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1 *Title*

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

3

4 *Original Investigation*

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25

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.

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

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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 <sup>1</sup>. 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 <sup>2</sup>.  
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 <sup>3</sup>. 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 <sup>4,5,6</sup>. 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 <sup>6,7</sup>,  
73 as this is widely regarded as a key discriminating factor of playing level and training status <sup>8,9</sup>.  
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 <sup>10</sup>, 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.

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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.  
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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 matches<sup>14</sup>. Research in elite  
199 AB football would suggest that physical performances are strong discriminators of level of  
200 play and subsequent success<sup>8,9</sup> 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 efficiency<sup>2</sup>. The onset of fatigue exacerbates problems with  
204 neuromuscular coordination<sup>15</sup> 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 1<sup>st</sup> to the 2<sup>nd</sup> half but a decline in total distance covered (is  
209 less pronounced than seen in the current study<sup>5</sup>. 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 gait<sup>2</sup>. 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)<sup>16</sup> 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 classifications<sup>17</sup>. 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 expenditure <sup>15</sup>.

260 There is much debate regarding operational definitions of movement activities <sup>10</sup> with  
261 inter-study variations commonplace. Walking, jogging, running, striding and sprinting have  
262 been used to categorise locomotion <sup>18</sup>. More recently, the terms 'high intensity' (HI) and 'very  
263 high intensity' (VHI) have been introduced <sup>5, 10</sup>. These semantics complicate meta-analyses of  
264 multiple study findings in AB literature. The use of absolute <sup>5, 19</sup> thresholds remains the most  
265 common method. Recently a study <sup>5</sup> on the English Premier League used defined zones based  
266 upon the Prozone<sup>®</sup> thresholds widely employed by professional clubs, based upon empirical  
267 data <sup>20</sup>. We made adjustments to thresholds for HI and VHI activity from ProZone<sup>®</sup> 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 play<sup>8</sup>. 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<sup>8,9</sup>. 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 performance<sup>3</sup>. 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 athletes<sup>3</sup>. 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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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

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

Class	Match Quarters (min)				Whole Match 0 - 60
	0 - 5 <sup>b</sup>	16 - 30 <sup>c</sup>	31 - 45	46 - 60	
8 <sup>a</sup>	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)

<sup>a</sup> different from C7 and C5/6 in each quarter ( $p = .011$  and  $.027$  respectively)  
<sup>b</sup> different from 16-30 min, 31-45 min and 46-60 min for all classes ( $p \leq .001$ )  
<sup>c</sup> 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) <sup>a</sup>	35 (8) <sup>b</sup>	12 (2)	6.8 (2.4)	9 (6) <sup>b</sup>	15 (4)	2.2 (1.7) <sup>c</sup>
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)

<sup>a</sup> different from C7 and C5/6 ( $p = .001$ )  
<sup>b</sup> different from C7 and C5/6 ( $p \leq .04$  respectively)  
<sup>c</sup> different from C7 and C5/6 ( $p = .008$  and  $p = .003$  respectively)

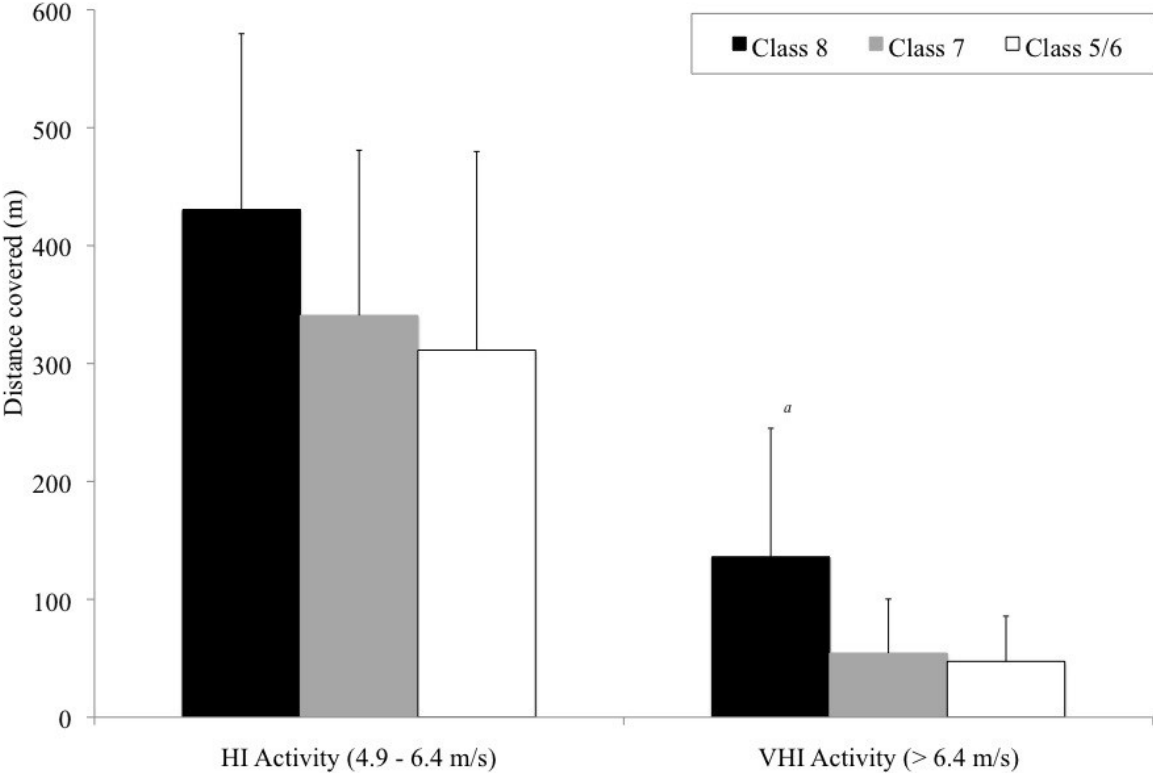
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419  
420**Table 4 Match play maximum and mean HR attained for each class**

Class	Maximum HR	Mean HR per match quarter			
		0 - 15	16 - 30	31 - 45 <sup>a</sup>	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)

<sup>a</sup> different from ( $p \leq .031$ )

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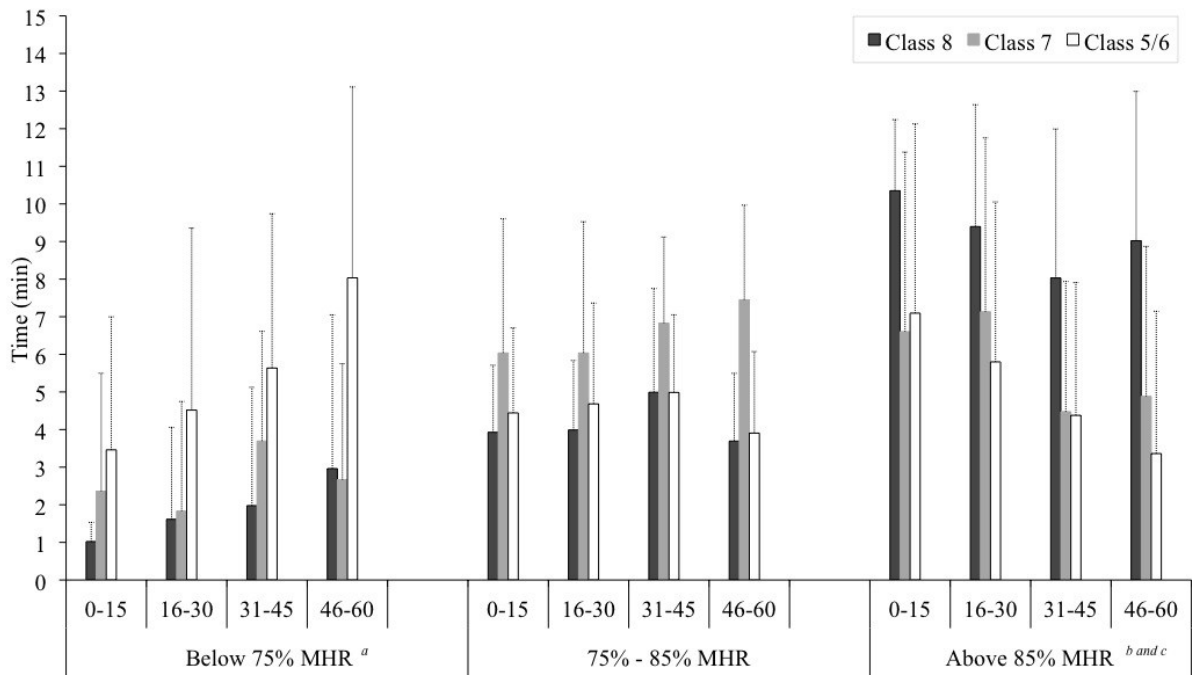
**Figure 1 Distances covered at HI and VHI for each class**

<sup>a</sup> 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**

<sup>a</sup> 2nd half greater than 1st half  $p \leq .015$ , <sup>b</sup> 1st half greater than 2nd half  $p \leq .021$ ,

<sup>c</sup> 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