Time–motion analysis of professional rugby union players during match-play

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Abstract
The aim of this study was to quantify the movement patterns of various playing positions during professional rugby union match-play, such that the relative importance of aerobic and anaerobic energy pathways to performance could be estimated. Video analysis was conducted of individual players (n = 29) from the Otago Highlanders during six “Super 12” representative fixtures. Each movement was coded as one of six speeds of locomotion (standing still, walking, jogging, cruising, sprinting, and utility), three states of non-running intensive exertion (rucking/mauling, tackling, and scrummaging), and three discrete activities (kicking, jumping, passing). The results indicated significant demands on all energy systems in all playing positions, yet implied a greater reliance on anaerobic glycolytic metabolism in forwards, due primarily to their regular involvement in non-running intense activities such as rucking, mauling, scrummaging, and tackling. Positional group comparisons indicated that while the greatest differences existed between forwards and backs, each positional group had its own unique demands. Front row forwards were mostly involved in activities involving gaining/retaining possession, back row forwards tended to play more of a pseudo back-line role, performing less rucking/mauling than front row forwards, yet being more involved in aspects of broken play such as sprinting and tackling. While outside backs tended to specialize in the running aspects of play, inside backs tended to show greater involvement in confrontational aspects of play such as rucking/mauling and tackling. These results suggest that rugby training and fitness testing should be tailored specifically to positional groups rather than simply differentiating between forwards and backs.

Keywords: Movement patterns, physiology, intermittent high-intensity exercise

Introduction
There is presently a lack of information regarding the physiological demands of professional rugby union. Time–motion analysis provides an objective yet non-invasive method for quantifying work rate during field sports such as rugby, and provides information directly applicable to the design of physical conditioning and testing programmes.

Docherty, Wenger and Neary (1988) classified movements during amateur club and international fixtures (regional vs. international touring teams). Modifying the movement classification system of Reilly and Thomas (1976), the relative times (expressed as percentages) spent standing still, walking and jogging, running, sprinting, shuffling, and engaged in intense static activity were analysed, for props and centres. The authors concluded that as only 5 – 10% of a match was spent performing high-intensity work, the creatine phosphate system was of major importance during intensive work bouts, the aerobic system was important for other movements, and the anaerobic glycolytic system was of little importance during rugby match-play (Docherty et al., 1988).

Although time data for various activities may provide an indication of energetic demand, the measurement of work-to-rest ratios is important when investigating the physiological demands of intermittent sports such as rugby. McLean (1992) quantified times spent in both work and rest during first division and international match-play. Players were assumed to be working when the ball was in play, and otherwise in a state of rest. Individual players were not investigated, so there was no way of investigating individual work rates.

Deutsch, Maw, Jenkins and Reaburn (1998) used time–motion analysis to quantify the physiological demands of under 19 (colts’) match-play. This analysis combined both absolute measurements [frequency, time (s), and relative (%) time spent in various activities] with individual work-to-rest ratio
data. These data revealed marked differences between positions for the relative time (%) spent walking, jogging, cruising, sprinting, utility, rucking/mauling, and scrummaging. During 70 min of match-play, forwards performed approximately three times more high-intensity work (11.2 ± 0.9 min; mean ± standard error of the mean) than backs (3.6 ± 0.5 min).

The observed differences between positional groups and playing levels in these previous investigations imply that players must be specifically prepared for the demands of rugby match-play. The purpose of the present investigation was to combine these previous time–motion analysis methods to estimate the physical demands of professional rugby union in various playing positions, so as to provide specific information for the preparation of elite rugby players.

Methods

Participants

Video analysis was performed on 29 Otago Highlanders players during a total of eight international “Super 12” professional fixtures. Eleven players were examined during a second fixture, and the two measures from these players were then averaged to provide only one series of data from each player for group data calculations. Preliminary investigations demonstrated the variability between games for these players was similar to the variability between different players in the same positions, indicating that variation in the data within each positional group was most likely due to the varying demands and styles of the matches, rather than the individual styles of the players investigated. Data were collected during home games over two seasons (1996–1997). The results of the fixtures are shown in Table I.

Either four or eight players were investigated during each match, consisting of one or two players from each of four positional groups:

- Front row forwards: prop and lock (n = 9)
- Back row forwards: flanker, no. 8, and hooker (n = 7)
- Inside backs: fly-half, 2nd 5/8th, and centre (n = 7)
- Outside backs: wing and full-back (n = 6)

The hooker position was classified as a back row forward due to the observation that players in this position play a roving role around line-outs, and do not push during scrummaging to the same degree as the other front row forwards. The half-back position was not included in any of the above groups due to its unique role.

All participants were asked to provide informed consent before testing, and videoing rights were obtained from the necessary governing bodies. Ethical approval for the project was received from the Southern Regional Health Authority Ethical Committee, Dunedin.

Equipment and procedures

Video recordings were made using video cameras (Panasonic MS-4, Matsushita Electronics, Japan) positioned on stationary tripods. Camera positions varied depending on venue, and were between 5 and 15 m from the field, at an elevation of 5–10 m. Each camera operator was trained to follow one player for the duration of each match investigated. Fifteen assistants were used during the study for video recording, all of whom underwent thorough training. The recordings were viewed before analysis to ensure complete footage. Time–motion analysis was performed by three assistants using an in-house computer program, video recorder, and modified video-editing interface (Pro-Log, Time Frame International, New Zealand). As opposed to real-time coding (Deutsch et al., 1998), this system allowed the initiation and completion of each movement to be coded accurately.

The movement classification system was based on that originally documented in the soccer literature (Reilly & Thomas, 1976) and recently modified for use in rugby (Deutsch et al., 1998; Docherty et al., 1988). Each movement was coded as one of six speeds of locomotion (standing still, walking, jogging, cruising, sprinting, and utility), three states of non-running intensive exertion (rucking/mauling, tackling, and scrummaging), and three discrete activities (kicking, jumping, passing). These codes are further explained by the following operational definitions:

- **Standing still**: standing or lying on the ground without being involved in pushing or any other game activities. This can include small movements when such movements are not purposeful (e.g. stumbling back and forth, turning sideways, etc.).

<table>
<thead>
<tr>
<th>Game</th>
<th>Result</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Won</td>
<td>57–17</td>
</tr>
<tr>
<td>2</td>
<td>Won</td>
<td>29–15</td>
</tr>
<tr>
<td>3</td>
<td>Lost</td>
<td>15–44</td>
</tr>
<tr>
<td>4</td>
<td>Won</td>
<td>33–32</td>
</tr>
<tr>
<td>5</td>
<td>Won</td>
<td>27–7</td>
</tr>
<tr>
<td>6</td>
<td>Won</td>
<td>37–29</td>
</tr>
<tr>
<td>7</td>
<td>Lost</td>
<td>28–45</td>
</tr>
<tr>
<td>8</td>
<td>Lost</td>
<td>16–27</td>
</tr>
</tbody>
</table>

Table I. Results and full-time scores for the eight matches investigated.
• Walking: walking forwards or backwards slowly with purpose. One foot is in contact with the ground at all times (e.g. walking to a scrum following a breakdown in play).
• Jogging: running forwards slowly to change field position, but with no particular haste or arm drive (e.g. jogging down-field to a lineout).
• Cruising: running with manifest purpose and effort, accelerating with long strides, yet not at maximal effort (3/4 pace) (Deutsch et al., 1998; Docherty et al., 1988) (e.g. running into a back line to receive the ball).
• Sprinting: running with maximal effort. This is discernible from cruising by arm and head movements.
• Utility: shuffling sideways or backwards to change field position. Usually a defensive or repositioning movement. This does not include aimlessly walking slowly backwards.
• Jumping: jumping in a lineout or to catch a ball in play.
• Rucking/mauling: attached to an active ruck or maul. Once the ball exits the ruck or maul, or the referee calls the end of the play, the player is no longer considered to be engaged in rucking/mauling, and is deemed to be standing still.
• Scrummaging: attached to an active scrum. As above, once the ball exits or the play is stopped, the scrum is no longer active.

Utility movements were distinguished from walking (Docherty et al., 1988), as these movements have been shown to result in greater physiological cost than walking in a forward direction, yet do not differ significantly from each other (Reilly & Bowen, 1984). Although it would have been desirable to separate various types of rucking and mauling (e.g. static or dynamic), this would most likely have affected the reliability of the analysis method employed.

Cruising, sprinting, rucking/mauling, scrummaging, and tackling were regarded as high-intensity work, while standing, walking, jogging, and utility activities were regarded as rest activities.

The duration of each interval of high-intensity work was divided by the duration of the following rest interval to give the work-to-rest ratio for that passage of play. On the rare occasion that a player moved out of view during any passage of play, calculation of the work-to-rest ratio for that interval was omitted, and the calculation of the next work-to-rest interval commenced at the beginning of the following work bout.

One operator performed coding of each video recording. At the end of the footage, the file containing this time log of movements was imported into an in-house computer program for the calculation of the summary output. Altogether, three system operators were employed to perform the analyses. The reliability of a similar time–motion analysis method has previously been documented, with technical error of measurement coefficients ranging from 1.7 to 4.9% for total time in various movement speeds, and from 1.9 to 4.9% for the average duration of movements at various locomotive speeds (Deutsch et al., 1998). As three assistants were used to code data in the present study, however, a reliability assessment of basic parameters was performed.

Reliability. Reliability of the time–motion analysis method was assessed by having each of the operators perform repeat analyses on 40 min of footage from the same player. Each experimenter was denied knowledge of the results by the other experimenters, and of their own results between the first and second analyses for intra-tester reliability. The precision of the coding technique was assessed using the technical error of measurement (Mueller & Martorell, 1988). The inter- and intra-coder technical errors of measurement are shown in Table II.

Data analysis

Data from the program outputs were compiled for each positional group at the two standards of competition. For each player, the following statistics were selected from the analysis program output for each movement mode, and for work and rest variables:

• Frequency: the total number of instances a particular mode was coded over the duration of a match.
• Relative time (%): the amount of time spent in a given movement mode as a proportion of the total match duration.
• Mean duration: the average duration of a single instance of a particular movement mode (e.g. “Player X” had a mean sprint duration of 3 s).
• Maximum duration: the duration of the longest instance of that particular movement mode (e.g. the longest sprint “Player X” performed lasted 6 s).

The data were analysed on two positional levels, to provide two levels of specificity for training

<table>
<thead>
<tr>
<th>Variable</th>
<th>Occurrences</th>
<th>Total time</th>
<th>Relative time (%)</th>
<th>Mean duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-coder</td>
<td>8.7</td>
<td>5.2</td>
<td>4.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Intra-coder</td>
<td>4.6</td>
<td>1.8</td>
<td>1.6</td>
<td>4.8</td>
</tr>
</tbody>
</table>
prescription. First, data were compared for the specific positional groups (front row forwards, back row forwards, inside backs, and outside backs) for between-group contrasts. Second, pooled data for forwards (front row and back row forwards) and backs (inside and outside backs) were also compared. Data are presented as means (± standard deviations). Statistical significance for all tests was set at 95%. Because of the wide range of data between groups, paired t-tests assuming unequal variances were used to make comparisons between groups. To compensate for the use of multiple t-tests for each variable, a Bonferroni adjustment was applied, effectively taking the significance level to 98.75%. Data from the discrete activities were not compared statistically, as they were assumed to have negligible physiological consequences.

For the interest of readers, the maximum single value recorded for each variable across the study was noted, though these were not analysed statistically as they are based on single instances only.

Results

Standing still

Front row forwards spent more total time standing still than inside or outside backs, and back row forwards spent more time standing still than outside backs (P < 0.0125; Figure 1). An overall difference between forwards and backs was also observed (47.7 ± 4.6 and 41.1 ± 5.5 min., respectively; P < 0.0125).

Walking

There was a tendency for players to spend more time walking as they moved outwards among the positional groups, with front row forwards performing less walking than any other positional group (P < 0.0125; Figure 1). Furthermore, back row forwards spent significantly less time walking than outside backs. These trends were reinforced by an overall difference between forwards and backs (17.9 ± 4.7 and 32.4 ± 8.4 min, respectively; P < 0.0125).

Jogging

Front row forwards spent more time jogging than any of the other positional groups (P < 0.0125; Table III). Combined data revealed a greater use of jogging by forwards than backs (P < 0.0125; Table III).

Cruising

Front row forwards spent less time cruising than inside and outside backs (P < 0.0125; Table III). Pooled data revealed a greater use of cruising by backs than forwards (P < 0.0125; Table III).

Sprinting

Outside backs engaged in more sprints during a game than front row forwards (P < 0.0125; Figure 2). As a result, outside backs spent significantly more total time sprinting than front row forwards (P < 0.0125; Table III). An overall difference between forwards and backs was also observed (10.2 ± 10.2 vs. 29.4 ± 22.2 s; P < 0.0125). Mean sprint duration was longer for outside backs than for all other positional groups (P < 0.0125; Table III), which contributed to a significantly longer mean sprint duration for backs than for forwards (P < 0.0125; Table III). Maximum sprint duration was also significantly longer for outside backs than front row or back row forwards (P < 0.0125; Table III), which

![Figure 1. Relative times (%) spent standing still or walking for the four positional groups (n = 29; mean ± s). Comparisons were made using paired t-tests assuming unequal variances (P < 0.0125). When the same superscript letter appears beside two or more positional groups, a significant difference is present. Front row and back row forwards spent more time standing still than outside backs. Front row forwards performed less walking than the other positional groups, while back row forwards also performed less walking than inside or outside backs.](image-url)
Table III. Data for six movement speeds and three states of static exertion (n = 29; mean ± s).

<table>
<thead>
<tr>
<th>Mode</th>
<th>Variable</th>
<th>Front Row Mean (S.D.)</th>
<th>Back Row Mean (S.D.)</th>
<th>Combined Mean (S.D.)</th>
<th>Inside Backs Mean (S.D.)</th>
<th>Outside Backs Mean (S.D.)</th>
<th>Combined Mean (S.D.)</th>
</tr>
</thead>
</table>
|               | Relative Time (%) | 22.5 (2.7)
|               | Average Time (s.)    | 7.0 (0.8)            | 6.2 (1.0)            | 6.6 (1.0)             | 5.6 (0.7)               | 5.8 (1.3)             | 5.7 (0.9)            |
| Jogging       | Frequency (n)    | 9.9 (8.7)             | 25.2 (16.5)          | 16.6 (14.5)          | 32.6 (16.9)            | 30.7 (7.4)             | 31.7 (12.8)          |
|               | Relative Time (%) | 0.7 (0.5)             | 1.8 (1.0)            | 1.2 (1.0)            | 2.4 (1.4)              | 2.6 (0.7)              | 2.5 (1.1)            |
|               | Average Time (s.) | 3.3 (1.8)             | 3.9 (1.1)            | 3.5 (1.5)            | 3.7 (1.2)              | 4.3 (1.3)              | 4.0 (1.2)            |
|               | Maximum Time (s.) | 3.2 (1.8)             | 3.4 (1.9)            | 3.29 (1.78)          | 5.2 (1.0)              | 7.2 (1.9)              | 6.22 (1.72)          |
| Sprinting     | Frequency (n)    | 6.9 (8.3)             | 0.9 (0.8)            | 6.2 (9.9)            | 0.9 (1.2)              | 0.8 (1.0)              | 1.0 (1.3)            |
|               | Relative Time (%) | 1.1 (0.9)             | 1.9 (0.7)            | 1.4 (0.9)            | 4.8 (2.5)              | 4.1 (2.8)              | 3.6 (1.1)            |
| Utility       | Frequency (n)    | 39.2 (9.1)            | 36.9 (8.8)           | 38.2 (8.7)           |                         |                          |                     |
|               | Relative Time (%) | 4.00 (1.14)           | 3.05 (0.92)          | 3.8 (1.0)            |                         |                          |                     |
|               | Average Time (s.) | 5.3 (0.9)             | 5.0 (0.8)            | 5.2 (0.8)            |                         |                          |                     |

Note: When the same superscript letter appears beside two or more positional groups, a significant difference is present.

*Significant difference between forwards and backs.
was also reinforced by a longer maximum sprint duration for backs than forwards \( (P < 0.0125; \text{Table III}) \).

**Utility movements**

Inside backs performed more utility movements (for a greater total time) than either front row or back row forwards \( (P < 0.0125; \text{Table III}) \). Backs performed more (and consequently spent a greater percentage of time in) utility movements than forwards \( (P < 0.0125; \text{Table III}) \).

**Jumping**

There were no significant differences in jumping frequency between groups, or between forward and backs \( (P > 0.0125; \text{Table III}) \).

**Rucking/mauling**

Front row forwards were involved in significantly more rucks and mauls than players in other positional groups, while back row forwards were also involved in significantly more rucks and mauls than inside and outside backs \( (P < 0.0125; \text{Table III}) \). Front row and back row forwards spent more time rucking and mauling than the inside and outside backs \( (P < 0.0125; \text{Figure 3}) \).

**Tackling**

Back row forwards and inside backs were involved in more tackles than front row forwards \( (P < 0.0125; \text{Figure 4}) \), while back row forwards also performed more tackles than outside backs. There was no trend for forwards to perform more tackles than backs \( (23.1 \pm 14.0 \text{ vs. } 23.4 \pm 10.2; P > 0.0125) \); tackling seemed to be more a function of specific positional group.

**Scrummaging**

As expected, there were no differences between front row and back row forwards for any of the scrummaging variables investigated \( (P > 0.0125; \text{Table III}) \).

**Work-to-rest ratios**

Front row and back row forwards performed more high-intensity work than inside and outside backs \( (P < 0.0125; \text{Table IV}) \), as the result of performing work more frequently \( (P < 0.0125; \text{Table IV}) \). This difference was reinforced by overall differences between backs and forwards for both variables \( (P < 0.0125; \text{Table IV}) \). Although there were no differences in mean work duration between groups, front row and back row forwards had significantly longer maximum work periods during play than did inside and outside backs \( (P < 0.0125; \text{Table IV}) \). Combined data revealed no difference between
forwards and backs for mean work period, although the greater maximum work period performed by forwards was reinforced \((P < 0.0125; \text{Table IV})\).

The mean rest period was significantly longer for inside and outside backs than for front row and back row forwards \((P < 0.0125; \text{Figure 5})\). Front row and back row forwards had significantly shorter maximum rest periods than inside and outside backs, which was reinforced by the overall backs versus forwards difference \((P < 0.0125; \text{Table IV})\). As a result of a shorter mean rest period, the inside and outside backs had significantly lower mean work-to-rest ratios than front and back row forwards \((P < 0.0125; \text{Table IV})\), which was again confirmed at the forwards versus backs level of comparison.

High-intensity work breakdown

Figure 6 demonstrates the relative contribution of various activities to the total amount of work performed by each group. It can be seen that for front row and back row forwards, rucking/mauling, scrumming, and tackling accounted for approximately 80–90% of their high-intensity work. For inside and outside backs, approximately 60–70% of high-intensity activities were either cruising or sprinting.

The maximum single data value recorded throughout the course of the investigation for each variable is shown in Table V, for the purposes of illustrating the upper limits of demands in the various positional groups.

Discussion

The present results add to our understanding of the physiological demands of rugby, and are among the first to be collected following the commencement of professional rugby in the southern hemisphere in 1996. Using such data to gain an understanding of the variety of positional demands in rugby union, improvements in current methods for the preparation of rugby players may be made.

Positional comparisons

As previously reported (Deutsch et al., 1998; Duthie, Pyne, & Hooper, 2003), the majority of contrasts in movement patterns in rugby occur at the upper level of comparison (forwards vs. backs). The current discussion will use this upper level of comparison to describe the game of rugby union, after which specific positional group differences will be highlighted and their implications discussed.

Forwards spend significantly more total time in high-intensity work than backs, because of their greater involvement in rucking, mauling, and scrumming. In the present study, forwards spent 12–13% of total match time performing high-intensity work, while the corresponding value for inside and outside backs was 4.5%. It is interesting to note, however, that there was also a significant difference between front row and back row forwards, with front row forwards attending approximately 25% more rucks and mauls than back row forwards. These data reflect the role of front row forwards in forming the

![Figure 5](image-url)
platform for offence, while back row forwards play a pseudo back-line role. This contention is further supported by data for tackling, with back row forwards being responsible for more tackling than their front row counterparts. Although previous investigations have shown similar differences between props and centres (Docherty et al., 1988) and between forwards and backs (Deutsch et al., 1998), the differences observed between front row and back row forwards were not revealed in the previous investigation of Colts players (Deutsch et al., 1998). This may reflect the recent law changes made since the beginning of international professional rugby, or may simply reflect a more organized team structure in the professional game.

As expected, backs spend approximately two to three times more time in high-intensity running modes than forwards. Based on observation, cruising is most often used (1) when cover defending and (2) when accelerating into attacking positions. Thus while back-line players, and to a lesser extent back row forwards, would be expected to perform both of these functions regularly, front row forwards’ running play is limited to mostly jogging between breakdowns (rucks, mauls, scrums, and lineouts). Once again, these data reflect the unique role of front row forwards in forming the platform for offence and defence, rather than being responsible for many of the running aspects of play.

While not attaining statistical significance with the present sample size, of particular interest is the almost three-fold greater use of sprinting by back row forwards than front row forwards. These data may reflect a greater need for back row forwards to use specific sprint training, although the total contribution of sprinting to total high-intensity work is still relatively low. Outside backs may, on occasion, be required to perform up to 20 sprints during any one
match, and they perform at least twice as much sprinting as any of the other positional groups. Sprint training for these players should therefore focus not merely on speed development, but also on the ability to perform repeated bouts of maximal sprinting over the course of a match.

The mean sprint duration data in the current investigation are similar to those previously reported. Deutsch et al. (1998) reported mean sprint times ranging from 2.3 s ($\mu = 0.6$) for back row forwards to 3.3 s ($\mu = 0.2$) for outside backs, corresponding to distances of 14.5 to 23.6 m, respectively. In the current investigation, sprint times ranged from 2.01 s ($\mu = 0.77$) for back row forwards to 3.84 s ($\mu = 0.41$) for outside backs. Based on fitness testing results on Super 12 players (M. Deutsch, unpublished observations), these times correspond to distances of approximately 12 to 28 m. This implies that specific sprint training should focus on distances of 10–15 m for forwards, 15–20 m for inside backs, and 20–30 m for outside backs.

Data for maximum sprint duration reveal that inside backs ($5.2 \pm 1.0$ s) and outside backs ($7.2 \pm 1.9$ s) are required to regularly sprint distances of 40 to 60 m, respectively. For the front row and back row forwards, the maximum sprint duration ($3.2 \pm 1.8$ and $3.4 \pm 1.9$ s, respectively) is closer to the mean sprint duration. Thus while backs are required to sprint over a large range of distances, forwards' sprinting tends to be quite uniform in distribution. In terms of preparation, this implies that forwards can still achieve a high degree of specificity by focusing on a more discreet range of sprint distances (10–25 m).

There is a distinct role for back row forwards and inside backs in tackling. As these data include both tackling and being tackled, it implies that players who are positioned loosely around the ruck area are most frequently responsible for offensive (and therefore defensive) play. The front row forwards therefore form the platform for this pattern, while the outside backs are responsible for the peripheral aspects of offence and defence. Back row forwards and inside backs also appear most similar in the running aspects of the game, as evidenced by the data for cruising and sprinting. While not reflected by the statistical analysis employed, there was a distinct role for front row forwards in jumping, most likely due to their role in receiving kick-offs and lineout play.

As observed in previous investigations (Deutsch et al., 1998; Docherty et al., 1988; Treadwell, 1988), front row forwards spend the most time standing still, with a trend for this time to decrease as one moves outwards among the positional groups. This is most likely due to the greater distances covered in repositioning movements as a player moves away from the ruck area, as the larger amount of time spent standing still by forwards corresponds to a greater use of walking by backs. Conversely, there is a greater use of jogging by forwards, particularly front row forwards, when compared with backs. The significantly longer mean jog duration observed in front row forwards would perhaps suggest that this greater use of jogging is due to these players repeatedly following the ball to breakdowns, as opposed to the positional play characteristic of most other positions. The finding that backs perform approximately three times as many utility movements during a game than forwards also reflects the specific movement patterns involved in repositioning by backs. Although not achieving statistical significance, the specific use of utility movements for repositioning around the ball in play was particularly evident in the inside backs, even when compared with the outside backs.

As in several previous studies of rugby (Deutsch et al., 1998, Docherty et al., 1988; McLean, 1992, Treadwell, 1988), the logistical nature of conducting time–motion analysis and the availability of players for investigation in the competitive (especially professional) environment, allowed us to describe patterns and theorize the physiological demands of the game for the small sample of players examined in each particular investigation. Duthie et al. (2003) alluded to the fact that no time–motion analysis data had been published following the significant rule changes and emergence of southern hemisphere professional rugby in 1995. It should be noted that the current data were collected on a specific population during a specific period of development for professional rugby in the southern hemisphere. It is interesting to note, however, that there are close similarities between investigations (Deutsch et al., 1998; Docherty et al., 1988; Treadwell, 1988), which suggests that the general movement patterns in rugby are somewhat characteristic, despite changes in playing rules, style of play, or when comparing different standards of competition. During the review period for the present article, further data were published on Super 12 rugby in another country in a different time period to the current data (Duthie, Pyne, & Hooper, 2005), using a similar methodology to present and previous (Deutsch et al., 1998) work. This periodic monitoring of a variety of playing populations is necessary to quantify and compare the evolving demands of the game.

It should be noted, however, that time–motion analysis is limited in its ability to assess the specific demands of certain activities at various levels, and also its ability to describe the combinations of activities with aspects such as skill, decision making, and tactics. Further research in these areas may help us to gain a better understanding of the effects of
playing position and rule changes on the game of rugby.

Implications for fitness training

Work-to-rest ratio data for backs in the current study (mean work \(\sim 5\) s, mean rest \(\sim 80–110\) s) indicates that the creatine phosphate system likely plays an important role in these positions (Balsom, Seger, Sjödin, & Ekblom, 1992). While not statistically significant, the difference in mean rest period between inside and outside backs \((\sim 25\) s) has important physiological implications. Despite a slightly longer mean sprint distance, the greater opportunity for outside backs to recover should be reflected in the design of fitness training sessions. With approximately 30% of work-to-rest periods being less than 1:7, however, there are still likely to be periods of play when the incomplete replenishment of creatine phosphate stores would result in an increased dependence on the anaerobic glycolytic pathway, in all positions. However, to develop maximal speed/power, it may be necessary to incorporate some training in which adequate recovery is provided between high-intensity sprints to allow the replenishment of creatine phosphate, particularly in outside backs.

On the other hand, the work-to-rest ratio data from forwards indicate that the creatine phosphate system may play a less significant role in energy provision in this group. While the mean work period for forwards was also about 5 s, the mean rest period of approximately 30–40 s would in most cases result in only a partial replenishment of creatine phosphate stores (Gaitanos, Casey, Hultman, & Sjoholm, 1993; Greenhaff, Bodin, Soderlund, & Hultman, 1994). Despite the similarities in mean work period between positional groups, the higher work rates characteristic of forwards’ play was once again evidenced by the significantly longer maximum work periods. While forwards are often required to perform work bouts of approximately 20–25 s, the corresponding figure for backs is only about half as long \((12–14\) s). Although some non-significant differences were evident when comparing front and back row forwards, in practical terms these are less likely to impact on physiological consequences than the larger discrepancies noted between the inside and outside backs.

During intermittent high-intensity sports such as rugby, anaerobic glycolysis represents an important source of energy for the repeated performance of high-intensity activities, as evidenced by the work-to-rest ratios in the present study. The creatine phosphate system, when fully replenished, has been shown to contribute very little to work bouts of longer than 10 s (Hultman, Greenhaff, Ren, & Soderlund, 1991). When average work periods are approximately 5 s, anaerobic glycolysis can be expected to contribute up to 50% of the energy required. Although the mean work duration in all positions was approximately 5 s, forwards could expect to complete at least one work period lasting over 20 s in duration. Furthermore, work-to-rest ratios demonstrate that over 20% of forwards’ work bouts are followed by rest periods of equal or lesser duration. The implication of this finding is that forwards will have to rely almost solely on anaerobic glycolysis and aerobic energy sources for the latter parts of these periods of play, and may be more likely to experience fatigue as a result of hydrogen ion accumulation (Deutsch et al., 1998; Docherty et al., 1988; McLean, 1992). In backs, fatigue resistance is less likely to be a limiting factor, as these players perform shorter periods of maximum work \((\sim 10\) s), and approximately 90% of work periods were followed by equal or longer rest periods. It has been shown that performance during repeated sprints of 5–6 s duration can be maintained when separated by passive recovery periods of 120 s (Balsom et al., 1992).

Kinematic specificity

One aspect of rugby that separates it from most other intermittent high-intensity sports is the large horizontal (pushing) component of the game, seen in activities such as rucking, mauling, scrumming, and tackling. Forwards in particular spend 8–10 min of match time actively engaged in these activities, representing 80–90% of their total high-intensity work component. Developing power, strength, and endurance in these activities should form a considerable portion of testing and conditioning fitness for rugby, particularly for forwards.

The large horizontal component of rugby also has implications for the way in which aerobic fitness is measured and interpreted. As 80–90% of high-intensity work performed by forwards involves pushing, wrestling, and tackling, the ability for these players to perform work on others is of great importance. Most field tests currently in use for aerobic fitness assessment in rugby players (e.g. the multi-stage “beep” fitness test, the 3-km time-trial, and Cooper’s 12-min run) provide estimates of maximal oxygen consumption in relation to body mass \((i.e. \dot{V}O_{2max} \text{ in } \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1})\). The observation that most of the high-intensity work performed by backs involves fast running suggests that expressing an athlete’s aerobic power in relation to their own body mass may be appropriate. In forwards, however, it may also be appropriate to also express maximal oxygen uptake in absolute terms.
reacting to others’ movements. It has previously been suggested that the efficiency of changes in direction may be improved by the training of these transitions during physical conditioning (Deutsch et al., 1998; Mayhew & Wenger, 1985; Reilly, 1994). In forwards in particular, these transitions are even more complex, as they often involve transitions from periods of high upper body and trunk exertion to running in various directions. By including many of these transitions in endurance training, the energy demands of training will be increased towards those of match-play, while also providing the possible benefit of being able to perform these transitions more economically through specific adaptations.

Conclusions

The current data demonstrate the highly intermittent and varied nature of play in the game of rugby. Players must therefore be prepared for a broad range of conditions, and most likely rely on significant energy utilization from all energy systems. Present evidence suggests that the anaerobic glycolytic pathway plays an important role in all positions, particularly the forwards. Training and testing aimed at enhancing anaerobic glycolytic metabolism should address these demands specifically for various positional groups. The present data indicate that work and rest periods should be structured to encourage maximal production and turnover of lactate, rather than resistance to fatigue during long, non-specific work bouts. The aerobic energy system is important for rugby players in all positions. Forwards are more likely to utilize this energy system to its full potential, particularly during periods of play when the length of work periods and/or shortness of recovery results in a partial or complete inhibition of the anaerobic glycolytic and creatine phosphate pathways. With rugby involving many different changes in movement modality over an 80-min period, endurance training should perhaps attempt to mimic the sport closely. The current data demonstrate that various positions in rugby are markedly different in terms of metabolic demand, and even more so in terms of kinematics (i.e. specific body positions). To achieve training specificity, fast running should form an important part of conditioning for backs, whereas the development of power, strength, and endurance in horizontal pushing/wrestling activities is of utmost importance for forwards.

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References


