Ball in Play (BiP) Demands of Elite Rugby Union Match-Play in the United Rugby Championship: Insight into a Champion

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Headline

Elite rugby union is renowned for its high-intensity running, collisions, and the need to adapt to matches' unpredictable flow and momentum (1,2,3). Players must also adequately prepare for the specific demands of each competition, which can vary across different competition structures (e.g., United Rugby Championship, European Champions Cup and International Competitions) (1,8). Although previous research has examined the demands of rugby union match-play (1-7), there is limited understanding about the specific requirements of ball in play (BiP) durations in elite rugby union, despite BiP durations been utilised by multidisciplinary teams (MDTs) to understand the demands of competitive play (3-7). Accordingly, it is a crucial consideration as MDTs within many organisations aim to integrate these BiP durations into the physical, physiological, technical, and tactical conditioning of players throughout the training process. In rugby, knowledge as to the BiP time is particularly important given the intermittent nature of the sport. Previous analyses have demonstrated that BiP time is shorter than ball-out-of-play time in Rugby World Cups, accounting for approximately 44% (00:25:45-00:34:21 minutes) of overall match time (8, 9). Furthermore, BiP periods have been examined in elite club matches (with an average duration of 00:02:31-00:02:41 minutes) (5), international matches (3), as well as attacking plays in the opposition 22-meter zone during European Rugby Championship, International, and Pro 12 League matches from a running performance perspective (5,6).

Indeed, BiP duration is frequently discussed within rugby union by coaches, players, and media organisations providing game commentary (3,9). The increasing professionalism of rugby union has resulted in the implementation of more comprehensive support structures by elite organisations. These structures aim to integrate physical, physiological, psychological, technical, and tactical development throughout weekly, monthly, and seasonal phases. With the advancements in players' game sense and physical capacities, the average BiP durations have steadily increased over the past three decades, reaching its highest average time in the recent iterations of the Rugby World Cup (8, 9) (Table 1). This trend underscores the importance of incorporating elements within the rugby training process that best replicate game requirements and expose players to an adequate number and durations of BiP instances to ensure their physical and physiological capacities can meet and exceed these demands when required. The increase in BiP durations also provide more opportunities for players to increase their output measures during competitive match-play, such as high-intensity efforts, carries, tackles, rucks, passes, kicks, kick chases, and set pieces (3-5,7).

Duration plays a crucial role in the physical demands of rugby union match-play (3-5). Extended periods of BiP are often considered critical moments that significantly impact performance and game outcomes (10,11). Therefore, rugby union MDTs need to understand how game composition affects the proportion of duration, as this provides valuable context regarding game demands and can help determine the cost of the game (3,9). This analysis can also assist MDTs in designing training drills and approaches that simulate in-game situations and BiP instances. Previous research conducted by Gabbett, and colleagues (10,11) has examined the differences between successful and non-successful teams by evaluating their physical abilities and performance output (10,11). These studies have shown that as the playing level increases, the overall active BiP time and the proportion of passages lasting longer than 45 seconds increase (10,11). Elite rugby union teams, including coaches and physical preparation staff, are particularly interested in understanding how higher-quality teams with enhanced technical (player-based), tactical (rugby coach-based), or physical (systems/physical support staff-based) abilities can extend BiP. Thus, further research regarding BiP passages within elite rugby union match-play is warranted.

Aim

This study aimed to investigate a championship-winning rugby union team's competitive season in terms of BiP instances (e.g., frequency and length). Other aims included: 1) To assess the association between BiP instances, success, and points differential; 2) Outline worst case BiP durations; and 3) Develop a practical framework for designing rugby-specific conditioning programs based on BiP data.

Table 1. The Average Ball in Play Per Game of the Rugby Union World Cup across Years of Competition. Reprinted with permission of Kingston and Bentley (8,9).

World Cup Year	BiP Time Per Game (hours: minutes: seconds)
1987	00:28:11
1995	00:25:45
2003	00:31:58
2011	00:32:12
2019	00:34:21
2023	00:34:18

Methods

Subjects

Forty ($n = 40$) elite rugby union players (age: 26 ± 4 years; height: 184.6 cm ± 6.7 cm; and body mass: 103.4 ± 6.7 kg) participated in this study. Players were split based on subgroups of Front 5 ($n = 11$), Middle 5 ($n = 13$), and Back 5 ($n = 16$). Before this study commenced, all subjects were informed of the aims and requirements of the research, and informed consent was obtained with ethical approval for the current investigation granted by the Institutional Human Ethics Committee of the Technological University of Dublin, Tallaght.

Match Sample

Instances of BiP for an elite European rugby union team were analysed across a single competition season (2022-2023). Data included league games (United Rugby Championship (URC; $n = 21$) and European Championship games (ECC; $n = 5$). Games were played between 13:00-21:00 across the season. Data included 1 x quarter-final, 1 x semi-final and 1 x final from the URC competition and 1 x round of 16 games from the ECC competition. Across the analysis period (i.e., 26 games), the total instance count of BiP passages was 1290.

Video Analysis

Match footage was obtained from a combination of external television media broadcasts of live games (RTÉ, Premier Sports, BT Sports, and TG4) and from internal team recordings of match-play. Across all games, five video sources were obtained, which enabled cross-referencing of BiP passages. These included the external television broadcast and four specific internal camera angle sources for analysis. All matches were coded using SportsCode software (Hudl SportsCode Elite V11, Sportstec, Nebraska, USA) on an Apple iMac (Apple Inc, Cupertino, CA, USA). To determine accurate BiP passages and durations across the season, a custom-built tagging panel was used to code games and document key BiP metrics (Table 2), with all matches coded by the same individual (AS; ≥ 10 years' experience analysing elite sporting performance). Following completion of the coding for each game, the BiP passages were visually inspected to detect and correct any operational tagging errors. Each BiP passage was then examined and checked for accuracy. The sequence of events was then observed and adjusted (where necessary) to ensure the tagging timeline correctly captured all BiP passages. Once the data validation was concluded, the coding events were exported into Microsoft Excel (Version 2407; Microsoft, Redmond, WA, USA). Data were then aggregated to identify typical BiP durations across all games. We divided the total data into bins based on 20-second increments to aid with coaching requirements. This supported the creation of BiP segmental buckets, providing a deeper understanding of rugby union BiP demands.

Reliability Assessment

To determine intra-rater reliability, two games that were randomly selected by the analyst (AS) and coded twice over a four-week period. Using the convention outlined by McGraw and Wong (12), a two-way mixed effects model evaluating the absolute agreement between the mean of four full-game measurements was selected to compute the intraclass correlation coefficient (ICC). All coded variables had an ICC ≥ 0.95, demonstrating excellent reliability across the coded BiP measures (13).

Table 2. Metric and Definition Labels for the Analysis of Rugby Union Match-Play.

Metric	Definition
Instances	Total count per game of BiP passages
Total BiP	Total BiP for the game passages.
Average BiP	Average of BiP across all passages.
Max BiP	Longest passage of BiP.
Count ≤ 00:45	Count of BiP passages less than or equal to 45 seconds in duration
Count > 00:45	Count of BiP passages greater than 45 Seconds in duration.
Count > 01:30	Count of BiP passages greater than 90 Seconds in duration.

BiP: Ball in Play

Statistical Analysis

All data analysis was conducted using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). To understand the distribution of time durations for BiP passages in elite rugby union, we employed a segmental bin analysis using Sturges' equation (see below) where k is the number of bins or class intervals, and n is the number of observations in the dataset.

$$k = 1 + 3.322 \log_{10}(n)$$

Using the number of bins calculated from the equation, a histogram was created using SPSS's Graphs and 'Histogram function. The x-axis represented the duration of BiP passages in seconds, while the y-axis showed the frequency of occurrences with descriptive statistics completed to provide a comprehensive understanding of the central tendency and spread of the data. A cumulative frequency curve was overlaid on the histogram to illustrate the proportion of BiP passages falling within designated standard deviations that were representative of short, typical, medium, long, extended and worse case duration thresholds. Segmental bins were calculated to provide insight into the distribution of BiP durations and to identify potential duration thresholds for short, typical,

medium, long, extended and worse case, duration passages of play. Furthermore, multiple linear regressions and multimodal logistic regression analyses were completed on the data set to identify key BiP parameters associated with match success in elite rugby union. Match outcome (win/loss) was coded as a binary variable (1 = win, 0 = loss), with drawn matches excluded from the analysis. The BiP parameters included counts of BiP, total BiP time, average duration of BiP passages, instances of BiP, and maximum BiP duration. A regression analysis of continuous variables was assessed for normality through a Shapiro-Wilk assessment with data transformed if required. Multiple linear regressions were completed to examine the relationship between BiP parameters and points differential (points scored minus points conceded). Assumptions of linearity, homoscedasticity, and multicollinearity were checked using scatterplots, residual plots, and variance inflation factors (VIF), respectively. Outliers were identified and removed from the data set using Cook's distance. Multimodal logistic regressions were conducted to assess the direct impact of BiP parameters on match outcomes. Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit, and the model's associative ability was evaluated using the area under the receiver operating characteristic (ROC) curve. The contribution of individual predictors was assessed using Wald tests and odds ratios with 95% confidence intervals. Data is presented as means ± SD unless stated otherwise.

Results

The BiP passage demands of elite rugby union are presented in Table 3. The analysis shows that there were 56 ± 5 instances of BiP within elite rugby union match-play with an average BiP time of 00:00:47 ± 00:00:09. Across the duration of elite-level competition, the total BiP time was observed to be 00:39:05 ± 00:05:52. With the typical match duration lasting 00:91:17 total time of play this resulted in 43 ± 6% of total time being active BiP time within the current analysis.

Table 3. The Ball in Play Passage Demands of Elite Rugby Union Competition Over a 26-Game Season.

Metric	Instances	Total BiP	Average BiP	Max BiP	BiP Count ≤ 00:45	BiP Count > 00:45	BiP Count > 01:30
Rugby Union Match-Play	56 ± 5	00:39:05 ± 00:05:52	00:00:47 ± 00:00:09	00:02:36 ± 00:00:38	30 ± 8	20 ± 4	6 ± 3

BiP: Ball in Play

Segmental Bin Analysis of Ball in Play

In total, 1290 observations of BiP instances were analysed using segmental bin analyses with a Sturges equation to determine the optimal number of bins. The equation yielded 11 bins ($k = 1 + 3.322 \log_{10}(1290) \approx 11.33$, rounded down to 11). These bins were further segmented based on standard deviations to provide a more representative bin analysis for practitioners within elite rugby union. The segmental analysis of the data revealed that 40% of all BiP periods lasted 28 seconds or less, with a further 21% and 30% of BiP periods lasting 46 and 101 seconds, respectively. Only 8% of the BiP periods were greater than 119 seconds, with only 3% of all BiP periods considered to be worst case (≥ 00:02:17).

Table 4. Bin Analysis of Ball in Play Demands of Elite Rugby Union Over a 26-Game Season.

Row Labels	Short	Typical	Medium	Long	Extended	Worst Case
Bin Number (n)	1	2	3	4	5	6
Standard deviation bands	0.5	1	1.5	2	2.5	8
Duration bands (hr: min: sec)	00:00:28	00:00:46	00:01:41	00:01:59	00:02:17	00:04:21
Duration in seconds (s)	28	46	101	119	137	261
Bin cumulative count of passage duration (n)	514	790	1182	1223	1251	1290
Bin count of passage duration (n)	514	276	392	41	28	38
Percentage of Total passage instances (%)	40%	21%	30%	3%	2%	3%

Table 5. Multiple Linear Regression Results for Points Differential.

Variable	β Coefficient	Standard Error	t-value	p-value
Instances	-0.15	0.04	-2.14	< 0.05
Total BiP	0.32	0.12	4.57	< 0.01
Average BiP Time	0.28	0.09	4.77	< 0.01
Maximal BiP	0.18	0.08	2.25	< 0.05
BiP Count > 00:45	0.16	0.11	2.29	< 0.05
BiP Count ≤ 00:45	-0.09	0.07	-1.13	0.26
BiP Count > 01:30	0.23	0.06	2.56	< 0.05

BiP: Ball in Play

Table 6. Multimodal Logistical Regression Results for Match Outcome Association.

Variable	Odds Ratio	95% CI	p-value
Instances	0.98	0.91-1.06	0.62
Total BiP	1.01	0.99-10.3	0.33
Average BiP Time	1.42	1.18-1.70	< 0.001
Maximal BiP	1.19	1.03-1.37	< 0.05
BiP Count > 00:45	1.28	1.09-1.51	< 0.01
BiP Count ≤ 00:45	1.05	0.97-1.14	0.24
BiP Count > 01:30	1.11	0.95-1.29	0.18

BiP: Ball in Play

Ball in Play and Points Differential

Linear regression analysis revealed significant correlations between several BIP parameters and points differential (Table 5). The regression model was statistically significant (F (7, 1290) = 15.63, $p < 0.001$) and explained approximately 36% of the variance in points differential (Adjusted $R^2 = 0.36$). The total BiP time ($\beta = 0.32$, $p < 0.01$) and average BiP time ($\beta = 0.28$, $p < 0.01$) showed the strongest positive relationships with points differential. The count of BiP instances ≥ 90 seconds also demonstrated a positive correlation ($\beta = 0.23$, $p < 0.05$). Interestingly, the total instances of BiP showed a weak negative correlation with points differential (β = -0.15, $p < 0.05$).

Ball in Play and Match Outcome

The impact of BiP parameters on match outcomes (Win/Loss) was examined via multimodal logistical regression analysis (Table 6). Our model included all seven BiP parameters as independent variables, with match outcome (Win/Loss) as the dependent variable. The model demonstrated a good fit (Hosmer-Lemeshow test: $\chi^2 = 8.24$, $p = 0.41$) and explained approximately 27% of the variance in match outcomes (Nagelkerke $R^2 = 0.27$). The analysis identified three key parameters that are significantly associated with match success. The analysis revealed that three BIP parameters were statistically significant predictors of match outcome. Average BiP time (OR = 1.42, 95% CI: 1.18-1.70, $p < 0.001$) was shown to have the highest association with match outcome, followed by Count of BiP instances > 45 seconds (OR = 1.28, 95% CI: 1.09-1.51, $p < 0.01$) and Maximal BiP time (OR = 1.19, 95% CI: 1.03-1.37, $p < 0.05$).

Discussion

The current investigation aimed to understand a championship-winning rugby union team's competitive season in terms of BiP instances (e.g., frequency and length). Secondary aims included: 1) To assess the association between BiP instances, success, and points differential; 2) Outline worst case BiP durations; and 3) Develop a practical framework for designing rugby-specific conditioning programs based on BiP data. Our data showed that the typical rugby union match comprised 56 ± 5 instances of BiP, with an average BiP time of 00:00:47 ± 00:00:09. The total BiP time was observed to be 00:39:05 ± 00:05:52. Considering that the typical match duration lasted 00:91:17, this resulted in approximately 43 ± 6% of the total time being active BiP time. Furthermore, the segmental analysis revealed that 40% of all BiP periods lasted 28 seconds or less. Additionally, 21% and 30% of BiP periods lasted 46 and 101 seconds, respectively. Finally, 8% of BiP periods were greater than 119 seconds, with only 3% of all BiP periods considered to be worst case BiP instances (≥ 00:02:17).

One of the secondary aims of the investigation was to understand the association between BiP measures and rugby union performance measures, such as points differential and match outcome. Total BiP Time showed the strongest positive relationship with points differential. For every one-minute increase in total BIP time, teams saw an average increase of 0.32 points in their scoring margin. This suggests that teams who can keep the BiP for longer overall durations tend to outscore their opponents significantly. When maximal BiP time was considered, although not as strong as the previous factors, the longest single instance of BiP showed a significant positive relationship with points differential. The model indicated that for each additional second of maximal BiP time added within match-play, there would be a 0.18-point increase in the scoring margin. Furthermore, each one-second increase in the longest BiP instance was associated with a 19% increase in the odds of winning. These data are important when considering training construction for coaches. They suggest that while the ability to sustain very long periods of play can contribute to success, it may be less crucial than consistently achieving moderate-to-long BiP instances. Therefore, it may be suggested that the construction of rugby-specific training drills that reflect the above BiP instances may be of more value within the rugby union training process (1-3).

Within the current investigation, the average BiP instance lasted 47 seconds. Furthermore, 61% of all BiP instances fell within this time range. The remaining 39% of instances could be highlighted as higher demanding instances. On average, a game comprised just six instances or 12% of passages of play greater than 90 seconds. Average BiP time was shown to have a strong association with match outcome and points differential, with an increase of one second in average BiP time associated with a 0.28-point increase in scoring differential. Additionally, each one-second increase in average BiP time increased the odds of match success (OR: 1.42; 95% CI: 1.18-1.70; $p < 0.001$). From a coaching perspective, these data reinforce the importance of total possession time and the ability to sustain longer individual periods of possession. They show that maintaining possession for longer average durations can significantly impact match outcomes and accumulation of positive points differential. Practically, these extended passages place high levels of physical, physiological, and psychological fatigue on players due to their extended nature in both attacking and defensive sets. This results in the requirement of accurate and elongated skill execution within possession for attacking teams, with increased importance being placed on the collision and counter-rucking components and defensive teamwork for defending teams (2,7). These demands were previously identified within elite rugby union (3,5), with Reardon and colleagues (5) highlighting differences associated with

positional demands within extended passages or worst-case scenario BiP instances, while the work by Pollard et al. (3) identified a decay in maximal intensity work-rate ($m \cdot min^{-1}$) within elongated BiP instances for elite international rugby union players.

The analysed data showed that the total instances of BiP had a weak negative relationship with points differential. This suggests that frequent changes in possession are associated with slightly lower scoring margins. It could be implied that teams who dominate possession keep the ball for longer and aim to reduce the total number of possessions during competitive match-play. From a practical standpoint, it is important to respect the specific breakdown of BiP instances throughout match-play. BiP instances $>$ 45 seconds showed a weak but significant positive relationship with points differential. This indicates that more instances of possession lasting 45 seconds or more were associated with higher scoring margins, although the effect was less pronounced than for longer ($>$ 90 seconds) possession instances. Additionally, BiP instances $>$ 45 seconds appeared to be an influential factor, with each additional instance of BiP lasting 45 seconds or more increasing the odds of winning by 28%. This highlights the importance of maintaining possession and doing so for extended periods. Furthermore, BiP instances $>$ 90 seconds showed a moderate positive relationship with points differential and match success. This emphasizes the value of very extended periods of possession in building a scoring advantage and increasing the likelihood of match success. This finding is also supported by previous research (10,11,16,17), that observed that that successful teams can sustain performance in both attacking and defensive phases. A notable trend within the current data is the importance of accruing more extended BiP instances within rugby union. This supports the anecdotal coaching saying, "It takes two to tango," where long passages of play often result from two teams capable and willing to play for extended durations. This is usually a direct result of players' technical execution, teams' tactical systems, and their ability to execute attacking and defensive sets. It also highlights the requirement of appropriate physical, physiological, technical, and tactical capacities within elite rugby union players to consistently perform with lower decay rates across these elongated BiP instances.

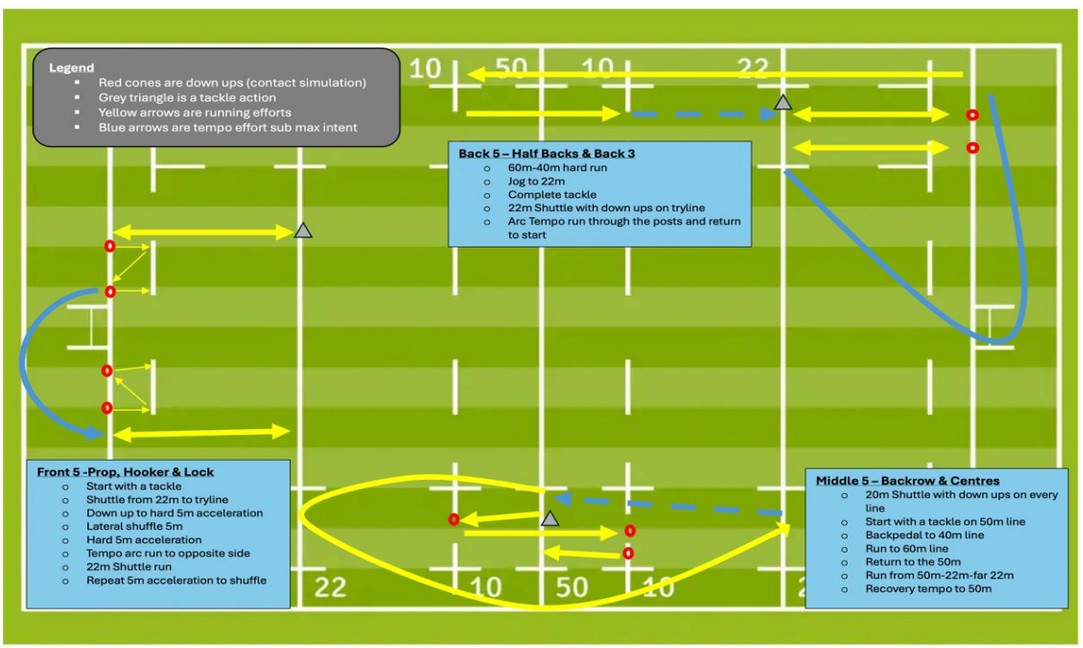

Fig. 1. Representation of position specific conditioning drills that target the specific requirements of Ball in Play(BiP) demands within Rugby Union.

We observed a maximal BiP of 00:02:36 ± 00:38 (156 ± 38s), with a worst case BiP instance noted within the data lasting 00:04:21 highlighting the potential for extremely long passages of play with multiple exchanges of possession within a game. While only accounting for 3% of the BiP instances analysed this highlights the requirement of some elements of elongated BiP instances within the elite rugby union training process, with the context that these instances need to be appropriately placed into a periodised training program (14,15). Within the current literature this is the first time that an outlier passage duration of 00:04:21 was observed sitting almost 00:01:00 minute outside the next largest passage. Previous work has highlighted the point of 00:01:30 as an upper limit of BiP instance, which occurred on average 5.85 ± 3.1 times per game, in this study. It is important to understand that while worst case passages may occur within this large passage of play and that an increasing duration of passage may cause peak relative intensities to decrease, absolute total demands are rising due to the opportunity to perform work (10, 15). Furthermore, knowing that these passages can cascade within a single game to ∼12 BiP instances over 00:01:30, as seen within these findings, it is vital that coaches provide moments within training where appropriate opportunities for this type of elongated physical demand and means by which to re-

peat it. This information provides user friendly information for a coach to use when designing training as duration is a commonly utilised tool to design drills and therefore is simple and easily digestible. These data show that durations of BiP within match-play can range between what is considered typically within games, and expand upwards to the maximal instance, while also including an outlier of worst-case duration. With this in mind, we present how best to utilise the BiP instances, frequencies, and durations to condition elite rugby union players in Table 7 and Figure 1.

Table 7. The Position Requirements of Elite Rugby Union concerning Ball in Play Instance Demands.

Positional Groups	Running Group Relative	Accelerations/Decelerations Group Relative	Contact Efforts Group Relative
Front 5	Low – short distance ∼20m linear with multiple efforts between 0-10m before acceleration or deceleration effort.	High - density - short distance low intensity – can be 0-5m in distance, often paired with a contact effort.	High + static Efforts – mix of tackle, ruck or poach style activities effort of static or low-speed exposures also useful.
Middle 5	Medium – shuttle, repeat or arc style running at all effect distances up to 60m, depending on desire.	Mixed – high intensity or frequent low-intensity acceleration and deceleration in multi-direction.	Mixed high can have high force singular collision replication or mixed contact and running efforts.
Back 5	High – large linear or arced-based running – half-backs may choose shorter distances at less intensity.	High-intensity - long distance - low density.	Low to moderate + jumping efforts.
Demands	Rep Duration	Set Duration	Rest Intervals
Front 5	$<$ 5-15s of a single activity.	High count of short-duration bouts (high weight power athlete needs recovery to sustain)	∼ 15-45s static to active rest.
Middle 5	∼ 5-20s of continuous multi-facet activity.	Varied set duration or towards longer bouts to allow for a mix of multiple effort types	∼ 10-60s static or active rest.
Back 5	∼ 10-30s of running-based activity, high-intensity accelerations or contacts.	Low count longer duration bouts (Can rapidly fatigue with contact and acceleration-based effort activities).	∼ 30-60s active – can have light active recovery locomotion between sets. Long rest periods for high-intensity velocity running bouts.

Groups: Front 5: Props, Hookers and Locks; Middle 5: Backrow, Centres; Back 5: Half Backs and Back Three

While the current investigation has elucidated additional insights related to BiP instances during rugby union match-play, the following limitations should be considered. Firstly, this study analyses BiP from a single team, which may not be generalisable across multiple rugby union teams with different systems of play across different competitions. Whilst it is unique as the data set, the data is ultimately a showcase of how a rugby union team progressed to a URC final game. However, the BiP framework provides an insight into what is typical of a game and what BiP durations were like across a championship-winning season. Secondly, the specific game plan of any team within rugby union will influence any points differential and match outcome, and whilst this data presents a trend towards increased duration of game with a similar trend in success, this is not true for all teams. A major limitation of this study was the result outcome of passages was not tracked. Another key insight to garner would be how, on a granular level, each passage resulted in positive or negative outcomes as assessed by the positive movement of position, possession or points scored or denied. At this more granular level of analysis, successive passages of increased duration may be posited to have an even larger effect on the physical and physiological demands of match-play, points differential or match outcome, than just total time, instances, or a singular maximal duration. However, considering the above, the presentation of conditioning requirements across positions reflective of BiP instances, frequencies, and durations presents a major novel insight from the current investigation.

Practical Applications

- The BiP demands of elite rugby union have been elucidated through a specific bin analysis, highlighting for the first time a significant elongated BiP demand that has not been reported to date. These data can be utilised by conditioning staff and coaches alike when designing training drills to replicate the BiP demands of elite rugby union.
- The association between BiP measures, points differential, and match outcome has been reported. Once again, these data provide insight into how BiP requirements within elite rugby union match-play can influence match outcome and points differential. This in turn may influence coaches and conditioning staff with respect to the design of specific training drills within the rugby union training process.
- We present a novel positional conditioning framework based on the BiP demands that coaches can use when designing drills to best replicate the technical and physical demands of rugby union.

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