Citation for published version:
Preatoni, E, Cazzola, D, Stokes, K, England, MH & Trewartha, G 2013, Tough but not rough: what does biomechanics feed into the rugby scrum? in *Proceedings of the 31st International Conference on Biomechanics in Sports (2013) Taipei, Taiwan, July 7 – 11, 2013.* XXXI International Conference on Biomechanics in Sports, Taipei, Taiwan, Province of China, 6/07/13.

Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

TOUGH BUT NOT ROUGH: WHAT DOES BIOMECHANICS FEED INTO THE RUGBY SCRUM?

Ezio Preatoni, Dario Cazzola, Keith A. Stokes, Michael E. England and Grant Trewartha

Sport, Health and Exercise Science, Dept. for Health, University of Bath, UK

The aim of this paper is to present the “Biomechanics of the Rugby Scrum” project, a three-year research programme that thoroughly studied the kinematics and kinetics of rugby union scrummaging with a view to identifying safer scrum engagement techniques. The outcomes of the study will be analysed and their implications for injury prevention and performance will be discussed.

KEY WORDS: impacts, mechanical stresses, injury prevention, performance, technique.

INTRODUCTION: The scrum is a fundamental component of the rugby union game and its stated purpose is “to restart play quickly, safely and fairly, after a minor infringement or a stoppage” (IRB, Law 20). During a scrum, eight players from each team (called forwards) bind together in three rows (front, second and third row) and contend with the opposing pack for the possession of the ball, under the supervision of the referee.

The engagement is a critical phase of the scrum as it involves an intense initial impact followed by a sustained push, both of which happen in a context characterised by multiple players’ interactions, destabilising forces and movements in the three planes of motion, variable turf conditions, and the additional need of getting control of the ball (Milburn, 1990; Preatoni, Stokes, England, & Trewartha, 2013). These factors generate very peculiar biomechanical demands on rugby forwards and make this event very interesting from both an injury prevention and a performance analysis perspective. Being the shock absorption interface between the two packs and also receiving a forward momentum from the back lines, front row players are the ones at higher injury risk.

The proportion of scrum-related injuries is relatively small and less than 8% of the overall rugby injuries (Brooks, Fuller, Kemp, & Reddin, 2005), but scrummaging reports the highest propensity for injury (risk per event) and the worst severity of injuries (days lost per event) for all contact events studied (Fuller, Brooks, Cancea, Hall, & Kemp, 2007). Scrum events are also the cause of 40% of rugby union catastrophic injuries (permanent impairment, mainly at spinal cord level) (Fuller, 2008), which are rare but may have an irreparable impact on players’ life. Furthermore, even in the absence of acute injuries, the repetitive submaximal stresses acting on the player’s musculo-skeletal structures may induce soft tissues degeneration and hence chronic pain and overuse pathologies (Panjabi, 2006).

The International Rugby Board (IRB) has promoted a three-year research programme to thoroughly address the biomechanics of union rugby scrummaging. The study, which has been undertaken by the Rugby Science group of the University of Bath (RS@Bath) aimed at quantitatively describing the kinematics and kinetics of the scrum, assessing the effect of different engagement techniques and playing levels on the scrum outcomes, and investigating possible routes to injury prevention in this relatively controllable event of the game. This paper describes the different phases of the project and their main outcomes, and discusses the relevance of those results for players’ safety and performance.

METHODS: The research consisted of two main phases. Phase 1 (June 2010 – December 2011) studied the biomechanics of machine scrummaging, i.e. a forward pack against a scrum machine (a sled-type aid used for scrum training). Phase 2 (January 2012 – May 2013) analysed the biomechanics of live scrummaging, i.e. two forward packs engaging against each other as in a real match (Figure 1). Both the studies were carried out trying to maximise the ecological validity of the test and to reduce the possible influence of the experimental

setup. All the sessions were carried out outdoor, on natural turf and without any substantial impact of measurement technologies on players' habits and freedom of movement.
Both phases utilised a cross sectional design, whereby a set of selected kinematic/kinetic (dependent variables) were analysed as a function of playing level (between-groups factor) and engagement techniques (within group factor). Thirty-four teams from 6 playing categories were included in Phase 1: International, Elite, Community, Academy, Women and School. Twenty teams from 5 playing levels (the same of Phase 1 with the exception of School players) have been tested in Phase 2 at the time this paper has been written. Five different engagement techniques were analysed in Phase 1. These included the current scrummaging practice at the initiation of the project (baseline, "Crouch-Touch-Pause-Engage") and four modified techniques that differed from the baseline condition in the referee's calls (e.g. the three-stage sequence later introduced by the IRB as a law amendment trial) or in aspects aimed to modify the loading conditions on players (e.g. the substitution of the initial impact with a fold-in procedure or sequential engagements). The review of Phase 1 findings identified a set of three engagement techniques to be analysed in Phase 2. These included the baseline condition, the three-stage one ("Crouch-Touch-Set") and a modification of this in which the front row players maintained the bind with their opposing counterparts after the referee's "touch" call. At least 4 valid trials were collected for each condition, team and phase, and later used in the analysis.

A bespoke control and acquisition system (cRIO-9024, National Instruments, USA) was devised to synchronise the multiple measuring devices and play pre-recorded audio files that simulated the referee's vocal commands with a consistent timing (Preatoni, et al., 2013; Preatoni, Wallbaum, Gathercole, Coombes, Stokes, & Trewartha, 2012). The players' movements were captured by four digital cameras from three different views (top, left and right, Figure 1). Side cameras (Sony HDR-HC9, Japan) operated at 50 Hz and were placed on tripods 18 m far from the centre of the scrum. Top cameras operated at 200 Hz (Sony HVR-Z5, Japan) and 50 Hz (Sony HVR-Z5, Japan) respectively, and were fixed to a horizontal truss at a height of 8 m from the ground. Video recordings were later digitised using Vicon Motus software (v.9, Vicon Motion Systems, USA) and the position of selected body landmarks was tracked to estimate a set of kinematic variables including displacements, angles and their derivatives (Preatoni, et al., 2012).

Figure 1: The three camera views (left, right, top) of a typical experimental set-up from Phase 2.

Different systems were used in Phase 1 and 2 to collect kinetic measures. A commercial scrum machine (Dictator, Rhino Rugby, UK), equipped with a bespoke force measurement system (Preatoni, et al., 2012) was used in Phase 1 to measure (500 Hz) the compression, lateral and vertical forces generated by the scrum pack. A set of parameters was selected to analyse applied forces in the subsequent phases of the engagement, from initial shock absorption to the sustained push. In Phase 2, a direct measure of scrum forces was no longer possible, therefore a F-scan pressure measurement system (Tekscan Inc, USA) operating at 500 Hz and including three pairs of pressure sensors (Model #3000E VersaTek-XL) and cuffs

(CV-1 VersaTek) was used to record the pressure distribution at the interface between the two scrum packs and hence estimate the forces exchanged. The sensors were shaped to be the same size, and fit into bespoke sleeves that were attached to the shoulder of each front row player of one of the two teams. Additionally, wireless inertia measurement units (MTw, Xsens Technology, The Netherlands) were used to have a more thorough depiction of the mechanical stresses acting on those players by measuring 3D accelerations on trunk and head segments of the six front row players. A mixed factor ANOVA was typically used to investigate the effect of playing level and/or scrummaging technique over the set of selected kinetic and kinematic variable.

RESULTS AND DISCUSSION: Results from machine scrummaging tests showed that forces measured across all playing levels were considerably higher than the ones reported in past research (Milburn, 1990). These differences may be associated with the changes in scrummaging techniques and players' physical characteristics over the last two decades (Quarrie & Hopkins, 2007), and with the improvements in measuring technologies that have increased ecological validity (Preatoni, et al., 2013; Preatoni, et al., 2012). In the baseline condition, peak compression forces ranged between 8700 N for the Women teams and 16500 N for the International male teams; sustained push was between 4790 N (Women) and 8300 N (International/Elite men); peak vertical forces during the early engagement were negative (downward) between -2000 N (School) and -3900 N (Elite). International and Elite men's groups generated significantly higher forces than all other groups, even after normalising forces to the pack weight in order to take out the possible influence of inertia. Engagement technique also had an effect on the measured variables. For example, substituting the initial impact with a fold-in procedure reduced engagement speed and peak compression forces (by approximately 50%) without altering the magnitude of the sustained push. It also lowered the peak downward forces and the excursion of the lateral ones which are both thought to be related to the risk of scrum collapse or disruption. It therefore appears that de-emphasizing the initial impact may go towards a more controlled scrummaging without limiting the ability of forward packs to generate an effective sustained push. This interpretation is further supported by the reduction of the 'hazard index', which is a combined measure of body alignment angles and force magnitudes.

Preliminary results from the live scrummaging tests tended to be in the same direction of Phase 1 findings. The condition in which front row players maintained the bind after the "touch" reduced biomechanical loading indexes (engagement speed, peak accelerations, peak forces) at the front row interface by about 20% (Figure 2). Once again, an increased control over the initial impact did not affect significantly the subsequent sustained phase of the push.

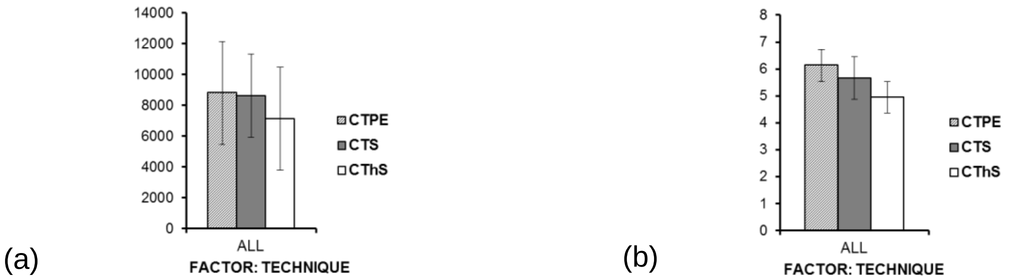

Figure 2: Some preliminary results from engagement technique comparison in Phase 2. All teams have been pooled. CTPE= baseline condition, "Crouch-Touch-Pause-Engage"; CTS= 3-stage call condition, "Crouch-Touch-Set"; CThS= 3-stage call with the bind kept after "Touch". (a) Peak of total compression force [N] estimated from pressure sensors. (b) Average of the individual peaks of acceleration [g] from IMUs on C7 of front-row players.

Differently from what was observed in Phase 1, live scrummaging seems to evidence fewer differences in kinematic and kinetic variables across the playing levels. This may appear surprising to a certain degree, but may be read as the outcome of multiple concurring factors, among which: the high variability coupled with the small number of teams currently available in some of the groups; the less controllable environment conditions (no static opposition from scrum machine, more variable weather); and, the different period within the competitive cycle when teams were tested, with some elite teams being tested closer to important competitions. Overall, a number of indications for both injury prevention and performance can be drawn by pooling together the outcomes from the two phases of the research programme. Given the mass of the forward packs, the speed of the engagement and the forces generated, it is advisable to spend any effort to reduce and/or add control over the dynamics of the early phases of the scrum. The lack of correlation found in Phase 1 testing between a powerful initial impact and the ability to produce a high and consistent sustained push further support this view. The magnitude and repetitiveness of the mechanical stresses acting on rugby forwards, associated to the possible misalignments and constraints of body-segment motion (head and trunk in particular) put those players (front row and second row particularly) in a situation which studies on cadaveric specimens have indicated has the potential to produce the repetitive subcritical injuries that in theory could lead to chronic pain and early degenerative changes to the cervical and lumbar spine (Preatoni, et al., 2013). Further investigations are needed to identify the precise mechanisms of how cervical spine injuries occur in scrum specific contexts and particularly the links between the external loads acting on the player and internal (i.e. at anatomical structures level) thresholds for such injuries.

CONCLUSION: This research programme has provided a thorough quantitative description of the biomechanics of rugby union scrummaging and has analysed the effects of playing levels and engagement conditions on the scrum outcomes. It has also provided a nice example of how a complex biomechanical investigation may inform practitioners and governing bodies about factors that may have an impact on performance and injury prevention.

REFERENCES:

Brooks, J.H., Fuller, C.W., Kemp, S.P., & Reddin, D.B. (2005). Epidemiology of injuries in English professional rugby union: part 2 training Injuries. *Br J Sports Med, 39*(10), 767-775.

Fuller, C.W. (2008). Catastrophic injury in rugby union is the level of risk acceptable? *Sports Med, 38*(12), 975-986.

Fuller, C.W., Brooks, J.H.M., Cancea, R.J., Hall, J., & Kemp, S.P.T. (2007). Contact events in rugby union and their propensity to cause injury. *Br J Sports Med, 41*(12), 862-867.

Milburn, P.D. (1990). The kinetics of rugby union scrummaging. *J Sports Sci, 8*(1), 47-60.

Panjabi, M. (2006). A hypothesis of chronic back pain: ligament subfailure injuries lead to muscle control dysfunction. *Eur Spine J, 15*(5), 668-676.

Preatoni, E., Stokes, K.A., England, M.E., & Trewartha, G. (2013). The influence of playing level on the biomechanical demands experienced by rugby union forwards during machine scrummaging. *Scand J Med Sci Spor*, [Epub ahead of print].

Preatoni, E., Wallbaum, A., Gathercole, N., Coombes, S., Stokes, K.A., & Trewartha, G. (2012). An integrated measurement system for analysing impact biomechanics in the rugby scrum. *Proc Inst Mech Eng Part P-J Sport Eng Technol, 226*(3-4), 266-273.

Quarrie, K.L., & Hopkins, W.G. (2007). Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *J Sports Sci, 25*(8), 895-903.

Acknowledgement

This project is funded by the International Rugby Board (IRB). The authors would like to acknowledge: the players, coaches and medical support staff; the technical contribution of Andreas Wallbaum; and, the support of close colleagues for assistance during scrum testing sessions.