*South African Journal for Research in Sport, Physical Education and Recreation, 2004, 26(2): 33-50.*
*Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2004, 26(2): 33-50.*
*ISSN: 0379-9069*

# KINETICS OF RUGBY UNION SCRUMMING IN UNDER 19 SCHOOLBOY RUGBY FORWARDS

David E. DU TOIT,* Danie J.L. VENTER,** Frederick J. BUYS* & Pierre E. OLIVIER*
**Department of Human Movement Science, University of Port Elizabeth, Port Elizabeth, Republic of South Africa*
***Department of Mathematical Statistics, University of Port Elizabeth, Port Elizabeth, Republic of South Africa*

**_ABSTRACT_**

*Two hundred and eight male rugby players from 13 high schools, whose ages ranged from 16 to 19 years, were used to examine the kinetics of Rugby Union scrumming. Force application, by each playing position, was recorded with the use of a force platform in the vertical (Fz), horizontal (Fx) and in the transverse horizontal (Fy) directions. The direction of force application in the vertical (Az) and horizontal (Ay) planes as well as the resultant force application (Fr) were calculated from the three orthogonal force components. The mean angle of force application during scrumming, in the horizontal plane (Ay), was 1.3° directed towards the tight head prop. During the initial shove and sustained scrumming phases, the front rows' direction of force application in the vertical plane (Az) was significantly greater (p<.01) than that of the second and back row forwards. No statistically significant difference (p>.01) was found between the various angles of force application (Az) produced by the second and back row forwards. The various resultant force applications (Fr) produced by the front, second and back row forwards during the initial shove and sustained scrumming phases however proved to be significantly different (p<.01). The greatest force application, in all directions, was achieved by the front row, followed by the second row and finally the back row. During the initial shove the average resultant force application (Fr) for the entire scrum was 8.6 kN and 1062 N per player. During sustained scrumming the average ground reaction force application for the entire scrum was 11.2 kN and 1400 N per player. Furthermore the results show that a significant correlation (p<.01) exists between the mass of the scrum and the resultant force application (Fr).*

**Key words:** Kinetics of rugby union scrumming; Force application; Direction of force application.

## INTRODUCTION

The tight scrum in Rugby Union has over the years developed from its intended purpose, as a mechanism to restart play, to a powerful offensive platform and defensive manoeuvre by which the opposition is denied clean possession. Milburn and O'Shea (1997) state that divergent opinions exist regarding which scrumming technique is considered to be the most effective. Furthermore the grounds on which these different scrumming methods are selected are almost solely based on anecdotal evidence. Moreover little is known about the force contributions of the different forward positions to the total force application of the Rugby Union tight scrum. It has been proposed that the total force application acting on the shoulders of the front row forwards may reach as high as 15 kN on engagement of two opposing packs (Scher, 1977a; Milburn, 1990 & 1993a), this is however only speculation.

Researchers have attempted to resolve the above-mentioned questions surrounding different scrumming techniques and their effectiveness. Much consideration has also been given to the potential injurious forces generated with the use of these different scrumming techniques. Cohen and Siff (1979) used an instrumented scrumming machine to measure the forward force exerted solely by the front row forwards. They determined the maximum static force exerted by the front row forwards to be 2800 N. From this measurement they "estimated" the static force of the entire scrum to be 7000 N. Hodge (1980) investigated the kinetics of different scrumming techniques with the use of tensiometers. He compared the forward force produced in eight different scrum formation techniques. He found that the entire scrum exerted the greatest force (8988 N) in the low-scrum formation (the front row forwards pushing as low as possible), with the double-push technique producing the second largest amount of force. All the kinetic data presented in the studies of Cohen and Siff (1979) and Hodge (1980) was however limited to force application in the forward direction. Similarly Quarrie and Wilson (2000) used strain gauge force transducers to measure forward scrummaging force. They found the average force applied by each individual during a full scrum to be 1370 N. No significant differences were observed between individually measured force applications (hookers, $\overline{X}$ =1340 N; props, $\overline{X}$ =1420 N; locks, $\overline{X}$ =1450 N; loose-forwards, $\overline{X}$ =1270 N) and the calculated individual average during a full scrum. No measurement of vertical or lateral shear forces experienced by the players occurred. This is significant as Scher (1983 & 1990) identified the lateral shear force experienced by forwards in the scrum as a causal factor in premature degenerative disease of the cervical spine. Premature degeneration of the cervical spine makes suffers more susceptible to hyperextension injury.

Furthermore these vertical and lateral shear forces were identified as particularly important factors affecting the stability of the scrum and play an important role in preventing the scrum from collapsing (Milburn, 1990). The direction of force application during scrumming was also not documented by Cohen and Siff (1979) and Hodge (1980), as tensiometers are not capable of recording the orthogonal force components needed to calculate the direction of force application.

Rodano and Pedotti (1988) adopted a different approach by using floor mounted force platforms to assess the three components of applied leg force during scrumming. The researchers assumed that the total horizontal force recorded was equal to the vertical force at the shoulder. The researchers measured leg thrust during sustained scrumming and 'impulsive' shoves. It was found that there was no difference between the measured leg thrust during sustained scrumming ( $\overline{X}$ =1520 N) and 'impulsive' shoves ( $\overline{X}$ =1529 N). Furthermore the researchers found no correlation between a player's body weight and leg thrust or between different joint angles of the leg and produced thrust.

Milburn (1987, 1990 & 1993a) and Milburn and O'Shea (1994 & 1997) realized the importance of assessing vertical and lateral shear forces during scrumming and used an instrumented scrum machine and three horizontally mounted force platforms to measure forward force application during scrumming. This also allowed the researchers to calculate vertical and lateral shear forces by investigating the three orthogonal components of force experienced by the front rows during various scrumming scenarios. Through the assessment of high school, university, club, under 23 and international standard packs, Milburn (1990) found that novice front row forwards experienced greater lateral shear than experienced players did. Lateral shear force, across the front row, was ascertained to be directed towards the loose head prop and the incoming ball during scrumming by high school, university and club standard packs (Milburn, 1990 & 1993a). An international standard pack of forwards however generated much less lateral shear force directed towards the loose head prop than that experienced by high school, university and club standard packs. The under 23 pack assessed actually produced lateral shear force directed towards the tight head prop (Milburn, 1990 & 1993).

Contradictory lateral shear force results were however recorded for separate front row positions during scrumming. The high school, university and club standard loose head props experienced lateral shear towards the outside (loose head side), whereas under 23 and international standard loose head props experienced lateral shear directed towards the tight head prop. The hookers of all packs assessed, except for the high school pack, experienced lateral shear force towards the loose head side. The lateral shear force experienced by all tight head props was directed towards the loose head prop (Milburn, 1990 & 1993a). The manner, in which Milburn (1987, 1990 & 1993a) and Milburn & O'Shea (1994 & 1997) however applied the force plates, made it impossible to determine the direction of force application.

Little data is currently available elucidating the individual contributions of players to the forces generated in the tight scrum. Hodge (1980) found that excluding the flankers from the tight scrum resulted in a 28% decrease in forward force. The further elimination of the eigthman did not reduce the forward force further. Similarly Milburn (1990) found that the flankers produced 20-27% of total forward force with the eigthman contributing very little additional imputes. The largest percentage of forward force generated by the tight scrum is contributed by the front row. Cohen and Siff (1979) measured the forward force generated by the front row alone as being equal to 2800 N. This represents 40% of the estimated forward force produced by a full scrum. Milburn (1990) found the percentage of forward force produced by the front row alone to be approximately 46%. This thus results in the second row's contribution to forward force being an estimated 27-34%.

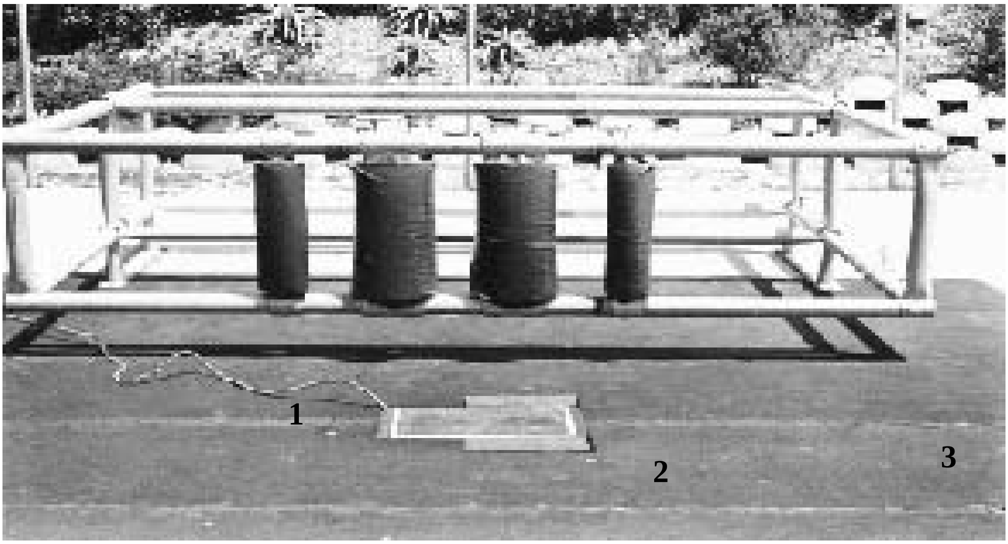
Due to many unanswered questions regarding the kinetics of Rugby Union scrumming, the necessity has occurred to investigate a different method of simulating and recording the forces generated during the scrum.

## METHOD AND PROCEDURES

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.

**Test Terrain**

The 8 $m^2$ test surface, composed of concrete and covered by a 12 mm thick rubber mat, was used (Figure 1).




1 – Cable to Electronic Unit 2 – Force Platform 3 – Rubber Matting

*FIGURE 1.* **APPARATUS FOR THE EVALUATION OF GROUND FORCE APPLICATION**

Scrumming on the test surface was performed in trainers and not in rugby boots. This was done as results from a pilot study revealed that greater force production was recorded whilst the forwards were wearing trainers as opposed to rugby boots. The rubber matting not only provided a realistic scrumming surface, but also unlike grass the rubber matting did not deteriorate due to the amount of scrums (1 664) performed on the surface.

The force platform was placed in a rectangular hole, sunk in the test surface, in front of the adjustable scrum machine. Once the force platform, covered by a piece of rubber matting the size of the rectangular hole, was positioned in the test surface it was flush with the surrounding rubber surface.

**Instruments**

A Kistler piezoelectric multi-component force platform (Type 9281 A11) was used to determine the vertical (Fz), horizontal (Fx) and transverse horizontal (Fy) ground reaction force components. The magnitude of the resultant force (Fr) as well as the angles of vertical (Az) and horizontal (Ay) force application were calculated with the use of the three orthogonal force components (Fz, Fx and Fy).

The scrumming machine is constructed from 100 mm and 110 mm galvanized tubing with a 6 mm wall thickness. The scrum machine can accommodate a 4 m lateral adjustment, to either side, as well as a 3 m forward and backward adjustment of the scrumming cages (Figure 2).

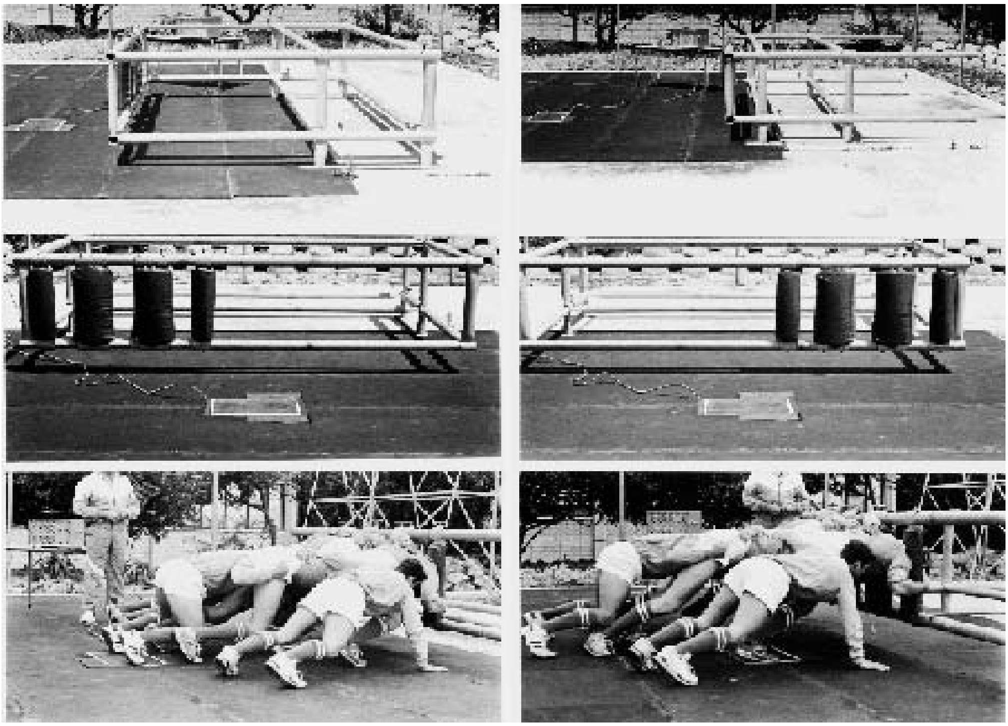


*FIGURE 2.* **THE ADJUSTABILITY OF THE SCRUM MACHINE AND RESULTING PLAYER POSITIONING OVER THE FORCE PLATFORM**

The adjustments that can be made due to the design of the scrum machine, ensure that it is possible to evaluate the players, one at a time on the force platform, in their normal scrumming position during a live scrum.

## DATA MANAGEMENT

The force application data were derived from measurements made whilst the subjects were scrumming on the force platform and into the adjustable scrumming machine. The measurements were recorded at 2024 Hz. Data recording lasted 6 seconds, starting just before the ball was put into the scrum. Only a 3 second segment, of the recorded data, was however used for final data analysis. The use of only 3 seconds of recorded data was considered sufficient, as the initial and sustained phases of scrumming would be completed within 3 seconds in the normal scrum. The force-time graphs were synchronized on the first trace of force application by the subjects.

Each subject performed two trails. The best performance of the two measurements, in terms of force production, was noted and used to calculate the average ground reaction force for the respective playing positions. The measurement of force application during the initial shove was defined and gauged as the force, which was applied by the player for a period of 0.2 seconds from the onset of force application, on the force platform at the beginning of the tight scrum. The measurement of force application during sustained scrumming was defined and gauged as the force, which was applied by the player for a period of 2 seconds (1 second before and 1 second after maximum force application was observed), on the force platform during the tight scrum.

The statistically significant differences in force application between the front, second and back rows were determined by means of one-way ANOVA. Scheffe's method was used to perform the multiple comparisons between the various positional groups' means. Scheffe's method was specifically selected because of the numerical differences between the positional groups and because of its conservative nature in identifying statistically significant differences (Thomas & Nelson, 1996).

## RESULTS AND DISCUSSION

### Vertical force application (Fz)

The average vertical force application produced by the front row players, during the initial shove, proved to be significantly greater (p<.01) than that delivered by the second and back row players. The initial vertical force application recorded for the second row forwards also proved to be significantly greater (p<.01) than that of the back row forwards (Table 1).

*TABLE 1.* **VERTICAL FORCE APPLICATION FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Fz (Newton) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| INITIAL SHOVE | Front row (n=78) | 1009 | 32.26 | 1357 | 37.18 |
| | Second row (n=52) | 852 | 29.12 | 1082 | 30.07 |
| | Back row (n=78) | 741 | 20.76 | 874 | 23.91 |
| | Forwards (n=208) | 869 | 17.97 | 1107 | 23.23 |
| | *Total scrum (n=26)* | *6952* | *189.56* | *8856* | *192.11* |
| SUSTAINED SCRUMMING | Front row (n=78) | 1386 | 35.54 | 1613 | 38.94 |
| | Second row (n=52) | 1014 | 31.91 | 1179 | 33.77 |
| | Back row (n=78) | 851 | 17.17 | 985 | 18.81 |
| | Forwards (n=208) | 1093 | 23.42 | 1269 | 26.49 |
| | *Total scrum (n=26)* | *8744* | *254.17* | *10152* | *298.23* |

Similar results to those found for average vertical force application during the initial shove, were observed when the maximum vertical force application produced by each positional group was compared. The maximum vertical force application results obtained indicate that the front rows achieved significantly greater ($p<.01$) maximum force application than both the second and back row players. The second row players' maximal vertical force application in turn was significantly greater ($p<.01$) than that of the back row players (Table 1). The average vertical force application of each member of the scrum and the total scrum, during the initial shove, was calculated to be 869 N and 6952 N respectively.

The average vertical force application, during the sustained phase of the scrum, did not differ significantly ($p>.01$) from maximum vertical force application during the initial shove phase of the scrum. The results displayed in Table 1 however do indicate that the front row players produced significantly greater ($p<.01$) vertical force than the second and back row players.

A comparison of the maximum vertical force application during sustained scrumming revealed similar results. The greatest vertical force application was produced by the front rows, followed by the second row and finally the back row forwards. Statistically significant differences ($p<.01$) were found to exist between all the relevant positional groups (front, second and back rows) for the measure of maximum vertical force application during sustained scrumming. The average sustained vertical force application during scrumming by each forward and the total scrum was measured at 1093 N and 8744 N respectively (Table 1).

A sudden decrease in vertical force application by all the investigated positional groups before the initial shove is initiated was observed. The sudden decrease is due to the forwards, engaged in the scrum, dropping their hips as the signal is given that the ball is about to be put in. The lowering of the hips ensure that their body positioning is correct (hips lower than shoulders) and that they are scrumming lower than their opponents are. This occurrence was not only observed in the application of vertical force, but was also evident in the measurement of the horizontal (Fx) and resultant (Fr) application (Figure 5) of the forwards during the scrum.

**Horizontal force application (Fx)**

The average horizontal force application during the initial shove phase of the tight scrum did not differ significantly ($p>.05$) between the front, second and back row forwards (Table 2). This insignificant difference observed between the positional groups was as a result of the small horizontal force that was applied before the ball was put into the scrum. As the ball was put into the scrum, the horizontal force application increased prodigiously. Similar to the observation made during the measurement of vertical force application (Fz), horizontal force application by the front, second and back row forwards also decreases markedly before the ball is to be put into the scrum.

The maximum horizontal force application produced by the front row forwards during the initial shove was significantly greater ($p<.01$) than that produced by the second and back row forwards. The maximum horizontal force application of the second row forwards proved to be significantly greater ($p<.01$) than that of the back row forwards (Table 2). The average horizontal force application, during the initial shove phase of the tight scrum, for the individual forward and the scrum as a whole, was 585 N and 4677 N respectively.

The largest horizontal force application, during sustained scrumming, was registered for the front rows, they were followed by the second row forwards and finally the back row forwards with the smallest horizontal force application. The measure of maximum horizontal force application, during sustained scrumming, proved to deliver significantly different ($p<.01$) results between all the relevant positional groups.

*TABLE 2.* **HORIZONTAL FORCE APPLICATION FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Fx (Newton) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| INITIAL SHOVE | Front row (n=78) | 610.5 | 27.98 | 919.73 | 30.72 |
| | Second row (n=52) | 615.1 | 29.28 | 846.24 | 29.11 |
| | Back row (n=78) | 538.4 | 21.91 | 682.19 | 25.38 |
| | Forwards (n=208) | 584.6 | 18.00 | 812.23 | 18.01 |
| | *Total scrum (n=26)* | *4677* | *141.1* | *6489* | *211.5* |
| SUSTAINED SCRUMMING | Front row (n=78) | 1029 | 26.53 | 1219 | 30.75 |
| | Second row (n=52) | 826 | 31.22 | 975 | 34.33 |
| | Back row (n=78) | 703 | 19.19 | 831 | 21.25 |
| | Forwards (n=208) | 856 | 17.53 | 1012 | 20.16 |
| | *Total scrum (n=26)* | *6848* | *223.4* | *8096* | *267* |

**Transverse horizontal force application (Fy)**

The average transverse horizontal force application of the front, second and back rows are much smaller in comparison to the measures of vertical (Fz) and horizontal (Fx) force application. No significant differences ($p>.01$) were however detected between the positional groups for the obtained values of average transverse horizontal application force, during the initial shove. The average transverse horizontal force application per forward and for the total scrum, during the initial shove, was recorded as 14.75 N and 118 N respectively.

During the initial shove phase of scrumming similar results were observed for the measure of maximum transverse horizontal force application than those discussed in relation to average transverse horizontal force application.

Results obtained during the sustained phase of the scrum corresponded with those obtained during the initial shove phase (Table 3). No statistically significant differences ($p>.01$) were found in the transverse horizontal force application between the positional groups of forwards.

The maximum transverse horizontal ground force application results of the front, second and back row forwards, during sustained scrumming, did also not prove to be significantly different ($p>.01$) from each other (Table 3).

The existence of no statistically significant differences has a twofold explanation. Firstly, the results obtained for transverse horizontal force application, from all the forwards, were very small. Secondly, the flankers, classed in the back row positional group, scrummed in the opposite direction to that recorded for the other forwards. This thus implies that although the displayed resultant transverse horizontal force application of the back row positional group is relatively small (Table 3), the force application recorded for the tight and loose head flankers in the transverse horizontal plane was considerably large. The above-mentioned explanation is verified by the observation that the transverse horizontal force application of the flankers were significantly greater ($p<.01$) than that of all the other forward positions both in the initial shove and sustained phase of scrumming. No significant differences ($p>.01$) in initial shove and sustained transverse horizontal force application was however found between the forward positions.

*TABLE 3.* **TRANSVERSE HORIZONTAL FORCE APPLICATION FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Fy (Newton) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| **INITIAL SHOVE** | Front row (n=78) | 16.06 | 9.53 | 20.14 | 14.61 |
| | Second row (n=52) | 34.68 | 9.59 | 64.26 | 13.56 |
| | Back row (n=78) | -5.85 | 17.71 | -5.06 | 23.25 |
| | Forwards (n=208) | 14.75 | 7.99 | 21.81 | 10.59 |
| | *Total scrum (n=26)* | *118* | *38.9* | *175* | *41.1* |
| **SUSTAINED SCRUMMING** | Front row (n=78) | 27.19 | 12.51 | 43.11 | 20.25 |
| | Second row (n=52) | 51.53 | 15.86 | 79.61 | 21.63 |
| | Back row (n=78) | -5.63 | 21.47 | 0.37 | 28.02 |
| | Forwards (n=208) | 20.97 | 10.21 | 36.21 | 14.15 |
| | *Total scrum (n=26)* | *168* | *49* | *289* | *87* |

The function of the flankers within the tight scrum serves as further explanation for the results they achieved. The flankers are responsible for pushing in laterally on the props. This adds stability to the tight scrum and prevents the props from being pushed out of the scrum by the second row forwards. Due to the flankers' positioning on either side of the scrum and their function, which essentially entails scrumming in opposite directions, the sum of their transverse horizontal force application is very small. Thus the resultant force application of the flankers in the transverse horizontal plane is comparable to that achieved by the front and second row forwards. The summation of the forces applied by the back row forwards thus explains the statistically insignificant differences in transverse horizontal force application observed between the front, second and back row forwards. The results, as displayed in the data tables, represent the sum totals of normal force and directional application during scrumming. Therefore only the sum totals will be referred to in the subsequent data analysis.

The positive transverse horizontal force application of the scrum during the initial shove and sustained scrumming phases indicates that the forwards scrum to the right, and that force application is directed towards the tight head prop (Table 3). Transverse horizontal force application data for each individual position within the scrum revealed that only the tight head prop, tight head lock and tight head flanker were scrumming towards the loose head prop and the incoming ball. All the players on the loose head side, including the hooker and eightman, were scrumming towards the tight head prop.

**Direction of force application in the horizontal plane (Ay)**

The direction of force application, during the initial shove, by the front, second and back row players do not differ significantly ($p>.01$) (Table 4). The observation that no statistically significant differences existed between the direction of force application of the tight forwards and loose forwards can be attributed to the summation of the forces delivered by the back row.

The results did however show a significant difference ($p<.01$) in the horizontal angle of force application between the flankers and other forwards. The tight head flank position produced the greatest horizontal angle of force application. This observed result is closely related to the function of the flank within the tight scrum as was previously explained.

*TABLE 4.* **ANGLE OF FORCE APPLICATION IN THE HORIZONTAL PLANE FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Ay (Degrees) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| INITIAL SHOVE | Front row (n=78) | 1.21 | 1.62 | 1.41 | 3.04 |
| | Second row (n=52) | 4.22 | 0.78 | 8.84 | 3.36 |
| | Back row (n=78) | -0.71 | 3.67 | -0.88 | 5.11 |
| | Forwards (n=208) | 1.27 | 1.88 | 2.53 | 3.04 |
| | *Total scrum (n=26)* | *1.27* | *1.88* | *2.53* | *3.04* |
| SUSTAINED SCRUMMING | Front row (n=78) | 2.05 | 0.75 | 5.26 | 3.66 |
| | Second row (n=52) | 3.17 | 0.81 | 6.28 | 2.33 |
| | Back row (n=78) | -0.66 | 2.72 | 0.51 | 4.81 |
| | Forwards (n=208) | 1.33 | 0.77 | 3.79 | 2.07 |
| | *Total scrum (n=26)* | *1.33* | *0.77* | *3.79* | *2.07* |

During the sustained phase of the scrum, similar results were observed as during the initial shove phase, with no significant differences being present between the horizontal direction of force application by the front, second and back rows (Table 4). Again the summation of the back row's force application was responsible for the insignificant result. Similar to the observation made during the initial shove phase, the tight head flank position produced the greatest horizontal angle of force application. The greater angle of force application (Ay) by the tight head flankers are due to their function of creating a wedge to counteract the natural sway of the scrum.

The mean angle of the force application (Ay) for the total scrum during the initial and sustained phases of scrumming was 1.3° in the direction of the tight head prop. This indicates that the resultant force application of the entire scrum is steered almost directly forward (Figure 3). This is the desired direction of scrumming force advocated by many (Craven, 1975; Winder, 1991).

Milburn (1990) identified a lateral shear force in the tight scrum, which is directed towards the loose head prop. This causes a natural lateral sway of the scrum towards the loose head side. Thus force application by the forwards directed slightly towards the tight head prop may be a further attempt by the loose head forwards to counteract the natural lateral sway of the scrum.

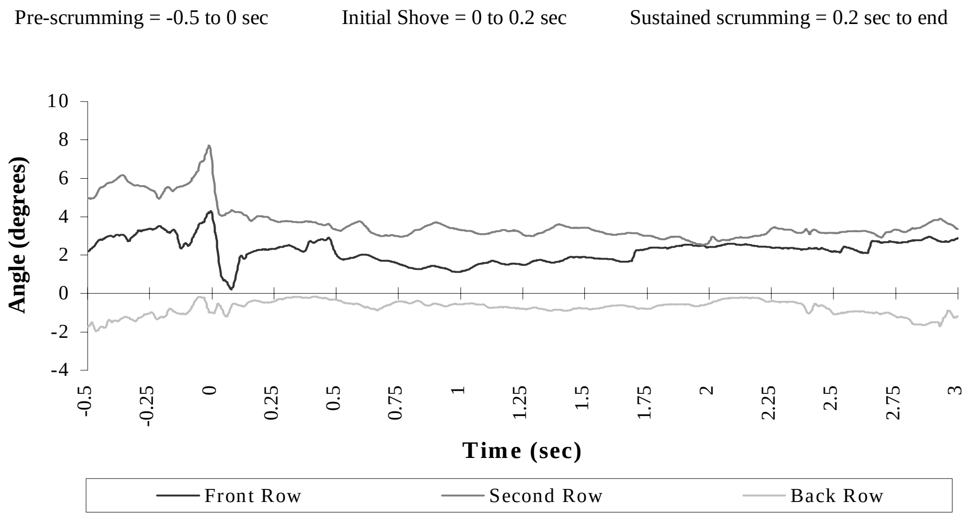



*FIGURE 3.* **THE HORIZONTAL ANGLE OF FORCE APPLICATION (Ay) BY THE FRONT, SECOND AND BACK ROW FORWARDS DURING SCRUMMING**

The small horizontal angle of force application (Ay) directed towards the tight head prop, promotes stability of the scrum in the horizontal plane (Figure 3). The small horizontal angle causes minimal lateral sway of the scrum, about its central axis, in the opposite direction to the normal lateral movement of the scrum (towards the loose head side) thus promoting scrum stability. The observation of excessive lateral sway during live scrumming must therefore be attributed to intentional manipulation, a mismatch of strength or incorrect scrumming techniques, and not necessarily the normal kinetics of scrumming.

**Angle of force application in the vertical plane (Az)**

During the initial shove phase of the tight scrum the direction of force application, in the vertical plane, produced by the front row forwards is significantly greater ($p<.01$) than that produced by the second and back row forwards. There is however no significant difference ($p>.01$) between the angle of force application (Az) produced by the second and back row forwards (Table 5).

The smallest angle of force application (Az) obtained during the initial shove phase of the scrum proved to be significantly greater (p<.01) for the front row forwards than for the second and back row forwards. The angle of force application in the vertical plane did however not differ significantly (p>.01) between the second and back row forwards (Table 5).

*TABLE 5.* **ANGLE OF FORCE APPLICATION IN THE VERTICAL PLANE FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Az (Degrees) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| INITIAL SHOVE | Front row (n=78) | 61.03 | 1.58 | 55.07 | 0.68 |
| | Second row (n=52) | 55.56 | 0.64 | 51.57 | 0.21 |
| | Back row (n=78) | 55.27 | 0.51 | 52.12 | 0.21 |
| | Forwards (n=208) | 57.51 | 0.51 | 53.08 | 0.21 |
| | *Total scrum (n=26)* | *57.51* | *0.51* | *53.08* | *0.21* |
| SUSTAINED SCRUMMING | Front row (n=78) | 53.31 | 0.02 | 49.44 | 1.09 |
| | Second row (n=52) | 51.17 | 0.22 | 48.94 | 0.18 |
| | Back row (n=78) | 50.89 | 0.21 | 48.21 | 0.21 |
| | Forwards (n=208) | 51.86 | 0.11 | 48.85 | 0.27 |
| | *Total scrum (n=26)* | *51.86* | *0.11* | *48.85* | *0.27* |

The direction of force application (Az) during the sustained phase of scrumming only differs significantly (p<.01) between the front row and second row forwards, and the front row and back row forwards. No statistically significant difference (p>.01) in angle of force application (Az) exists between the second and back row forwards. Contrary to the observations made during the initial phase of scrumming, no significant differences (p>.01) were detected in the minimum angle of force application between any of the positional categories during sustained scrumming (Table 5). All three positional categories displayed smaller average angles of force application in the vertical plain, during sustained scrumming than during the initial shove phase of the tight scrum. The observed change in the vertical direction of force application from the initial shove phase to sustained scrumming is only significant (p<.01) within the front row positional category. The significantly greater (p<0.1) angle of force application, in the vertical plane, by the front row forwards can be attributed to a deliberate effort by them to prevent the scrum from collapsing. The observation of a greater initial angle of force application (Az) followed by a notable decrease in this angle may be attributed to the attempts made by the front row to first achieve vertical stability before engaging in the forward shove.

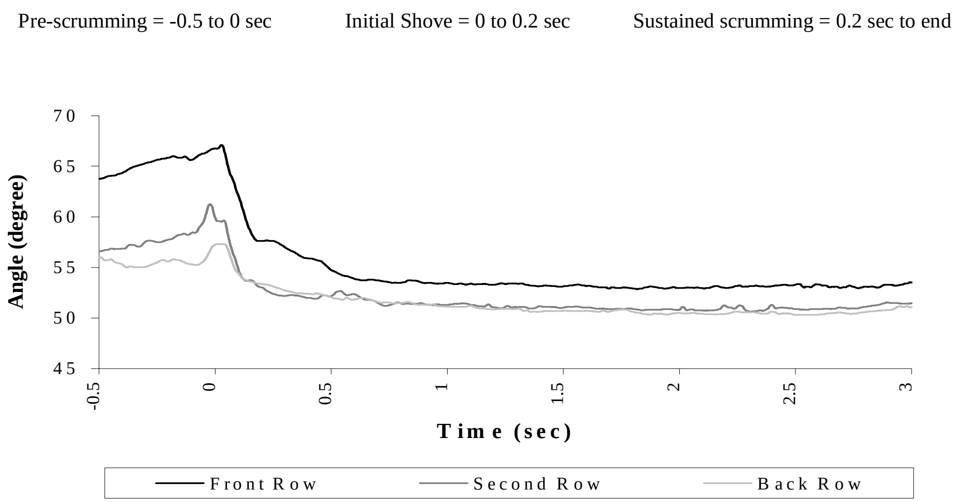



*FIGURE 4.* **THE VERTICAL ANGLE OF FORCE APPLICATION (Az) BY THE FRONT, SECOND AND BACK ROW FORWARDS DURING SCRUMMING**

The average minimum angle of force application in the vertical plane (48.85°) during any stage of the scrum is another factor, which supports the vertical stability of the scrum (Table 5 & Figure 4). Collapsing of a tight scrum, under normal playing conditions, due to a small angle of force application in the vertical plane must be the exception rather than the rule. As mentioned previously the collapsing of a live scrum can therefore be attributed to intentional manipulation, incorrect scrumming techniques or to a mismatch in the scrumming abilities of the players, and not due to normal scrumming kinetics.

It must however be noted as this point that the scrums, from which data were collected for this study, were performed against a scrum machine which provided less movement and thus increased stability. It can therefore be deduced that two evenly matched packs of forwards, contesting the tight scrum equally, can contribute to the stability of the scrum. Furthermore it provides a logical explanation for the occurrence of more injuries in schoolboy rugby, due to the collapsing of the tight scrum, opposed to senior rugby where mismatches of strength are unlikely to occur.

**Resultant force application (Fr)**

It has been shown that the front row forwards recorded the greatest horizontal and vertical force application followed by the second row and finally the back row forwards. The results also revealed that the mean angle of force application in the horizontal plane (Ay) does not significantly differ between the front, second and back row forwards during both phases of scrumming and that approximately all the force is applied in the direction of scrumming. It can therefore be presumed that similar results will be obtained for the resultant force application.

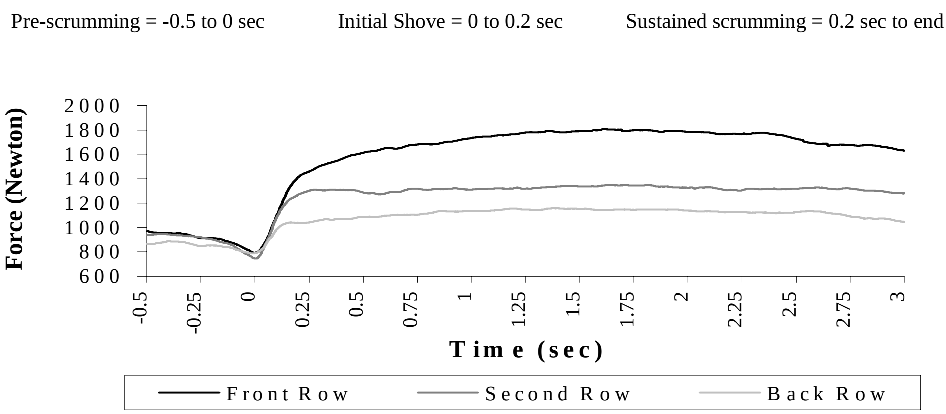



*FIGURE 5.* **RESULTANT FORCE APPLICATION (Fr) OF THE FRONT, SECOND AND BACK ROW FORWARDS**

The resultant force application during the initial shove differs significantly ($p<.01$) between the front, second and back row forwards. As expected the front row forwards produced the greatest force application (Fr), followed by the second and finally the back row forwards (Table 6 and Figure 5).

The front row forwards furthermore produced a force application (Fr) during the initial shove phase, which was significantly greater ($p<.01$) than that produced by the second and back row forwards. On this measure the second row forwards also proved to have produced a significantly larger ($p<.01$) resultant force than the back row forwards. As seen from Table 6 the average resultant force application by each forward was 1062 N, with a resultant force application of 8496 N for the entire scrum during the initial shove phase.

Results obtained for force application (Fr) during sustained scrumming are similar to those observed during the initial shove phase with the greatest resultant force application produced by the front row forwards. They are followed by the second and back row forwards respectively (Table 6 and Figure 5).

The average resultant force application for each forward during sustained scrumming was 1400 N with an average resultant force of 11.2 kN for the entire scrum (Table 6). Statistical analysis furthermore indicated that there was a significant correlation ($p<.01$) between the combined mass of the scum and the produced resultant force. This correlation is justified as the body mass of the player forms a major component of his force application.

A total ground force application of 11.2 kN for a single scrum seems high if the total force application of two packs is estimated to be 15 kN (Burry & Gowland, 1981; Milburn, 1990). The large resultant force application observed in this study can however be explained by factoring in the large contribution made by gravity on the measure of vertical force application. Scrumming against an instrumented or opposition scrum eliminates the influence of gravitational forces and only vertical shear force is recorded.

*TABLE 6.* **RESULTANT FORCE APPLICATION FOR THE FRONT, SECOND AND BACK ROW FORWARDS**

| PHASE | POSITION | Fr (Newton) | | | |
|---|---|---|---|---|---|
| | | MEAN | SEM | MAX | SEM |
| **INITIAL SHOVE** | Front row (n=78) | 1194 | 39.93 | 1642 | 46.32 |
| | Second row (n=52) | 1059 | 39.79 | 1375 | 40.16 |
| | Back row (n=78) | 933 | 29.49 | 1124 | 34.36 |
| | Forwards (n=208) | 1062 | 22.42 | 1381 | 28.41 |
| | *Total scrum (n=26)* | *8499* | *277* | *11048* | *361* |
| **SUSTAINED SCRUMMING** | Front row (n=78) | 1734 | 42.79 | 2015 | 47.71 |
| | Second row (n=52) | 1316 | 43.73 | 1529 | 46.89 |
| | Back row (n=78) | 1123 | 24.61 | 1300 | 26.76 |
| | Forwards (n=208) | 1400 | 28.41 | 1626 | 32.11 |
| | *Total scrum (n=26)* | *11203* | *370* | *13001* | *421* |

Milburn (1990) tested an under 19 schoolboy scrum and recorded a vertical shear force application of 190 N for the entire scrum as they scrummed against an instrumented scrumming machine. As the combined mass of the scrum (5584 N) was not taken into account, the vertical force application and the direction of force application in the vertical plane could not be calculated. It is important to note that the ground force application during scrumming discussed in this study, represent the total force applied by every member of the scrum and does not only represent the forces that are impinged on the shoulders of the front row forwards.

The forces that are absorbed inside the scrum is another factor that can account for the large ground reaction force application and further explains the relatively smaller estimated values for the shoulder force application as two opposing packs engage. The results obtained for shoulder force application on engagement and during sustained scrumming by Du Toit (1993), supports the above statement.

The observed resultant force applications produced by the front, second and back row forwards corresponds to their function within the tight scrum.

**Contributions of positional categories during scrumming**

Little data is currently available elucidating the individual contributions of players to the forces generated in the tight scrum. The present data made it possible to investigate the positional contributions to total resultant force (Fr) generated in the scrum (Table 7). The results displayed in Table 7 show that similar results were obtained in this study as reported by other researchers (Cohen & Siff, 1979; Hodge, 1980; Milburn, 1990). The largest percentage of forward force was generated by the front row players during both the initial and sustained scrumming phases (42 and 46% respectively). This is equivalent to the 46%

contribution made by the front row to total forward force reported by Milburn (1990). The tight five produce approximately 67 and 70% of the total resultant force during the initial and sustained scrumming phases of the scrum respectively. This thus results in the back row forwards contributing approximately 33 and 30% of the total resultant force during the initial and sustained scrumming phases of the tight scrum respectively. This is comparable to the 20 -28% percent contribution measured by Hodge (1980) and Milburn (1990). Milburn (1993b), using a subtraction model, however reports somewhat different results. It was calculated that the front row contributed 37%, the second row 42% and the back row 21% to the force of the total scrum.

It is interesting to note that the back row forwards contribute slightly more force (± 3%) to the scrum during the initial phase than during sustained scrumming. This may be attributed to their function in the scrum of assisting their prop on engagement. Furthermore the back row forwards are expected to break quickly once the ball has left the scrum and reach the next breakdown point, thus their smaller contribution during sustained scrumming can be attributed to their eagerness to break away from the tight scrum. Conversely the front row contributes more force (± 4%) during sustained scrumming than during the initial phase of scrumming. This due to the decrease in force production by the hooker as he hooks the incoming ball. Once the ball has been successfully won, all attention can again be focussed on scrumming.

*TABLE 7.* **AVERAGE PERCENTAGE RESULTANT FORCE CONTRIBUTION BY THE VARIOUS POSITIONAL CATEGORIES DURING 26 SIMULATED SCRUMS**

| PHASE | POSITION | | | TOTAL SCRUM |
|---|---|---|---|---|
| | FRONT ROW | SECOND ROW | BACK ROW | |
| INITIAL SHOVE | 42 (3582) | 25 (2118) | 33 (2799) | 100 (8499) |
| SUSTAINED SCRUMMING | 46 (5202) | 24 (2632) | 30 (3369) | 100 (11203) |

(*) = Percentage expressed in Newton

## CONCLUSION

The front row's vertical force application (Fz), produced during both phases of scrumming, was significantly greater (p<.01) than that of the other positional categories. In turn the second row's vertical force application was significant larger (p<.01) than that of the back row.

No significant differences (p>.01) were found between the horizontal force applications (Fx) of the positional categories during the initial shove phase. The front rows' horizontal force application (Fx), during sustained scrumming, was however significantly greater (p<.01) than that of the second and back rows. The second row forwards also produced a significantly greater (p<.01) horizontal force application than the back row forwards.

Transverse horizontal force applications (Fy) by the positional categories were significantly smaller (p<.01) than the corresponding vertical (Fz) and horizontal (Fx) force applications. Transverse horizontal force applications (Fy), during both scrumming phases, by the positional categories did not differ significantly (p<.01) from each other. Furthermore the transverse horizontal force application of the entire scrum was directed towards the tight head prop. Only the tight head prop, - lock and - flanker were scrumming towards the loose head prop and the incoming ball. The scrum’s mean angle of force application in the horizontal plane (Ay) was 1.3° directed towards the tight head prop. The scrum’s resultant force application (Fr) thus approximated the desired direction of scrumming advocated by Craven (1975) and Winder (1991).

The front row forwards’ direction of force application in the vertical plane (Az), during both phases of scrumming, were significantly greater (p<.01) than that of the other forwards. Furthermore the vertical direction of force application (Az) was smaller during sustained scrumming than during the initial shove for all positional categories. The observed change in vertical direction of force application, from the initial shove to the sustained phase of scrumming, was only significant (p<.01) within the front row positional category.

The resultant force application (Fr), during both phases of scrumming, differed significantly (p<.01) between all positional categories. The front row produced the greatest resultant force application during both scrumming phases. Average resultant force application for the scrum equaled 11.2 kN, and a significant correlation (p<.01) exists between the mass of the scrum and this resultant force application. This correlation is justified as the forward’s mass forms a large component of his vertical force application. During scrumming the ground force application is channeled through the players’ shoulders (shoulder force application). The shoulder force application for the front row, second row and back row forwards, although much less than the ground force application, revealed a similar sequence of force application (Du Toit, 1993), and thus supports the findings of this study. The magnitude of these forces have been speculated upon, but has not yet been established and thus warrants further investigation. Furthermore valuable information can be gained by repeating this research with senior players. The effect of different binding techniques, engagement techniques and scrumming methods on the kinetics of the rugby union scrum must also be investigated.

## REFERENCES

BURRY, H.C. & GOWLAND, H. (1981). Cervical injury in Rugby Football – A New Zealand survey. *British Journal of Sports Medicine*, 15(1): 56-58.

COHEN, I. & SIFF, M. (1979). Increased safety in Rugby scrums. *South African Medicinal Journal*, 56(16): 625-630.

CRAVEN, D.H. (1975). *Rugbyhandboek.* Kaapstad: Tafelberg.

DU TOIT, D.E. (1993). The kinetics of Rugby scrumming and the neck’s force capabilities as a cause of cervical spinal injuries. Unpublished D.Phil. dissertation. Port Elizabeth: University of Port Elizabeth.

HODGE, K.P. (1980). Spinal injuries in Rugby scrums. *Research Papers in Physical Education*, 2(4): 82.

MILBURN, P.D. (1987). A comparison of the mechanics of hip and crotch binding techniques in Rugby Union scrummaging. *The Australian Journal of Science and Medicine in Sport*, 19(1): 3-9.

MILBURN, P.D. (1990). The kinetics of Rugby Union scrummaging. *Journal of Sport Science*, 8(1): 47-60.

MILBURN, P.D. (1993a). Biomechanics of Rugby Union scrummaging: Technical and safety issues. *Sports Medicine*, 16(3): 168-179.

MILBURN, P.D. (1993b). Player contributions in a Rugby Union scrum. *Journal of Biomechanics*, 27(6): 677.

MILBURN, P.D. & O'SHEA, B. (1994). The sequential scrum engagement: A biomechanical analysis. *The Australian Journal of Science and Medicine in Sports*, 26(½): 32-35.

MILBURN, P.D. & O'SHEA, B. (1997). The 2-3-2 scrum formation: A biomechanical analysis. *New Zealand Journal of Sports Medicine*, 25(4): 57-60.

RODANO, R. & PEDOTTI, A. (1988). A quantitative analysis of thrust and motor coordination in a Rugby scrum. In T. Reilly, A. Lees, K. Davids & W.J. Murphy (Eds.), *Science and football* (476-486). London, E & FN Spon.

SCHER, A.T. (1977a). A plea for routine radiographic examination of the cervical spine after head injury. *South African Medical Journal*, 51(24): 885-887.

SCHER, A.T. (1977b). Rugby injuries to the cervical spinal cord. *South African Medical Journal*, 51(14): 473-475.

SCHER, A.T. (1983). Serious cervical spinal injury in the older Rugby player. *South African Medical Journal*, 64(5): 138-140.

SCHER, A.T. (1990). Premature onset of degenerative disease of the cervical spine in Rugby players. *South African Medical Journal*, 77(11): 557-558.

THOMAS, J.R. & NELSON, J.K. (1996). *Research methods in physical activity* (3rd ed.). Champaign, IL: Human Kinetics.

WINDER, P. (1991). *Rugby tactics.* London: A & C Black.

QUARRIE, K.L. & WILSON, B.D. (2000). Force production in the Rugby Union scrum. *Journal of Sports Sciences*, 18(4): 237-246.

Dr. D.E. du Toit: Department of Human Movement Science, University of Port Elizabeth, Private Bag 1600, Port Elizabeth 6000, Republic of South Africa. Tel.: +27 (0)41 504-2518 (w), +27 (0)41 379-3062 (h), Fax.: +27 (0)41 504-2770, E-mail: hmadet@upe.ac.za

*(Subject editor: Prof. P.E. Krüger)*