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KINETICS OF FULL SCRUM AND STAGGERED SCRUM ENGAGEMENT IN UNDER 19 SCHOOLBOY RUGBY UNION PLAYERS

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ABSTRACT

Two hundred and eight male Rugby Union players from 13 high schools, whose ages ranged from 16 to 19 years, were used to examine the kinetics of the full scrum versus staggered scrum engagement techniques. Telemetric pressure transducers were used to measure the engagement and sustained forces acting on the shoulders of the players. The front, second and back row forwards applied a significantly greater ($p<0.01$) engagement force during the implementation of the full scrum engagement technique as opposed to when the staggered scrum technique was utilised. No differences in the magnitude of sustained force applications by the front, second or back row forwards, with implementation of the respective techniques, were recorded. The large engagement force recorded during full scrum engagement is therefore unnecessary and may only increase the incidence of injury to the cervical spine should misalignment of the front row occur at engagement. The largest total engagement force applied (9.971 kN) by an individual front row during the implementation of the full scrum engagement technique was significantly greater ($p<0.01$) than the average engagement force application (7.526 kN) of the sample. Similar results were obtained during sustained scrumming with the largest force applied, with the implementation of both engagement techniques (9.758 kN), by an individual front row being significantly greater ($p<0.01$) than the average sustained force application (6.145 kN). The great difference in measured force application in the various schools tested emphasises the importance of different leagues to accommodate the varying strengths observed amongst rugby playing schools. Although the staggered scrum engagement technique ensures a soft and controlled engagement, thus protecting the weaker side, a mismatch of scrumming ability could still be detrimental during sustained scrumming.

Key words: Rugby Union; Force application; Sustained force application; Engagement; Full scrum engagement; Staggered scrum engagement.

INTRODUCTION

The original purpose of the scrum in Rugby Union was for it to serve as a means of restarting play. The scrum's original intent has however been lost in a scramble to gain a competitive edge over the opposition. Successful scrumming has become a powerful offensive skill, providing a base for attacking play and a means of wearing down the opposition. Furthermore the scrum is also successfully used as a defensive measure where the objective is to deny the opposition clean possession. The competitiveness of the tight scrum led to the adoption of techniques that are contrary to the spirit of the game and in some cases increases the risk of cervical spinal injuries occurring. Milburn and O'Shea (1994) highlights frequently employed

improper scrumming techniques. These included "charging" of the opposing front rows at engagement due to them standing to far from each other, front rows standing to close to each other at engagement causing incorrect engagement, early shoving by the second row before the front row is properly set, props "boring" in (deliberately scrumming in skew) on the opposition, and finally, deliberately collapsing the tight scrum.

The great engagement force exerted on the shoulders of the front rows with the full scrum engagement technique has been condemned by many (Silver, 1984; Milburn, 1987; Williams & McKibbin, 1987; Milburn, 1993; Du Toit, 1993; Milburn & O'Shea, 1994; Milburn & O'Shea, 1997; Scher, 1998). To eliminate the large amount of force transmitted to the shoulders of the front row during full scrum engagement, a staggered scrum engagement technique has been used. The staggered scrum engagement technique reduces the forward impulsive force during engagement by having the opposing front, second and back rows bind sequentially to form the tight scrum. The staggered scrum engagement technique also eliminates the opportunity for forwards to employ the potentially hazardous techniques highlighted by Milburn and O'Shea (1994).

A significant reduction, approximately 18%, in forward impulsive force has been reported with the implementation of the staggered scrum engagement technique compared to the full scrum engagement technique (Milburn & O'Shea, 1994). The observed reduction in forward force, due to the alteration in engagement technique, could possibly reduce the risk of cervical spine injury within the tight scrum. Milburn and O'Shea (1994) however notes that a decrease in scrum stability due to the increased variability in lateral shear forces acting across the front row with the use of the staggered scrum engagement technique seemingly negates the possible reduced risk of cervical spine injury in the staggered scrum. Du Toit *et al.* (1999) however showed that strengthening of the back and leg musculature improved scrum stability by decreasing lateral shear forces and the lateral direction of force application. Other researchers (Mills & Robinson, 2000; Robinson & Mills, 2000) have however shown, without the investigation of the orthogonal force components, that leg power is poor to moderately correlated to scrumming force when scrumming technique is not considered.

METHOD AND PROCEDURE

Subjects

The subjects were selected from under 19 first and second teams in the Eastern Cape region. The sample consisted of 208 rugby forwards selected from 13 high schools. The subjects' ages ranged from 16 to 19 years, with a mean age of 17.21 years.

Instruments

To measure the engagement and sustained force exerted, a telemetric system was developed. The developed system consisted of eight portable VHF transmitters, eight lightweight harnesses, eight air-filled shoulder pads and eight VHF receivers. The lightweight harness, which fitted around the player's shoulders and chest, housed the pressure pads and transmitter unit (Figure 1).

Procedure

The force application by the eight forwards for the whole duration of the live scrum was recorded simultaneously. The engagement and sustained force application was measured, as described above, during the implementation of both full and staggered scrum engagement techniques. The obtained force-time graphs were synchronised on the first trace of force application as the player engaged in the scrum. The test procedure (designed to measure the engagement and sustained force experienced by the forwards) simulated real scrumming conditions as accurately as possible. The test procedure required the opposing packs to perform eight scrums. During four of the eight scrums, the opposing packs used the full scrum engagement technique. The remaining four scrums were performed using the staggered scrum engagement technique. The data that were recorded telemetrically were sampled at 500 Hz. Sampling was performed for 12 seconds to ensure that data for the full duration of the scrum were recorded. The lengthy time traces were necessary as the staggered scrum engagement technique and subsequent formation of the scrum took longer than the conventional scrum formation utilizing the full scrum engagement technique.

FIGURE 1. **THE LIGHTWEIGHT HARNESS FITTED AROUND THE PLAYER'S SHOULDERS AND CHEST WITH ACCOMPANYING PRESSURE PADS AND TRANSMITTER UNIT**

The engagement force applied onto the players' shoulders represents the average maximum force that is experience at the engagement of the opposing scrums. The sustained force application is the average force brought to bear on the shoulders of the forwards during the shove phase after the ball has been put into the scrum.

The trails for both utilised engagement techniques were compared and the best effort in terms of force production by every subject for the respective engagement techniques was selected. The selected effort was then used to determine the average shoulder force application for the different playing positions during the engagement and sustained phases of the scrum.

Design

All hypotheses were tested at the 99% and then the 95% confidence level. The significant differences between the front, second and back row forwards with respect to shoulder force application was determined by means of one-way ANOVA. Scheffe's method was used to perform the multiple comparisons between the means of various positional groups. Scheffe's method was specifically selected because of the numerical differences between the positional groups and because of its conservative nature in identifying significant differences (Thomas & Nelson, 1996). The 5% level was set as the confidence level. The level of significance between the full and staggered scrum engagement techniques was determined by means of a one-way T-test ($p<0.05$).

RESULTS AND DISCUSSION

Back Row

Engagement force application by the back row forwards

The eighthmen recorded a greater engagement force application than the flankers with the implementation of both the full and staggered scrum engagement techniques. The measured force applications, between the back row players (#6 vs. #7; #6 vs. #8 and #7 vs. #8), were however not significant. The greater engagement force achieved by the eighthmen can be attributed to their better footing at engagement. Although not significant the engagement force produced by the tight-head flankers was greater than that recorded for the loose-head flankers during the implementation of both engagement techniques (Table 1).

The flankers produced a significantly greater ($p<0.05$) engagement force application when full scrum engagement was employed as opposed to when the staggered scrum engagement technique was used (Table 1). This can be explained by the fact that the flankers engage with the front rows when the full scrum engagement technique is used. The engagement force applications measured for the eighthmen were slightly larger with the use of the full scrum engagement technique. There was however no significant difference between the full and staggered scrum engagement techniques with regard to the force application of the eighthmen. The insignificant results of the back row forwards are explained by their position in the scrum. Because the eighthman forms the last line of player participating in the scrum, he engages into the scrum after it is formed. With the employment of both techniques, his force application is not affected by the respective technique used.

The engagement force application of the back row forwards is significantly greater ($p<0.01$) with the use of the full scrum compared to the staggered scrum engagement technique (Table 1 & Figure 2). This is due to the greater engagement force application of the flanks when the full scrum engagement technique is used ($p<0.05$).

TABLE 1. **SHOULDER FORCE APPLICATION (N) FOR THE BACK ROW**

Position	STAGGERED SCRUM						FULL SCRUM					
	Engagement		Sustained mean		Sustained max		Engagement		Sustained mean		Sustained max	
	mean	sem	mean	sem	mean	sem	mean	sem	mean	sem	mean	Sem
# 6	549	83	565	91	706	94	914	130	649	81	809	90
# 7	665	84	827	144	967	155	996	130	683	81	921	119
# 8	992	105	825	80	1137	96	1134	87	771	71	1031	71
Back Row	*719*	*58*	*739*	*64*	*937*	*73*	*1048*	*70*	*707*	*47*	*921*	*56*

Sustained force application of the back row forwards

The eighthmen and the tight-head flankers recorded a greater sustained force application than the loose-head flankers with the implementation of the full and staggered scrum engagement techniques. The obtained results were however not significant (Table 1). The observed greater sustained force application by the eighthmen and the tight-head flankers is in accordance with the greater ground force application during scrumming and the greater body mass of the tight-head flankers (Du Toit, 1993).

The loose-head flankers recorded a greater sustained force application with the implementation of the full scrum engagement technique. An opposite result was however recorded during the sustained force application produced by the eighthmen and tight-head flankers. The observed results show that there is no significant difference in the sustained force application by the loose forwards with the implementation of either of the engagement techniques under investigation (Table 1 & Figure 2).

The sustained force application of the loose forwards is smaller than their engagement force application with the implementation of the full scrum engagement technique. Opposite results were however recorded for their force application during the staggered scrum engagement (Table 1 & Figure 2). As there are no differences in the sustained force application, irrespective of the technique being used, the greater engagement force application of the full scrum engagement technique does not contribute to the force application during sustained scrumming. The great engagement force application with the implementation of the full scrum engagement technique by the loose forwards is therefore unnecessary and supports the implementation of the staggered scrum engagement technique.

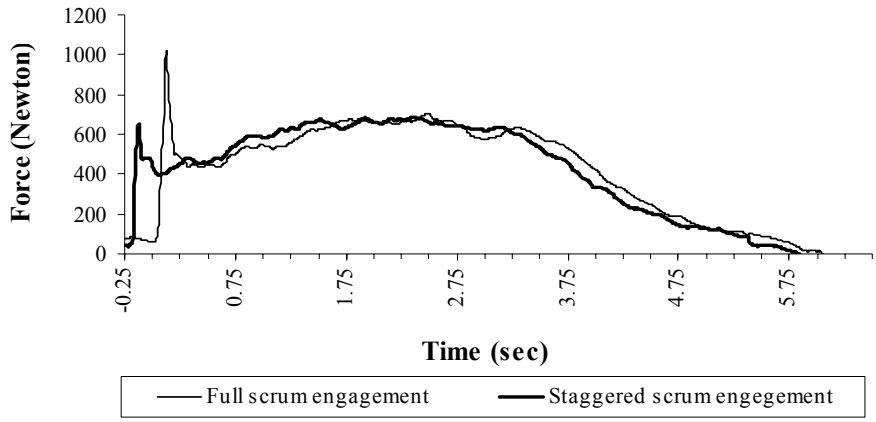

FIGURE 2. **SHOULDER FORCE APPLICATION OF THE BACK ROW FORWARDS WITH THE IMPLEMENTATION OF THE FULL AND STAGGERED SCRUM ENGAGEMENT TECHNIQUES**

Second Row

Engagement force application by the second row forwards

The tight-head locks recorded a greater engagement force application than the loose-head locks with the implementation of both techniques, but the results were not significant (Table 2). The greater force application of the tight-head locks can be as a result of their greater mass and their greater ground force application (Du Toit, 1993).

Both the tight-head and the loose-head locks recorded a significantly greater ($p<0.01$) engagement force application with the implementation of the full scrum engagement technique as opposed to the staggered scrum engagement technique (Table 2). The significantly greater engagement force application observed with the use of the full scrum engagement technique can be attributed to the simultaneous engagement of the locks and the front row into the opposition pack.

The second row also recorded a significantly greater ($p<0.01$) engagement force application than the back row forwards with the implementation of both techniques (Table 2). The significant difference ($p<0.01$) observed between the engagement forces produced by the second and back row forwards can be attributed to the greater ground force application and body masses of the second row forwards (Du Toit, 1993).

TABLE 2. **SHOULDER FORCE APPLICATION (N) FOR THE SECOND ROW**

Position	STAGGERED SCRUM						FULL SCRUM					
	Engagement		Sustained mean		Sustained max		Engagement		Sustained mean		Sustained max	
	mean	sem	mean	sem	mean	sem	mean	sem	mean	sem	mean	Sem
# 4	997	187	1215	110	1632	126	1867	182	1210	160	1555	160
# 5	1049	118	1395	129	1696	149	1889	206	1264	175	1688	259
Second Row	*1024*	*112*	*1304*	*85*	*1664*	*96*	*1878*	*150*	*1245*	*113*	*1622*	*149*

Sustained force application of the second row forwards

Similar to the observed engagement force application results, the tight-head locks recorded a greater sustained force application than the loose-head locks with the implementation of the full scrum engagement technique. The results were however not significant (Table 2). The greater sustained shoulder force application by the tight-head locks is in accordance with their greater resultant ground force application and greater body masses compared to the loose-head locks (Du Toit, 1993).

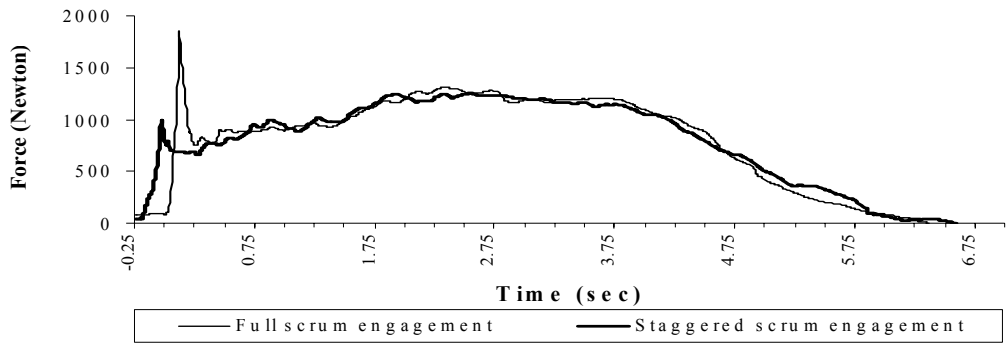

FIGURE 3. **SHOULDER FORCE APPLICATION OF THE SECOND ROW FORWARDS WITH THE IMPLEMENTATION OF THE FULL AND STAGGERED SCRUM ENGAGEMENT TECHNIQUES**

The sustained force application of the second row is greater than their engagement force application with the implementation of the staggered scrum engagement technique (Table 2 & Figure 3). This is similar to the results recorded for the back row forwards (Table 1 & Figure 2). Differing results were however recorded for the second row forwards during the use of the full scrum engagement technique (Table 2 & Figure 3). These results were again similar to the results observed in the sample of back row forwards when they employed the full scrum engagement technique (Table 1 & Figure 2).

Both the loose-head and tight-head locks recorded a greater sustained force application with the implementation of the staggered scrum engagement technique compared to the full scrum engagement technique. The results were however highly insignificant. These results demonstrate that there are no differences in the sustained force application for the second row forwards with implementation of the respective engagement techniques.

Front Row

Engagement force application by the front row forwards

The hookers recorded the greatest engagement force application with the implementation of both techniques under investigation. Following the hookers were the tight-head props and finally the loose-head props. Both engagement techniques produced the same order of engagement force application by the three positional groups.

The engagement force application of the hookers is significantly greater ($p<0.05$) than that of the loose-head props but it does not differ significantly from that of the tight-head props with the implementation of either engagement technique (Table 3). Although the force application of the tight-head props is greater than that of the loose-head props there is no significant difference. The results are in accordance with the function of the tight-head props who engage first and experience a larger engagement force application than the loose-head props. The engagement force produced by the front rows is significantly greater ($p<0.01$) than that of the second and back row forwards irrespective of the engagement technique employed (Table 3). According to Du Toit (1993) the greater engagement force of the front rows compared to the second and back row forwards, with the use of the staggered scrum engagement technique, is due to their greater ground force application, larger body masses and greater speed of engagement.

The front rows recorded a significantly greater ($p<0.01$) engagement force application with the implementation of the full scrum engagement technique as opposed to the staggered scrum engagement technique (Table 3). The significant difference in the engagement force application is the result of the summation of the force application of the second and back row forwards on the shoulders of the front rows.

The magnitude of the total engagement force application (combined force application of the front row forwards) as it is applied onto the shoulders of the front rows is also significantly greater ($p<0.01$) with the implementation of the full scrum engagement technique (Table 3). The average total engagement force application of 7.5 kN with the implementation of the full scrum technique is only half of the predicted engagement force of 15 kN often reported in literature (Scher, 1977; Burry & Gowland, 1981; Milburn, 1990 & 1993).

The reason for this apparent contradiction must firstly be attributed to the fact that the test group consisted of schoolboys who do not possess the same scrumming abilities, are much lighter, and are not as strong as senior players for whom the prediction was made. The positive correlation ($p<0.01$) that exists between the engagement force application of the full scrum engagement technique of the total scrum and the combined mass if the scrum supports this conclusion. Secondly, the results obtained are representative of the mean force application of

all the schoolboy packs tested and not of the greatest force application produced by a single front row. The greatest total engagement force application (9.971 kN) by a front row is significantly greater than the average total engagement force application (7.526 kN). The predicted force application of 15 kN for two senior teams whose players have larger body masses and greater strength does therefore seem possible.

TABLE 3. **SHOULDER FORCE APPLICATION (N) FOR THE FRONT ROW**

Position	STAGGERED SCRUM						FULL SCRUM					
	Engagement		Sustained mean		Sustained max		Engagement		Sustained mean		Sustained max	
	mean	sem	mean	sem	mean	sem	mean	sem	mean	sem	mean	Sem
# 1	1150	193	1813	204	2275	255	2111	218	1929	245	2366	194
# 2	2138	177	1926	222	2317	249	2866	226	2063	193	2376	242
# 3	1307	194	2130	178	2582	220	2549	275	2203	262	2506	256
Front Row	*1532*	*127*	*1957*	*115*	*2392*	*138*	*2509*	*144*	*2065*	*132*	*2416*	*131*
Second Row	*1024*	*112*	*1304*	*85*	*1664*	*96*	*1878*	*150*	*1245*	*113*	*1622*	*149*
Back Row	*719*	*58*	*739*	*64*	*937*	*73*	*1048*	*70*	*707*	*47*	*921*	*56*
Total	**4596**	**333**	**5971**	**499**	**7167**	**4871**	**7526**	**385**	**6145**	**316**	**7248**	**297**

Sustained force application of the front row forwards

The tight-head props recorded the greatest sustained force application followed by the hookers and finally the loose-head props irrespective of which engagement technique was used (Table 3). The obtained results during the implementation of both engagement techniques did not prove to be significant between any of the front row forwards. The greater force application of the tight-head props, who are followed by the hookers, are supported by their greater sustained ground force application, and by the direction of force application which during scrumming is directed towards the opposing tight-head prop (Du Toit, 1993; Du Toit *et al*., 2004).

Milburn (1990 & 1993) and Milburn and O'Shea (1994) recorded similar results for the tight-head and loose-head props, but found the force application of the hookers to be greater than that of the tight-head props during both the full and staggered scrum. It is important to note that Milburn (1990 & 1993) and Milburn and O'Shea (1994) used an instrumented scrumming machine that did not allow for individual differences in body alignment, particularly in the lateral direction, and this made it impossible to totally isolate a single player's force contribution. The absence of an opposition pack, which would have provided further motion, opposing force and additional binding opportunities for the props are further limitations that can account for the contradictory results reported by Milburn (1990 & 1993).

The sustained force application of the front rows is greater than their engagement force application with the implementation of the staggered scrum engagement technique. Contrary

to the staggered scrum, the engagement force application of the front rows with the implementation of the full scrum engagement technique is greater than their sustained force application (Table 3 & Figure 4).

The loose-head props and the hookers recorded a greater sustained force application with the implementation of the staggered scrum engagement technique whereas the tight-head props recorded a greater sustained force application with the full scrum engagement technique. The results were however insignificant. The results thus indicate that there are no differences in the sustained force application of the front rows with the implementation of the respective engagement techniques. The two engagement techniques however do differ in respect of the duration of the sustained scrumming phase. The implementation of the staggered scrum engagement technique increased the sustained scrumming phase of the front rows by 0.93 seconds (Figure 4). The increase in scrumming duration occurs before the second row joins the scrum, this ensures that the front rows do not misalign on engagement, and that they bind properly on to the opposition front rows before the second and back row forwards join the tight scrum. Due to the fact that there is no difference in sustained force application, irrespective of what engagement technique is used, the significantly greater engagement force application of the full scrum engagement technique does not contribute to the force application during sustained scrumming. The results thus indicate that the greater engagement force generated by the front rows with the implementation of the full scrum engagement technique is unnecessary, and can possibly increase the incidence of injury to the cervical spine especially if the scrum should misalign on engagement.

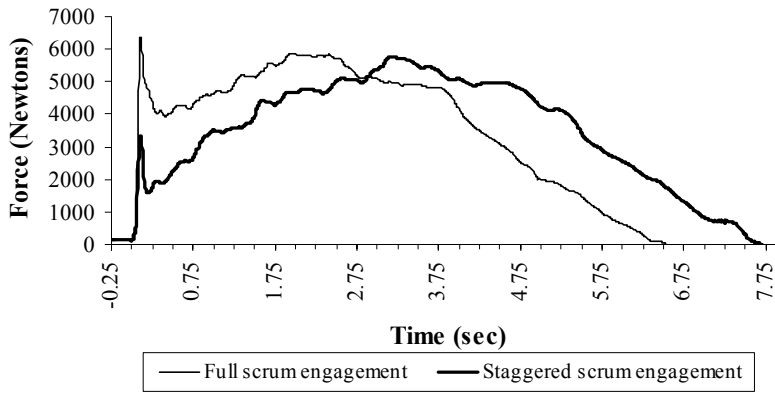

FIGURE 4. **SHOULDER FORCE APPLICATION OF THE FRONT ROW FORWARDS WITH THE IMPLEMENTATION OF THE FULL AND STAGGERED SCRUM ENGAGEMENT TECHNIQUES**

The magnitude of the total sustained force application as it is applied onto the shoulders of the front rows does not differ with the implementation of alternate engagement techniques (Table 3). The average total sustained force application of 6.145 kN and 5.971 kN with the implementation of the full- and staggered scrum engagement techniques respectively, is however significantly less ($p<0.01$) than the engagement force application with the full scrum engagement technique (7.526 kN). The maximum total force application on the shoulders of the front rows in the sustained phase (7.248 kN) of the scrum is also less than their

engagement force application (7.248 kN). This result is however not statistically significant. The large sustained force application illustrates the importance of neck strengthening, especially for the front row forwards.

The magnitude of the average sustained force application in the sustained phase of some of the individual schools is much greater than the average force application recorded for all the schools. The largest average engagement force application for all the schools was recorded with the implementation of the full scrum engagement technique (Table 4). The greatest mean sustained force application and the maximum and the greatest maximum force application in the sustained phase of scrumming varied between the investigated engagement techniques.

No correlation was found between the engagement force application and the sustained force application of the different teams with the implementation of the respective engagement techniques. The results do however prove that there is a significant correlation ($p<0.01$) between the engagement force application and the combined mass of the opposing packs when the full scrum engagement technique is employed. No correlation however was found to exist between the engagement force application with the use of the staggered scrum engagement technique and the combined mass of the scrum. This important observation proves that a heavier pack of forwards has a greater engagement force application only when the full scrum engagement technique is employed.

The speed of engagement and the mass of the front rows determine the engagement force. A greater speed and body mass would therefore lead to a greater engagement force application. The objective of the staggered scrum binding technique is thus to "depower" the engagement phase of the tight scrum by ensuring a soft and controlled engagement of the opposing packs. Milburn and O'Shea (1997) proposed a return to the 2-3-2 scrum formation as a means of "depowering" the tight scrum and thereby reducing the risk of cervical spinal injury during scrumming. The introduction of the staggered scrum engagement technique was however much less disruptive to the structure of the game. Furthermore in conjunction with cervical musculature strengthening, which improves the energy-absorption capabilities of the neck muscles (Du Toit *et al*., 2003) thus allowing for more successful dissipation of contact forces to the cervical spine through controlled spinal motion (Torg *et al*., 1990), the staggered scrum engagement technique reduces the risk of cervical spinal injury in the tight scrum.

The staggered binding however causes great variation in the front rows' engagement speed and this explains the fact that no correlation was found for the engagement and sustained force applications of the different teams with the implementation of the staggered scrum engagement technique. The variation in the engagement speed might also contribute to scrum instability.

Contrary to the engagement force application the sustained force application was not correlated to the combined mass of the opposing packs, irrespective of the engagement technique employed. The results thus emphasized the importance of the correct scrumming technique and the ability of the players to synchronize their force application during sustained scrumming. Table 4 indicates the great variation in the force application for the scrums tested, and emphasises the importance of establishing a league structure to accommodate the differing strengths of rugby playing schools. Although the staggered scrum binding technique ensures a soft and controlled engagement of the opposing front rows and would therefore protect the

weaker side on engagement, a mismatch of scrumming ability could still be detrimental during sustained scrumming.

TABLE 4. **THE COMBINED MASS OF THE OPPOSING PACKS OF FORWARDS AND THE TOTAL SHOULDER FORCE APPLICATION (N) OF THE FRONT ROWS ON ENGAGEMENT AND DURING SUSTAINED SCRUMMING**

Front Row	Mass (kg)	STAGGERED SCRUM						FULL SCRUM					
		Engagement		Sustained mean		Sustained max		Engagement		Sustained mean		Sustained max	
School A	1368	4882		5419		5311		8188		5735		6536	
School B	1358	2819		6105		9101		6717		6889		8317	
School C	1349	3749		3366		4185		9073		3922		4138	
School D	1343	4181		5029		7027		9971		5400		8786	
School E	1317	6525		7880		9287		7879		7600		8554	
School F	1315	4365		5145		6352		8917		5223		6930	
School G	1312	5745		5234		5991		8209		5804		6746	
School H	1309	3831		8456		9153		5283		8038		9586	
School I	1298	6659		5964		6945		6844		5934		6282	
School J	1291	4260		4974		6327		6106		5100		6207	
School K	1271	4516		8711		9758		8248		8763		9368	
School L	1224	4989		6460		7868		6368		6102		6832	
School M	1211	3187		4883		5874		6036		5384		5946	
All Schools	**mean**	**mean**	**sem**	**mean**	**sem**	**mean**	**sem**	**mean**	**sem**	**mean**	**sem**	**mean**	**Sem**
	1301	4596	333	5971	499	7167	4871	7526	385	6145	316	7248	297

The greatest average force application during sustained scrumming was 8.763 kN with a maximum force application of 9.758 kN. It is also evident that the maximum force application in the sustained phase of the scrum is almost as great as the engagement force application (9.971 kN) with the implementation of the full scrum engagement technique (Table 4). The maximum force application on engagement and during the sustained phase of a senior scrum may therefore reach 15 kN as predicted by literature (Scher, 1977; Milburn, 1990 & 1993).

CONCLUSION

Engagement Force Application

The front rows' engagement force was greater ($p<0.01$) than that of the other positional categories, irrespective of the engagement technique employed. The front rows, when using the full scrum engagement technique, recorded a significantly greater ($p<0.01$) engagement force application as opposed to when the staggered scrum engagement technique was employed. The significant difference in the engagement force application was the result of the summation of the force application by the second and back row forwards on the shoulders of the front rows. During full scrum engagement the magnitude of total engagement force application by the front rows was also significantly greater ($p<0.01$) than during staggered scrum engagement.

Sustained Force Application

The sustained force application of the front rows was significantly greater ($p<0.01$) than that of the other positional categories, irrespective of the engagement technique employed. Sustained force application by the front rows, when the staggered scrum engagement technique was used, was significantly greater ($p<0.01$) than their engagement force application. Conversely, the front rows' full scrum engagement force application was significantly greater ($p<0.01$) than their sustained force application. No significant differences in the sustained force application of the front rows, during the respective engagement techniques were observed. Thus the significantly greater full scrum engagement force application did not contribute to the force application during sustained scrumming.

A positive correlation ($p<0.01$) exists between the full scrum engagement force application and the combined mass of the opposing packs. Sustained force application is however not correlated to the combined mass of the opposing packs, irrespective of the engagement technique employed. Thus a greater mass does not contribute to a greater sustained force application, and that the force application during scrumming is not only determined by the mass of the players but also by their scrumming technique.

The maximum force application (9.758 kN) during sustained scrumming, with the use of the both engagement techniques, was almost as great as the full scrum engagement force application (9.971 kN). The maximum sustained force application of a senior scrum may therefore reach 15 kN, as predicted in literature (Scher, 1977; Milburn, 1990 & 1993). This large sustained force application highlights the importance of neck strengthening exercises, especially for front row forwards. Although staggered scrum engagement force will be less, the force generated during the sustained scrumming remains large, and if the scrum should collapse these forces could be applied detrimentally to the cervical spines of the forwards.

The great disparity in the measured force applications of the schools tested emphasises the importance of different leagues to accommodate the varying strengths of rugby playing schools. Although the staggered scrum engagement technique ensures a soft and controlled engagement of the opposing front rows and would therefore protect the weaker side on engagement, a mismatch of strength and scrumming abilities would still be exploited during sustained scrumming.

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