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Running title: Relative intensity of team sport match-play

The use of relative speed zones increases the high-speed running performed in team sport match-play

Tim J. Gabbett

School of Exercise Science, Australian Catholic University, Brisbane, Australia

School of Human Movement Studies, The University of Queensland, Brisbane, Australia

Address correspondence to:

Dr. Tim J. Gabbett

School of Exercise Science,

Australian Catholic University,

Brisbane, AUSTRALIA 4014

Email: tim_gabbett@yahoo.com.au

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ABSTRACT

This study investigated the activity profiles of junior rugby league players competing in three distinct age groups (Under 13, 14, and 15), and two distinct playing standards (Division 1 and 4). In addition, we reported GPS data using pre-defined absolute speed thresholds, and speed thresholds expressed relative to a players' individual peak velocity. Ninety male junior rugby league players, representing one of six teams competing in the Brisbane junior rugby league competition, underwent measurements of peak velocity (via a 40 m sprint) and global positioning system (GPS) analysis during competitive matches. Data were described as both absolute speed zones, and relative to the individual player's peak velocity. Absolute measures of moderate, high, and very-high speed running distances increased with age, with the differences among groups typically small to moderate (ES = 0.24 to 0.68) in magnitude. However, when data were expressed relative to a players' capacity, younger players, and those from lower playing divisions, exhibited higher playing intensities and performed greater amounts of high-intensity activity. Moderate, negative relationships (r = -0.43 to -0.46) were found between peak velocity and the amount of relative high-speed running performed. These findings suggest that individualisation of velocity bands increases the high-speed running attributed to slower players and decreases the high-speed running attributed to faster players. From a practical perspective, consideration should be given to both the absolute and relative demands of competition in order to provide insight into training prescription and the recovery requirements of individual players.

KEY WORDS: time-motion analysis, activity profiles, rugby league, physical demands, relative stress

INTRODUCTION

Time-motion analysis has been used extensively to investigate the movement patterns and activity profiles of high-intensity, intermittent team sports (4, 19, 25). Recently, the time-intensive challenges of video-based time-motion analysis have been circumvented by the development and application of global positioning system (GPS) technology to the sporting environment (8). While recommendations for reporting GPS data have been presented (9), there is generally a wide range of reporting methods employed in the scientific literature, making comparisons between studies problematic (8, 9).

To date, there are no standardized methods for reporting velocity 'zones', and several definitions of what constitutes an 'effort' (9). Sport scientists from professional and elite field sports typically characterize a sprint effort as any movement above a threshold sprinting velocity (ranging between 6 and 7 $m.s^{-1}$) (9). A limitation of this approach is that it fails to account for the individual sprinting 'capacity' of players, whereby faster players are likely to perform at a relatively lower percentage of their maximum sprinting speed, and slower players are likely to perform at a relatively higher percentage of their maximum sprinting speed.

Abt and Lovell (1) compared the distance run at high-intensities during soccer match-play using an absolute speed threshold of 19.8 $km.hr^{-1}$ and an individualized high-intensity speed threshold based on the speed at the second ventilatory threshold (15 km. hr^{-1}). Significant differences were found in the high-intensity distance run at the absolute (845 m) and relative

(2258 m) threshold, demonstrating that the use of absolute speed thresholds may underestimate the high-intensity running performed during match-play. Buchheit et al (6) investigated the number of repeated-sprint sequences that occurred during match-play in junior (Under 13-Under 18) soccer players. While the frequency of repeated-sprint sequences was greater in the older players when a pre-defined (>19 $km.hr^{-1}$) sprinting threshold was used, when sprints were expressed relative to each individual players' capacity (>61% of peak velocity), younger players performed a greater number of repeated-sprint sequences. Collectively, these findings suggest that individualisation of speed bands increases the high-speed running attributed to relatively slower players and decreases the high-speed running attributed to relatively faster players.

Across a wide range of team sports, the absolute intensity of match-play has been shown to increase with higher playing standards (2, 11-13, 26). However, a limitation of most studies is the failure to account for the individual physical capacities of players. In this study, we investigated the activity profiles of junior rugby league players competing in three distinct age groups (Under 13, 14, and 15), and two distinct playing standards (Division 1 and 4). In addition, we reported GPS data using pre-defined absolute speed thresholds, and speed thresholds expressed relative to a players' individual peak velocity. We hypothesized that when data were expressed relative to a players' capacity that younger players, and those from lower playing divisions, would exhibit higher playing intensities and perform greater amounts of high-intensity activity.

METHODS

Experimental Approach to the Problem

To test our hypothesis, we used a cross-sectional experimental design. Junior rugby league players competing in three distinct age groups (Under 13, 14, and 15), and two distinct playing standards (Division 1 and 4) underwent time-motion analysis during match-play using global positioning system devices. The high-speed running performed was expressed as absolute speed zones, and relative to the individual player's peak velocity. Differences in the physical demands (i.e., distance covered at low, moderate, and high-speeds, collisions, and repeated high-intensity effort activity) between playing divisions and age groups were analyzed using Cohen's effect size (ES) statistic (7) and magnitude-based inferences (18).

Subjects

Ninety male junior rugby league players (mean ± SD age 13.7 ± 0.9 yr; playing experience 5.1 ± 2.4 yr; height 164.1 ± 9.2 cm; body mass 58.2 ± 14.8 kg) participated in this study. The project was first discussed with the Executive Committee of the rugby league club. The committee provided their support for the project, and permission to contact individual players and their parents/legal guardians. A letter was sent to players and their parents/legal guardians, advising them of the project, and inviting them to attend an information session about the project. During this session, participants received a clear explanation of the study, including information on the risks and benefits. Written parental or guardian consent was obtained prior to participation. All experimental procedures were approved by the Institutional Ethics Committee for Human Investigation.

Subjects were participants in one of six teams competing in the Brisbane junior rugby league competition. Players were members of the first or fourth division, competing in either the Under 13 (mean ± SD age, 12.6 ± 0.3 yr), 14 (mean ± SD age, 13.8 ± 0.3 yr), or 15 (mean ± SD age, 14.6 ± 0.3 yr) teams of a Brisbane metropolitan rugby league club (Table 1).

Insert Table 1 About Here

Speed

The running speed of players was evaluated with a 10 m, 20 m, and 40 m sprint effort using dual beam electronic timing gates (Swift Performance Equipment, New South Wales, Australia). The timing gates were positioned 10 m, 20 m, and 40 m cross wind from a pre-determined starting point. Players were instructed to run as quickly as possible along the 40m distance from a standing start. Speed was measured to the nearest 0.01 s with the fastest value obtained from three trials used as the speed score. The calculated speed between the 20 m and 40 m gates was used as a measure of peak velocity. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for the 10 m, 20 m, and 40 m sprint tests were 0.95, 0.97, and 0.97, and 1.8%, 1.3%, and 1.2%, respectively.

Match Activity Profiles

Global positioning system (GPS) analysis was completed during 18 matches (totalling 270 appearances). Each match was 60 minutes in duration (30 minute halves separated by a 5 minute half-time break). Each team consisted of 20 players (13 on field with 7 replacements). Consistent with the majority of junior rugby league competitions, an unlimited interchange rule was applied. Players from each division were monitored during 3 competition matches. Up to 15 players wore a GPS unit during any given match.

Movement was recorded by a minimaxX GPS unit (Catapult Innovations, Melbourne, Australia) sampling at 10 Hz. The GPS signal provided information on speed, distance, position, and acceleration. The GPS unit also included a tri-axial accelerometer and gyroscope sampling at 100 Hz, to provide information on physical collisions and repeated high-intensity efforts. The unit was worn in a small vest, on the upper back of the players.

Data were described as both absolute speed zones, and relative to the individual player's peak velocity. Data were categorized into (i) movement speed bands, corresponding to low (0-3.5 $m.s^{-1}$), moderate (3.6-5.0 $m.s^{-1}$), and high (> 5.0 $m.s^{-1}$) speeds; (ii) collisions; and (iii) repeated high-intensity effort bouts. A repeated high-intensity effort bout was defined as 3 or more high acceleration ($\geq$ 2.79 $m.s^{-2}$), high speed, or contact efforts with less than 21 seconds recovery between efforts (16). Data were also categorized as low (0-25%), moderate (25-50%), high (50-70%) and very high-speed (>70%) relative to each individuals' peak velocity ($m.s^{-1}$, 20-40 m). The minimaxX units have been shown to have acceptable validity and reliability for estimating longer distances at walking through to striding speeds, and acceleration and sprint efforts commonly observed in team sport competition (27). The minimaxX units have also been shown to offer a valid measurement of tackles and repeated efforts commonly observed in collision sports (11, 14).

Statistical Analyses

Differences in the absolute and relative activity profiles between the different age groups and playing divisions were compared using a practical approach based on the real-world relevance of the results. Differences in the physical demands (i.e., distance covered at low, moderate, and high-speeds, collisions, and repeated high-intensity effort activity) between playing divisions and age groups were analyzed using Cohen's effect size (ES) statistic (7). Effect sizes of <0.2, 0.21-0.60, 0.61-1.20, and >1.20 were considered trivial, small, moderate, and large, respectively (5). Magnitudes of differences between groups were classified as a substantially greater or lesser when there was a ≥75% likelihood of the effect being equal to or greater than the smallest worthwhile change estimated as 0.2 x between-subject standard deviation (small ES). Effects with less certainty were classified as trivial and where the ± 90% CI of the ES crossed the boundaries of ES −0.2 and 0.2, the effect was reported as unclear (21).

RESULTS

Speed

A progressive increase in acceleration and peak velocity values were found with increases in playing age, and standard (Table 2).

Insert Table 2 About Here

Match Activity Profiles Expressed as Absolute Speed Zones

The absolute amount of low-speed activity, and moderate, high, and very-high speed running for Under 13, 14, and 15 players is shown in Figure 1. Trivial differences (ES = -0.16 to 0.20) were found among age groups for low-speed activity. Absolute measures of moderate, high, and very-high speed running distances increased with age, with the differences among groups typically small to moderate (ES = 0.24 to 0.68) in magnitude.

Insert Figure 1 About Here

Match Activity Profiles Expressed Relative to Peak Velocity

Under 13 players performed less relative low-speed activity than both Under 14 (ES = 0.90) and Under 15 (ES = 0.50) players (Figure 2). However, Under 13 players performed moderately greater amounts of relative high-speed running than both Under 14 (ES = 0.68) and Under 15 (ES = 0.61) players, and likely greater amounts of relative very-high speed running than both Under 14 (ES = 0.43) and Under 15 (ES = 0.58) players. Trivial differences (ES = -0.14 to -0.04) were found among age groups for the relative percentage of moderate-speed running performed. No meaningful differences were found between Under 14 and Under 15 players for the relative proportion of low-speed activity (ES = 0.02), high (ES = 0.09), and very-high speed (ES = 0.21) running performed.

Insert Figure 2 About Here

Comparison of Division 1 and 4 Players

When comparing Division 1 and 4 players, variable responses were observed. Under 13 division 1 players covered greater distance per minute of match time (ES = 0.99), including greater distances at low-speeds (ES = 1.33) than division 4 players. Expressed relative to peak velocity, division 1 players also covered greater distances in moderate-speed running (ES = 0.95) than division 4 players. Conversely, Under 14 division 4 players covered greater low-speed activity (both expressed relative to match time and peak velocity; ES = 0.82-1.31), but less high-speed running per minute of match time (ES = -0.79) than division 1 players. Under 15 division 4 players performed less high-speed (ES = -1.03) and very high-speed running (ES = -1.05) and fewer RHIE bouts per minute of match time (ES = -0.80) than division 1 players. However, expressed relative to peak velocity, division 4 players performed more high-speed running (ES = 0.64) than division 1 players (Table 3).

Insert Table 3 About Here

DISCUSSION

This study investigated the activity profiles of junior rugby league players competing in three distinct age groups (Under 13, 14, and 15), and two distinct playing standards (Division 1 and 4). In addition, we reported GPS data using pre-defined absolute speed thresholds, and speed thresholds expressed relative to a players' individual peak velocity. Consistent with our hypothesis, when data were expressed relative to a players' capacity, younger players, and those from lower playing divisions, exhibited higher playing intensities and performed greater amounts of high-intensity activity. These findings suggest that individualisation of velocity bands increases the high-speed running attributed to slower players and decreases the high-speed running attributed to faster players.

In general, the amount of moderate, high, and very high-speed running per minute of match-play increased with playing age. These findings may be expected given the greater physical qualities of older players in relation to their younger counterparts (10, 16). However, relative to peak velocity, the amount of low-speed activity increased, and the amount of high and very high-speed running decreased as playing age increased. These findings demonstrate that expressing GPS data relative to an individual's capacity results in difference conclusions than if pre-defined absolute speed thresholds are used.

When data were expressed as pre-defined absolute speed thresholds, Division 1 players performed more high-speed (Under 14 and Under 15) and very high-speed (Under 15) running, and a greater frequency of repeated high-intensity effort bouts (Under 15) than Division 4 players. These findings are in agreement with other studies from both junior (13) and senior (11, 12, 24) players, that have found greater playing intensity as the standard of competition increases. Playing division differentially affected low-speed activity, with lower standard Under 13 players performing less low-speed activity, and lower standard Under 14 players performing more low-speed activity than their higher-standard counterparts. However, when expressed relative to an individual player's peak velocity, differences in high-speed running distances were only evident in Under 15 players, with Division 4 players performing more high-speed running than Division 1 players. Collectively, these results demonstrate (1) the variability in match activity profiles of junior rugby league players aged 13-15 years, and (2) the differences in relative and absolute match intensities in players of vastly different standards.

In conclusion, we investigated the activity profiles of junior rugby league players competing in three distinct age groups (Under 13, 14, and 15), and two distinct playing standards (Division 1 and 4). In addition, we reported GPS data using pre-defined absolute speed thresholds, and speed thresholds expressed relative to a players' individual peak velocity. While older players, and those from higher playing divisions generally had greater absolute work-rates, when data were expressed relative to individual capacity, younger players, and those from lower playing divisions, exhibited higher playing intensities and performed greater amounts of high-intensity activity. These findings suggest that individualisation of velocity bands increases the high-speed running attributed to slower players and decreases the high-speed running attributed to faster players.

PRACTICAL APPLICATIONS

The present findings have direct application to strength and conditioning staff and applied sport scientists involved in the monitoring of team sport athletes. Firstly, our results demonstrate differences in the amount of high-speed running performed when data are expressed as absolute speed zones or relative to individual capacity. Consequently, two individuals could perform the same absolute amount of high-speed running, but due to differences in peak velocities, result in a significantly greater relative stress on the individual with slower peak running speed. Consideration should be given to both the absolute and relative demands of competition in order to provide insight into training prescription and the recovery requirements of individual players.

Secondly, this is the first study to report the activity profiles of junior rugby league players competing at different playing standards and age levels. With the majority of time-motion analyses conducted on senior rugby league players, these results provide strength and conditioning coaches with objective data to inform the programs of junior rugby league players. The results show the amount of high-speed running, collisions, and repeated high-intensity effort bouts in which players engage during junior rugby league match-play, which in turn provides insight into the individual training requirements of players. For example, players are engaged in collisions, on average every 2-3 minutes, and are required to perform a repeated high-intensity effort bout every 11.8-25.5 minutes. High-speed running contributes between 5.6 and 9.7% of the overall movement demands, with a further 2.0-3.3% of movement performed at very high speeds. Ensuring players are prepared to perform these repeated high-intensity demands of the game is likely to improve playing performance (15, 18, 19), and the likelihood of competitive success (3), promote faster recovery (22), and reduce injury risk (20). Moreover, our results demonstrate greater high-speed running demands in relatively slower players. Improving the speed of players is likely to improve performance, and also reduce the relative strain associated with competition.

Finally, our findings demonstrate that different interpretations can be made from GPS data depending on whether that data is expressed as pre-defined absolute speed thresholds, or relative to an individual's peak velocity. These findings emphasise the importance of universally accepted, and standardized speed zones for GPS monitoring in team sport athletes. Our results suggest a need for the development of a consensus statement for the use of GPS tracking technology in team sports.

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FIGURE LEGENDS

Figure 1. Absolute amount of low-speed activity, and moderate-, high-, and very-high speed running performed during match-play in Under 13, 14, and 15 junior rugby league players.

Data are reported as mean ± SD.

Figure 2. Amount of low-speed activity, and moderate-, high-, and very-high speed running performed relative to each player's individual peak velocity during match-play in Under 13, 14, and 15 junior rugby league players.

Data are reported as mean ± SD.

Table 1. Physical characteristics of Division 1 and 4 junior rugby league players.

	Under 13		Under 14		Under 15	
	Division 1	Division 4	Division 1	Division 4	Division 1	Division 4
Age (yr)	12.8 ± 0.2	12.3 ± 0.1[b]	13.9 ± 0.2	13.9 ± 0.3	14.6 ± 0.3	14.6 ± 0.3
Playing Experience (yr)	5.4 ± 1.9	2.8 ± 1.8[b]	5.9 ± 1.2	3.5 ± 2.3[b]	5.7 ± 2.1	7.3 ± 2.1[a]
Height (cm)	156.9 ± 5.9	153.0 ± 3.8[a]	172.4 ± 4.9	164.8 ± 7.7[a]	171.1 ± 2.7	167.5 ± 8.8
Body Mass (kg)	53.1 ± 11.4	47.1 ± 8.8	65.0 ± 12.1	58.9 ± 15.3	65.3 ± 8.1	60.3 ± 21.9

Data are means ± SD. a = moderate effect size difference between Division 1 and 4; b = large effect size difference between Division 1 and 4.

Table 2. Maximum acceleration and peak velocity of Division 1 and 4 junior rugby league players.

	Under 13		Under 14		Under 15	
	Division 1	Division 4	Division 1	Division 4	Division 1	Division 4
10 m Sprint (s)	2.20 ± 0.12	2.27 ± 0.04[a]	2.00 ± 0.12	2.15 ± 0.21[a]	1.91 ± 0.03	2.09 ± 0.15[b]
Maximum Acceleration ($m.s^{-2}$)	2.08 ± 0.23	1.95 ± 0.07[a]	2.51 ± 0.27	2.21 ± 0.38[a]	2.75 ± 0.08	2.31 ± 0.29[b]
20 m Sprint (s)	3.79 ± 0.22	3.90 ± 0.08[a]	3.40 ± 0.19	3.58 ± 0.19[a]	3.22 ± 0.08	3.58 ± 0.27[b]
40 m Sprint (s)	6.94 ± 0.44	7.15 ± 0.15[a]	6.14 ± 0.33	6.50 ± 0.32[a]	5.75 ± 0.27	6.48 ± 0.59[b]
Peak Velocity ($m.s^{-1}$)	6.38 ± 0.48	6.16 ± 0.16[a]	7.33 ± 0.37	6.88 ± 0.37[b]	7.93 ± 0.59	6.98 ± 0.67[b]

Data are means ± SD. a = moderate effect size difference between Division 1 and 4; b = large effect size difference between Division 1 and 4.

Table 3. Activity profiles of Division 1 and 4 junior rugby league players.

	Under 13		Under 14		Under 15	
	Division 1	Division 4	Division 1	Division 4	Division 1	Division 4
Time (min)	55.4 ± 13.5	53.9 ± 15.6	49.4 ± 13.8	48.8 ± 15.7	48.3 ± 15.1	51.9 ± 9.3
Activity Profiles (Relative to Playing Time)						
Distance ($m.min^{-1}$)	85.5 ± 12.4	75.4 ± 7.3[a]	80.7 ± 12.2	82.5 ± 8.0	87.7 ± 9.0	83.5 ± 17.2
Low-Speed Activity ($m.min^{-1}$)	70.5 ± 7.8	61.6 ± 5.4[b]	61.6 ± 8.0	67.3 ± 5.8[a]	67.1 ± 6.8	65.3 ± 11.5
Moderate-Speed Running ($m.min^{-1}$)	6.9 ± 2.7	6.0 ± 2.5	8.1 ± 2.5	6.7 ± 2.7	8.6 ± 2.9	8.2 ± 5.4
High-Speed Running ($m.min^{-1}$)	1.3 ± 0.9	1.9 ± 1.5	2.8 ± 1.1	1.8 ± 1.4[a]	3.4 ± 1.4	1.8 ± 1.7[a]
Very High-Speed Running ($m.min^{-1}$)	0.1 ± 0.2	0.2 ± 0.3	0.2 ± 0.3	0.2 ± 0.4	0.5 ± 0.5	0.1 ± 0.2[a]
Collisions ($no.min^{-1}$)	0.4 ± 0.2	0.3 ± 0.1	0.3 ± 0.1	0.4 ± 0.2	0.4 ± 0.2	0.3 ± 0.2
Repeated High-Intensity Effort Frequency (min between bouts)	19.4 ± 20.2	25.5 ± 18.4	14.7 ± 10.9	23.7 ± 19.6	11.8 ± 11.8	23.8 ± 17.5[a]
Activity Profiles (Relative to Peak Velocity)						
Low-Speed Activity (0-25%)	33.0 ± 6.3	30.5 ± 3.2	33.9 ± 3.3	38.3 ± 3.4[b]	36.2 ± 14.4	36.7 ± 7.4
Moderate-Speed Running (26-50%)	30.1 ± 7.8	24.0 ± 4.6[a]	26.7 ± 7.2	27.0 ± 6.3	23.8 ± 10.3	28.2 ± 10.1
High-Speed Running (51-70%)	9.7 ± 5.3	9.5 ± 2.6	7.2 ±1.5	7.2 ± 2.9	5.6 ± 3.1	8.4 ± 5.3[a]
Very High-Speed Running (>70%)	3.2 ± 1.9	3.3 ± 2.4	2.6 ± 1.2	2.5 ± 1.5	2.0 ± 1.1	2.5 ± 1.8

Data are means ± SD. a = moderate effect size; b = large effect size.

Figure 1

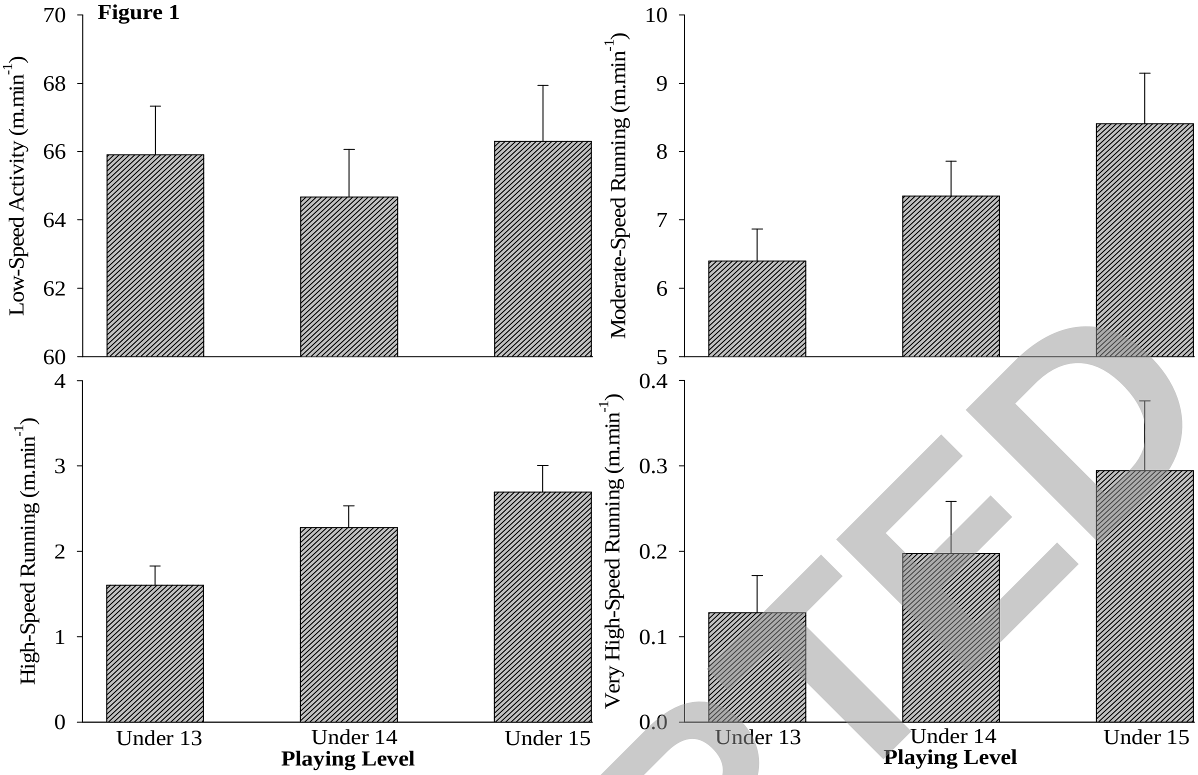
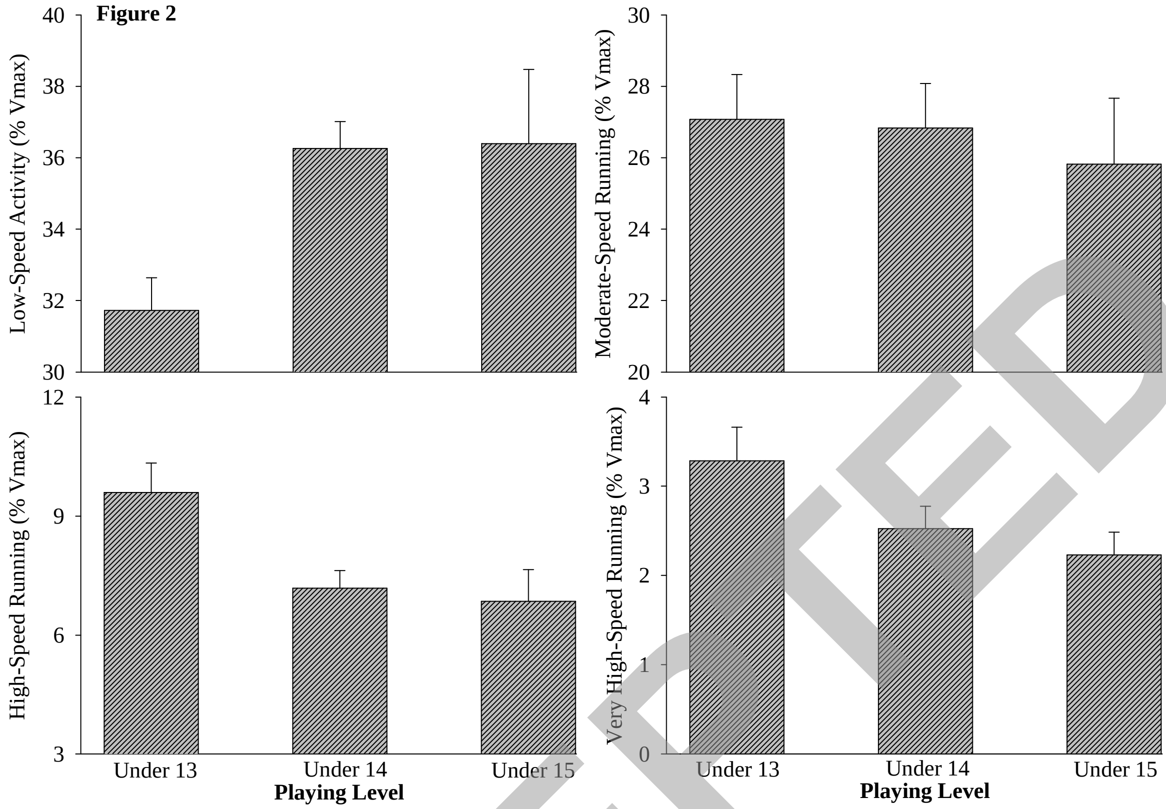

Low-Speed Activity (m.min-1)
70
68
66
64
62
60
Moderate-Speed Running (m.min-1)
10
9
8
7
6
5
High-Speed Running (m.min-1)
4
3
2
1
0
Very High-Speed Running (m.min-1)
0.4
0.3
0.2
0.1
0.0
Under 13
Under 14
Under 15
Playing Level

Figure 2


Low-Speed Activity (% Vmax)
40
38
36
34
32
30
Moderate-Speed Running (% Vmax)
30
28
26
24
22
20
High-Speed Running (% Vmax)
12
9
6
3
Very High-Speed Running (% Vmax)
4
3
2
1
0
Under 13
Under 14
Under 15
Playing Level