INFLUENCE OF PLAYING LEVEL ON THE KINEMATICS AND KINETICS OF THE RUGBY SCRUM

Svein Mensaert[1], Tristan Sharp[2] and Benedicte Vanwanseele[1]

KU Leuven, Department of Kinesiology, Leuven, Belgium[1]
University of Sydney, Exercise and Sport Science, Sydney, Australia[2]

The aim of this study was to examine the force production, lower body kinematics and kinetics of front row rugby union forwards during the engagement phase of a simulated rugby union scrum. Twenty-eight male front row players were divided into three groups; professional, senior and junior amateur players. Players performed five trials based on the International Rugby Board scrum engagement sequence. Three dimensional motion analysis and force plate data were used to determine joint angles and reaction forces both on the scrum machine and on the ground. Professional front row forwards generated significantly greater force during the engagement phase compared to both senior and junior amateur players. Professional players had a significantly greater knee abduction angle and generated larger peak hip joint power compared to both junior and senior players.

KEY WORDS: motion analysis, sport, moments, joint power.

INTRODUCTION: The scrum is a means to restart play quickly, safely and fairly after a minor infringement or a stoppage. Engagement of the scrum starts after a ‘crouch, touch, pause, engage’ sequence, but amendments have been made to a ‘crouch, bind, engage’ sequence to reduce initial impact (“International Rugby Board,” 2014). Two studies showed that this pre-bind technique reduced initial impact by 35% and 50% during live (Cazzola, Preatoni, Stokes, England, & Trewartha, 2015) and instrumented (E. Preatoni, Stokes, England, & Trewartha, 2015) scrummaging respectively. A few studies have investigated biomechanical parameters during both instrumented (Milburn, 1990; E. Preatoni et al., 2015; Ezio Preatoni, Stokes, England, & Trewartha, 2013; Quarrie & Wilson, 2000; Sharp, Halaki, Greene, & Vanwanseele, 2014; Wu, Chang, Wu, & Guo, 2007) and live scrummaging (Cazzola et al., 2015). These studies reported high initial impact forces up to 16.5kN for professional players with a sustained push around 8.0kN (Ezio Preatoni et al., 2013). The sustained push has a magnitude of about 50% (Ezio Preatoni et al., 2013) to 75% (Milburn, 1990) of the initial impact force. Although only 6% to 8% of rugby injuries result from the scrum, 40% of all catastrophic injuries in rugby occur during scrummaging. Injuries have originally been ascribed by a hyper flexion mechanism, but more recently the ‘buckling’ mechanism has been proposed (Trewartha, Preatoni, England, & Stokes, 2015). A study by Preatoni et al. (2013) showed that professional and elite players generated higher initial impact and sustained push forces than community, academy, women and school level players. This has been ascribed by a better technique and/or physical conditioning, but a biomechanical analysis that goes beyond force-production and joint angles is still lacking. This study wants to address to this shortcoming by having a closer look at joint angles and moments in the three planes of movement and the produced power in each joint at three playing levels.

METHODS: Twenty-eight male front row players were recruited and classified into three groups: professional (n=8), senior (n=7) and junior players (n=13). All participants had to compete regularly in a club affiliated with the Australian Rugby Union and be free from current injury. Individual scrum force was tested indoor on an individual “enforcer” scrum sled (Enforcer Scrum Machines, NSL, Australia), attached to a force platform sampled at 1000Hz (Kistler Model 9287, Kistler Instruments Corp., AG Winterthur, Switzerland). Two additional force-plates measured the ground reaction forces generated by each subject. Kinematic information was measured with a 3D motion analysis system (Motion Analysis Corporation, Santa Rosa, USA) including 14 Eagle video cameras sampled at 100Hz. A set of forty retro-reflective markers (20mm diameter) were attached bilaterally on the subject’s lower and upper extremities, trunk and head. A model consisting of 7 segments was created for the analysis of ankle, knee and hip angles, moments and power using Visual 3D v.5 software (C-Motion, Inc., Rockville, MD, USA). Joint moments and power were calculated by inverse dynamics. Moments are expressed as internal moments and are normalized to body weight. To maximize real scrummaging conditions, live refereeing was used to make the engagement call ("International Rugby Board," 2014). Five trials per subject were recorded and for each subject the trial with the highest initial impact peak force was selected. The selected time periods are the preparation phase (500ms prior to initial contact) and the contact phase (from initial contact until end of the engage). Initial contact was defined as the onset of a horizontal force (>20N) on the force platform with the attached enforcer scrum sled. The end of the engage was defined as the minimal force after the initial impact force-peak. Peak joint angle of ankle, knee and hip, as well as moments and power were calculated for the preparation and the contact phase using a custom-written program in Matlab (Matlab R2013b, MathWorks, Natick, Massachusetts, USA). Statistics were performed using SPSS (IBM Corp. Version 22.0. Armonk, NY). Because assumptions for normality were not always met, a Kruskal-Walice test was performed to look at main group effects with a multiple comparison procedure using the minimum significant difference. Data are reported as median and range. Significance level for all tests was set at $\alpha=0.05$.

RESULTS: Peak forward, lateral and downward forces are presented in Table 1. A main group effect was found for peak forward and downward forces. Professional players had significantly higher peak forward forces than both the junior and senior level players. For the downward forces, all groups differed significantly, with the professional players generating the highest force before respectively the junior and senior players. Professional players had a significantly larger lateral force production compared to the junior players.

Table 1: Comparison between professional, senior and junior amateur players for force production (N) on the scrum machine during the engagement phase.

	Juniors (n=13)	Seniors (n=7)	Professional (n=8)
Peak forward force	3205 (3093)	3076 (1014)	5010 (1195)^{S,J}
Range of the lateral force	271 (311)	281 (350)	376 (277)^{J}
Peak downwards force	437 (639)	328 (1014)^{J}	699 (796)^{S,J}

Data are reported as median and range. S=different from seniors, J=different from juniors (significance level $p<0.05$).

Results of peak joint angles in the sagittal plane are presented in Table 2. No significant group effects are found. During the preparation phase, professional players had a significantly greater knee abduction angle (26(42) deg), compared to the junior (17(64) deg) and senior players (6(28) deg). During the contact phase, the only significant difference was found in the transverse plane for the hip joint. Maximal external hip rotation was significantly different between the three groups, with professional players showing the greatest external hip rotation (29(47) deg), followed by junior (20(52) deg) and senior players (11(57) deg).
Data of peak internal joint moments are presented in Table 3. No significant main group effect was found.

Table 2: Comparison between professional, senior and junior amateur players for peak joint angles (deg) in the sagittal plane during the engagement phase.

		Juniors (n=13)	Seniors (n=7)	Professional (n=8)
Preparation Phase	Ankle flexion	105 (35)	105 (23)	103 (16)
	Knee flexion	109 (48)	103 (31)	105 (29)
	Hip flexion	46 (64)	49 (54)	70 (64)
Contact Phase	Ankle extension	93 (35)	90 (28)	93 (13)
	Knee extension	77 (42)	76 (50)	83 (29)
	Hip extension	4 (89)	12 (63)	37 (67)

Data are reported as median and range.

Table 3: Comparison between professional, senior and junior amateur players for peak joint moments (Nm/kg) during the engagement phase in rugby scrum.

		Juniors (n=13)	Seniors (n=7)	Professional (n=8)
Preparation Phase	Ankle extension	-0.72 (0.58)	-0.81 (1.01)	-0.87 (1.18)
	Knee extension	1.16 (1.85)	0.82 (1.11)	1.27 (1.19)
	Knee abduction	-0.03 (0.89)	-0.05 (0.25)	-0.18 (0.32)
	Hip extension	-1.09 (0.37)	-1.39 (1.18)	-1.16 (1.11)
Contact Phase	Ankle extension	-0.16 (0.57)	-0.28 (0.39)	-0.11 (0.38)
	Knee extension	1.01 (0.74)	1.30 (1.41)	1.37 (1.63)
	Knee adduction	0.44 (1.31)	0.44 (2.12)	0.43 (1.05)
	Hip flexion	0.14 (1.01)	0.24 (1.62)	0.36 (0.6)

Data are reported as median and range.

There was a significantly higher hip generating power during the engagement phase in the professional players compared to the junior and senior amateur players (Table 4). No significant differences were found in the contribution of the ankle, knee and hip to the total generating power. The ankle contributed the least to the total power generation (14%, 11% and 11% in the junior, senior and professional players respectively). The knee and the hip contributed almost equal in the juniors (45% and 41% respectively), seniors (41% and 49% respectively) and the professionals (43% and 47% respectively).

Table 4: Comparison between professional, senior and junior amateur players for peak joint power (W/kg) during the engagement phase in rugby scrum.

	Juniors (n=13)	Seniors (n=7)	Professional (n=8)
Ankle power	0.58 (1.11)	0.50 (0.78)	0.43 (1.61)
Knee power	1.86 (4.78)	2.72 (4.57)	2.37 (4.26)
Hip power	1.74 (2.8)	1.54 (3.32)	3.22 (1.74)[J,S]

Data are reported as median and range. J=different from juniors, S=different from seniors (significance level $p<0.05$)

DISCUSSION: The current study shows that professional players generate significantly greater peak horizontal and downwards force on the scrum compared to amateur front row forwards during the engagement phase of scrummaging. The capacity to generate greater horizontal force during engagement can determine the success of the scrum, it is therefore crucial for coaches and athletes to get a better insight into the kinematic and kinetic variables that determine this horizontal force. Quarrie & Wilson (2000) and Wu et al. (2007) reported average individual scrummaging forces of about 140% of bodyweight. This study shows that the impact forces as high as 300% to 450% of bodyweight. Our results are in line with the findings of Preatoni et al. (2013), who also showed that professional and elite players had a higher initial impact peak force than community, academy and school level players, although this was for the full scrum pack. In the current study we tried to explain this difference on the basis of an analysis of peak internal joint moments and power. We found a higher peak generating hip power in professional player which was correlated to the higher forward force generation. As the hip moment is not significantly different it seems that the speed at which the hip is extended might be higher in the professional players. This would indicate that not only muscle force but also an optimal coordinated execution of the motion is crucial to generate a higher forward force. This is supported by results of Preatoni et al. (2014), who showed that Elite players had a significantly higher engagement speed compared to school level players, but these results have to be interpreted cautiously because we are comparing the full scrum versus individual scrummaging.

CONCLUSION: This study showed that the difference in force-generation during the engagement phase between different playing levels cannot be explained by kinematic differences or internal moments. However it seems that the hip power generation contributes to the higher forward force during the engagement phase.

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