Title: Maximum running intensities during English academy rugby union match-play

Preferred Running Head: Maximum running intensities during rugby union

Article Type: Original article

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Word Count: 3658

Abstract Word Count: 200

Tables: 1

Figures: 2

Abstract

Purpose: To quantify and compare the maximum running intensities during rugby union match-play.

Methods: Running intensity was quantified using micro-technology devices (S5 Optimeye, Catapult) from 202 players during 24 matches (472 observations). Instantaneous speed was used to calculate relative distance ($m \cdot min^{-1}$) using a 0.1 s rolling mean for different time durations (15 and 30 s and 1, 2, 2.5, 3, 4, 5, and 10 min). Data were analysed using a linear mixed-model and assessed with magnitude-based inferences and Cohen's *d* effect sizes (ES).

Results: Running intensity for consecutive durations (e.g., 15 s vs. 30 s, 30 s vs. 1 min, etc.) decreased as time increased (ES = 0.48-2.80). Running intensity was lower in forwards than backs during all durations (-0.74 ±0.21 to -1.19 ±0.21). Running intensity for the second row and back row positions was greater than the front row players at all durations (-0.58 ±0.38 to -1.18 ±0.29). Running intensity for scrum-halves was greater (0.46 ±0.43 to 0.86 ±0.39) than inside and outside backs for all durations besides 15 and 30 s.

Conclusions: Front rowers and scrum-halves were markedly different from other sub-positional groups and should be conditioned appropriately. Coaches working in academy rugby can use this information to appropriately overload the intensity of running, specific to time durations and positions.

Keywords: Worst case scenario; GPS; Physical preparation; Running demands

Introduction

The quantification of match-play using global positioning systems (GPS) allows the appropriate planning, 'live' monitoring and retrospective analysis of training practices (Weaving et al. 2017). Both research and practice have helped evolve the quantification of team sport match-play, in particular regarding the maximum running intensity (Varley et al. 2012). The maximum running intensity is established using a novel rolling mean method to analyse the raw instantaneous speed from a GPS device for a given time duration. Recent studies have established the maximum running intensities for several team sports including Australian football (Delaney et al. 2017), rugby league (Delaney et al. 2015) and professional rugby union (Delaney et al. 2017a). However, the use of data from professional players might not be applicable for academy rugby union players (e.g., under-18 (U18)) given the difference in physical characteristics (Argus et al. 2012; Darrall-Jones et al. 2015) and length of matches (i.e., 70 vs. 80 min).

The whole-match physical characteristics of several playing standards in age-grade rugby union have been quantified (Hartwig et al. 2011; Read et al. 2017, 2017a), including academy (Read et al. 2018) and international competition (Cunningham et al. 2016). Academy rugby is one of the final steps prior to youth international representation and professional squads. Players have been shown to cover 5639 ± 368 m during a full academy match, which equates to ~75.2 $m \cdot min^{-1}$ (Read et al. 2018). Previous research has also quantified the intensities of attacking (112.2 – 114.6 $m \cdot min^{-1}$) and defensive (114.5 – 109.0 $m \cdot min^{-1}$) phases during academy match-play for forwards and backs (Read et al. 2016), which exceed the whole-match intensities (Read et al. 2018). The intensities were similar between forwards and backs during attacking phases, and greater in forwards during defensive phases (Read et al. 2016). However, attack and defence analysis does not necessarily capture the maximum running intensities as the most intense periods of play might come from action containing both phases of play. It is therefore vitally important to quantify the maximum running intensities of match-play so practitioners can appropriately prepare players for the most intense periods of play. In addition, the majority of previous research on academy rugby has only split players into forwards and backs, often due to a small sample size of players (Read et al. 2017, 2017a, 2018). This is despite research in professional players highlighting differences between sub-positional groups (e.g., front row, second row and back row) (Lindsay et al. 2015) and therefore should be applied to academy players so practitioners can prescribe position-specific training.

Previous research has used a predefined time duration (i.e., 1, 5, and 10 min) to highlight the fluctuations in running intensity during a match, with the first 10 min shown to be the most intense (Jones et al. 2015; Tee et al. 2017). More recently, research has investigated the maximum running intensities of international rugby union using the rolling mean method for time durations between 1 and 10 min (Delaney et al. 2017a). For example, half-backs (scrum halves and fly halves) have a greater maximum running intensity at all time durations, including 1 min (184 ± 28 $m \cdot min^{-1}$) and 10 min (93 ± 12 $m \cdot min^{-1}$) than all other sub-positional groups (Delaney et al. 2017a). The use of 1 min intervals between 1 and 10 min is a logical analysis to use for training prescription and monitoring, as training efforts and games are often prescribed by the minute (e.g., 4 min). In addition to these traditionally used time durations (i.e., 1, 5 and 10 min) practitioners may want to replicate training that is specific to the ball in-play cycles of academy rugby matches (Read et al. 2016). The mean and maximum ball in-play cycles for academy rugby are 33 ± 24 s and 149 s, respectively; therefore, including 30 s and 2.5 min as time durations in this analysis is applicable. Moreover, given the current use of conditioning practices in rugby such as high-intensity interval training (HIIT), providing practitioners with data from appropriate time durations (i.e., short <30 s and long 2-4 min HIIT bouts) will allow the prescription of training for the appropriate physiological adaptations (Buchheit & Laursen 2013b).

The purpose of the study was to quantify the maximum running intensities during match-play from multiple English rugby union academies. The study aimed to compare: 1) the differences in running intensity between consecutive time durations (e.g., 15 s vs. 30 s, 30 s vs. 1 min, etc.) within forwards and backs 2) the difference in running intensity at each time duration between forwards and backs and 3) the difference in running intensity at each time duration among six sub-positional groups.

Methods

Participants

A total of 472 observations were collected from 202 male rugby union players (age: 17.7 ± 0.6 years; height: 183.3 ± 6.3 cm; body mass: 90.8 ± 12.0 kg) across seven rugby union regional academies in England. The players were initially split into forwards (*n* = 109, 263 observations) and backs (*n* = 93, 209 observations). Players were then split into six sub-positional groups: front row (props and hooker, *n* = 51, 117 observations), second row (locks, *n* = 19, 47 observations), back row (flankers and number 8, *n* = 39, 99 observations), scrum half (*n* = 14, 38 observations), inside backs (fly half and centres, *n* = 35, 81 observations) and outside backs (wingers and fullback, *n* = 44, 90 observations) (Cahill et al. 2013). Ethics approval was granted by the Leeds Beckett University ethics committee.

Design

An observational research design was used to determine the position and time-specific maximum running intensities. A total of 24 matches were analysed from the U18 annual competitive league fixtures during the 2014/2015, 2015/2016 and 2016/2017 seasons. All matches were 35 min per half.

Procedures

Players wore a micro-technology device that contained a 10 Hz GPS (S5 Optimeye, Catapult Innovations, Melbourne, Australia). When repeated measurements on individual players were conducted they were assigned the same device. The units were worn in a customised vest provided by the manufacturer, with the unit positioned on the upper back. The validity and reliability of 10 Hz Catapult units for assessing team sport movements have previously been reported (Varley et al. 2012a; Johnston et al. 2014). Optimeye S5 devices have shown a *small* typical error of the estimate (1.8%) compared to a radar gun for assessing maximal sprint speed (Roe et al. 2017) although to the authors' knowledge there is no further data available for other speeds. The horizontal dilution of precision and satellites connected (mean ± standard deviation (SD)) from all data files in the study was 0.61 ± 0.11 and 14.2 ± 0.8, respectively.

The data were downloaded to the manufacturer's software (Sprint 5.1.7, Catapult Innovations, Melbourne, Australia) and trimmed so it only included actual playing time. A playing time of 10 min was used as the minimum requirement for participants to be included in the study (Delaney et al. 2016). Using instantaneous speed ($m \cdot s^{-1}$) downloaded at 10 Hz, relative distance ($m \cdot min^{-1}$) was calculated through the use of a 0.1 s rolling mean for numerous time durations (15 and 30 s and 1, 2, 2.5, 3, 4, 5, and 10 min) relevant to academy rugby union match-play and training. The maximum relative distance for each player and time duration from each match were calculated using the *zoo* package with R (version 3.3.1, R Foundation for Statistical Computing, Vienna, Austria). These calculations were made by establishing the maximum value during each half of play; then, the maximum of the two was retained and the lower value was discarded. This analysis of each half is vital as the maximum running intensity could occur from data during the end of the first and beginning of the second half. The mean and range are reported so the 'maximum' value for each time duration and position can be used by coaches to prepare players for the most intense periods of play instead of solely using the mean data.

Statistical Analyses

Descriptive data are reported as mean ± SD. Prior to analysis the data were checked for normality using the Shapiro-wilk test. All data were then log-transformed to reduce the error occurring from non-uniform residuals that is typical of GPS data in athletic performance (Hopkins et al. 2009) and then analysed using a linear mixed-model (SPSS v.22, NY: IBM Corporation). Three separate analyses were conducted; first for the consecutive time durations, second for the comparisons between forwards and backs and, finally, between the six sub-positional groups. In the first two models, the 'time duration' and 'position' of the player (i.e., forwards or backs) were treated as the fixed effects. In the second analysis, 'sub-positional group' (i.e., front row, second row, back row, scrum half, inside back or outside back) was treated as the fixed effect, whereas the random effects were 'individual player-code' and 'match-code' for all analyses. Relative distance was used throughout as the dependent variable. Magnitude-based inferences were used to assess the practical importance via a spreadsheet (Batterham & Hopkins 2006). A value equivalent to 0.2 of a Cohen's *d* effect size (ES) was set as the smallest worthwhile difference and then assessed qualitatively as follows: 25-74.9%, *possibly*; 75-94.9% *likely*; 95-99.5%, *very likely*; and >99.5%, *almost certainly* (Hopkins et al. 2009). Where the confidence interval (CI) crossed both the upper and lower boundaries of the smallest important effect, the difference was reported as *unclear* (Batterham & Hopkins 2006). Cohen's *d* ES are shown with ±90% CI with thresholds of <0.20, 0.20-0.59, 0.60-1.19, 1.20-1.99 and 2.00-3.99 used for *trivial*, *small*, *moderate, large* and *very large* effects, respectively (Hopkins et al. 2009).

Results

The differences in consecutive time durations between forwards and backs are shown in Figure 1. There were *almost certain* differences between all consecutive time durations for both forwards and backs. In the second analysis, the difference in running intensity at all time durations was *almost certainly* lower in the forwards than backs. The ES ±CI (forwards-backs) were -1.19 ±0.21 (15 s), -1.18 ±0.24 (30 s), -0.85 ±0.24 (1 min), -0.74 ±0.21 (2 min), -0.82 ±0.21 (2.5 min), -0.83 ±0.22 (3 min), -0.90 ±0.24 (4 min), -0.84 ±0.24 (5 min) and -0.84 ±0.23 (10 min).

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

The descriptive data (mean ± SD and range) of the running intensities for each of the six sub-positional groups and time durations are reported in Table 1. All front row, second row and back row comparisons are shown with an ES ±CI in Figure 2(A). The difference in second row and back row players was either *very likely* or *almost certainly* greater at all time durations than front row players. Second row and back row players had *possibly trivial* differences at 2 and 3 min. The difference in relative distance was *likely* greater in back row players than second row players at 15 and 30 s, with *unclear* differences found for 1, 2.5, 4, 5 and 10 min.

All scrum half, inside back and outside back comparisons are shown with an ES ±CI in Figure 2(B). Differences between scrum halves and inside backs were *unclear* for 15 s, whereas the differences were *possibly* and *likely* greater in scrum halves for 30 s and 10 min. All other time duration differences were *very likely* greater in scrum halves compared to inside backs. The differences between scrum halves and outside backs were *unclear* for 15 s, and *possibly* and *likely* greater in scrum halves for 30 s and 10 min, respectively. The difference in time durations of 1, 2, 4 and 5 min was *very likely* greater in scrum halves, and *almost certainly* greater for 2.5 and 3 min compared to outside backs. In the inside backs and outside backs comparison, 15 s, 30 s, 1 min and 4 min differences were *unclear*, while all other time durations were *possibly trivial* between the same positions.

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

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

Discussion

The aims of the study were to compare the difference in running intensity between consecutive time durations (e.g., 15 s vs. 30 s, 30 s vs. 1 min, etc.) within forwards and backs. Second was to compare the difference in running intensity at each time duration between forwards and backs. The final aim was to compare the difference in running intensity at each time duration between six sub-positional groups during academy rugby union match-play. The findings show that running intensity decreased as time increased, with all comparisons between consecutive time durations showing clear changes. The comparisons show that forwards had a lower running intensity in all time durations than backs. Further sub-positional comparisons show that running intensities of front row players are markedly different from those of second and back row players at the U18 age, whereas back row and second row players were largely similar. In addition, scrum halves were greater than both inside and outside backs at all time durations besides 15 and 30 s, whereas inside and outside backs were largely similar. These data provide time specific reference values in maximum intensity running for coaches preparing academy rugby union players for the most intense periods of play.

The analysis between consecutive time durations in the current study indicates that as the time duration increases, the maximum running intensity decreases. The greatest decreases in both positions were seen during 15 s, 30 s, 1 min and 2 min, all showing *very large* ES. Similar findings have also been shown by Delaney et al (2015) where the greatest difference in running intensity for consecutive times was between the shortest durations (i.e., 1 vs. 2 min) in professional rugby players. Previous research in rugby league has shown that longer ball in play durations was associated (r = -0.67) with a lower running intensity (Gabbett 2015). Collectively, this highlights not only the fluctuations in running during rugby union but also the relationship between length of physical effort and intensity that can be maintained (Buchheit & Laursen 2013a).

In the current study, the difference in running intensity was *almost certainly* greater in backs compared to the forwards group at all time durations, showing *moderate* ES (-0.74 ±0.21 to -1.19 ±0.21). Previous research has shown lower magnitudes of difference between the two positions in academy rugby for total distance covered (5639 ± 368 vs. 5461 ± 360 m, ES = 0.67 ±0.57) (Read et al. 2018). Furthermore, *trivial* (-0.00 ±0.23) and *small* (0.32 ±0.23) ES were observed between the two positions during the attacking and defending phases (Read et al. 2016). This demonstrates that the use of the rolling mean method highlights greater differences between forwards and backs in academy rugby players than previous whole match and phase of play analyses. These findings suggest this method can be employed to establish the positional demands of match-play and used to prescribe position-specific training (Phibbs et al. 2018).

Within the front row, second row and back row comparisons, the difference in running intensity was either *very likely* or *almost certainly* lower for front row players. Similar maximum running intensity distances are apparent for front row players in this study compared to international players, despite the previous research using slightly different sub-positional groupings (e.g., tight five; front and second row together) (Delaney et al. 2017a). In addition, second row players had a greater running intensity in the current research study for multiple time durations (e.g., 1 min: international 154 ± 21 $m \cdot min^{-1}$, front row 154 ± 17 $m \cdot min^{-1}$, second row 165 ± 12 $m \cdot min^{-1}$; 5 min: international 91 ± 12 $m \cdot min^{-1}$, front row 93 ± 14 $m \cdot min^{-1}$, second row 100 ± 12 $m \cdot min^{-1}$; 10 min: international 79 ± 11 $m \cdot min^{-1}$, front row 80 ± 12 $m \cdot min^{-1}$, second row 87 ± 9 $m \cdot min^{-1}$) (Delaney et al. 2017a). The greater anthropometric and physical characteristics of professional players such as body mass might contribute towards the similar or lower running intensities in international players (Argus et al. 2012; Darrall-Jones et al. 2016). The shorter halves of academy rugby might also contribute to differences compared to professional players, while it is also worth noting the difference in GPS manufacturers used by Delaney et al (2017a) and the current study as the differences between these are unknown. In summary, it appears academy front row and second row players experience similar or greater maximal running intensities during match-play as international players. This has implications for how practitioners prepare players in progression for a transition into professional rugby, as it appears players need to maintain their running intensity during match-play while increases in height and body mass are likely.

In the current study the second row and back row players were similar for all time durations besides 15 and 30 s, in which the back row players had a *likely* greater difference. This difference might be explained by the greater maximum speed (5.72 vs. 4.90 $m \cdot s^{-1}$) and high speed running (6.0 vs. 4.9 $m \cdot min^{-1}$) that back row professional players have been shown to complete in the longest ball in play periods during match-play (Reardon et al. 2017). Overall, these data suggest that second row players are more comparable to back row players at the U18 age, whereas studies in professional players show more similarities between front and second row players (Delaney et al. 2017a; Quarrie et al. 2013). Second row players are typically the tallest players in rugby union teams; however, the difference in anthropometric measures between positions is far greater at the professional level than academy (Lindsay et al. 2015; Wood et al. 2018). Therefore, as previously stated, this lack of difference between positions (e.g., height and body mass) might be linked to the similar running intensity during match-play.

Scrum halves in the current study had either *very likely* or *almost certainly* greater differences in all time durations between 1 and 5 min compared to inside backs and outside backs. Differences in the shorter durations (i.e., 15 and 30 s) were not as clear and suggests that the running intensity is similar between all back positions during durations <1 min. This might be due to the negligible difference between the positions in speed over shorter distances (Wood et al. 2018), while differences in longer durations are likely to be attributed to scrum halves continually getting to rucks to pass the ball (Quarrie et al. 2013). Measures from scrum halves in this study were similar to international players for shorter durations (e.g., 1 min: 185 ± 20 vs. 184 ± 28 $m \cdot min^{-1}$), while measures showed a trend to be greater in the current study for longer time durations (e.g., 5 min: 116 ± 14 vs. 108 ± 15 $m \cdot min^{-1}$) (Delaney et al. 2017a). Notably, inside and outside backs were both comparable to each other and international players (Delaney et al. 2017a). The similar or greater running intensity shown in the current study may be because of greater defensive structures in the international level and defences in academy rugby might provide more space for players to run.

Researchers should make coaches aware of the 'true maximum' values that are provided in this research, and have previously been omitted from studies. However, the use of the rolling mean method provides limited context such as location on the pitch, time of the match and the current phase of play (i.e., attack or defence). Despite this, maximum running intensity should be used as one of the metrics to analyse match-play data in order to prepare players for the most intense periods of play. It is also recommended for coaches to use it for its use in discriminating between positions, whereas other analyses might not provide this. Future research should look to quantify the maximum collision exposures during academy match-play, as the current study only examined running, which is acknowledged as a limitation.

Conclusion

This study is the first to quantify the maximum running intensities from academy rugby union match-play. In addition, seven of the 14 regional academies are included in this study and thus is a substantial representation of U18 academy players in England. Within both forwards and backs, there were clear differences between each consecutive time duration, with greater changes shown in the short durations (i.e., 15 s, 30 s, 1 min and 2 min). The results highlight the substantial differences between forwards and backs at all time durations, whereas previous studies using different types of analyses have shown a smaller disparity between the two positions for U18 players. The further sub-positional comparisons show that front row players are markedly different from both second and back row players. Equally, scrum halves were distinctly different from inside and outside backs besides 15 and 30 s time durations. Notably, it appears academy players experience similar or greater maximal running intensities during match-play as international players. These data provide time specific reference values for maximum running intensity so coaches can prepare English academy rugby union players for the most intense periods of play.

Practical Applications

Coaches working in rugby union can use the information provided to appropriately replicate and overload the intensity of match-play running through the use of traditional conditioning practices or small-sided games specific to relevant time durations and positions. For example, coaches might wish to perform a drill in training for 2.5 min, which corresponds to the longest ball in-play cycle during academy match-play. The reference values provided in this study for 2.5 min in front row (112 ± 15 $m \cdot min^{-1}$), scrum halves (138 ± 18 $m \cdot min^{-1}$) and all players (range: 71-179 $m \cdot min^{-1}$) can be used to either monitor 'live' or retrospectively analyse ensuring the appropriate stimulus is provided. In addition, practitioners working with U18 squads could group second row and back row players together within the forwards, while also grouping inside and outside backs together for conditioning. Front row and scrum halves are distinctly different from other sub-positional groups. Coaches should also be aware that substantial changes in anthropometric measures (e.g., height and body mass) occur between U18 and professional levels and therefore practitioners should look to maintain and increase maximal running intensities alongside this where applicable.

Acknowledgments

The authors would like to thank all clubs, players and coaches involved in the research. 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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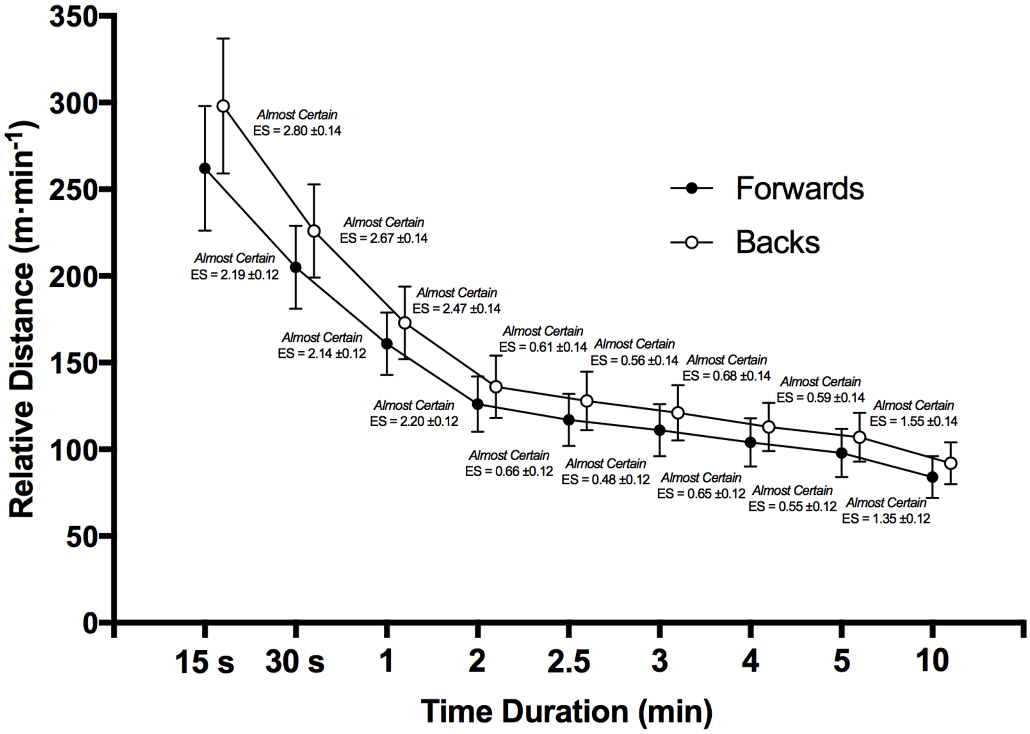

Figure 1. Maximum relative distance (m·min^{-1}) of forwards and backs during academy rugby union match-play. Comparisons for consecutive time durations (e.g., 15 s vs. 30 s, 30 s vs. 1 min, etc.) within each position are shown with magnitude-based inferences and Cohen's *d* effect sizes ±90% confidence intervals. Differences are calculated as A-B. Effect size thresholds are <0.20 = trivial, 0.20-0.59 = small, 0.60-1.19 = moderate, 1.20-1.99 = large and 2.00-3.99 = very large.

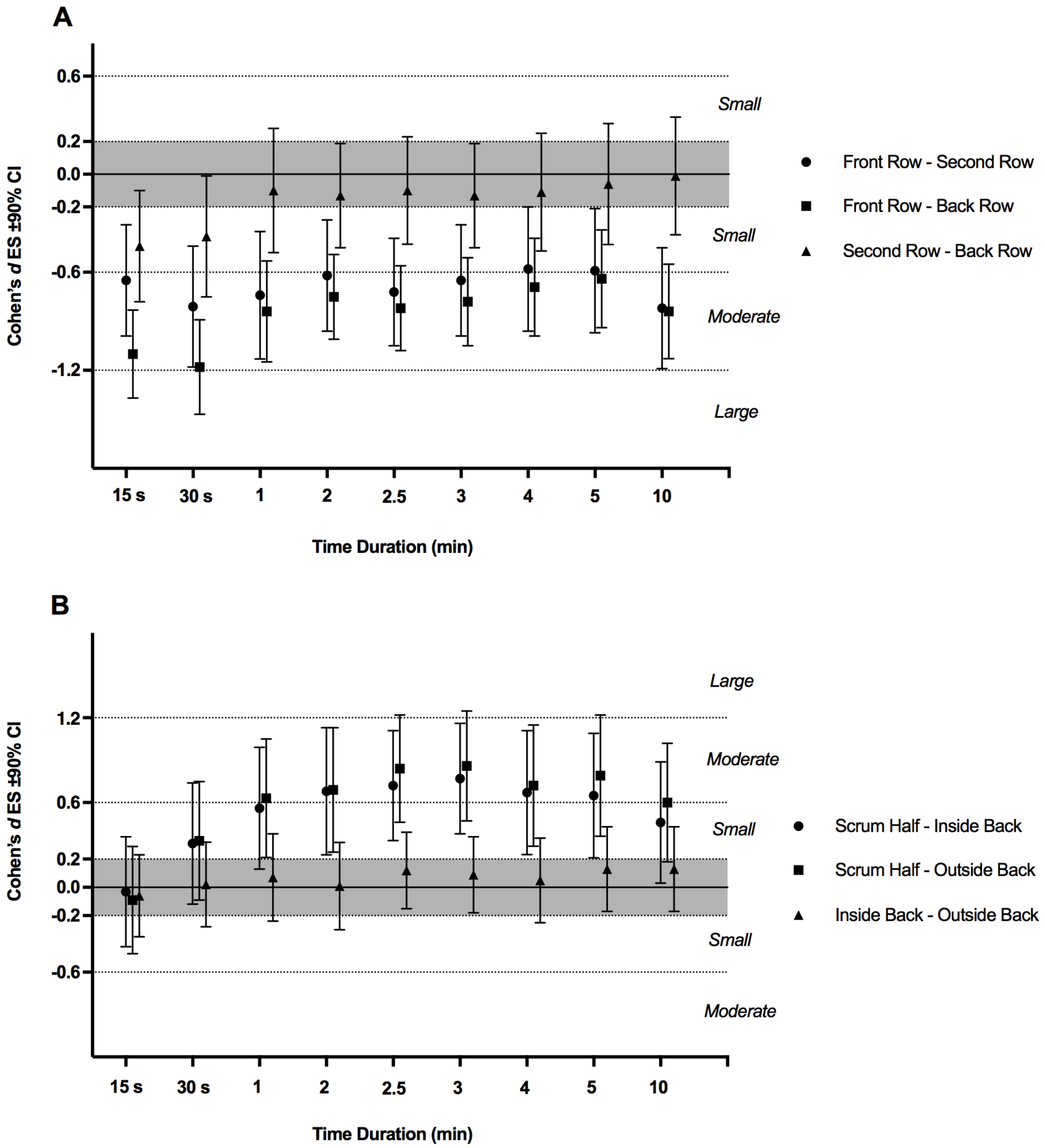

Figure 2. Positional comparisons for front row, second row and back row (A) and scrum half, inside backs and outside backs (B) in relative distance ($m \cdot min^{-1}$). Data are reported as Cohen's *d* effect sizes ±90% confidence intervals. Differences are calculated as A-B. Effect size thresholds are <0.20 = trivial, 0.20-0.59 = small, 0.60-1.19 = moderate and 1.20-1.99 = large.

Table 1. Maximum relative distance ($m \cdot min^{-1}$) during academy rugby union match-play for six positional groups

	Front Row	Second Row	Back Row	Scrum Half	Inside Backs	Outside Backs
15 s	245 ± 32	264 ± 29	280 ± 36	298 ± 44	297 ± 33	299 ± 42
	[175 - 342]	[219 - 345]	[202 - 377]	[212 - 383]	[170 - 380]	[166 - 389]
30 s	193 ± 21	207 ± 19	217 ± 23	233 ± 25	245 ± 23	224 ± 30
	[149 - 251]	[164 - 242]	[166 - 273]	[193 - 297]	[153 - 283]	[148 - 302]
1 min	154 ± 17	165 ± 12	168 ± 19	185 ± 20	172 ± 19	170 ± 22
	[111 - 201]	[141 - 198]	[121 - 205]	[136 - 217]	[102 - 219]	[111 - 231]
2 min	121 ± 16	130 ± 12	132 ± 15	146 ± 19	135 ± 16	133 ± 17
	[72 - 151]	[106 - 158]	[86 - 163]	[105 - 183]	[84 - 180]	[81 - 167]
2.5 min	112 ± 15	121 ± 13	123 ± 14	138 ± 18	128 ± 16	124 ± 15
	[71 - 144]	[96 - 152]	[81 - 157]	[103 - 179]	[73 - 168]	[75 - 162]
3 min	106 ± 14	115 ± 14	116 ± 14	132 ± 17	120 ± 14	118 ± 15
	[67 - 138]	[87 - 145]	[76 - 147]	[98 - 178]	[69 - 158]	[71 - 157]
4 min	99 ± 14	106 ± 12	108 ± 14	122 ± 15	112 ± 13	111 ± 14
	[56 - 137]	[84 - 137]	[73 - 143]	[82 - 148]	[63 - 142]	[67 - 142]
5 min	93 ± 14	100 ± 12	102 ± 14	116 ± 14	106 ± 12	104 ± 14
	[49 - 129]	[80 - 134]	[64 - 139]	[80 - 138]	[54 - 131]	[60 - 129]
10 min	80 ± 12	87 ± 9	88 ± 11	97 ± 13	92 ± 10	89 ± 11
	[47 - 102]	[70 - 105]	[54 - 110]	[62 - 120]	[50 - 112]	[53 - 113]

Data are reported as mean ± SD. [range].