**Title:** The physical characteristics of specific phases of play during rugby union match-play

**Submission Type:** Original investigation

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**Preferred Running Head:** Phases of play in rugby union

**Word Count:** 3493
**Abstract Word Count:** 250

**Tables:** 2
**Figures:** 2

**Abstract**

*Purpose:* This study quantified the frequencies and timings of rugby union match-play phases (i.e., attacking, defending, ball in play (BIP) and ball out of play (BOP)) and then compared the physical characteristics of attacking, defending and BOP between forwards and backs.

*Methods:* Data were analysed from 59 male rugby union academy players (259 observations). Each player wore a micro-technology device (Optimeye S5, Catapult) with video footage analysed for phase timings and frequencies. Dependent variables were analysed using a linear mixed-effects model and assessed with magnitude-based inferences and Cohen's *d* effect sizes (ES).

*Results:* Attack, defence, BIP and BOP times were 12.7 ± 3.1, 14.7 ± 2.5, 27.4 ± 2.9 and 47.4 ± 4.1 min, respectively. Mean attack (26 ± 17 s), defence (26 ± 18 s) and BIP (33 ± 24 s) phases were shorter than BOP phases (59 ± 33 s). The relative distance in attacking phases was similar (112.2 ± 48.4 vs. 114.6 ± 52.3 m·min$^{-1}$, ES = 0.00 ±0.23) between forwards and backs, while greater in forwards (114.5 ± 52.7 vs. 109.0 ± 54.8 m·min$^{-1}$, ES = 0.32 ±0.23) during defence and greater in backs during BOP (ES = -0.66 ±0.23).

*Conclusion:* Total time in attack, defence and therefore BIP was less than BOP. Relative distance was greater in forwards during defence, while greater in backs during BOP and similar between positions during attack. Players should be exposed to training intensities from in play phases (i.e., attack and defence) rather than whole-match data and practice technical skills during these intensities.

*Keywords:* Physical preparation; Player development; GPS; Skill involvements; Contact sports

## Introduction

The physical characteristics of match-play (i.e., running and collisions) in age-grade (e.g., U18) rugby union players is a growing area of research.[1–3] Studies using global positioning systems (GPS) have published data from county representative,[4] school,[5] academy[2] and international competition.[3] Read and colleagues[2] showed that U18 academy backs covered more distance (5639 ± 368 vs. 5461 ± 360 m, effect size (ES) = 0.67) and achieved greater maximum speeds (8.1 ± 0.4 vs. 7.0 ± 0.7 $m \cdot s^{-1}$, ES = 1.08) during match-play compared to forwards. The differences between positions corroborate similar findings from senior rugby union.[6] The lower locomotor activities in forwards are likely because of the higher collision rates (0.56 ± 0.23 vs. 0.36 ± 0.17 $n \cdot min^{-1}$, ES = 0.99),[7] differences in player physical characteristics[8,9] and tactical roles they undertake[10] compared to backs. These findings collectively lead to the common belief that for backs, the physical characteristics of rugby union are dominated by running. However, these data are typically reported as a mean or total from a whole match and due to the stoppages in team sports are likely to underestimate the intensity of match-play when the ball is in play, which could also lead to players being unprepared for the most intense periods of play.[11]

The demands of match-play have been categorised using different methods, for example, time when the ball is in play (BIP) and when the ball is out of play (BOP).[10] Senior rugby union international matches in 1992 had a mean BIP time of 29 min over an 80 min game, while the mean and maximum BIP cycle were 19 and 70 s, respectively.[12] Further research has highlighted a trend for an increase in BIP time between 2000 and 2002 to approximately 31 min[13] and again to 36.3 ± 2.7 min between 2004 and 2010.[10] However, BIP can also be further split into attacking and defensive phases for rugby union which often occur in isolation without the transition between attack and defence and therefore are often trained separately. Despite this, little is known about the frequencies or timings of these phases of play, or the overall physical characteristics of each phase. Previously, a study in rugby league quantified the locomotor characteristics of attacking and defending and highlighted that relative distance was greater while defending (109 ± 16 vs. 82 ± 12 $m \cdot min^{-1}$, ES = 1.35).[14] Despite this, the study only reported data from forwards in senior rugby league and thus the applicability for age-grade rugby union players is limited.

In England, age-grade rugby union players can participate in several playing standards (e.g., amateur club, school and representative) concurrently, with academy rugby perceived to be the highest standard besides international competition.[15] Academy rugby is the final step before age-grade international and professional rugby and therefore sport scientists and strength and conditioning coaches require information on the most demanding phases of play to appropriately prepare players. Therefore, the aim of the study was to quantify and compare the physical characteristics of the three phases of play; attacking, defending and BOP between forwards and backs during academy rugby union match-play.

## Methods

### *Participants*

Fifty-nine male rugby union players were recruited from a regional academy. The participants were split by position; forwards (age: 17.5 ± 0.6 years; stature: 185.9 ± 5.7 cm; body mass: 95.0 ± 8.9 kg) and backs (age: 17.7 ± 0.6 years; stature: 180.3 ± 5.2 cm; body mass: 81.8 ± 10.5 kg). There were repeated measurements of individual participants and therefore 259 observations were collected (mean ± standard deviation (SD); 4 ± 3 observations per player). The repeated measurement of participants if appropriately accounted for and outlined in the statistical analysis.[16] Ethics approval was granted from Leeds Beckett University institutional ethics committee and adhered to throughout. Written informed consent was gained from all participants prior to starting the study, with a parent or guardian providing this for participants under the age of 18.

### *Design*

The study used an observational research design whereby data were collected during competitive matches from the regional academy annual league during the 2014/2015 and 2015/2016 seasons, totalling 12 matches. In England, the 14 regional academies are split into two groups of seven (north and south leagues), meaning each academy plays six competitive matches per year. Therefore, this study consists of two full seasons data. Of the 12 matches, there were an equal number of home and away fixtures, with a mean points scored and conceded per game of 12 ± 10 and 30 ± 10. Matches at the U18 age-grade are 70 min in length.

### *Methodology*

Video footage from the matches was obtained (AX100 4K Camcorder, Sony, Tokyo, Japan) and analysed manually for attacking, defending, BIP and BOP timings. Attacking phases were defined as when the team under investigation were in possession of the ball, whereas when the opposition were in possession this was classified as a defensive phase. The referee blowing the whistle was used to signify the beginning of a BOP period (e.g., try scored, penalty awarded).[14] When kicks into touch were made, the raising of the flag from the assistant referee was used to signify the beginning of a BOP period. Instances where a team restarted play within 5 seconds or less after being awarded a penalty were not considered as a BOP phase.[17] When a scrum occurred, the BOP phase ended with the call of 'set' from the referee, as this is the point at which the front rowers of both teams engage in physical contact.[13]

The total number of phases and total time spent in attacking, defending, BIP and BOP phases were recorded. The mean, mean of the maximum, maximum and minimum cycle time for the three phases were analysed in addition to a frequency distribution of each cycle based on the following classifications: 0-15, 16-30, 31-45, 46-60, >60 s.[17] In order to assess inter-rater reliability of the video analysis, the time spent in attack and defence was analysed by a second trained individual. The coefficient of variation ±90% confidence intervals (CI) for attack, defence and BOP was 1.98 ±0.80%, 1.17 ±0.70% and 1.52 ±0.72%, respectively.

During the match, each player wore a micro-technology device (Optimeye S5, Catapult, Melbourne, Australia) that contained a GPS system sampling at 10 Hz and a tri-axial accelerometer, gyroscope and magnetometer sampling at 100 Hz. The devices were fitted in a vest provided by the manufacturer and worn under the playing shirts. The devices were switched on outside at the start of the warm up and switched off at the end of the match. However, each file was trimmed so it only contained data from actual playing time for each participant. Similar GPS units have shown acceptable validity and reliability for measuring movements that are common during team sport match-play.[18] The accelerometer used in the current study has also been shown to have an acceptable CV for within (0.9–1.1%) and between (1.0–1.1%) unit reliability.[19] The mean ± SD number of satellites connected during all data collection was 14.5 ± 0.9, while the horizontal dilution of precision was 0.69 ± 0.13.

The timings of attack, defence and BOP phases were synchronised and manually entered into the GPS software (Sprint 5.1.7, Catapult, Melbourne, Australia). Relative distance ($m \cdot min^{-1}$) was downloaded to assess the locomotor characteristics of match-play. PlayerLoad™ per minute ($PL \cdot min^{-1}$) ($AU \cdot min^{-1}$) was downloaded to quantify the additional external load such as accelerations that rugby players experience. PL is a vector magnitude and sums the frequency and magnitude of accelerations in the three axial planes.[20] A very large ($r$ = 0.79) relationship between PL and collisions in rugby union has previously been shown, although it is acknowledged this measure is limited in its ability to distinguish between actions.[21].

*Statistical Analyses*

All estimations were made using the *lme4* package with R (version 3.3.1, R Foundation for Statistical Computing, Vienna, Austria). A linear mixed-effects model was used to model the main and interactive effects of phase of play (attacking, defending, and BOP), positional group (forwards and backs) and time classification (0-15, 16-30, 31-45, 46-60 and >60 s) upon match-play physical characteristics (relative distance and PL·min$^{-1}$). Dependent variables were log transformed before modelling, and then effects and standard deviations were back-transformed to percentages. The random-effects in the model were match identity (differences between mean match demands not accounted for by the fixed-effects), athlete identity (differences between athletes' mean locomotor characteristics) and the residual (within-athlete and match-to-match variability). Magnitude-based inferences were applied using the estimates from the linear mixed model (representing percentage differences between the levels of the fixed effects) and were compared against a smallest worthwhile effect threshold equivalent to 0.2 of the between-subject standard deviations (relative distance = 4.7% and PL·min$^{-1}$ = 4.9%) using a spreadsheet.[22] Effects were classified as *unclear* if the percentage likelihood that the true effect was positive and negative were both >5%. Otherwise, the effect was deemed clear, and was qualified with a probabilistic term using the following scale: <0.5%, *most unlikely*; 0.5-4.9%, *very unlikely*; 5-24.9%, *unlikely*; 25-74.9%, *possible*; 75-94.9%, *likely*; 95-99.5%, *very likely*; >99.5%, *almost certainly*.[23] Cohen's $d$ ES are shown ±90% CI.

## Results

A breakdown of the attacking, defending, BIP and BOP phases are shown in Table 1.

***** INSERT TABLE ONE NEAR HERE *****

The distributions for all time classifications in attack (A), defence (B), BIP (C) and BOP (D) are shown in Figure 1. The frequency distribution was the greatest in the 0-15 and 16-30 s classifications for both attacking (31.9 ± 6.2 and 39.2 ± 7.1%) and defending (30.0 ± 8.3 and 40.0 ± 7.0%). While 16-30 s

(31.7 ± 5.8%) and >60 s (39.7 ± 9.5%) had the greatest distribution during BIP and BOP phases, respectively.

***** INSERT FIGURE ONE NEAR HERE *****

Figure 2 presents the relative distance (A) and PL·min$^{-1}$ (B) for the three phases of play and two positions. The difference in relative distance in attacking phases of play was *unclear* (ES = 0.00 ±0.23) between forwards (112.2 ± 48.4 m·min$^{-1}$) and backs (114.6 ± 52.3 m·min$^{-1}$), while measures during defending were *likely* (ES = 0.32 ±0.23) greater in forwards (114.5 ± 52.7 m·min$^{-1}$) compared to backs (109.0 ± 54.8 m·min$^{-1}$). During BOP time backs (54.3 ± 29.2 m·min$^{-1}$) were *almost certain* (ES = -0.66 ±0.23) to have a greater relative distance than forwards (47.7 ± 27.5 m·min$^{-1}$). The difference in PL·min$^{-1}$ was *almost certainly* greater in forwards during both attacking (12.6 ± 5.0 vs. 12.0 ± 6.7 AU·min$^{-1}$, ES = 0.76 ±0.33) and defending (12.8 ± 5.2 vs. 11.0 ± 6.3 AU·min$^{-1}$, ES = 1.19 ±0.33) phases than backs. The difference in PL·min$^{-1}$ was *unclear* during BOP (4.2 ± 2.4 vs. 4.3 ± 3.0 AU·min$^{-1}$, ES = 0.12 ±0.33) time between the two positions.

Within the forwards group, the difference in attacking and defending was *likely trivial* for relative distance (ES = 0.07 ±0.19) and PL·min$^{-1}$ (ES = 0.02 ±0.18). Within the backs group, the difference in attack phases were *likely* greater compared to defence phases for relative distance (ES = 0.39 ±0.22) and PL·min$^{-1}$ (ES = 0.41 ±0.22).

***** INSERT FIGURE TWO NEAR HERE *****

The relative distance for each time classification, position and phase of play is presented in Table 2. Differences between positions are analysed for each time classification and phase of play. In attack, the difference in relative distance during 31-45 s phases was *possibly* lower (ES = -0.23 ±0.37) in forwards (118.3 ± 35.6 m·min$^{-1}$) than backs (124.2 ± 39.2 m·min$^{-1}$). All other attack comparisons were *unclear*. In defence, forwards were *possibly* (ES = 0.24 ±0.34) to *very likely* (ES = 0.53 ±0.33) greater than backs at all time classifications. During BOP, forwards were *possibly* (ES = -0.32 ±0.34) to *very likely* (ES = -0.36 ±0.11) lower than backs at all time classifications.

***** INSERT TABLE TWO NEAR HERE *****

## Discussion

The aim of the study was to quantify and compare the physical characteristics of the three phases of play (i.e., attacking, defending and BOP) between forwards and backs during academy rugby union match-play. The results highlight that less than half of the match is spent with the BIP (37%), while the mean time for phases in attack (26 ± 17 s), defence (26 ± 18 s) and BIP (33 ± 24 s) are lower than BOP (59 ± 33 s). This is the first study to show that relative distance during attacking phases was similar between forwards and backs, while forwards had a greater relative distance during defensive phases. In contrast, during BOP phases relative distance was greater in backs than forwards. Based on whole match data, previous studies[2,6,10] have reported backs to cover greater distances during a match, whereas this study shows that forwards cover more distance per minute in defence and were similar to backs in attack. These data provide new information for applied practitioners working in rugby union and can be used to prepare players for the specific phases of play.

Senior international rugby union match-play has a greater BIP (36.3 ± 2.7 vs. 27.4 ± 2.9 min) and BOP (53.5 ± 5.5 vs. 47.4 ± 4.1 min) time than the current study, as U18 matches in England last 70 min in comparison to 80 min at the senior level.[10] However little information exists on the attack and defence timings in rugby union. Differences between rugby league and union are evident in the mean length of attacking (40 ± 6 vs. 26 ± 17 s) and defending (40 ± 6 vs. 26 ± 18 s) phases, while the BOP (48 ± 4 vs. 59 ± 33 s) phases were longer in the current study.[24] Differences between rugby codes are likely because of the additional stoppages in rugby union for events such as lineouts and scrums, but could also be attributed to the participants used by Sykes et al.[24], as differences between standards (e.g., U18 vs. professional) are unknown. Based on the mean BIP, attack and defence cycles, it may be questioned whether academy matches are demanding enough to challenge players with the most potential to progress toward the senior professional pathway. Match-play represents the greatest opportunity for players to develop skills under pressure against opposition and therefore BIP time should be maximised for age-grade players. Caution is advised when extrapolating these data to an entire league as it is taken from one team and previous research has highlighted that top 4 teams in the NRL have longer BIP cycles than the bottom 4 teams in the same league.[25] Future studies should look to incorporate data from multiple teams to negate this issue.

In the current study, the frequency distributions of attacking and defensive phases were weighted towards the shorter classifications (0-15 and 16-30 s), while BOP phases were concentrated towards the longer classifications (31-45 and >60 s). It should be noted that several attack and defence phases could occur in between BOP phases, and therefore on occasions might be longer than the BOP phase. However, the

BIP time was still relatively low (27.4 ± 2.9 min; 37%) in the context of a whole match, with each BIP cycle lasting an mean of 33 s, only 7 s longer than the mean attack and defence phase highlighting the need for this type of analysis. Previous research has reported that BIP cycles were longer during international sevens competition compared to provincial matches and this was related to skill execution (e.g., fewer handling errors).[17] The impact of skill execution on BIP time is currently unknown within this cohort but future research should investigate this, as it would provide further insight into rugby union match-play and has potential implications for player development.

A previous conception of rugby union is that for backs the game is dominated physically by running, however the current study questions this. In attack, the difference in relative distance was *unclear* between the two positional groups, but *likely* greater in forwards during defence. It is unknown if the preparation of this specific team impacted this. It is acknowledged the use of relative distance is a limitation and the inclusion of high-speed running would have provided further insight. However, it is also generally accepted that as players get older more position specific skills are practiced, physical characteristics develop[8,26] and therefore the physical characteristics of age-grade matches might not always reflect the same pattern as the senior game.[4,5]

The mean relative distance ranged from 109.0 – 114.6 $m \cdot min^{-1}$ in attack and defence for the current study, which is substantially higher than mean match data (71.7 – 74.0 $m \cdot min^{-1}$) from regional academy players.[2] The mean values for attack and defence are within the range presented by Tierney et el.[27] during entries into the attacking 22 m area for front row props (97.5 $m \cdot min^{-1}$) and scrum halves (121.0 $m \cdot min^{-1}$). However, research from Delaney et al.[28] has shown the peak running intensities of international rugby union match-play to be as high as 175 ± 22 $m \cdot min^{-1}$ for a 1 min rolling mean. Furthermore, previous research has indicated that there is a drop in distance covered and skill involvements from less experienced, younger players following an intense period of play compared to more experienced, older players.[29] Therefore, coaches should expose age-grade players to peak running intensities during training to increase their ability to sustain physical and technical output following intense periods of play in preparation for senior rugby. In addition, the difference in $PL \cdot min^{-1}$ was *almost certainly* greater in forwards during attacking and defending, which is likely representative of the greater amount of running, carries, tackles and rucks entered and should be considered when designing training practices.[10]

A novel finding of this study was that backs covered an *almost certainly* greater relative distance than forwards during BOP time. It is hypothesised this is because backs reposition around the pitch while forwards are waiting for the match to restart (e.g., lineouts, scrums, etc). Future research should investigate if the current findings are replicated in senior players or if this is specific to age-grade players, as this would potentially change the current understanding of the locomotor characteristics for forwards and backs and inform the physical preparation of players.

It is also important to understand how the phases of play compare within the same position as this has potential implications for the way coaches prepare specific positional groups. For forwards, the difference between attacking and defending for both relative distance and $PL \cdot min^{-1}$ was *likely trivial* and therefore preparation for these two phases of play can be similar in physical characteristics. In contrast, backs had a *likely* greater difference in relative distance and $PL \cdot min^{-1}$ in attack compared to defence, which indicates attacking play is the most demanding phase of play for backs. This suggests backs are involved in more of the play in attacking situations than defensive, which has previously been shown in junior rugby league[30]. The use of data from specific phases of play provides context to the preparation of rugby players, in that training is often focussed on these phases. Despite that, this type of analysis could underestimate the true worse case scenario, as this could come from BIP action that involves both attacking and defending and is acknowledged as a limitation to the study. The quantification of the peak running intensities using a rolling mean of the instantaneous velocity would encapsulate these periods.

## Practical Applications

Players should be exposed to training that uses intensities from in play phases (i.e., attack and defence) rather than means from whole match data. Coaches should incorporate this into rugby training to ensure that executions of technical skills are practiced during these intensities. Age-grade rugby coaches should use the timings provided in Table 1 to appropriately manipulate training and where possible place conditions on match-play to increase BIP time in preparation for players progressing to professional rugby.

## Conclusions

This study quantifies and compares the physical characteristics of attacking, defending, BIP and BOP phases during academy rugby union match-play. The current study is the first to provide reference values for specific phases of match-play in academy rugby union, with values for attacking and defending substantially greater than previously reported whole match data. While the game of rugby union requires all positions to undertake many roles and responsibilities, backs roles are predominately described as locomotor based (i.e., high speed running, greater total distance). However, novel findings in the current study show that forwards covered more distance per minute when in defence while the backs covered more during BOP time. The greater $PL \cdot min^{-1}$ in forwards likely represents the more actions they undertake which have been shown in notational analysis studies. As noted in previous studies, the ball is in play for a low percentage of time with the mean attacking and defending phase as low as 26 s. Therefore, policy-makers should consider the impact of competition demands at an age-grade (academy) level upon player development, and consider opportunities to modify laws or game formats to allow greater development opportunities.

**Acknowledgments**

This research was part funded by Yorkshire Carnegie Rugby Union Football Club as part of the Carnegie Adolescent Rugby Research (CARR) project. No financial assistance was provided for the preparation of the manuscript. The authors can confirm no conflict of interest.

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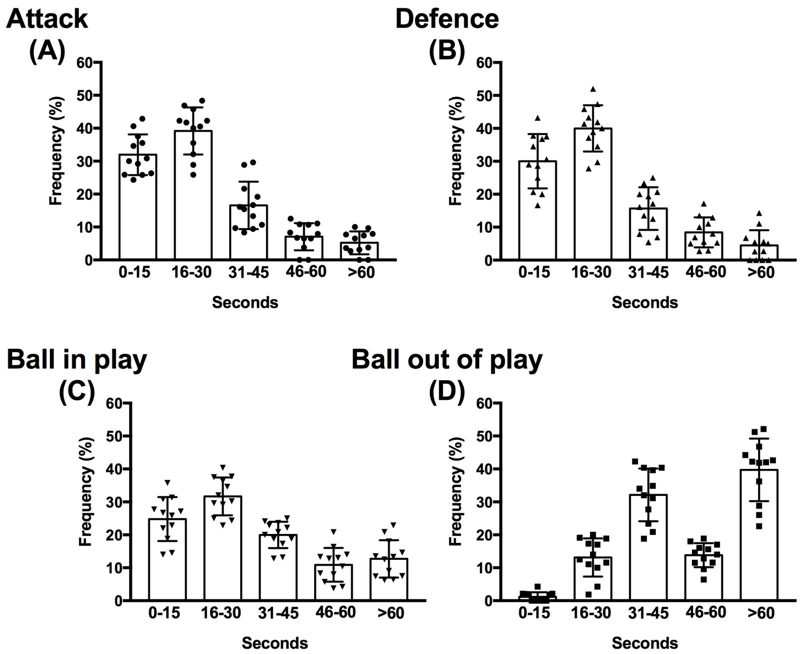


**Figure 1.** The distribution times of attack (A), defence (B), ball in play (C) and ball out of play (D) phases during academy rugby union match-play

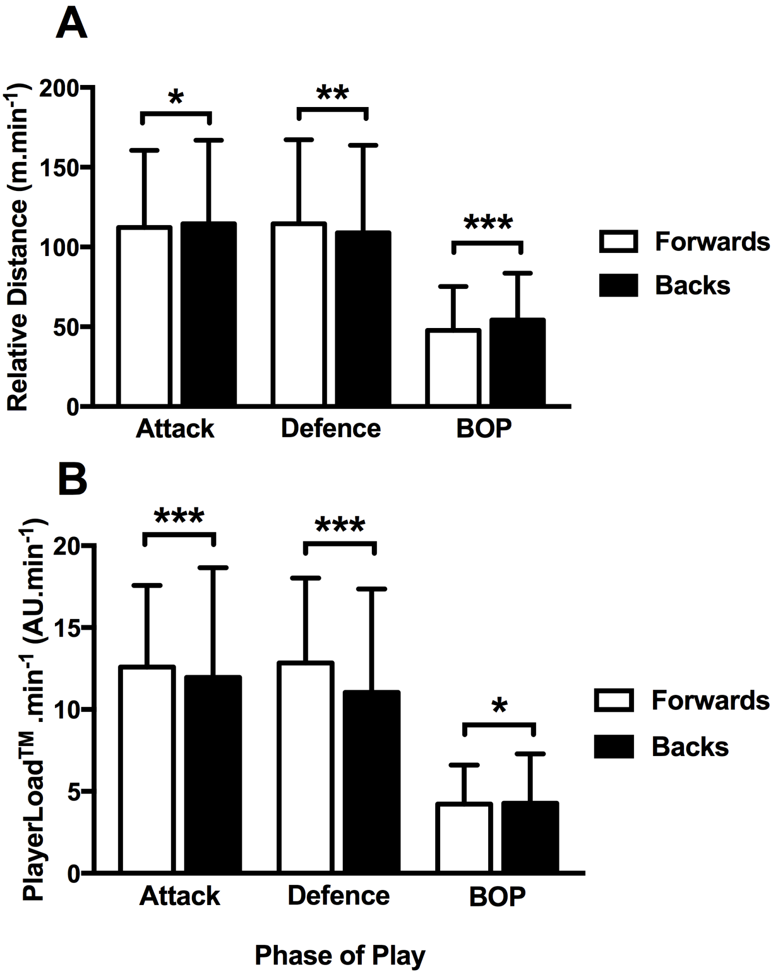


**Figure 2.** Relative distance (A) and PL·min$^{-1}$ (B) of attacking, defending and ball out of play phases during academy rugby union match-play for forwards and backs. * = *Trivial* effect size (<0.20), ** = *Small* effect size (0.20-0.59), *** = *Moderate* effect size (0.60-1.20)

**Table 1.** Attacking, defending, BIP and BOP phases during academy rugby union match-play

| | Attacking | Defending | Ball in play | Ball out of play |
|---|---|---|---|---|
| Time (min, %) | 12.7 ± 3.1 (17%) | 14.7 ± 2.5 (20%) | 27.4 ± 2.9 (37%) | 47.4 ± 4.1 (63%) |
| Phases (*n*) | 27 ± 9 | 31 ± 10 | 49 ± 4 | 48 ± 3 |
| Mean Phase Time (s) | 26 ± 17 | 26 ± 18 | 33 ± 24 | 59 ± 33 |
| Mean Maximum Phase Time (s) | 73 ± 14 | 79 ± 18 | 103 ± 35 | 142 ± 60 |
| Maximum Phase Time (s) | 96 | 113 | 149 | 259 |
| Minimum Phase Time (s) | 7 | 7 | 7 | 9 |

Data are presented as mean ± standard deviation. BIP = Ball in play. BOP = Ball out of play.

**Table 2.** Relative distance for forwards and backs in 0-15, 16-30, 31-45, 46-60 and >60 s classification times during academy rugby union match-play

| Time Classification | Position | Attack (m·min$^{-1}$) | MBI; ES ±CI | Defence (m·min$^{-1}$) | MBI; ES ±CI | Ball out of play (m·min$^{-1}$) | MBI; ES ±CI |
|---|---|---|---|---|---|---|---|
| 0-15 s | Forwards | 103.3 ± 62.2 | *Unclear* | 109.4 ± 67.1 | *Possibly* ↑ | 72.0 ± 29.3 | *Possibly* ↓ |
| | Backs | 102.0 ± 64.2 | 0.08 ±0.41 | 106.5 ± 68.6 | 0.24 ±0.34 | 86.4 ± 37.2 | -0.32 ±0.34 |
| 16-30 s | Forwards | 115.9 ± 44.8 | *Unclear* | 118.4 ± 52.5 | *Very Likely* ↑ | 65.0 ± 36.6 | *Likely* ↓ |
| | Backs | 118.3 ± 50.4 | -0.02 ±0.25 | 110.5 ± 54.5 | 0.53 ±0.33 | 73.0 ± 39.3 | -0.25 ±0.13 |
| 31-45 s | Forwards | 118.3 ± 35.6 | *Possibly* ↓ | 117.4 ± 35.5 | *Likely* ↑ | 48.2 ± 27.8 | *Very Likely* ↓ |
| | Backs | 124.2 ± 39.2 | -0.23 ±0.37 | 113.2 ± 41.1 | 0.37 ±0.40 | 56.6 ± 28.7 | -0.36 ±0.11 |
| 46-60 s | Forwards | 116.9 ± 28.6 | *Unclear* | 112.6 ± 30.9 | *Likely* ↑ | 47.4 ± 24.3 | *Likely* ↓ |
| | Backs | 121.9 ± 33.4 | -0.19 ±0.52 | 106.7 ± 34.3 | 0.40 ±0.49 | 55.0 ± 26.5 | -0.32 ±0.13 |
| >60 s | Forwards | 112.7 ± 23.3 | *Unclear* | 108.4 ± 20.9 | *Possibly* ↑ | 40.7 ± 20.6 | *Likely* ↓ |
| | Backs | 118.7 ± 29.8 | -0.21 ±0.56 | 102.0 ± 28.2 | 0.44 ±0.59 | 45.0 ± 21.1 | -0.20 ±0.10 |

Data are presented are mean ± standard deviation. MBI = Magnitude-based inferences. ES = Effect size. CI = Confidence interval (90%).
↑ = Forwards are greater than backs. ↓ = Forwards are lower than backs.