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1 *Title*

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

3

4 *Original Investigation*

5

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26 ABSTRACT

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

39

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

41

42 INTRODUCTION

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

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

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

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

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

84
85
86

87 METHODS

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

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

97
98 <<<<INSERT TABLE 1: participant characteristics>>>>>>>>>

99
100 *Measurements* - During the eight matches of the 2012 BT Paralympic World Cup
101 (Manchester, UK) all participants wore a body vest fitted global positioning satellite (GPS)
102 10Hz device (MinimaxX S4, Catapult, Australia) and a heart rate monitor (Team System,
103 Polar, Finland) fitted prior to taking part in their respective matches. The GPS device was
104 recently validated for high levels of reliability and low levels of measurement error^{11, 12}.

105 All matches were played in the afternoon on a grass pitch adhering to CPISRA
106 modified rules for 7-a-side football². Data were collected throughout each game and only
107 whole game samples were included for analysis (excluding data collected from players who
108 were replaced by substitutes or who later entered the field of play as a substitute).

109 The calculation of quantified threshold speeds for high intensity activity (HI) and very
110 high intensity activity (VHI) was based upon the adjustment for age of Prozone[®] thresholds⁵
111 for age in youth football¹³. We deemed it necessary to adjust our activity thresholds for
112 players with CP who are incapable of attaining a peak velocity V_{peak} akin to senior elite AB
113 players. Although absolute threshold speeds may have inherent shortcomings, Prozone[®]
114 thresholds are commonly used to determine wearable GPS technology threshold speeds. In
115 order to adjust appropriately, during earlier pilot field-testing we attained flying 20 m sprint
116 times from a cohort of elite players with CP across the spectrum of classes (C5 – C8) (n=39).
117 Subsequently, we were able to establish a mean (SD) V_{peak} of 7.31 (0.14) m/s. Relative to elite
118 AB players (8.3 m/s)¹³ the CP players V_{peak} was 88%. Applying this ratio to the Prozone[®]
119 thresholds of 7.0 m/s and 5.5 m/s, adjustments to the thresholds for HI and VHI were derived
120 for this study. All players within the study were capable of attaining the full range of
121 threshold speeds.

122 The GPS-related parameters recorded included: total distance travelled (m); distance
123 travelled at HI (m), 4.9 – 6.4 m/s and VHI (m), > 6.4 m/s; frequency of HI and VHI activity.
124 Heart Rate (HR) data were collected and reported as mean HR, maximum HR, time spent
125 <75%, between 75 – 85% and > 85% of maximum HR (MHR).

126
127 *Data and Statistical Analysis*- Due to the nature of the competitive match play environment in
128 which the data were collected, we considered the time being added by match officials for
129 stoppages in play. Quarter and whole-match data were converted from the uncorrected values
130 recorded to *pro rata* values to provide data sets for 15-minute quarter- and 60-min whole-
131 match times. This permitted comparisons to be made over equal time periods.

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

135 Geisser alpha level adjustments were applied to account for sphericity violations found in
136 Mauchly's Test. One-way ANOVAs were used to analyse maximum velocity, frequency and
137 distance of HI and VHI activity and maximum heart rate. Alpha was set at 0.05.
138
139

140 RESULTS

141 The total distances covered (Table 2) by players during match play were different between
142 classifications and between match play quarters. C8 players covered 811m more than C7 (p =
143 0.011) and 701m more than C5/6 (p = 0.027). With the exception of the quarter periods either
144 side of half-time, distances covered per quarter were different and declined progressively
145 throughout the matches for all classes in each quarter (p ≤ 0.001). Collectively, the three
146 classes showed a 17.5% decline in distance covered from the first (1587m) to the last quarter
147 (1309m) as a consequence of 60 minutes of match-play. It is notable that C7 players and C5/6
148 players did not cover different distances at any point during match-play.
149

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

151
152 There were no differences between the classes (C8 v C7 v C5/6) for HI activity (Figure 1).
153 However C8 covered more ground at VHI activity than C7 and C5/6 (p ≤ 0.041) while the
154 other two classes did not differ (Figure 1).
155

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

157
158 In Table 3 the percentage contribution of VHI activity to the total distance covered was
159 greater in C8 than C7 (p = 0.008) and C5/6 (p = 0.003). C8 players' VHI activity contributed
160 to 2.2% of the overall distance covered in comparison to a significantly lower contribution for
161 C7 (p = 0.008) and C5/6 (p = 0.003). No differences were observed across the classes for the
162 percentage contribution of HI activity to the total distance covered.
163

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

165
166 C8 players engaged more frequently in HI and VHI activity than C7 and C5/6 (p ≤ 0.04)
167 completing on average 35 HI and 9 VHI activity bouts per game. The distances covered
168 during each HI and VHI activity bout were not different across the classes and so when a
169 player engaged in HI or VHI activity they covered approximately 12-15 m. Once again C5/6
170 players demonstrated an ability to match the performance levels of their C7 counterparts with
171 no differences being observed between these groups. Another discriminating feature between
172 classes was the maximum velocity attained. C8 players attained higher maximal velocities
173 than C7 and C5/6 (p = 0.001) while C7 and C5/6 attained similar maximal velocities. The
174 maximum velocities attained by all players exceeded the threshold values set for HI and VHI
175 activity.
176

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

178
179 No differences were evident across the classes for maximum or mean HR. The mean HR
180 during the 3rd quarter (immediately after half time) was lower than during the other three
181 quarters (p ≤ 0.031, Table 4).
182

183
184 >>>>>>INSERT FIGURE 2<<<<<<<<<<<

185
186 C8 players spent 61% of time during match play above 85% MHR, which was more than both
187 C7 (39%) and C5/6 (31%) (p = 0.05), C7 and C5/6 did not differ (Figure 2). The time spent

* in 2013 CPISRA made changes to the rules and now only one C8 is permitted to play at any given time

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

192

193 DISCUSSION

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

197 We found that C8 players demonstrated an ability to cover more ground at higher
198 intensities that are associated with the critical phases of play in matches¹⁴. Research in elite
199 AB football would suggest that physical performances are strong discriminators of level of
200 play and subsequent success^{8,9} and so we would hypothesise that the performance C8 players
201 is linked to successful team play. With the most minimal impairments, often through post-
202 natal brain trauma or injury, C8 players can often seem uninhibited with near normal gait
203 patterns and mechanical efficiency². The onset of fatigue exacerbates problems with
204 neuromuscular coordination¹⁵ and so a decline in distance covered over the period of the
205 game is not surprising, but our data show that the decline in distance covered from the first
206 quarter to the last was approximately 17.5% in all classes – thus supporting a sustained class
207 distinction throughout a match. HI activity has been observed to decline by 20% in the
208 English Premier League from the 1st to the 2nd half but a decline in total distance covered (is
209 less pronounced than seen in the current study⁵. The relative contribution of VHI activity to
210 total distance was higher in C8 than C7 and C5/6, which suggests that these players make a
211 greater contribution to successful team play.

212 However, our findings did show that C7 and C5/6 players covered similar distances
213 with similar contribution of HI and VHI activity. C7 players tend to present a range of
214 severity of spastic hemiplegia, sometimes with only minor lower limb impairment leading to
215 an asymmetrical gait². When running, asymmetry often disappears and so the impairment
216 seems to have less effect at speed. Our study however, does show that C7 players could not
217 attain the maximal speeds of the C8 players while C5/6, who are commonly affected by
218 diplegic, athetoid or ataxic CP attained similar maximum speeds to their C7 counterparts.
219 This finding suggests the level of impairment associated with C8 is quite distinct from the
220 other classes, while the level of impairment is more comparable between C7 and C5/6.

221 The dominance of C8 players is further evidenced by their maximum velocity attained
222 and frequency of HI and VHI activity, both were greater than the other classes. The ability to
223 sprint, change direction and accelerate quickly over short distances are important movements
224 for key performance indicators (KPIs)¹⁶ such as turnover of possessions, pressing, tackling,
225 intercepting, dribbling and supporting team play. It seems therefore, that the value of the C8
226 class to the team is substantial. Interestingly, the distance travelled per HI and VHI bout did
227 not differ between the classes and so we can infer that direct involvement in specific game
228 activities probably determined the mean distance per bout of HI and VHI. The lower distance
229 covered and the frequency and time spent at VHI in C5-7 maybe indicative of the
230 neuromuscular impairments associated with CP. Muscular weakness has been associated with
231 impaired gross motor function and gait in individuals with CP and it is possible that the
232 weakness associated with spastic CP accounts for the reduced level of VHI activity in the
233 lower classifications¹⁷. Other related factors that may explain the variance could be range of
234 motion and coordination issues. This level of impairment may also explain the ability for C8

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

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

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

254 The progressive decline in time spent above 85% MHR during a match mirrors the
255 decline in distance covered with the exception of the last quarter where an elevation of time
256 spent above 85% MHR was observed. The local muscular fatigue associated with reduced
257 distance covered is likely to be exacerbated by the limitations of muscle function in spastic,
258 ataxic and athetoid CP. Commonly, CP impairments have been shown to alter gait patterns
259 and display a relative increase in energy expenditure¹⁵.

260 There is much debate regarding operational definitions of movement activities¹⁰ with
261 inter-study variations commonplace. Walking, jogging, running, striding and sprinting have
262 been used to categorise locomotion¹⁸. More recently, the terms 'high intensity' (HI) and 'very
263 high intensity' (VHI) have been introduced^{5, 10}. These semantics complicate meta-analyses of
264 multiple study findings in AB literature. The use of absolute^{5, 19} thresholds remains the most
265 common method. Recently a study⁵ on the English Premier League used defined zones based
266 upon the Prozone[®] thresholds widely employed by professional clubs, based upon empirical
267 data²⁰. We made adjustments to thresholds for HI and VHI activity from ProZone[®] thresholds
268 for senior AB players to accommodate the impairments of CP players and permit the
269 threshold zones to be sensitive to the participants' capabilities. We believe the future utility of
270 individualised velocity thresholds in this research paradigm may be of great benefit to gain a
271 clearer insight into player activity levels in all studies of time-motion analysis using GPS
272 devices.

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

283 minutes of competitive match play⁸. Further work that may analyse the contribution of
284 substitutes would add further insight to this area.

285
286 CONCLUSION

287 It is generally accepted in AB football that high intensity activities such as high speed
288 running and sprinting are significant discriminators between levels of play and levels of
289 fitness in soccer^{8,9}. The HI and VHI data for C8 players suggests that they are able to sustain
290 and repeat levels of activity associated with the critical moments of match play. The role of
291 disability classification intends to be selective by type of impairment rather than by
292 performance³. However, where inter-classification competition is a component of the sport,
293 impairment differences may influence team performance. The challenge for classification
294 while establishing impairment parity is not to penalise those athletes that through their own
295 endeavours develop themselves into superior athletes³. Further investigation into the
296 spectrum of impairment that exists within classes would be beneficial.
297 In terms of classification criteria, this study may be of use in the final assessment of
298 classification, namely match play observation. Currently, this is a purely qualitative process
299 and to our knowledge has no evidence base to assist in the process. In particular, our study
300 raises questions regarding the severity of impairments within each class and the manner in
301 which C8 dominance can be accounted for. See footnote

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

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

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

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401
402

403
404**Table 1 Participants' characteristics**

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

405
406
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408
409**Table 2 Total distances covered per quarter of match play for each class**

Class	Match Quarters (min)				Whole Match 0 - 60
	0 - 5 ^b	16 - 30 ^c	31 - 45	46 - 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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420**Table 4 Match play maximum and mean HR attained for each class**

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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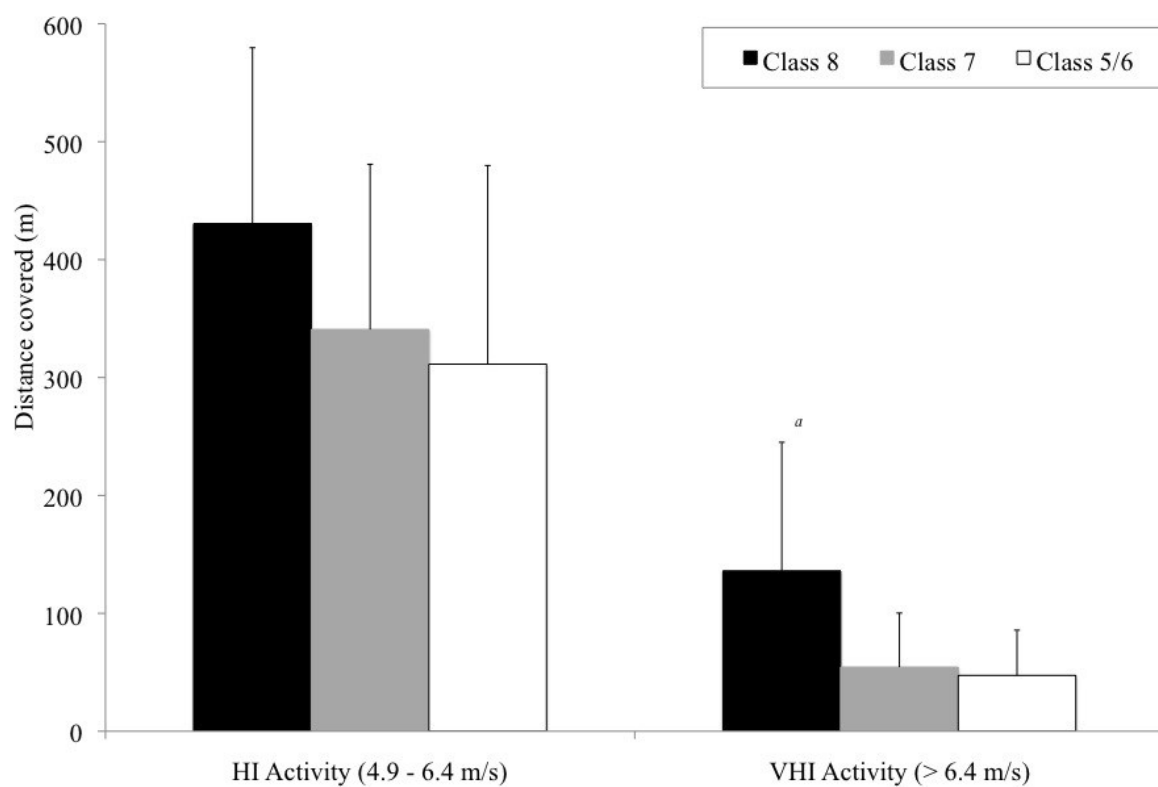


Figure 1 Distances covered at HI and VHI for each class

^a C8 different from C7 and C5/6 $p \leq .041$

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* in 2013 CPISRA made changes to the rules and now only one C8 is permitted to play at any given time

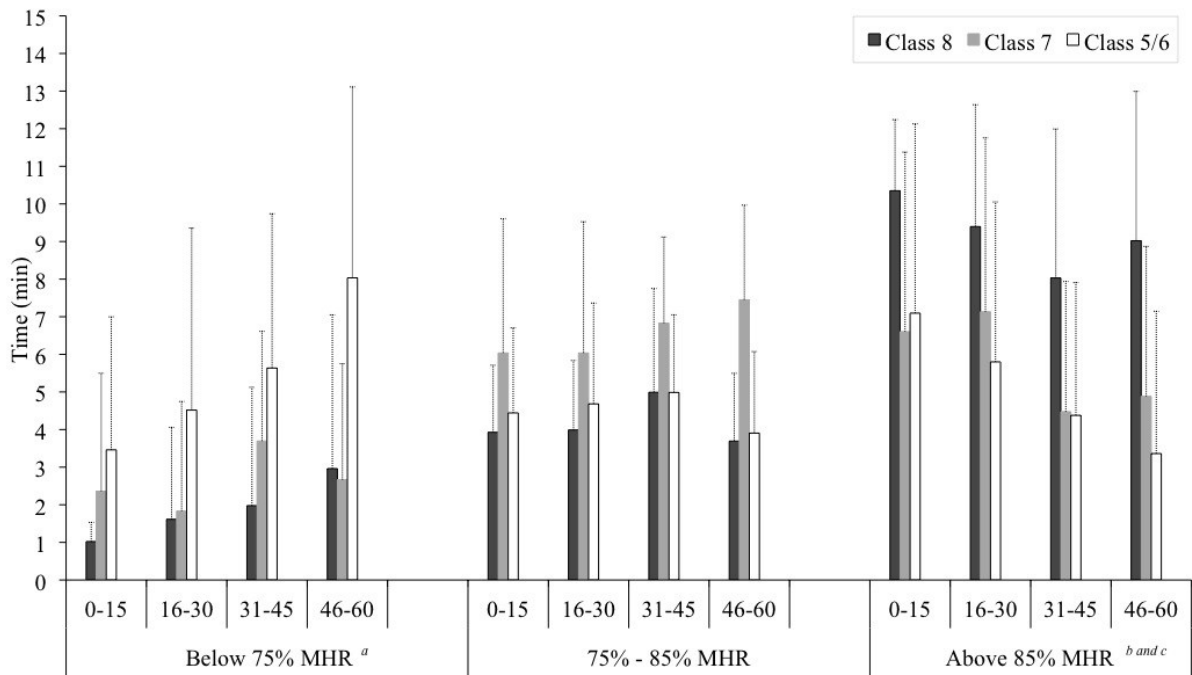


Figure 2 Time spent in heart rate zones for each class across match quarters

^a 2nd half greater than 1st half $p \leq .015$, ^b 1st half greater than 2nd half $p \leq .021$,

^c C8 greater than C7 and C5/6 $p = .05$

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* in 2013 CPISRA made changes to the rules and now only one C8 is permitted to play at any given time