# ASSESSING THE KINEMATICS OF A NOVEL COLLISION SPORT SIMULATOR

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The tackle is a common and dynamic phase of play in rugby union and other collision sports. It is necessary to study the tackle to characterise its various facets that include impact force, biological markers, and technical and skill-related requirements. Therefore, a novel collision sport simulator was designed to replicate front-on tackle situations. This study describes the movement and velocity properties of the simulator relative to the force of pressure exerted by a pneumatic system. Future research using this simulator may guide the development of skill training/conditioning sessions and injury prevention programs.

**KEY WORDS:** tackle, rugby union, performance analysis

**INTRODUCTION:** The tackle is a dynamic phase of play in rugby union (Brooks et al., 2005) and the high injury rate in the sport is primarily due to tackle-related injuries (Fuller et al., 2007). Tackling involves the transfer of energy between an attacking player (ball-carrier) and one or more defenders (tacklers) who attempt to impede the progress of the ball-carrier, regardless of whether or not the ball-carrier is brought to ground (Fuller et al., 2010). These activities expose players to a high physical load (Hendricks and Lambert, 2014) and require a high level of technical proficiency (Burger et al., 2016). Therefore, it is worthwhile that physiological, technical and biomechanical factors associated with the tackle are analysed in detail to characterise this event and help guide training routines, physical conditioning regimes and injury prevention strategies. This may be achieved by formulating ecologically valid study protocols. However, there are few studies in this area. A previous study assessed the impact forces of tackling using a stationary punching bag (Usman et al., 2011). A dynamic representation of the tackle situation may yield more valid results (Seminati et al., 2015). Laboratory protocols should replicate real-life tackle situations as accurately as possible. The aim of this study was to assess the kinematics of a novel automated collision sport simulator.

**METHODS:** *Equipment:* The simulator comprises of two A-frames spanned by three horizontal beams (Figure 1A). A pneumatic system was built to automate the simulator (Figure 1B). The lever arm of the system is secured to the central horizontal beam via a movable trolley (trolley ‘A’). This trolley is situated adjacent to a second ‘floating’ trolley (trolley ‘B’) that has a hook for the attachment of a detachable tackle dummy. The dummy has a mass of 37,8 kilograms

and comprises of three separate metal shells (trunk, upper leg/thigh and lower leg) enclosed by three layers of foam and rubber. The design allows for flexion and extension. Trolley ‘B’ and the dummy are propelled forward by the lever arm and trolley ‘B’ of the pneumatic system along the central horizontal beam. The desired velocity is determined via the force of pressure exerted by the compressor that drives the pneumatic system.
*Testing protocol:* The compressor was initially set at 2 psi (pounds per square inch) and performed 7 repetitions (same protocol was performed for 3-7 psi).
*Video analysis:* Video footage was recorded and analysed using Dartfish Pro (Version 8, Dartfish, Switzerland). Distance was measured using a scale of 1 metre (known distance marked on horizontal beam). The dummy’s centre of gravity (CoG) was set at the point adjoining the trunk and upper leg/thigh i.e. hip region, and the estimated point of contact in the simulator was subjectively set at approximately 2.3 metres from the start point of the dummy.
*Analysis:* Angular velocity (ω) of the dummy was calculated in degrees per second (deg/s) (Hall, 2007). A positive ω indicated the vertical axis or ‘spine’ of the dummy was rotating in an anticlockwise direction i.e. extending/pivoting backwards, and negative ω indicated the vertical axis was rotating in a clockwise direction i.e. flexing/pivoting forwards (Hall, 2007). The linear acceleration of trolley ‘B’ ($m.s^{-2}$) was also calculated to describe the speed of movement of the dummy in relation to the trolley. Means and standard deviations (±SDs) were reported for both measures. The mean angle of the dummy’s vertical axis at the estimated point of contact (95% confidence intervals (95%CIs) were reported) and the mean resultant linear velocity ($m.s^{-1}$) ±SDs of the dummy’s CoG at the estimated point of contact were also calculated.

A

B

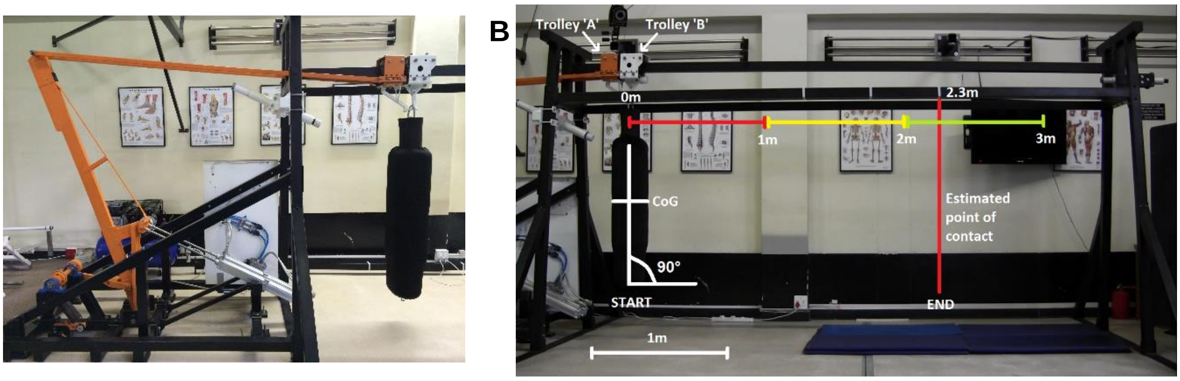


**Figure 1: A: Pneumatic system; B: collision sport simulator.**

**RESULTS:** There was a large range in angular velocity at the third metre (Table 1). The results were more consistent at the first and second metres. Angular velocity increased steadily with higher pressures at the second metre. These values were all positive and indicate that the vertical axis of dummy moved in an anticlockwise direction during this phase. The greatest rate of change occurred at 7 psi (202.7 deg/s; ±9.36).
The mean acceleration of the vertex of the dummy or trolley ‘B’ was calculated and tabulated alongside the angular velocity (Table 1). The data show that as angular velocity had decreased at the first and third metres i.e. there was no forward swing or anticlockwise movement by the dummy, the acceleration of trolley ‘B’ had increased. Vice versa as angular velocity of the dummy had increased at the second metre i.e. the ‘feet’ of the dummy swung forward and its vertical axis or ‘spine’ was extended backwards, trolley ‘B’ had decelerated.
The mean angle of the dummy at the estimated point of contact was greater than 90 degrees i.e. in a backward extension position, for all pressure force values (2 psi=92.74°, 95%CI:79.2-106.3; 3 psi=121.8°, 95%CI:112.6-130.9; 4 psi=128.2°, 95%CI:120.8-135.7; 5 psi=134.9°, 95%CI:132.1-137.6; 6 psi=135.1°, 95%CI:131.2-139.0; 7 psi=136.9°, 95%CI:134.5-139.3).

The mean resultant linear velocity of the dummy's CoG at the estimated point of contact was greatest at 7 psi (2.12 m.s$^{-1}$, ±0.09) (Figure 2).

**Table 1. The mean angular velocity for the whole dummy (deg/s) ±SDs and mean linear acceleration for trolley 'B' (m.s$^{-2}$) ±SDs over three metres. (SD – standard deviation).**

| | 1st metre | | 2nd metre | | 3rd metre | |
|---|---|---|---|---|---|---|
| **Pressure** | **Velocity** | **Acceleration** | **Velocity** | **Acceleration** | **Velocity** | **Acceleration** |
| **2 psi** | 12.34 (±18.66) | 1.05 (±0.39) | 27.06 (±59.88) | 1.24 (±1.15) | -23.75 (±52.57) | 1.74 (±2.55) |
| **3 psi** | -35.60 (±9.80) | 2.21 (±0.11) | 121.22 (±85.21) | 0.39 (±0.86) | 30.05 (±88.88) | 3.35 (±2.41) |
| **4 psi** | -45.08 (±17.23) | 3.04 (±0.20) | 175.62 (±24.75) | -0.47 (±0.48) | -4.16 (±82.88) | 4.99 (±2.92) |
| **5 psi** | -38.02 (±10.38) | 3.19 (±0.00) | 158.87 (±43.26) | -0.74 (±0.04) | -79.48 (±36.45) | 6.20 (±1.87) |
| **6 psi** | -45.20 (±14.22) | 3.64 (±0.43) | 191.78 (±24.04) | -0.87 (±0.12) | -41.88 (±56.48) | 5.81 (±1.75) |
| **7 psi** | -60.91 (±9.53) | 4.16 (±0.31) | 202.70 (±9.36) | -1.02 (±0.08) | 1.10 (±65.08) | 5.23 (±1.54) |

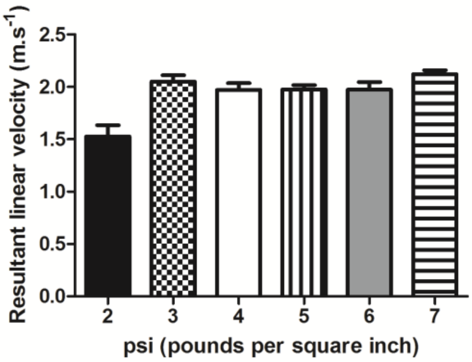


**Figure 2: The mean resultant linear velocity (m.s$^{-1}$) and ±SDs of the dummy's CoG at the estimated point of contact. (SD – standard deviation).**

**DISCUSSION:** This is the first automated collision sport simulator of its kind. This initial study sought to characterise the kinematical properties of this device. It may be hypothesized, based on the data in table 1, that there is an inverse relation between the dummy's velocity and the acceleration of the trolley. However, this has yet to be confirmed and there is a large amount of variability in the findings, particularly at the third metre. The next phase of research will be to elucidate the reasons for this and to stabilise the discrepancies in speed and movement of the dummy. This is necessary before validity and reliability testing can commence. A proposed solution could be to propel the dummy from its CoG and not from the vertex at trolley 'B', although this observation has been made anecdotally. This may result in greater linear velocity of the dummy at higher pressure forces to match ball-carrier speeds observed in high-level rugby union (Hendricks et al., 2012). This method could also lead to a more consistent and upright position of the dummy at the point of contact.

With this said, the movement of the simulator does replicate a front-on tackle at low-to-moderate speeds. The simulator still requires robust validity and reliability assessment (Impellizzeri and Marcora, 2009) before it may be included in a longitudinal study or as an intervention. However, if proven to be reliable and valid, it may be used to study characteristics pertinent to the tackle in rugby union and a variety of other collision sports including rugby league, rugby sevens, Australian rules football and American football.

These characteristics include but are not limited to (1) tackle technique which may improve performance and reduce injury risk (Seminati et al., 2015; Burger et al., 2016), (2) biological markers which may indicate physiological stress/muscular damage and describe training load (Hendricks and Lambert, 2014), (3) impact forces and contact loading and display shoulder mechanics (Usman et al., 2011; Seminati et al., 2015), and (4) the acceleration and impact forces experienced by the head during tackling which may help understand concussive and sub-concussive events and ways in which to prevent them (McIntosh et al., 2000).

**CONCLUSION:** Preliminary findings indicate that the simulator functions in a manner that replicates a real-life dynamic front-on tackle in a safe and controlled environment. Although validity and reliability tests are still required, it is possible that this novel device may help further develop our understanding of contact events and may highlight new areas in which player safety and performance may be enhanced.

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