BIOMECHANICAL LOADS IN RUGBY UNION TACKLING ARE AFFECTED BY TACKLE DIRECTION AND IMPACT SHOULDER

Elena Seminati, Dario Cazzola, Grant Trewartha, Sean Williams and Ezio Preatoni

Department for Health, University of Bath, Bath, UK

Approximately 25% of Rugby Union injuries occur to players executing a tackle and they mostly involve upper-body regions. We designed novel tackle simulator to investigate upper-body loading under different tackling conditions: direction of approach and side of body used. Dominant shoulder tackles in the frontal direction generated the highest impact forces, 5.3 ± 1.0 kN (15% higher than non-dominant) and the lowest range of neck flexion (20% lower than non-dominant) at impact. Impact load decreased going from frontal to diagonal (-3%) and lateral tackling (-10%). The lowest peak head acceleration and angular velocity resulted from diagonal tackles with the dominant shoulder. For injury prevention, the tackler should approach from an offset angle from frontal and coaching should aim to reduce the deficiencies in tackling technique on the non-dominant side.

KEY WORDS: Rugby Union, sport collisions, injury prevention, kinematics, kinetics.

INTRODUCTION: Rugby Union (rugby) is a team sport that involves collisions between players, and is associated with high injury incidence (Williams, Trewartha, Kemp, & Stokes, 2013). Evidence from the 2014-15 season of the English Premiership Rugby Injury Surveillance Project (englandrugby.com) confirmed that the tackle is the match event causing the greatest proportion of injuries (36% of 645 injuries in one season), and three out of four of the most common injury types for tacklers involve upper body regions.
The tackle is an open and unpredictable event in which the tackler typically engages with the ball carrier in the attempt to bring the ball carrier to the ground. Given the broad spectrum of impact scenarios that a tackle can generate (e.g. different techniques used, relative speed between tackler and ball carrier, directions and height of tackles), the biomechanics of the tackle is a very difficult situation to reproduce experimentally and to assess through reliable and ecologically valid measurements. Indeed, very few studies are currently available in the literature, and most of them have adopted very controlled laboratory set-ups (Pain, Tsui, & Cove, 2008; Usman, Mcintosh, & Frechede, 2011). In addition, even in the most realistic experimental protocols (Seminati, Cazzola, Preatoni, & Trewartha, 2016) only frontal tackles were simulated and the simulator did not allow bringing the mock ball carrier to the ground.
In this investigation we improved the design and validity of the tackle simulator by incorporating some additional elements of the tackle situation observed from video incident analysis (Seminati, Cazzola, Preatoni, & Trewartha, 2015) and we investigated the loads experienced by the tackling players and their upper body kinematics as a factor of laterality (dominant vs non dominant side tackling) and tackle direction (frontal, diagonal, lateral).

METHODS: In a repeated measures cross-sectional design, 6 male community- and university-level Rugby Union players (age 26.7 ± 7.6 years, height 1.82 ± 0.09 m, mass 95.7 ± 14.0 kg) performed multiple tackle trials under six different tackling conditions (independent factors) to assess the effect on impact forces and kinematics (dependent variables). A 40 kg punch-bag, held in contact by a magnetic clamp, was accelerated manually to simulate the ball carrier and its effective mass (Milburn, 1995). The tackler executed a full tackling movement bringing the punch-bag to the ground. All the players approached the tackles with a 3-step run up, and performed their action with dominant or non-dominant shoulder (factor 1) and from three different run up directions (frontal [0°], 45° and 90° to the direction of travel of the dummy ball carrier – factor 2). After the warm up and the familiarisation trials, participants completed up to 2 dynamic tackles in each of the 6 testing conditions, which were presented in randomised order.

Four pressure sensor matrices (12 cm by 38 cm, Model #3005 VersaTek XL, FScan, Tekscan Inc, USA) were attached to the punch bag, to allow the estimation of the impact forces during the tackle (sampling frequency 500 Hz). Participant and punch bag motion were captured at 250 Hz through a 16-camera motion capture system (Oqus, Qualisys, Sweden). Eight reflective markers on the punch bag and a 74-landmarks total-body marker-set (Seminati et al., 2016) were used to capture the kinematics of tackling. In addition an inertial measurement unit (IMU) (MTw, Xsens Techology B.V., NL) was used to measure 3D accelerations and angular velocities (sampled at 1800 Hz and transmitted at 100 Hz) on the participant's forehead. A bespoke control and acquisition system (cRIO-9024, National Instruments, Austin, Texas, USA) synchronously triggered the acquisition hardware (IMU, Tekscan and Qualysis). Raw pressure data from the individual pressure sensors were used to estimate peak contact forces (Cazzola, Trewartha, & Preatoni, 2014). Neck angles (flexion/extension, lateral bending and rotation) were computed in Visual 3D (v5, C-Motion Inc, Usa) from head and upper trunk displacement. Peak resultant punch bag velocity was defined as the peak velocity of its centre of mass.
Peak values of forces, angles, head accelerations and angular velocities were calculated for each of the trials performed by the players. Linear mixed models and magnitude-based inferences were used to assess the effect of different tackling conditions on the selected biomechanical variables (Hopkins, 2010) and bag velocity at impact was included as a covariate. For all effect sizes, 90% confidence intervals (CI) were calculated and magnitude-based inferences derived (Batterham & Hopkins, 2006). Effects sizes were interpreted on the following scale: < 0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, large; and > 2.0, very large, (Hopkins, Marshall, Batterham, & Hanin, 2009). Thus, a threshold for a practically important effect was set at 0.2, with the values between -0.2 and +0.2 signifying a trivial effect. As 90% CI provide a range within which the true effect statistic is likely to fall, effects were considered to be substantially positive only if the effect statistic was greater than +0.2 and the lower confidence limit did not cross -0.2. Conversely, if the effect statistic was less than -0.2 and the upper confidence limit did not extend past +0.2, the effect was deemed substantially negative. An effect was considered unclear if the 90% CI crossed over both +0.2 and -0.2.

RESULTS: Dominant (right) shoulder tackles in the frontal direction generated the highest impact forces (5.3 ± 1.0 kN), and overall they were substantially higher (by 15%) than non-dominant (left) shoulder tackles (effect size ± 90% CI = 1.40 ± 0.84). Impact load decreased going from frontal to diagonal (-3%) and lateral tackling (-10%). The lowest peak head accelerations (substantially lower [-5%] compared to frontal tackles) were recorded during diagonal tackles, with the dominant shoulder (9.1 ± 3.5 g), (effect size ± 90% CI = 0.64 ± 0.85).
Resultant head angular velocity was substantially lower when tackling from 45° and 90° than from a frontal position and the lowest head angular velocities (13.5 ± 5.2 rad/s) were recorded when tackling with the non-dominant shoulder at 90° (effect size ± 90% CI = 1.10 ± 0.94), (Figure 1).
For all the conditions, cervical motion at the instant of impact was characterised by simultaneous flexion, lateral bending and rotation of the neck away from the contact shoulder. Mean neck flexion angles at impact were substantially greater (by 20%) for non-dominant than for dominant shoulder in each of the three tackling directions evaluated (effect size ± 90% CI = 1.50 ± 0.81). Also, the lowest neck flexion angles were recorded when players tackled from 45 degrees (Table 1).

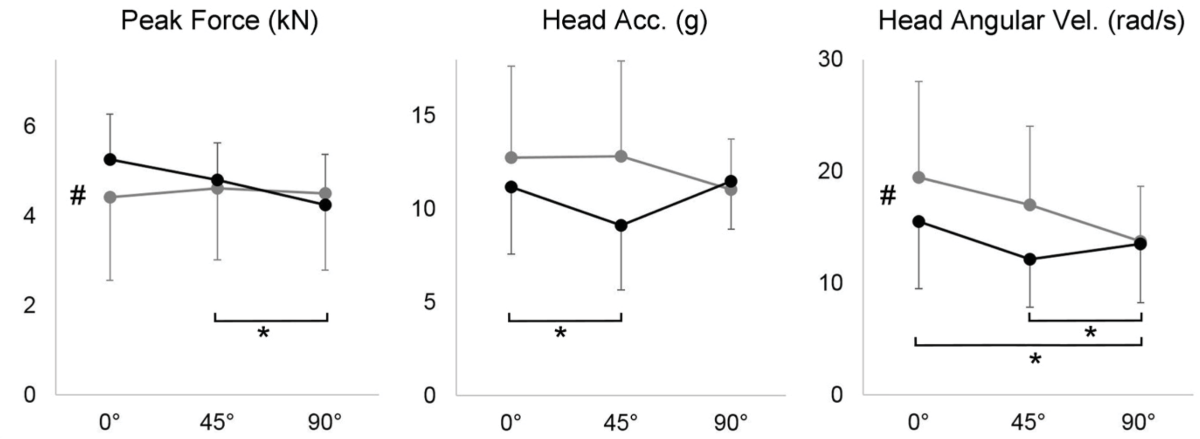
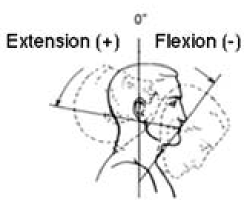
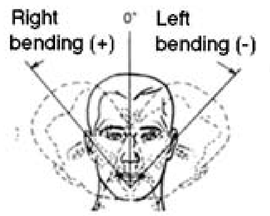
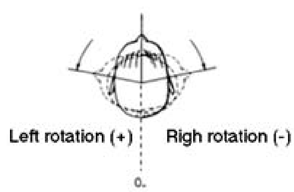


Figure 1: Peak force, peak head accelerations and peak head angular velocities measured at impact between the tackling player and the punch bag simulating the ball carrier. The circles represent the averaged value and standard deviation for each direction for both dominant (black) and non-dominant (grey) shoulder. * indicates substantial differences between directions. # indicates substantial differences between dominant and non-dominant shoulder across the three different directions.

Table 1: Neck angle outcomes. # indicates substantial differences between dominant and non-dominant shoulder across the three different directions (statistical analysis was performed on the angles' absolute values).

		Flexion	Bending	Rotation
				
Side	**Direction**	**(°)**	**(°)**	**(°)**
Non-dominant shoulder	**0°**	-23 ± 8	13 ± 11	-5 ± 7
	45°	-17± 8	23 ± 14	-12 ± 6
	90°	-21 ± 8	15 ± 15	-13 ± 9
Dominant shoulder	**0°**	-16 ± 12 #	-12 ± 16	12 ± 16
	45°	-13 ± 7 #	-13 ± 9	16 ± 14
	90°	-19 ± 16 #	-11 ± 10	22 ± 15

DISCUSSION: Dynamic tackles performed with the dominant side shoulder generated the highest contact forces, with values 15% higher than the ones measured during tackles performed with the non-dominant shoulder. In addition neck flexion angles at impact were substantially greater (by 20%) for non-dominant than for dominant shoulder in each of the three tackling directions evaluated. These outcomes confirmed the results obtained in previous studies, which analysed tackling without a run-up phase (Seminati, et al., 2016) and suggested dominant shoulder tackles being more proactive and non-dominant shoulder tackles occurring without the 'head-up' technique. However, the impact forces values reported in the present study (~4-5 kN) are much higher compared with impact forces recorded in static tackles (Seminati, et al., 2016) and they are close to the forces described by Milburn (1995) who applied Newton's second law to empirical data.
The angle between the direction of travel of ball carrier and tackler prior to contact also affected the biomechanics of tackling and the loading conditions on the tackler. Impact forces decrease when increasing the tackle angle, with the lowest forces measured when tackling at 90 degrees when the impact is oblique and the tackle is less 'confrontational'. We observed a

different behaviour for the head segment: head accelerations were higher when tackling with the non-dominant shoulder suggesting the use of an overall inferior or less controlled technique compared with the dominant shoulder tackles.
When tackling with the dominant shoulder the highest impact forces were measured during a frontal tackle. Since the tackler and the punch bag had similar speeds (~3m/s) the opposite momenta of the punch bag and the tackler sum up to a larger value compared with 45° or 90° conditions: at 0° the tackler manages to bring the bag to the ground by fully changing the direction of the bag whilst at 45° and 90° the player can only deviate it and the change in momentum due to the impact is lower. However, this behaviour was not observed when tackling with the non-dominant shoulder. In these conditions, tacklers seemed to adopt a different biomechanical strategy and assumed a more passive behaviour (i.e. lower peaks and longer duration of impact forces) to generate the impulse needed to stop the momentum of the punch bag. Also, in non-dominant side tackles there seems to be less control of head-neck movement (i.e. neck more flexed and laterally bent; higher head accelerations) compared with the dominant side conditions, which may create hazardous situation in relation to what have been identifies as possible injury factors.

CONCLUSION: Both laterality (dominant side) and tackle direction have a substantial effect on the loads applied to the upper-body of a rugby tackler. These data confirm the guidelines for safe and effective rugby techniques (i.e. BokSmart and Rugby Safe) that support the idea to direct the tackle approach to come in at an angle between 15-45 degrees to the oncoming attacker/target and thereby reduce the force of the impact on the tackler's body, while still making the tackle effective. Where feasible, the tackler should approach from a slightly offset angle from frontal and coaching should aim to reduce the deficiencies in tackling technique on the non-dominant side, including encouraging better control of the head-neck complex.

REFERENCES:

Batterham, A.M., & Hopkins, W.G. (2006). Making meaningful inferences about magnitudes. *International journal of sport physiology and performance, 1*, 50-57.

Cazzola, D., Trewartha, G., & Preatoni, E. (2014). Time-based calibrations of pressure sensors improve the estimation of force signals containing impulsive events. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 228*(2), 147-151.

Hopkins, W.G. (2010). Linear models and effect magnitudes for research, clinical and practical applications (Vol. 14, pp. 49-57). Sportscience.

Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc, 41*(1), 3-13.

Milburn, P.D. (1995). The Rugby Tackle - A time for Review. *Journal of Physical Education of New Zealand, 28*(1), 9-15.

Pain, M.T., Tsui, F., & Cove, S. (2008). In vivo determination of the effect of shoulder pads on tackling forces in rugby. *J Sports Sci, 26*(8), 855-862.

Seminati, E., Cazzola, D., Preatoni, E., & Trewartha, G. (2015). Evaluation of tackling biomechanics in rugby: video incident analysis and experimental set up.

Seminati, E., Cazzola, D., Preatoni, E., & Trewartha, G. (2016). Specific tackling situations affect the biomechanical demands experienced by rugby union players. *Sports Biomech*, 1-18.

Usman, J., Mcintosh, A.S., & Frechede, B. (2011). An investigation of shoulder forces in active shoulder tackles in rugby union football. *J Sci Med Sport, 14*(6), 547-552.

Acknowledgement

The project was funded by RFU Injured Players Foundation.