EFFECT OF SHOE MASS ON SOCCER KICKING VELOCITY

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The aims of this study were to establish whether soccer boots mass has an effect on ball velocity in maximal instep soccer kicks. Ten male semi-professional soccer players participated in the study, performing several maximal instep kicks in three different boot weight conditions. Kinematic variables such as joint angles, joint angular and linear velocities and ball-to-foot linear velocity ratio were collected at 200 Hz in Peak Motus and processed in Visual 3D. The increase in boot mass mainly affected the knee and hip joints. Slower speeds of the centre of gravity of the kicking foot were recorded with heavier boots, however no significant differences in ball speed were found. It was concluded that the increase in mass must has acted as a compensating mechanism, transferring energy more effectively during impact, despite the slower speed of the foot.

KEY WORDS: boots, ball, technique, kinematics, 3D lower body.

INTRODUCTION: One of the most important skills in the game of soccer is undoubtedly the maximal instep soccer kick, for which the maximum velocity of the ball depends on how much of the energy generated by the leg during the kicking action is effectively transferred to the ball. One of the parameters used to quantify the effectiveness of a soccer kick is the ball-to-foot velocity ratio (maximum linear velocity of the ball divided by the linear velocity of the foot at the moment of impact); the bigger the ratio is, the more effective the resulting kick (Asami & Nolte, 1983). If we think of the football kick as a swing movement, the mass of the boot is very likely to have an influence on the movement: a bigger mass could enhance the momentum, yet also increase the moment of inertia, which may result in a slower movement transferring less energy. Modern soccer boots are being made ever lighter to enhance players' agility, acceleration and velocity in changes of direction. This decrease in weight (therefore the employment of less protective material) has been suggested to be related to the increase of traumatic injuries in soccer players, and could also have an impact on ball velocity in maximal instep soccer kicks.
Research for the effect of mass on soccer boots is very limited, and to the researcher's knowledge only two studies have investigated the effect of boots' mass on soccer kick performance (Amos & Morag, 2002; Sterzing & Hennig, 2008), both showing no influence on ball velocity. The aim of this study is to determine whether kicking with different weight of boot affects the maximal speed achieved by the ball (performance) and the kicking technique during the movement in the form of lower body kinematics.

METHODS: Ten male University students consented to participate in the study (21 ±1 y; 74.4 ±6.4 kg; 1.79 ±0.11 m). In order to be selected as a participant, each subject was required to have played at least at a semi professional level during the last 5 years, to be actively involved on a weekly basis in soccer training, and have a dominant right foot. Before the start of the testing procedure, each subject was asked to perform his own warm-up in order to avoid musculo-skeletal injuries during the session. A subsequent brief familiarization session was carried out to make sure the subject fully understood what he was being asked to do during the actual testing session. Each participant then performed nine maximal instep soccer kicks, divided into three trials for each boot weight condition. Throughout all the testing, Adidas F50 Adizero TRX FG© soccer boot was used. Lead plates were attached to two different insoles to create the three different conditions of boots mass. The three boot resulting masses were: light (180.8 g), medium (260.6 g) and heavy (356.1 g). Each participant was left free to use his own technique, however they were all asked to minimise the run-up to a simple two or three steps approach. The kicking action was captured by means of four high-speed Basler A602fc-2 cameras (Germany) sampling at a speed of 200 Hz, with the aid of four photobeam 800 spotlights (photobeam.com); kinematic data were collected, digitised and processed via Peak Motus software v9 (Vicon, Oxford, UK). Thirty-three retro-reflective spherical markers (15 mm in diameter) were placed on the lower body of the participants before the start of the testing session in order to serve as reference points for the construction of the 3D lower-body model using the CAST system (Cappozzo, 2005). Once the raw data were processed, they were exported to Visual 3D software version 4 (C-motion Inc., MD, USA) in order to extrapolate the variables necessary for the analysis of the trials. A 7 segment lower body biomechanical model was constructed. Model segments were identified as: pelvis, right and left thigh, right and left shank and right and left foot. Joint angles, angular and linear velocities were determined. All the variables generated by Visual 3D were smoothed around the point of ball impact (from one frame before to three after) with a polynomial extrapolation technique, to avoid data being affected by the noise generated by the impact (Knudson & Bahamonde, 2001). Ball speed was determined for all trials, within the three trials performed by each participant for each condition, the trial with the median ball speed was taken into consideration for further analysis. All parameters obtained from Visual 3D were averaged across participants for each weight condition and subsequently analysed using Microsoft Excel. Utilising the PASW 18 software (SPSS Inc.), a series of paired samples t-tests were conducted where appropriate to identify significant differences; statistical significance is defined as $p<0.05$. Prior to conducting the t-tests, all data were checked for normal distribution by means of several Shapiro-Wilk tests of normality.

RESULTS: Hip, knee and ankle flexion-extension angles were measured at the time of placement of the left foot on the force platform and at the moment just before the right foot made contact with the ball (one frame before). T-tests revealed significant differences in knee angles at foot placement between the light and maximum conditions ($t_{(7)}=-6.976$, $p=0.00$, $p<0.05$). The same occurrence was observed again for knee angle just before ball contact between the light and maximum boot weight conditions ($t_{(7)}=3.185$, $p=0.015$, $p<0.05$). Angular velocities of the kicking limb on the sagittal plane just before ball contact were also computed, revealing a greater general value for the knee (mean value for the light condition=1638 ±251 deg/s), followed by the ankle (mean value for the light condition=482 ±109 deg/s). The mean value for the hip in the light condition was 134 ±46 deg/s). Again, no significant differences were found regarding this data. Based on the linear velocity of the centre of gravity of the right foot and on the maximum ball in-flight velocity, the ball-to-foot ratio was determined. Results are summarised in figures 1, 2 and 3. Although the ball-to-foot ratio increased with the weight of the boot, no significant differences were found regarding this parameter. Foot centre of gravity linear velocity on the other hand decreased with heavier boots and significant differences were found between light and medium ($t_{(7)}=2.727$, $p=0.029$, $p<0.05$) and light and maximum conditions ($t_{(7)}=3.187$, $p=0.015$, $p<0.05$).

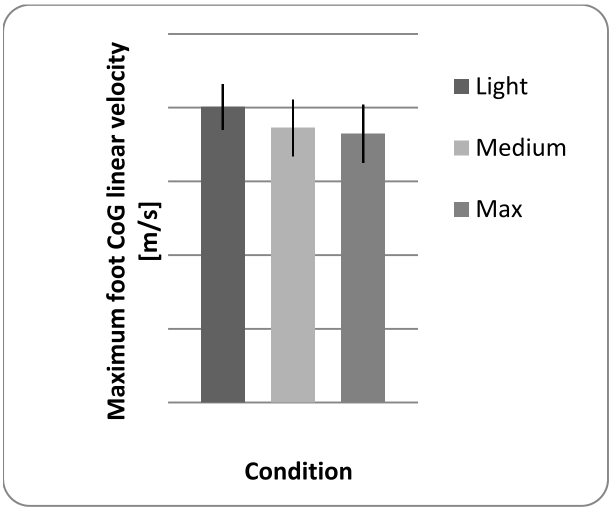
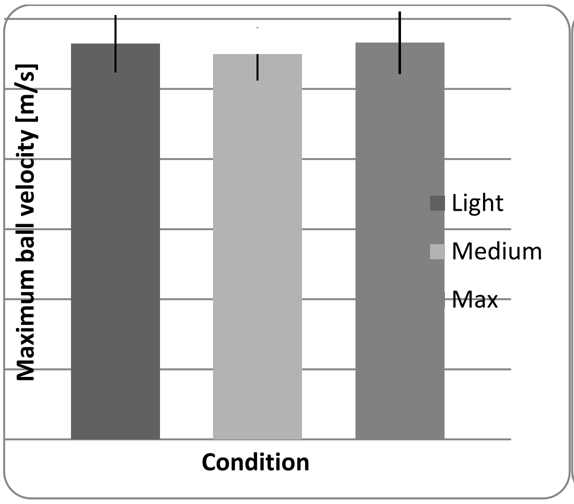


Figure 1: Foot centre of gravity maximum linear velocity.



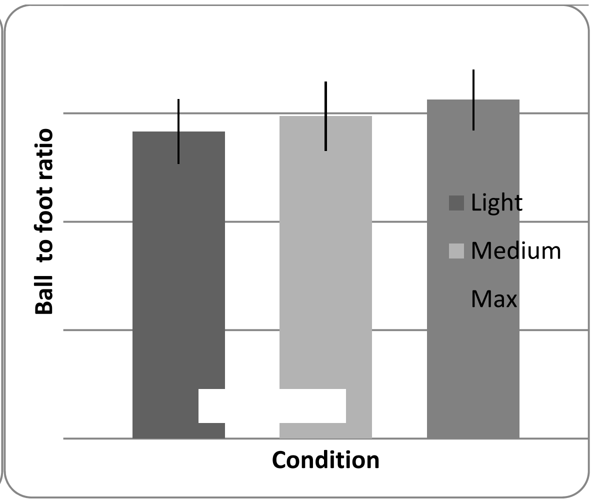


Figure 2: maximum ball linear velocity. **Figure 3: ball-to-foot ratio.**

DISCUSSION: No significant differences in ball maximal velocity were found between the three different conditions. Regarding joint angles, our results show that only the knee reported significant differences. At foot placement, the joint is less extended in the light condition (101 ±7°) compared to the maximum condition (108 ±7°). At ball contact however, the knee is more extended in the light condition (137 ±8°) than the maximum one (134±6°). This implies a bigger range of movement (36°) in the lighter condition compared to the one achieved by participants with the heavier boot (26°). If we presuppose the time between foot placement and ball contact to be reasonably the same throughout the trials, this finding should result in a greater knee angular velocity; in other words the rate of angle change should be greater. This is actually the case, with participants in the light condition registering a maximum knee angular velocity of 1638 ±330 deg/s compared to 1586 ±229 deg/s of the maximum condition. This difference however was not significant. Perhaps the most interesting finding of this study regards the foot centre of gravity linear velocity and maximum in-flight ball absolute velocity. Whilst the foot c.o.g. linear velocity decreased with the increase of weights placed on the inoles of the boots (velocities in the light, medium and maximum conditions were respectively 20 ±1.55 $m \cdot s^{-1}$, 18.64 ±1.93 $m \cdot s^{-1}$ and 18.24 ±1.97 $m \cdot s^{-1}$), there was no change in ball velocity. Therefore, the ball-to-foot ratio ratio constantly increased with heavier boots, reaching a peak of 1.56 ±0.14. This finding is in accordance with Amos & Morag (2002). This may be explained by the physics law of the conservation of kinetic energy; when two objects collide in an elastic manner, the kinetic energy is transferred from one object to the other. The kinetic energy is a function of the mass of the object, therefore an object with a bigger mass has a greater kinetic energy when travelling at a certain speed. Obviously, kinetic energy is also a function of the velocity of the object. Our finding suggests that the decrease in velocity is compensated by the increase in mass, resulting in the same ball velocity being generated.

CONCLUSION: Performing a maximal instep soccer kick with a heavier boot has the effect of decreasing the hip and knee range of flexion/extension in the support phase; the knee registers a decrease in angular and linear velocity towards ball contact. No significant differences regard the ankle joint, however our findings show that the foot linear velocity does decrease with a heavier boot. Ball velocity is not affected, therefore the increase in mass must compensate for the decrease in velocity. Our results, in accordance with the work by Sterzing and Hennig (2008) and Amos and Morag (2002), suggest that ball velocity is not affected by shoe mass; the new, lighter soccer boots might be beneficial for players' performances in the form of agility and acceleration of movements, however concerns about potential impacts on injuries such as metatarsal fractures due to less protective material in the boot must still be kept in mind, and further research on the subject is strongly recommended.

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