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Introduction

Measuring impact variables for a football serves the purpose of understanding and quantifying its behaviour during impacts with surfaces or objects. They provide crucial insights into the dynamics of the collision, the deformation of the football and the forces involved. The information can be used to train mathematical models to advance the scientific knowledge about the behaviour of footballs under impact conditions [1-3]. This can be valuable for improving the design and for the quality control of footballs, enhancing player safety and optimising game performance.

Method

Twelve footballs from various licensees (FIFA-Certified, Size 5, 0.80 ± 0.01 bar) were each impacted 25 times at a velocity of approximately 6 and 20 m·s^{-1}. To achieve 6 m·s^{-1}, the football was dropped from 2 m and to achieve the higher velocity a bespoke 4-wheel ball-launching device accelerated the football. The football impacted a floor-mounted piezoelectric force platform (Kistler 9281EA, Kistler Holding AG; dimensions: 600 x 400 mm, natural frequency: 1kHz) without spin and above one of the corner sensors to maximise the dynamic response of the system. The impact was recorded using a single high-speed camera (Phantom MIRO 311, Vision Research Ltd., USA; resolution 320x800 p, sample rate 10,000 fps) calibrated using planar checkerboard calibration. The deformation (δ_b) and contact length (l) were measured to characterise the change in shape of the football at maximum deformation (Figure 1). These variables along with the COR and contact time (T) were measured using automated and manual digitisation of the high-speed video frames. The peak impact force (F) and impulse (I) were calculated from the output of the force platform.

Statistical analysis was carried out using SPSS (SPSS, 26.0.0.1, IBM Corporation). The normality of each metric was assessed using Shapiro-Wilk tests, $\alpha \geq 0.05$. The Pearson correlation between impact variables was calculated using all repeated impacts for the footballs (n=300).

Results

The correlation between COR and contact time with the other impact variables are shown in Figure 1. Figure 2 shows a force trace for a single impact of the football with the lowest and highest contact time at both velocity conditions.

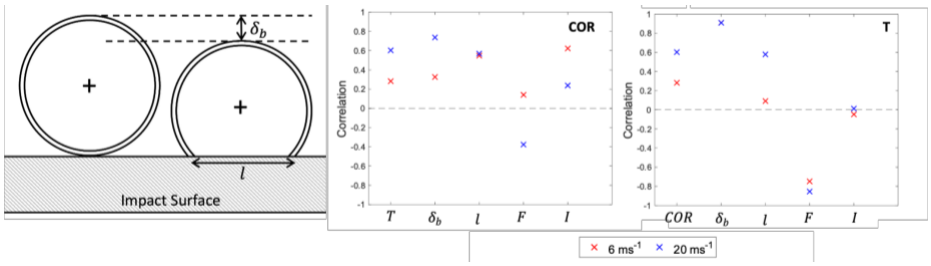

Figure 1 Diagram of deformation measurements (Left). The correlation between COR (middle) and contact time (right) with the other impact variables

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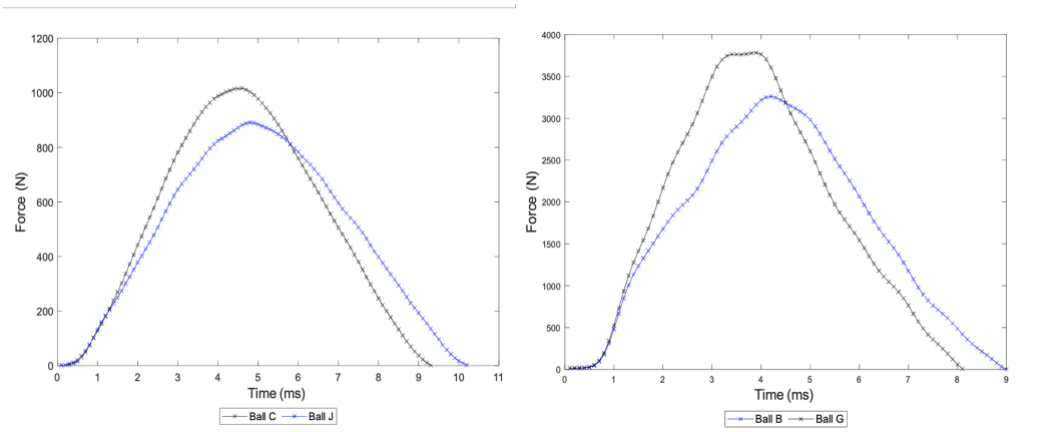

Figure 2: The force-time profile for a single impact for the footballs with the shortest (black line) and longest (blue line) contact time. 6 m·s^{-1} (left). 19 m·s^{-1} (right).

Discussion

The study measured rebound variables for an impact between a football and a force platform at two velocities. Differences in the impact variables were measured between the 12 footballs. The contact time is governed by the material properties and internal air pressure of the football, it is affected by how quickly the materials can deform and then restore their original spherical shape. A football with a stiffer construction will exert higher restoring forces that leads to less deformation and shorter contact times, and this was reflected in the correlations shown in Figure 1. The force-time profiles shown in Figure 2 also confirmed the association between contact time and impact force. Each football experienced a similar magnitude of momentum change during the impact, the negative correlation between contact time and force is logical since a football that has a longer contact time will require less force to achieve the same momentum change. The correlations observed among the impact variables emphasised the complexity of analysing the impact behaviour of a football, indicating the potential need for multiple variables to comprehensively describe it.

Conclusion

The linear correlations revealed the associations between the impact variables at two inbound velocities, but a single impact variable cannot solely explain the rebound characteristics. There is a need to explore a modelling technique that can establish a relationship between a dependent variable and multiple independent variables to fully comprehend how impact variables might reflect outbound performance.

References

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