DIFFERENCES IN KICKING DYNAMICS OF FUTSAL AND SOCCER BALL

James Peacock[1], Alessandro Garofolini[1], Luca Oppici[1], Fabio Serpiello[1] and Kevin Ball[1]

College of Sport and Exercise Science, Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne, Australia[1]

Differences in equipment influence the execution of a skill. To date, no literature has identified if ball properties influence foot-ball impact of kicking. The aim of this study was to compare kick impact characteristics of a futsal (FB) and soccer ball (SB). A mechanical limb impacted each ball to standardise all kicking characteristics. High speed video camera (4,000 Hz) captured impact characteristics of each ball. Significant differences ($P < 0.05$) were observed between the two balls. The SB displayed a higher coefficient of restitution, average force and ball velocity. The timing of key events during impact differed; the FB velocity was higher for the first 75% of impact duration, where it was then exceeded by the SB. The SB was characterised by decreased energy losses, notable during the reformation phase. This work identified that ball properties do influence the impact phase of kicking.

KEY WORDS: football, equipment, mechanical properties, equipment modification.

INTRODUCTION: Equipment influences the execution of sport skills and it can be altered to improve performance, decrease the risk of injury and promote the learning process of a skill (Araújo, Davids, Bennett, Button, & Chapman, 2004; Kulessa, Gollhofer & Gehring, 2017; Sterzing & Hennig, 2008). Equipment used for kicking, one of the most important skills across the football codes, includes footwear and the ball. Previous literature has focused on footwear, both in contact with the ground or ball, leaving the effect of ball properties during kicking almost unexplored (Kulessa, et al., 2017).

The use of a Futsal ball (FB) compared to a classic soccer ball (SB) has been argued to better promote the acquisition of ball 'handling' (Button, Smith, & Pepping, 2005). It is anecdotally reported that a FB can be 'handled' more easily; it is felt the ball does not bounce off the foot uncontrollably. Elite soccer players often state that practicing with a futsal ball early in their career facilitated the development of ball-related skills. However, no research to date has investigated whether differences do exist between the two balls and how these differences may change the foot-ball impact of kicking.

Therefore, the aim of the present study was to compare kick impact characteristics of a FB and SB. The website of the Federation Internationale de Football Association (FIFA, 2017) specifies each ball must adhere to a different size, weight, inflation and bounce height. The bounce height requirements indicate the FB should have a coefficient of restitution (COR) (where $COR = \sqrt{Bounce\ height/Drop\ height}$) between 0.5 to 0.57, and the SB 0.82 to 0.88. Therefore, it is hypothesized that if both balls are impacted with a constant foot speed, no difference is expected in the force applied to the ball during deformation, but a greater force is expected during reformation for the SB, to ultimately produce a greater ball velocity for the SB.

METHODS: A mechanical kicking machine performed multiple instep kicks under a controlled setting. This limb was previously identified to validly represent the impact phase of punt kicking (Peacock & Ball, 2016), and due to similarities between the instep and punt kicks, where the ball is impacted on the dorsal aspect of the foot, the use of the machine appropriately provided a controlled setting for the comparison. Two balls were used for the comparison, a FIFA approved SB (Adidas Beau Jeu; size = 5; mass = 0.44kg; inflation = 83.4 kPa) and a FIFA approved FB (Adidas Conext15; size = 4; mass = 0.42 kg; inflation = 73.5 kPa). Inflation was standardised by choosing the midpoint between the range specified on each respective ball. Five trials were captured for each ball; the mechanical leg impacted the ball with a foot speed of 16.7 ± 0.02 m/s and all other impact characteristics were held constant (i.e. impact location approximated on the foot centre).

Two-dimensional sagittal plane data of the leg and ball were captured with high-speed-video camera (Photron MC2, Photron Inc., USA) at a sample frequency of 4,000 Hz. The geometric centre of the ball was measured from six markers attached to the right edge of the ball. The foot centre was calculated from the midpoint between the ankle and fifth metatarsal head. Markers were tracked from 20 frames before to 20 frames after foot-ball contact using ProAnalyst software (Xcitex Inc., USA). Raw X-Y coordinate data were exported into Visual3d (C-Motion Inc., USA) for analysis with a custom made script. Data during impact were smoothed with a low-pass Butterworth filter with a cut-off frequency of 130 Hz and 50 points reflected. The choice of cut-off frequency was based on Direct Fourier Transform analysis and visual inspection of the time-series curves at different cut-off frequencies. Foot and ball velocity were measured from the first derivative of positional data. Time-series data were normalised to 100 frames from ball contact to ball release, and four phases of impact (i.e., Phase 1, 2, 3 and 4) were identified using the criteria of Shinkai, Nunome, Isokawa & Ikegama (2009). Ball deformation was calculated from the change in displacement between foot and ball at ball contact; deformation and reformation phases were identified using the point of maximum deformation. Average force was calculated from the change in ball velocity, ball mass and time of the respective phases.

To determine if differences existed between balls, a two sample equal variance t-test with one tail ($p = 0.05$) was used to test for significance, and effect sizes (Cohen's d) described the magnitude of difference ($d < 0.2$ = none; $d < 0.5$ = small; $d < 0.8$ = medium; $d > 0.8$ = large).

RESULTS: No difference was observed for the change in foot speed from the start to end of impact, therefore this measure was not considered for further analysis. Impact characteristics differed significantly between the two balls, apart from contact time (Table 1). The SB displayed greater ball velocity, COR and average force.

The profile of impact (Figure 1) identifies the timing of individual phases differed between the balls. The FB displayed a higher velocity for the first 75% of impact duration, where it was then exceeded by the SB. Phase 2, 3 and 4 all began earlier in the duration of impact for the FB.

Deformation and reformation characteristics differed between the FB and SB (Table 2). Force and ball velocity increase during deformation were greater for the FB. In contrast, force and ball velocity increase during reformation were greater for the SB.

Table 1
Impact characteristics for Futsal (FB) and Soccer (SB) ball.

	Coefficient of restitution	Ball velocity (m/s)	Average force (N)	Contact time (ms)
FB	0.51 (0.01)	19.8 (0.1)	789 (10)	10.6 (0.1)
SB	0.60 (0.02)	21.2 (0.2)	887 (8)	10.5 (<0.1)
T.test (p-value)	<0.01	<0.01	<0.01	0.17
Effect size (Cohen's d)	6.36	9.41	10.74	0.63
Magnitude of difference	Large	Large	Large	Medium

Values reported are mean (standard deviation).

Table 2
Deformation and reformation characteristics for Futsal (FB) and Soccer (SB) ball.

	Maximum deformation (cm)	Def. force (N)	Def. ball velocity increase (m/s)	Ref. force (N)	Ref. ball velocity increase (m/s)
FB Mean	5.2 (0.1)	1137 (19)	13.1 (0.2)	488 (27)	6.7 (0.3)
SB Mean	5.5 (0.2)	1096 (23)	12.5 (0.2)	698 (21)	8.7 (0.2)
T.test (p-value)	<0.01	0.01	<0.01	<0.01	<0.01
Effect size (Cohen's d)	2.26	1.90	2.84	8.73	8.20
Magnitude of difference	Large	Large	Large	Large	Large

Values reported are mean (standard deviation). Abbreviations are deformation (def.) and reformation (ref.).

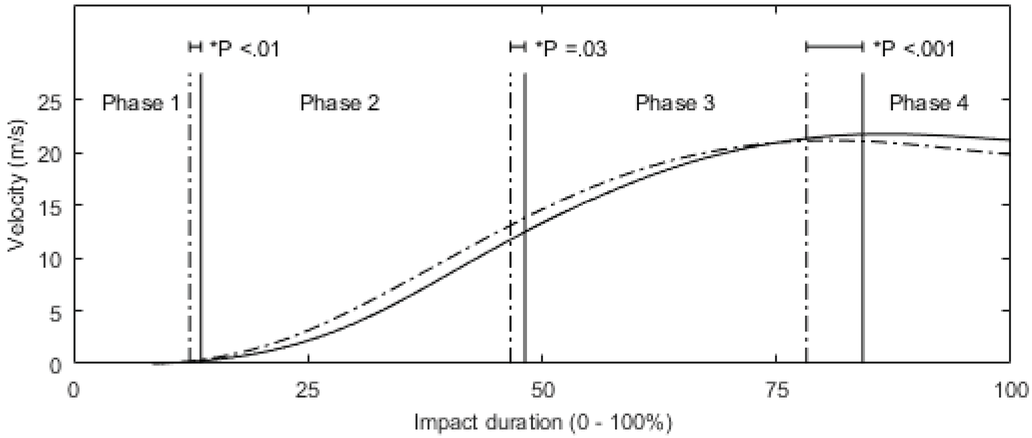

Figure 1: Ball velocity during impact of FB (dashed line) and SB (solid line). The vertical lines represent the separation between each phase of impact for the respective ball, and the timing of these phases were tested for significance.

DISCUSSION: The aim of the present study was to identify differences in impact characteristics between a FB and a SB. Different deformation and reformation characteristics were observed between the two balls; the velocity of the FB was greater than the SB for the first 75% of impact duration where it was then exceeded by the SB.

A greater COR for the SB during a football kick coincides with the requirements of FIFA (2017), whom specify a SB (0.82 to 0.88) must be greater than the FB (0.5 to 0.57). However, the magnitude of COR for the SB in our study was considerably lower than that during the bounce test. Andersen, Dörge & Thomsen (1999) reported a COR of kicking a SB with human performers to be 0.575, similar to the values for the present study. This highlights the importance of measuring COR through sport-specific test when examining the influence of ball properties on performance.

The soccer ball had a greater ball velocity at the end of impact, achieved by a greater average force but with no difference in contact time. Interestingly, the profile of impact (Figure 1) shows ball velocity for the FB to be greater until 75% of impact duration, due to differences in timing of the four phases throughout impact. Phases 2, 3 and 4 all began earlier into the duration of impact for the FB, but the time spent in phase 4, where ball velocity plateaued, was greater. This indicates different ball properties can influence the timing of individual phases during impact.

Ball deformation characteristics differed between the two balls, with a greater increase in ball velocity for the FB. During deformation, the foot applies a force to the ball (Shinkai et al., 2009), and because foot velocity was held constant, it might have been expected no differences to occur during this phase. However, the two balls showed a different behaviour during deformation, with a greater force and greater ball velocity increase for the FB.

Ball reformation characteristics differed between the two balls. The force applied to the ball and, most notably, the increase in ball velocity during reformation were both significantly larger for the SB, indicating a decreased energy loss for the SB. During reformation, the ball applies a force to the foot from the stored elastic energy (Shinkai, et al., 2009), and the differences observed must be due to the different properties of the balls. The COR represents the portion of elastic energy stored during deformation that is converted to kinetic energy during reformation, and energy losses are represented by a decreased force during reformation compared to deformation (Cross, 2014). The larger reformation force and greater increase in ball velocity for the SB indicates greater energy loss for FB, and coincides with the measured values of COR.

Anecdotally it is commonly reported that a FB can be ‘controlled’ more easily than a SB; it is felt the ball does not bounce off the foot uncontrollably. This study identified differences between a FB and a SB, where the key difference of a lower ball velocity due to increased energy losses for the FB may explain why a FB is easier to control. In game situations, this might be expressed by kicking with a FB to be more accurate, but with a lower velocity. Modified equipment that simplifies the execution of a skill has been shown to reduce conscious processing during performance. This promotes implicit learning that eventually leads to the development of movement automaticity, which is a fundamental feature of skill acquisition (Buszard, Farrow, Reid & Masters, 2014). In the context of this study, the properties of FB that facilitate ball control could reduce learners' cognitive processing, in turn, fast-tracking the development of movement automaticity. Put simply, controlling FB may feel more 'natural' and it may require less 'thinking' than SB. Therefore, novices may be able to kick and control FB with more ease than SB and the learning curve is expected to be steeper. As such, the results of this study might suggest practitioners to prefer FB over SB in the early phase of the learning process to facilitate the acquisition of ball-related skills. Once the skill becomes automatic, performers might then be able to transfer the acquired skill to soccer. Future research direction is to investigate the benefits of practicing with FB or SB, and the potential transfer of skills from FB to SB.

CONCLUSION: This study has provided a comparison of a soccer ball and a futsal ball, on which more anecdotal rather than scientific data were available. Driven by a known difference between ball properties, we tested their behaviour during the kicking movement. Coefficient of restitution was greater for the soccer ball, coinciding with the specifications by FIFA (2017). Ball velocity and force during specific phases of impact displayed interesting differences. The futsal ball had a higher force during deformation, and its velocity was higher for the first 75% of impact duration. The soccer ball had a higher force during reformation, where its velocity exceeded that of the futsal ball during the phase due to less energy losses. It could not be identified specifically which property caused the differences, but the implication of these results indicate ball properties can influence the impact between foot-ball of kicking that, in turn, may fast-track the acquisition of ball-related skills. Future work should directly examine the influence of specific ball properties on i) the impact phase, ii) performance, iii) risk of injury and iv) skill learning process.

REFERENCES:

Andersen, T.B., Dörge, H.C., & Thomsen, F.I., (1999). Collisions in soccer kicking. *Sports Engineering, 2*, 121-125

Araújo, D., Davids, K., Bennett, S.J., Button, C., & Chapman, G. (2004). Emergence of sport skills under constraints. In A. M. Williams & N. J. Hodges (Eds.), *Skill acquisition in sport: research, theory, and practice*: London; New York: Routledge.

Buszard, T., Farrow, D., Reid, M., & Masters, R. S. (2014). Scaling sporting equipment for children promotes implicit processes during performance. *Consciousness and Cognition, 30*, 247-255.

Button, C., Smith, J., & Pepping, G. (2005). The influential role of task constraints in acquiring football skills. In Thomas Reilly, Jan Cabri, & Duarte Araujo (Eds.), *Science and football V. the proceedings of the Fifth World Congress on Science and Football*: London: Routledge.

Cross, R. (2014). Impact of sports balls with striking implements. *Sports Engineering, 17*, 3-22.

Federation Internationale de Football Association (accessed February 14th, 2017). *Laws of the game.* Retrieved from http://quality.fifa.com/en/Footballs/Quality-Programme-for-Footballs/Laws-of-the-Game/.

Kulessa, D.J., Gollhofer, A., & Gehring, D., (2017). The influence of football shoe characteristics on athletic performance and injury risk – a review. *Footwear Science,* doi:10.1080/19424280.2017.1284273

Peacock, J., & Ball, K., (2016). The impact phase of drop punt kicking: Validation and experimental data of a mechanical kicking limb. *Paper presented at the 34th International Conference on Biomechanics in Sport*, Tsukuba, Japan.

Shinkai, H., Nunome, H., Isokawa, M., & Ikegami, Y. (2009). Ball impact dynamics of instep soccer kicking. *Medicine & Science in Sports & Exercise, 41*, 889–897. doi:10.1249/MSS.0b013e31818e8044

Sterzing, T., & Hennig, E.M., (2008). The influence of soccer shoes on kicking velocity in full-instep kicks. *Exercise and Sport Sciences Reviews, 36*, 91-97.