KINEMATICS OF THE AXIAL SKELETON DURING ONE-MAN RUGBY UNION SCRUMS

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Understanding kinematics and movement variability (MV) of the axial skeleton (head, thorax, spine, and pelvis) during scrums in Rugby Union is important from a performance and injury prevention perspective. The aim of this study was to investigate repeatability (or MV) of axial skeleton kinematics during one-man simulated scrums. Nine front row players performed scrums against a scrum machine. Results showed high levels of repeatability. The outcomes of this study suggest that the difficulty in performing scrums well might not reside in the basic technique, but be more associated with external factors, such as the interaction between players in a full scrum. Therefore, the results suggest that expert movement may better be achieved by practicing scrums under more realistic conditions than against a scrum machine.

KEY WORDS: repeatability, movement variability, front rower, motion capture

INTRODUCTION: Spinal kinematics during Rugby Union (Rugby) scrummaging has been investigated previously with respect to performance improvement and injury prevention. To date, most kinematic studies have considered the spine as one rigid segment (Cazzola, Preatoni, Stokes, England, & Trewartha, 2015; Wu, Chang, Wu, & Guo, 2007). While Swaminathan, Williams, Jones, and Theobald (2016a, 2016b) divided spinal kinematics into five spinal regions, these studies examined the effect of factors that are extrinsic to the basic scrum movement (i.e. playing surface and engagement sequence), rather than investigating factors independent of external changes (e.g. individual technical skills). Moreover, these studies were based on analyses of full scrums involving the usual 16 players, even though it is recognised that full scrums are complex events where the interaction between players has the potential to influence an individual's kinematics. Player interactions may increase the risk of injury and/or decrease performance, especially if there is a lack of spinal control.
Practicing scrums with a focus on keeping spinal control in a consistent "straight, flat back" posture is a common component of players' training programs (O'Shea, 2003). Coaches frequently 'decompose' the scrum, where, for example, individual players scrummage against a scrum machine or one or two opponents, to repeatedly practice technical skills and minimize deviation from the 'ideal' scrum technique (O'Shea, 2003). However, while repeated and consistent practice is often employed to achieve expert movement, the importance of within- and between-individual movement variability (MV) in skilled performance and injury prevention has gained attention over recent years. For example, MV in tasks such as the javelin throw (Bartlett, Wheat, & Robins, 2007) has been found to be greater in skilled compared to less-skilled athletes. Hence, investigating kinematics and MV of the axial skeleton (head, thorax, spine, and pelvis) during scrums will provide better understanding of movement expertise and spinal injury mechanisms, especially if the effect of different player interactions is controlled. A logical first step would be to determine MV (representative of spinal control) during the simplest version of the task i.e. a one-man scrum. Therefore, this study aimed to investigate the repeatability of axial skeleton kinematics during one-man scrums.

METHODS: Nine male front row players (mean ± SD age, 23.8 ± 4.6 years; height, 181.0 ± 6.1 cm; weight, 105.2 ± 10.0 kg; years playing in front row, 6.9 ± 6.5 years) attended one

testing session in a laboratory. Relative kinematics between three-dimensional (3D) body segments (head, thorax, and pelvis) and for the spine, represented by four connecting vectors (upper and lower thoracic and lumbar spines), were measured using an optoelectronic motion capture system consisting of 12 infrared cameras (Vicon T40S cameras, Vicon, Oxford, UK) and the Vicon Nexus software (v2.2.1, Vicon, Oxford, UK). Data were sampled at 240 Hz. A set of 14 reflective markers was used to track segmental kinematics and to create local coordinate systems for the head (four markers on a head band), thorax (xiphoid process, spinous processes of C7 and T7) and pelvis (both posterior and anterior iliac spines). The four spinal vector segments were defined using markers attached to C7, T7, T12, L3, and L5 spinous processes. Relative orientations between the 3D segments were calculated with a rotation sequence representing 1) flexion/extension (FE), 2) lateral-flexion (LF), and 3) axial rotation (ROT) (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2014). Kinematics of spinal vector segments were calculated in FE and LF using the fixed angle method (Craig, 2005). Hence, a total of five joints with two (FE, LF) or three (FE, LF, ROT) degrees of freedom were investigated, producing 12 joint angles.
Following a standardised 10-minute warm-up and marker application, range of motion (ROM) of the cervical spine was measured in FE, LF, and ROT. Participants were familiarised with the test procedure and practiced at least three times before data were collected from seven one-man scrums against the machine.
Impact was defined as the point at which the C7 marker stopped moving in the scrum direction. The beginning of the trial (T1) was then defined as 1 s before impact (T2), and the sustained push phase (T3), and the end of the trial (T4) as 2.5 s and 5 s after T2 respectively. All data were filtered using a 2^{nd} order, zero-lag Butterworth filter with a cut-off frequency of 6 Hz (Swaminathan et al., 2016b). Descriptive statistics, intraclass correlation coefficients ($ICC_{3,1}$), and minimal detectable change (MDC) (Weir 2005) were calculated for the 12 joint angles at three time points (T1-T3) (i.e. for 36 joint angles). Repeatability of segmental kinematics was also calculated for the entire scrum motion using the coefficient of multiple correlation (CMC) and standard deviation (SD).

RESULTS: The average cervical spine ROM amplitudes were 98° (FE), 68° (LF), and 142° (ROT). During scrums, participants used, on average, 39.1% (FE), 12.2% (LF), and 5.2% (ROT) of their cervical spine motion capacity. Repeatability of joint kinematics at discrete time points is presented in Table 1. Relative repeatability of kinematic curves showed CMC values ranging from 0.26 + 0.12i to 0.78. In terms of absolute kinematic curve repeatability, the mean SD of the kinematic curves ranged from 1° to 4°. Figure 1 illustrates a mean FE curve (±SD) of the head relative to the thorax in a representative participant.

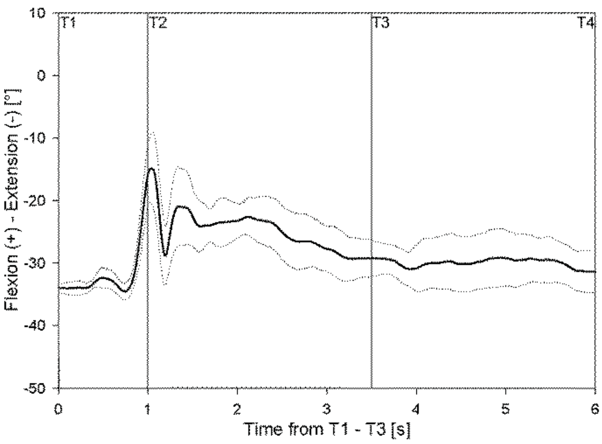

Figure 1
Mean (solid line) ± SD (dashed lines) kinematic curve representing FE of the head relative to the thorax in a representative participant.

DISCUSSION: This study explored axial skeleton kinematics and repeatability of Rugby players during one-man scrums. Compared to previous studies, players used less of their available cervical spine ROM during the one-man scrum task than when performing full

scrums (Swaminathan et al. 2016a). The decreased amplitude of cervical movement observed is likely due to the simplicity of the simulated scrum task against a scrum machine, compared to the complex interactions between players that occur in full scrums.
Relative repeatability results were mixed. Intraclass correlation coefficients were generally high with 34 out of 36 ICCs higher than 0.71. Conversely, nine out of 12 CMC values were considered low to moderate. Only the three kinematic curves representing FE between the four vector segments showed CMC values between 0.71-0.78. However, the low ICC and CMC values did not appear to reflect a true lack of repeatability. An analysis of the data underlying the moderate ICC values revealed that the mean intra-subject variability was only 2° ± 1, but also that the mean between-subject variability was only 3° ± 1. It is well-known that repeatability is not well-measured using ICCs when the difference between participants is low (Weir, 2005). In contrast, for instance FE at T1, where the ICC was 0.92, the difference between intra- and between-subject variability was larger (9°). Coefficients of multiple correlations also have drawbacks in that they are sensitive to variations in movement amplitude, and to the number of participants tested (Røislien, Skare, Opheim, & Rennie, 2012). A comparison with the outcomes of absolute repeatability supports the view that lower ICC and CMC values were due to range and sample-size constraints rather than due to low repeatability. Of all 36 MDC values, only one was >10°, 21 were between 5° and 10°, and 14 were even <5°. In addition, no curve SD value exceeded 4°, again indicating very high repeatability. Interestingly, the highest variability values were found in FE between the head and the thorax, especially at impact (T2) and during the sustained push phase (T3), even though these phases represent the most technical, but also the most physically constraining scrum phases. It is conceivable that participants were not focussed on ensuring a consistent head position given they were performing a simple task against a fixed object compared to scrummaging against opposing players where they are anticipating their head will be forced into flexion. However, the MDC of 11º in FE suggests that players and coaches should focus on ensuring consistent head movements at impact and the push phase when using scrum machines. For tactical purposes, practicing a consistent head position to resist forced flexion and to destabilise opposing front row players might be of value. Moreover, resisting forced flexion might have a protective effect on the cervical spine. However, these hypotheses need further investigation.
A limitation of this study was that the scrum machine was not instrumented so repeatability of compression forces could not be examined. However, the fact that high levels of repeatability of axial skeleton kinematics were found suggests a low probability of inconsistent effort. Additionally, while the data smoothing method was not based on a frequency analysis, the method employed was comparable to previous work (Swaminathan et al., 2016b).
Although the exact role of MV in scrummaging remains unclear, this study showed that players can perform a basic scrum task consistently and that a scrum machine may be a useful starting point for learning this skill. However, one-man scrum machine-based training is unlikely to reduce MV or achieve movement expertise. The findings also suggest that the complexity of the scrummaging task resides in other aspects of the scrum, such as the unstable nature of full scrums with players pushing in somewhat different directions.

CONCLUSION: This study showed that high levels of repeatability of axial skeleton kinematics can be expected in front row players during one-man simulated scrums, which suggests that once a player has learned the scrum technique, scrum machine-based training should not be used to reduce MV. However, if a scrum machine is used, coaches should focus on players' head position at impact and during the sustained pushing phase. The exact role of MV remains unclear and this study is the first in a series investigating MV and injuries in scrums with planned stepwise increasing complexity of scrum conditions.

Table 1
Joint kinematic repeatability at discrete time points (T1-T3)

	ICC (95% CI)	MDC (°)	ICC (95% CI)	MDC (°)	ICC (95% CI)	MDC (°)
	T1		**T2**		**T3**	
H-T						
FE	0.92 (0.83-0.98)	8	0.78 (0.57-0.93)	11	0.78 (0.58-0.93)	9
LF	0.86 (0.71-0.96)	5	0.89 (0.75-0.97)	6	0.84 (0.66-0.95)	6
ROT	0.93 (0.84-0.98)	4	0.49 (0.23-0.80)	5	0.77 (0.55-0.93)	5
T-P						
FE	0.95 (0.88-0.99)	7	0.84 (0.67-0.95)	8	0.90 (0.78-0.97)	8
LF	0.92 (0.82-0.98)	5	0.87 (0.73-0.96)	5	0.69 (0.46-0.90)	5
ROT	0.89 (0.75-0.97)	4	0.85 (0.69-0.96)	5	0.87 (0.72-0.96)	5
UTs-LTs						
FE	0.98 (0.94-0.99)	2	0.91 (0.80-0.98)	4	0.93 (0.84-0.98)	5
LF	0.94 (0.87-0.99)	5	0.84 (0.66-0.95)	5	0.88 (0.74-0.97)	6
LTs-ULs						
FE	0.95 (0.89-0.99)	3	0.78 (0.58-0.93)	4	0.93 (0.83-0.98)	4
LF	0.86 (0.70-0.96)	3	0.83 (0.66-0.95)	3	0.95 (0.88-0.99)	3
ULs-LLs						
FE	0.97 (0.92-0.99)	3	0.87 (0.73-0.96)	6	0.93 (0.84-0.98)	7
LF	0.95 (0.88-0.99)	2	0.95 (0.88-0.99)	3	0.91 (0.80-0.98)	3

H-T: Kinematics between the head and thorax, T-P: Thorax-pelvis, UTs-LTs: Upper thoracic-lower thoracic spine, LTs-ULs: Lower thoracic-upper lumbar spine, ULs-LLs: Upper lumbar-lower lumbar spine

All ICC values were statistically significant with $p < 0.001$

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