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THE INFLUENCE OF FOOTBALL BOOT CONSTRUCTION ON BALL VELOCITY AND DEFORMATION

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ABSTRACT

Running footwear research on the biomechanical properties of football boots has received little scientific attention. Recently, modern and scientific football boots has been developed that affords excellent ball control, shooting and running ability. Different construction of football boots delivers different velocity and deformation of the ball. In this study, three commercially available football boots were compared during kicking experiment in terms of, ball velocity and deformation of the ball. A subject performed three repetitive shots of the ball into the net for each football boot model. The footballer foot and the ball velocity were recorded using a high speed camera. From the recorded video, the kicking velocity, ball velocity and ball deformation were measured. Based on the foot and ball velocity data, the Coefficient of Restitution (COR) was calculated. The results obtained show the COR value varies with different boots (COR_{bootA} = 0.89, COR_{bootB} = 0.59, COR_{bootC} = 0.47) thus delivers different ball velocities at same kicking foot velocity (U_{leg} = 14 ms^{-1}). It is apparent that the Boot A was made with the best upper material (Teijin synthetic leather), design and also construction of the boot.

***Keywords*:** COR, Ball velocity, Football boot, Soccer, Deformation

INTRODUCTION

Kicking is the most specific technique in football, so it is appropriate to give considerable attention for our understanding of this skill from a biomechanical perspective. Researchers have widened their interest to consider the kick beginning from the way a player approaches the ball to the end of the ball flight. This field of study has encapsulated the overall technique and the influences of the upper body, support leg and pelvis on the kicking action, foot-ball impact and the influences of footwear and soccer balls, ball launch characteristics and corresponding flight of the ball.

When a ball is kicked, the leg is putting energy into the ball and the ball deformed. The part of the ball impacted by the foot was flattened for a few milliseconds. The energy going into the collision is the kinetic energy of the foot plus the stored energy in the deformed ball and the energy coming out is the kinetic energy of the ball. The conservation of energy causes the ball to go faster than the velocity of the foot

As kicking the ball is categorized as a collision mechanics (Sterzing and Hennig, 2007) , the ball velocity can be determined by using the law of the conservation of momentum and Coefficient of Restitution (COR).

$$M_{leg}U_{leg} + M_{ball}U_{ball} = M_{leg}V_{leg} + M_{ball}V_{ball} \quad (1)$$

$$e = \frac{V_{ball} - V_{leg}}{U_{leg} - U_{ball}} \quad (2)$$

From the above equations, the derivation of the actual formula for the velocity of the ball is (Lees et al., 1993):

$$V_{ball} = U_{leg} \frac{M_{leg}}{M_{leg} + M_{ball}} (1+e) \quad (3)$$

The velocity of the kicking leg (U_{leg}) is controlled by the player before contact. It has been proven that powerful kicking at impact results in differing ball velocities (Kellis and Katis, 2007). The term $M_{leg} / (M_{leg} + M_{ball})$ relates to the muscles involved in the kick, and their strength at impact. The (1+*e*) term relates to the rigidity of the foot at impact (Lees et al., 1993). In this study, the effort to manipulate the mass of leg can be neglected as the player cannot gain the mass of leg while kicking to achieve maximum ball velocity. The focus of this study is on the football boot construction where the COR (*e*), is the variable that can be measured to increase the ball velocity.

The COR in kicking determine the transfer of velocity from the foot to the ball during the impact phase and is the ratio between relative velocity ($V_{ball} - V_{leg}$) after impact and the relative velocity before impact (Andersen et al., 2005). The factors determining the COR are the mechanical properties of the foot and ball, i.e. stiffness, contact area and contact point.

There are several studies that had been done by researchers to evaluate the best method for football kicking. In Japan, a study claimed that for a more precise ball, the side-foot kick are the most suitable style while for a faster ball, the instep kick should be used (Shinkai et al., 2008). It was found that the difference in the passive foot angular motion during ball impact was due to the difference of the ball impacting part of the two kicks and that foot motion of both side-foot kicking and instep kicking were different but the quality of the ball impact was similar for both type of kicking. For this current study, the toe kick is selected to be used for the kicking experiment. A study in Denmark (Andersen et al., 2005) had found that the toe kick produce a larger COR compared to the instep kicking.

Several kicking experiments had been done by researchers to evaluate the factors influence the ball velocity in kicking. Previous research had found that football boot also contributed towards the ball velocity. In UK, a study was done to analyze whether football boot mass has an effect on ball velocity (Moschini and Smith, 2012). Ten male university students participated in the study to kick a ball with three different masses of boots that was attached with three different lead plates (180.8 g, 260.6 g, and 356.1 g). They had concluded that the foot linear velocity does decrease with heavier boots but the ball velocity was not affected.

A research to quantify the influence of different shoe upper friction properties on ball velocity during kicking was done in Germany (Sterzing and Hennig, 2007). They have used four boots with different friction properties of the upper materials during their experiment. In this study, they concluded that friction materials of football boot uppers did not show any statistically significant influence in achieving different ball velocity during instep kicking.

METHODS

One male university soccer player with no lower limb injury in the previous six month was chosen as the subject in this study (23 y; 74.3 kg; 1.77 m). Before the experiment, the subject was asked to perform warm up in order to avoid musculo-skeletal injuries during the session. A simple briefing session was carried out to make sure the subject was fully understood the experiment procedures. Three different type of football boot was chosen for the kicking experiment (Nike Mercurial Vapor VIII FG (Boot A); Adidas AdiPower Predator TRX FG (Boot B); Puma King Finale SL I FG (Boot C)). The participant had to perform three maximal toe kicks for each football boot with a mandatory rest period between single kicks to avoid fatigue. The subjects were instructed to take three steps before kicking the ball into the net 2 m from the kick area.

A green Adidas FIFA standard football ball size 5 with diameter of 220 mm and weight 450 g was used for the experiment. The ball was inflated with a pressure of 0.65 bar. Markers were placed on the specific area on the foot and ball to aid in velocity and ball deformation measurement. The kicking action was captured using EPIX SV643C high-speed camera with 2,500 frames per second recording speed. The recorded video was than analyzed using the XCAP high-speed camera build-in software to calculate the foot kicking velocity (U_{leg}), foot after kicking velocity (V_{leg}), and also the ball velocity (V_{ball}). The COR of each football boot was calculated using Eq. (2). The ball deformation on one selected kicking velocity was measured and grouped based on the type of football boot.

RESULTS

The kicking action was captured using a high speed camera and analysed to get foot kicking velocity (U_{leg}), foot after kicking velocity (V_{leg}), and also the ball velocity (V_{ball}). The COR varies with the foot kicking velocity for each boot as shown in Fig 1 to 3.

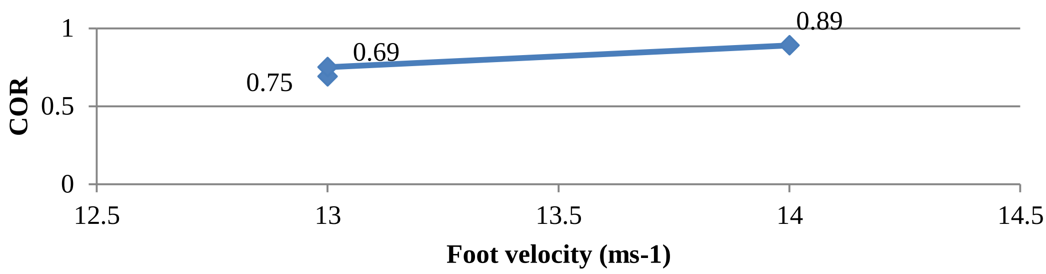

Figure 1. Calculated COR for Boot A with different kicking velocity

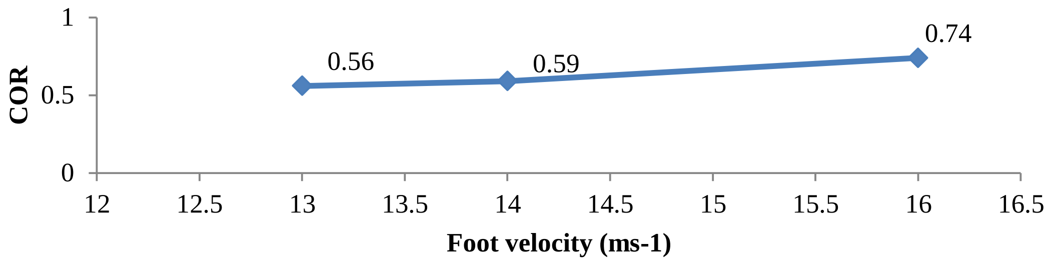

Figure 2. Calculated COR for Boot B with different kicking velocity

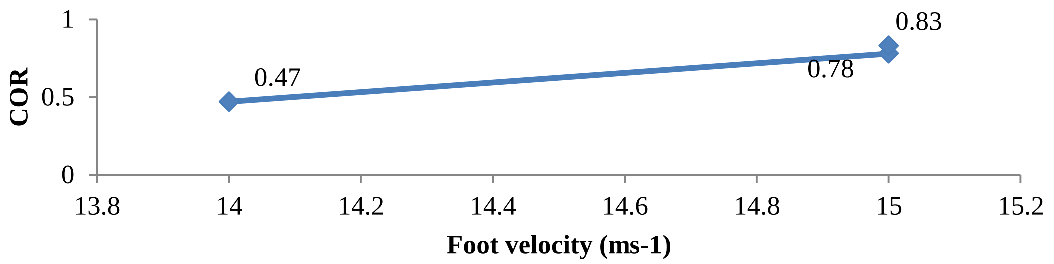

Figure 3. Calculated COR for Boot C with different kicking velocity

From three calculated analysis above, Boot A recorded the highest COR value (0.89) while Boot B and Boot C recorded 0.59 and 0.47 respectively at a specific selected kicking foot velocity (U_{leg} = 14 ms^{-1}) as shown in Fig 4.

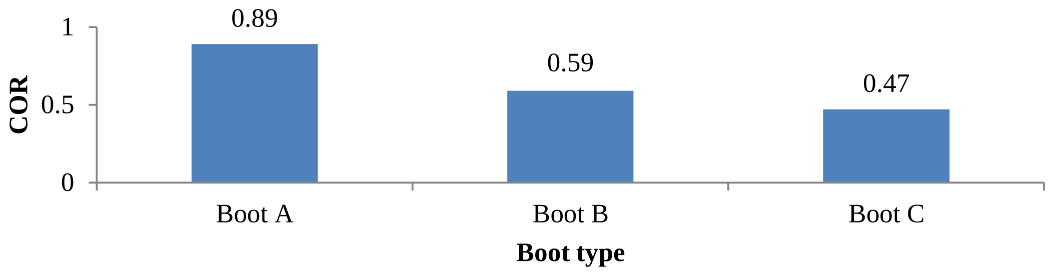

Figure 4. COR of each boot at 14 ms^{-1} kicking foot velocity

The maximum deformation of the ball was measured using the XCAP build-in measuring software. The measured data was grouped into certain kicking velocity based on each football boot model. The largest ball deformation was produced with Boot A (≈36 mm). The maximum ball deformation picture by boot type is shown in Fig 5.

Figure 5. Maximum ball deformation for each boot type

A summary of the foot kicking velocity, maximum ball deformation, ball velocity and also COR are shown in the table 1.

Table 1. Experiment result summary

	Boot A	Boot B	Boot C
Foot kicking velocity (ms^{-1})	14	14	14
Max ball deformation (mm)	36	30	26
Ball velocity (ms^{-1})	20.8	19.2	16.2
COR	0.89	0.59	0.47

CONCLUSION

From the experiment, the COR value varies with different boots (COR_{bootA} = 0.89, COR_{bootB} = 0.59, COR_{bootC} = 0.47) thus delivers different ball velocities at same kicking foot velocity (U_{leg} = 14 ms^{-1}). A high COR results a high ball velocity and also ball deformation. It can be concluded that the Boot A was designed with the best upper material construction properties for toe kicking compared with other two football boots. This type of upper material (Teijin synthetic leather) and the boot construction design with forefront thickness (*t*) of 1.88 mm would be the best to be use to produce high ball velocity with the lowest kicking velocity compared to the Boot B (full-grain calfskin, *t* = 2.59 mm) and Boot C (premium kangaroo leather, *t* = 1.75 mm). An experiment with larger sample sizes could be conduct in future to obtain precise and statistically analysis results.

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