanical testing procedures naturally show higher variability as subjects are involved. Also, biomechanical testing accounts for movement adaptation strategies of subjects according to the given circumstances.

The results of this study indicate that the higher mechanical traction properties of the soft ground design do not lead to a more dynamic foot strike and thus do not provide advantages to players. With regard to the cutting movement even a considerable disadvantage is present for the players. It is concluded that hard ground and firm ground stud designs containing more and also shorter studs are better suited with regard to the loading behaviour of the human body. These results are supported by the findings of Müller et al. (2008). In further studies movement variation of subjects due to altered shoe-surface interface conditions should be monitored by motion capturing systems with particular interest on kinematic data of the lower extremities and also on variations of upper body movements.

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