Title
A time-motion analysis of paralympic football for athletes with cerebral palsy

Original Investigation

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ABSTRACT

To investigate the soccer match-play work of players with Cerebral Palsy (CP), 40 elite players were monitored for cardiovascular and locomotive demands of tournament match-play. Using GPS and HR monitors, total distance travelled, distance travelled at high intensity (HI) and very high intensity (VHI)(m); frequency of HI and VHI activity; heart rate (HR). Disability classes C5/6, C7, C8 were compared. The results showed C8 players covered the greatest distance. Frequency, contribution and maximum speed of HI and VHI activity was greater in C8. There was a progressive decline in distances covered in all classes across match quarters. C8 spent more time above 85% HRmax. No differences were observed between C5/6 and C7 classes. In conclusion, C8 players most notably perform best in VHI activity associated with game-defining moments. C5/6 and C7 players performed equitably. This study is the first to provide an insight for practitioners and coaches interested in the work rates in soccer for athletes with CP.

KEYWORDS**:** Paralympic, soccer, GPS, workload, time-motion.

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INTRODUCTION

Football for athletes with cerebral palsy (CP) is a format of Association Football played under the Laws of the Game with a number of notable modifications [1]. The game is 60 minutes in duration while the pitch dimensions are also abridged to 70-75 m x 50-55 m with 2 m x 5 m goals. It is essentially a small-sided game, with only 7 players per team and no offside law [2]. Consequently, the application of work rate analysis from the able-bodied (AB) game is of limited use here. Other modifications to the laws to accommodate player impairment, mean that the game functions very differently to AB football.

As with all Paralympic sports, football also involves the classification of players based upon the degree and form of physical impairment they possess due to CP. The classification system permits the inclusion of a spectrum of CP induced impairments and other acquired brain injury (ABI) such as cerebral strokes or head injuries, which commonly lead to neuromuscular dysfunction. The Cerebral Palsy International Sports and Recreation Association (CPISRA) are responsible for the ratification of events and classification of athletes with CP in accordance with International Paralympic Committee (IPC) standards. An IPC Position Stand stated that a classification system should be 'selective' and not performance-related and athletes are classified by types of impairment and not severity [3]. To this end, CPISRA conduct a combination of clinical and field-based tests in the classification assessment and establish each player's final class.

Players in the ambulatory classes (Classes C5 - C8) are eligible to compete but restrictions are placed upon the distribution of classes permitted on the field of play at any given time. As C8 players are often least affected by impairment, teams may field a maximum of two C8 players at any time*. C5 (commonly diplegic CP) and C6 players (commonly ataxic or athetoid CP) tend to be most affected and teams must field a minimum of one C5 or C6 player at all times. C7 players (commonly hemiplegic) are without playing restrictions. Three substitutions are permitted during game play but the classification rule remains throughout games.

Currently there are no published time-motion analysis studies for disability football but the research paradigm is now well established in the able-bodied (AB) game [4, 5, 6]. Most contemporary work has utilised camera based tracking systems or individual player GPS devices to study the physical demands of players with a focus upon high intensity activity [6, 7], as this is widely regarded as a key discriminating factor of playing level and training status [8,9]. The widespread use of this technology has informed the training methods, periodisation and monitoring of player exposure to match play at elite level [10], but the benefits of such information may not be applicable to modified football for players with a disability. The widespread development of elite level Paralympic sports requires a scientific approach to preparation and to this end, quantifiable match data is essential for continued progress.

Our study applied the time-motion analysis research paradigm to the Paralympic domain and explored the fundamental aspects of time-motion analysis in football for athletes with CP. The aim was to establish landmark competitive time-motion analysis data and examine the relative levels of work done by players across the classification spectrum, with a view to informing football-specific conditioning in the future.

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METHODS

Participants- 40 elite male footballers with CP (Table 1) from four nations consented to take part in the study. Ethical approval was obtained from the local ethics committee of Manchester Metropolitan University, and conformed to the guidelines set out in the Declaration of Helsinki. All participants were outfield players and the four competing teams were ranked in the top eight 7-a-side football teams in the world.

Due to playing restrictions on class distribution (a C5 or a C6 must be present on the field of play) and the smaller outfield player sample size of these classes (C5 and C6 players commonly feature as goalkeepers) data from C5 and C6 players were pooled. Conversely, C7 and C8 players tend to be outfield players and so no such sampling issues were of concern.

<<<<INSERT TABLE 1: participant characteristics>>>>>>>

Measurements - During the eight matches of the 2012 BT Paralympic World Cup (Manchester, UK) all participants wore a body vest fitted global positioning satellite (GPS) 10Hz device (MinimaxX S4, Catapult, Australia) and a heart rate monitor (Team System, Polar, Finland) fitted prior to taking part in their respective matches. The GPS device was recently validated for high levels of reliability and low levels of measurement error [11, 12].

All matches were played in the afternoon on a grass pitch adhering to CPISRA modified rules for 7-a-side football [2]. Data were collected throughout each game and only whole game samples were included for analysis (excluding data collected from players who were replaced by substitutes or who later entered the field of play as a substitute).

The calculation of quantified threshold speeds for high intensity activity (HI) and very high intensity activity (VHI) was based upon the adjustment for age of Prozone® thresholds [5] for age in youth football [13]. We deemed it necessary to adjust our activity thresholds for players with CP who are incapable of attaining a peak velocity V_{peak} akin to senior elite AB players. Although absolute threshold speeds may have inherent shortcomings, Prozone® thresholds are commonly used to determine wearable GPS technology threshold speeds. In order to adjust appropriately, during earlier pilot field-testing we attained flying 20 m sprint times from a cohort of elite players with CP across the spectrum of classes (C5 – C8) (n=39). Subsequently, we were able to establish a mean (SD) V_{peak} of 7.31 (0.14) m/s. Relative to elite AB players (8.3 m/s) [13] the CP players V_{peak} was 88%. Applying this ratio to the Prozone® thresholds of 7.0 m/s and 5.5 m/s, adjustments to the thresholds for HI and VHI were derived for this study. All players within the study were capable of attaining the full range of threshold speeds.

The GPS-related parameters recorded included: total distance travelled (m); distance travelled at HI (m), 4.9 – 6.4 m/s and VHI (m), > 6.4 m/s; frequency of HI and VHI activity. Heart Rate (HR) data were collected and reported as mean HR, maximum HR, time spent <75%, between 75 – 85% and > 85% of maximum HR (MHR).

Data and Statistical Analysis- Due to the nature of the competitive match play environment in which the data were collected, we considered the time being added by match officials for stoppages in play. Quarter and whole-match data were converted from the uncorrected values recorded to *pro rata* values to provide data sets for 15-minute quarter- and 60-min whole-match times. This permitted comparisons to be made over equal time periods.

Using SPSS v19.0 (IBM, Chicago, Illinois), two-way ANOVAs were used to analyse the main effects of classification (x3) and playing time quarters (x4). Subsequently, post-hoc pair-wise comparisons were conducted on distance variables and heart rate. Greenhouse-

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Geisser alpha level adjustments were applied to account for sphericity violations found in Mauchly's Test. One-way ANOVAs were used to analyse maximum velocity, frequency and distance of HI and VHI activity and maximum heart rate. Alpha was set at 0.05.

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RESULTS

The total distances covered (Table 2) by players during match play were different between classifications and between match play quarters. C8 players covered 811m more than C7 ($p = 0.011$) and 701m more than C5/6 ($p = 0.027$). With the exception of the quarter periods either side of half-time, distances covered per quarter were different and declined progressively throughout the matches for all classes in each quarter ($p \leq 0.001$). Collectively, the three classes showed a 17.5% decline in distance covered from the first (1587m) to the last quarter (1309m) as a consequence of 60 minutes of match-play. It is notable that C7 players and C5/6 players did not cover different distances at any point during match-play.

>>>>INSERT TABLE 2<<<<<<

There were no differences between the classes (C8 v C7 v C5/6) for HI activity (Figure 1). However C8 covered more ground at VHI activity than C7 and C5/6 ($p \leq 0.041$) while the other two classes did not differ (Figure 1).

>>>>>>INSERT FIGURE 1<<<<<<<<<<<

In Table 3 the percentage contribution of VHI activity to the total distance covered was greater in C8 than C7 ($p = 0.008$) and C5/6 ($p = 0.003$). C8 players' VHI activity contributed to 2.2% of the overall distance covered in comparison to a significantly lower contribution for C7 ($p = 0.008$) and C5/6 ($p = 0.003$). No differences were observed across the classes for the percentage contribution of HI activity to the total distance covered.

>>>>>>>INSERT TABLE 3<<<<<<<

C8 players engaged more frequently in HI and VHI activity than C7 and C5/6 ($p \leq 0.04$) completing on average 35 HI and 9 VHI activity bouts per game. The distances covered during each HI and VHI activity bout were not different across the classes and so when a player engaged in HI or VHI activity they covered approximately 12-15 m. Once again C5/6 players demonstrated an ability to match the performance levels of their C7 counterparts with no differences being observed between these groups. Another discriminating feature between classes was the maximum velocity attained. C8 players attained higher maximal velocities than C7 and C5/6 ($p = 0.001$) while C7 and C5/6 attained similar maximal velocities. The maximum velocities attained by all players exceeded the threshold values set for HI and VHI activity.

>>>>>>>INSERT TABLE 4<<<<<<<<

No differences were evident across the classes for maximum or mean HR. The mean HR during the 3rd quarter (immediately after half time) was lower than during the other three quarters ($p \leq 0.031$, Table 4).

>>>>>>>INSERT FIGURE 2<<<<<<<<

C8 players spent 61% of time during match play above 85% MHR, which was more than both C7 (39%) and C5/6 (31%) ($p = 0.05$), C7 and C5/6 did not differ (Figure 2). The time spent

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above 85% MHR during the first half was higher than the second half ($p \leq 0.021$). There were no differences observed for time spent at 75-85% MHR. The time spent below 75% MHR was higher during the second half than during the first half ($p \leq 0.015$), corresponding with the gradual decline in time spent above 85% MHR across the quarters.

DISCUSSION

In this study we investigated time-motion performance variables in CP football - a form of football that has thus far been overlooked. The main findings were that C8 players physically outperformed C7 and C5/6 players in various categories of distance covered.

We found that C8 players demonstrated an ability to cover more ground at higher intensities that are associated with the critical phases of play in matches [14]. Research in elite AB football would suggest that physical performances are strong discriminators of level of play and subsequent success [8, 9] and so we would hypothesise that the performance C8 players is linked to successful team play. With the most minimal impairments, often through post-natal brain trauma or injury, C8 players can often seem uninhibited with near normal gait patterns and mechanical efficiency [2]. The onset of fatigue exacerbates problems with neuromuscular coordination [15] and so a decline in distance covered over the period of the game is not surprising, but our data show that the decline in distance covered from the first quarter to the last was approximately 17.5% in all classes – thus supporting a sustained class distinction throughout a match. HI activity has been observed to decline by 20% in the English Premier League from the 1st to the 2nd half but a decline in total distance covered (is less pronounced than seen in the current study [5]. The relative contribution of VHI activity to total distance was higher in C8 than C7 and C5/6, which suggests that these players make a greater contribution to successful team play.

However, our findings did show that C7 and C5/6 players covered similar distances with similar contribution of HI and VHI activity. C7 players tend to present a range of severity of spastic hemiplegia, sometimes with only minor lower limb impairment leading to an asymmetrical gait [2]. When running, asymmetry often disappears and so the impairment seems to have less effect at speed. Our study however, does show that C7 players could not attain the maximal speeds of the C8 players while C5/6, who are commonly affected by diplegic, athetoid or ataxic CP attained similar maximum speeds to their C7 counterparts. This finding suggests the level of impairment associated with C8 is quite distinct from the other classes, while the level of impairment is more comparable between C7 and C5/6.

The dominance of C8 players is further evidenced by their maximum velocity attained and frequency of HI and VHI activity, both were greater than the other classes. The ability to sprint, change direction and accelerate quickly over short distances are important movements for key performance indicators (KPIs) [16] such as turnover of possessions, pressing, tackling, intercepting, dribbling and supporting team play. It seems therefore, that the value of the C8 class to the team is substantial. Interestingly, the distance travelled per HI and VHI bout did not differ between the classes and so we can infer that direct involvement in specific game activities probably determined the mean distance per bout of HI and VHI. The lower distance covered and the frequency and time spent at VHI in C5-7 maybe indicative of the neuromuscular impairments associated with CP. Muscular weakness has been associated with impaired gross motor function and gait in individuals with CP and it is possible that the weakness associated with spastic CP accounts for the reduced level of VHI activity in the lower classifications [17]. Other related factors that may explain the variance could be range of motion and coordination issues. This level of impairment may also explain the ability for C8

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players to attain greater time above 85%MHR. However, the relative neuromuscular function in each CP class remains unreported and difficult to ascertain.

It is noticeable that only 8% of outfield players were C5/6 while they contributed 50% of the goalkeepers in the tournament. In most cases, teams elect to play their mandatory C5/6 player as goalkeeper, while C8 and C7 players assume the outfield positions. Our data suggest that outfield C5/C6 players might have been identified as capable of physically competing with C7 players prior to selection, so impairment issues of diplegia, ataxia and athetoid states does not materialise in match play. C5/6 and C7 players also engaged in HI and VHI activity with similar frequency and attained similar maximal velocities. This could indicate that the severity of neuromuscular impairments were similar between classes even though the type of impairment differs. Additionally, the players selected may show a greater aptitude for ball control and skill elements of the game due to coordinative and range of motion capabilities.

C8 players spent more time above 85% MHR with greater time spent above 85% MHR in the first half. The movement capability of C8 players may be capable of stimulating a greater CV response and thus service the need for oxygen delivery during such activities. C7 and C5/6 may not have been able to challenge the CV system sufficiently with C7 spending more time in the 75% - 85% HR range while C5/6 spent increasingly more time in the lower HR range. The greater neuromuscular impairments of C7 and C5/6 may prevent the repeated attainment of the short HI and VHI activity and as such limit CV response.

The progressive decline in time spent above 85% MHR during a match mirrors the decline in distance covered with the exception of the last quarter where an elevation of time spent above 85% MHR was observed. The local muscular fatigue associated with reduced distance covered is likely to be exacerbated by the limitations of muscle function in spastic, ataxic and athetoid CP. Commonly, CP impairments have been shown to alter gait patterns and display a relative increase in energy expenditure [15].

There is much debate regarding operational definitions of movement activities [10] with inter-study variations commonplace. Walking, jogging, running, striding and sprinting have been used to categorise locomotion [18]. More recently, the terms ‘high intensity’ (HI) and ‘very high intensity’ (VHI) have been introduced [5, 10]. These semantics complicate meta-analyses of multiple study findings in AB literature. The use of absolute [5, 19] thresholds remains the most common method. Recently a study [5] on the English Premier League used defined zones based upon the Prozone® thresholds widely employed by professional clubs, based upon empirical data [20]. We made adjustments to thresholds for HI and VHI activity from ProZone® thresholds for senior AB players to accommodate the impairments of CP players and permit the threshold zones to be sensitive to the participants’ capabilities. We believe the future utility of individualised velocity thresholds in this research paradigm may be of great benefit to gain a clearer insight into player activity levels in all studies of time-motion analysis using GPS devices.

Where we must be cautious in our interpretations is in the consideration of the dynamics of the games and specific modified rules of the CP game. C5/6 players are rarely substituted because one must play at all times and teams often prefer a squad with a second C5/6 as a goalkeeper, while substitutions of C7 and C8 players are more common. The use of substitutes towards the end of a match is likely to lead to increased effort from those players who started the match as competing teams look to equalise or win. However with the 7 a-side nature of the sport, the inclusion of substitutes’ data would dilute the patterns of work rate in the latter stages of the matches and so we decided for this initial study to focus upon whole game data only. Previous work has noted greater high intensity activity by substitutes than starting players in the latter stages of matches and this may cloud patterns emerging from 60

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minutes of competitive match play [8]. Further work that may analyse the contribution of substitutes would add further insight to this area.

CONCLUSION

It is generally accepted in AB football that high intensity activities such as high speed running and sprinting are significant discriminators between levels of play and levels of fitness in soccer [8, 9]. The HI and VHI data for C8 players suggests that they are able to sustain and repeat levels of activity associated with the critical moments of match play. The role of disability classification intends to be selective by type of impairment rather than by performance [3]. However, where inter-classification competition is a component of the sport, impairment differences may influence team performance. The challenge for classification while establishing impairment parity is not to penalise those athletes that through their own endeavours develop themselves into superior athletes [3]. Further investigation into the spectrum of impairment that exists within classes would be beneficial.

In terms of classification criteria, this study may be of use in the final assessment of classification, namely match play observation. Currently, this is a purely qualitative process and to our knowledge has no evidence base to assist in the process. In particular, our study raises questions regarding the severity of impairments within each class and the manner in which C8 dominance can be accounted for. See footnote

The relative differences between classes should therefore inform coaches and sport scientists when preparing their athletes for competitive match play. Our data suggests that it is possible to identify players in the classes C5/6 who can physically match the performances of class C7. Understanding the classes' capacity for work may assist coaches evaluations on relative levels of performance and could better inform the selection of players in line with the rules regarding classification while still employing effective tactics for the team.

The findings in this study are an initial insight into the demands of soccer for athletes with CP and ABI but would benefit from complementary research in the discipline of match analysis. It remains to be seen whether the physiological contrasts seen here are borne out in tactical, technical and strategic aspects of successful match play, but it is rational at this point to suggest that physiological dominance of C8 players is likely to contribute to match play success.

In summary, in aspects of the game where defining moments are seen it seems that C8 players are able to move faster, more often and over greater distances making them the physical dominant force in match play. Conversely, C5/6 are comparable to C7 players in all aspects examined here. The nature of impairments within classes needs further examination if the rules imposed upon class participation in matches are to promote equality in competition.

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403 **Table 1 Participants' characteristics**
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Class	Cohort Size (n)	Age (years (SD))	Body Mass (kg (SD))	Number of observations
C8	7	25 (10)	71.0 (3.3)	10
C7	29	21 (6)	67.8 (9.2)	28
C5/6	4	24 (8)	77.2 (1.6)	9
Combined	40	22 (7)	69 (8.5)	47

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408 **Table 2 Total distances covered per quarter of match play for each class**
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Class	Match Quarters (min)				Whole Match
	0 - 5 [b]	16 - 30 [c]	31 - 45	46 - 60	0 - 60
8 [a]	1748 (130)	1608 (172)	1582 (173)	1434 (248)	6343 (551)
7	1473 (239)	1347 (247)	1351 (235)	1237 (167)	5532 (814)
5/6	1541 (218)	1380 (240)	1410 (130)	1256 (226)	5642 (674)
Combined	1587 (184)	1445 (202)	1448 (185)	1309 (318)	5839 (668)

[a] *different from C7 and C5/6 in each quarter ($p = .011$ and $.027$ respectively)*
[b] *different from 16-30 min, 31-45 min and 46-60 min for all classes ($p \leq .001$)*
[c] *different from 46-60 min for all classes ($p \leq .001$)*

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Table 3 Maximum velocity, frequency, mean distance per activity and percentage of total distance covered of HI and VHI runs for each class

Class	Maximum Velocity (m/s)	HI Activity (4.9 - 6.4 m/s)			VHI Activity (> 6.4 m/s)		
		Frequency	Distance (m)	%	Frequency	Distance (m)	%
8	7.74 (0.34)[a]	35 (8)[b]	12 (2)	6.8 (2.4)	9 (6)[b]	15 (4)	2.2 (1.7)[c]
7	6.97 (0.56)	25 (10)	13 (2)	5.8 (2.2)	4 (3)	12 (4)	0.9 (0.8)
5/6	6.73 (0.44)	23 (11)	13 (2)	5.3 (2.5)	4 (2)	12 (4)	0.8 (0.6)
Combined	7.15 (0.45)	31 (10)	13 (2)	6.0 (2.4)	6 (4)	13 (4)	1.4 (1.0)

[a] *different from C7 and C5/6 ($p = .001$)*
[b] *different from C7 and C5/6 ($p \leq .04$ respectively)*
[c] *different from C7 and C5/6 ($p = .008$ and $p = .003$ respectively)*

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419 **Table 4 Match play maximum and mean HR attained for each class**
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Class	Maximum HR	Mean HR per match quarter			
		0 - 15	16 - 30	31 - 45[a]	46 - 60
8	200 (6)	170 (5)	171 (7)	168 (7)	169 (10)
7	194 (11)	164 (14)	166 (13)	159 (14)	160 (13)
5/6	196 (18)	161 (20)	157 (19)	153 (19)	158 (18)
Combined	197 (12)	165 (13)	165 (13)	160 (13)	162 (14)

[a] *different from ($p \leq .031$)*

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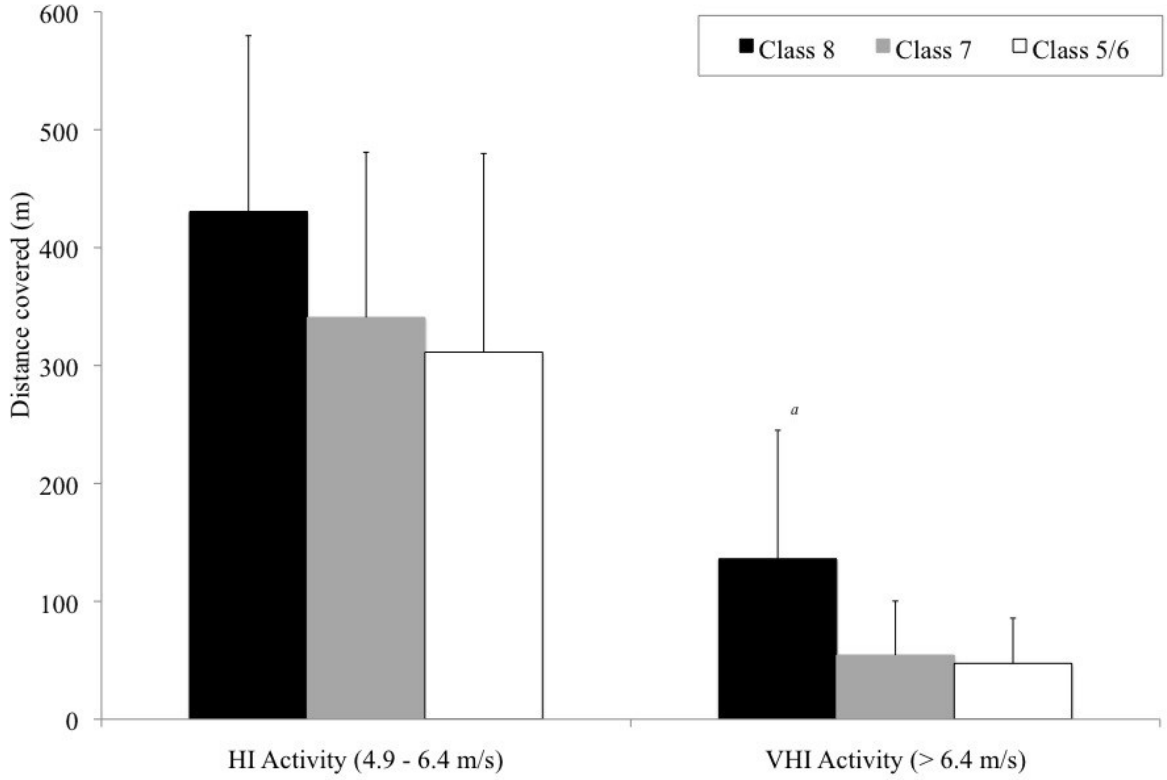

Figure 1 Distances covered at HI and VHI for each class

[a] *C8 different from C7 and C5/6 p ≤ .041*

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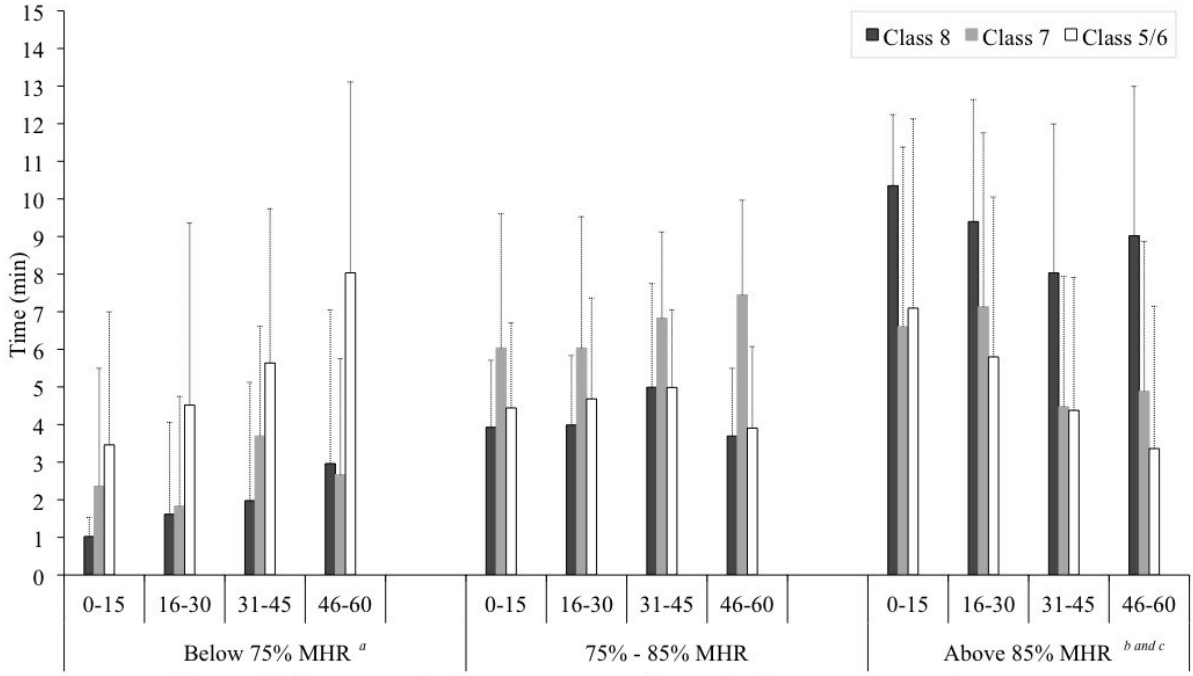

Figure 2 Time spent in heart rate zones for each class across match quarters

[a] 2nd half greater than 1st half p ≤ .015, [b] 1st half greater than 2nd half p ≤ .021, [c] C8 greater than C7 and C5/6 p = .05

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