Title: Activity profiles of elite wheelchair rugby players during competition

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Abstract

Purpose: To quantify the activity profiles of elite wheelchair rugby and establish classification-specific arbitrary speed zones. Additionally, indicators of fatigue during full matches were explored. ***Methods:*** Seventy-five elite wheelchair rugby players from eleven national teams were monitored using a radio-frequency based, indoor tracking system across two international tournaments. Players who participated in complete quarters (n = 75) and full matches (n = 25) were included and grouped by their International Wheelchair Rugby Federation functional classification: group I (0-0.5), II (1.0-1.5), III (2.0-2.5) and IV (3.0-3.5). ***Results:*** During a typical quarter, significant increases in total distance (m), relative distance ($m \cdot min^{-1}$), and mean speed ($m \cdot s^{-1}$) were associated with an increase in classification group (P < 0.001), with the exception of group III and IV. However, group IV players achieved significantly higher peak speeds (3.82 ± 0.31 $m \cdot s^{-1}$) than groups I (2.99 ± 0.28 $m \cdot s^{-1}$), II (3.44 ± 0.26 $m \cdot s^{-1}$) and III (3.67 ± 0.32 $m \cdot s^{-1}$). Groups I and II differed significantly in match intensity during very low/low speed zones and the number of high-intensity activities in comparison with groups III and IV (P < 0.001). Full match analysis revealed that activity profiles did not differ significantly between quarters. ***Conclusions:*** Notable differences in the volume of activity were displayed across the functional classification groups. However, the specific on-court requirements of defensive (I and II) and offensive (III and IV) match roles appeared to influence the intensity of match activities and consequently training prescription should be structured accordingly.

Keywords: movement demands, performance analysis, fatigue, classification, Paralympic

Introduction

Quantifying the activity profiles of elite athletes during competition facilitates the prescription of training programmes specific to the demands of the sport, which can optimise performance and minimise injury risk for individuals.[1] Typically, automatic video tracking techniques and global positioning systems (GPS) have been used to identify activity profiles within able-bodied (AB) team sports.[2-6] Unfortunately, owing largely to technological limitations, an accurate quantification of the activity profiles during indoor sports such as wheelchair rugby (WCR) remains relatively unknown.

A limited number of studies have previously investigated the activity profiles of WCR.[7,8] Sporner et al. [7] revealed that WCR players typically covered 2364 ± 956 m at a mean speed of 1.33 ± 0.25 $m \cdot s^{-1}$ during match-play. Unfortunately, this information was derived using a wheel-mounted data logger, which has been associated with inaccuracies during high speed (> 2.5 m·s^{-1}) movements.[9] Moreover, the analysis was confined to recreational players and was therefore not representative of an elite population. Through the use of image-based processing techniques, Sarro et al.[8] reported that elite WCR players covered greater distances (4540 ± 817 m) at a mean speed of 1.14 ± 0.21 m·s^{-1}. However, as a result of the time consuming analysis procedures involved using this method, the results were restricted to a small sample size (*n* = 8).

Whilst only limited information regarding the volume of activity performed has been addressed in WCR, little is also known about the impact of functional classification on activity profiles. At present, WCR players are classified into one of eight classification groups based on their functional ability, ranging from 0 (least function) to 3.5 (most function). Previous research has shown classification-dependant trends in performance, with higher game-efficiency patterns,[10] and greater total distance and mean speed values (Sarro et al., 2010) associated with higher functional classifications. Moreover, Sarro et al.[8] also suggested that fatigue was more prominent in players with reduced function, due to a greater decrease in distance and mean speed values across match-halves. Despite this, previous research has demonstrated total distance to be a weak indicator of fatigue across competitive match-play in AB sports such as soccer.[11,12] Alternatively, high-intensity activities,[4] relative distance,[13] and peak speeds[5] have been advocated as better indicators of fatigue over time.

To further quantify the intensity of exercise during competition and training, activities have commonly been categorised into pre-determined arbitrary speed zones.[2,11] Arbitrary speed zones facilitate the longitudinal assessment of an athlete's performance over time. However, given that sprint performance has been shown to be dependent on functional classification in WCR,[14,15] the use of arbitrary speed zones for all classification groups is likely to misrepresent match-play intensity. Subsequently, recent studies have improved the specificity by relativizing speed zone design through the use of an individual's peak speed.[16,17] Whilst technological limitations have previously prevented the analysis of such variables in WCR, the recent development and validation of a radio-frequency based indoor tracking system (ITS) has enabled a broader assessment of elite WCR match-play to be possible.[18] Therefore, through the use of the ITS the aims of the current study were to: (1) quantify the demands of WCR between classification groups and to establish arbitrary speed zones specific to each classification; and (2) to explore any changes in activity profiles across full matches to establish indicators of fatigue in WCR.

Methods

Participants

A total of 11 national WCR teams participated in the study with data collected across 21 competitive matches over two international tournaments (2013 European and Americas Zonal Championships). Approval for the study was obtained from the International Wheelchair Rugby Federation (IWRF) and the organising committee of each tournament in addition to the University's local ethical advisory committee. Written informed consent was provided by each player prior to data collection. Data was collected from all consenting teams and players (age = 32 ± 7 years), however data was only presented for players who completed complete quarters (*n* = 75) or full matches (*n* = 25). Players were categorised into four groups according to their IWRF classification, based on previous guidelines.[14,19] The breakdown of data collected from each group is presented in Table 1.

INSERT TABLE 1 HERE

Design

Data was collected during WCR matches using a radio-frequency based ITS (Ubisense, Cambridge, UK). Sensors were located in each of the four corners of the court, with two additional sensors parallel to the halfway line, to maximise court coverage. Each sensor was secured to ceiling beams above the court, at a height of 5-7 m (depending on venue). A calibration procedure outlined by Rhodes et al.[18] was performed at the beginning of each day.

Each player was equipped with a small, lightweight tag (size = 40 x 40 x 10 mm; mass = 25 g) which was fixed to the foot-strap of the wheelchair. Where a foot-strap was not feasible (e.g. lower limb amputees), the tag was securely mounted onto the wheelchair frame as close to the foot-strap region as possible. All players were familiarised with the tags during training sessions prior to the start of the competitions. Tags sampled at 8 Hz, which has previously been confirmed as an acceptable sampling frequency for the collection of movement parameters specific to WCR.[18] Data collection commenced at the beginning of each quarter and terminated at the end of the quarter. Collection was only paused during any periods of extended stoppages (time-outs, equipment calls) throughout each quarter since WCR players also remain active during the stopped game clock.[8] This resulted in a mean collection time of 15.1 (± 1.4) minutes per quarter. Raw data files were exported using software developed specifically for WCR (Nottingham, UK).

Measures

Total distance (m) and relative distance covered ($m \cdot min^{-1}$; relative to time spent on court), mean and peak speed ($m \cdot s^{-1}$) was determined for each player during complete quarters of

WCR. Using an approach similar to Venter et al.[16] and Cahill et al.,[17] five arbitrary speed zones were established specific to each classification. Using the 'mean' peak speed (Vmax) of each classification group the following five speed zones, relative to Vmax were calculated: very low (≤ 20% Vmax), low (21-50% Vmax), moderate (51-80% Vmax), high (81-95% Vmax), and very high (> 95% Vmax). The time spent in each of the arbitrary speed zones was calculated for each classification. Analyses of high-intensity (HI) activities (high and very high speed zones) were extended to include the total number of HI activities performed and both the mean and maximum duration and distance of these activities.

To assess the influence of fatigue on activity profiles across full matches of WCR, total distance (m), relative distance ($m \cdot min^{-1}$), mean speed, peak speed ($m \cdot s^{-1}$), and HI activities were explored. Only full match datasets (all 4 quarters completed by an individual) were analysed, with movement variables compared between quarters and halves.

Statistical Analyses

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS version 21, Chicago, IL). Descriptive statistics (mean ± standard deviation [SD]) were calculated for each participant for all movement variables. Normality and homogeneity of variance was confirmed by Shapiro-Wilk's and Levene's tests respectively. Since players differed in the number of repeated quarters they participated in and the varying sample sizes between classification groups, mixed linear modelling was applied to account for the unbalanced design.[20] Interactions between classification and quarter were also analysed using the full match datasets. Main effects and interactions were accepted as statistically significant whereby $P \leq 0.05$. Pairwise comparisons were utilised to explore any significant main effects between classification groups (I, II, III and IV), with a Bonferroni-corrected alpha level used to account for multiple contrasts ($P = 0.008$). Effect sizes (ES), estimated from the ratio of the mean difference to the pooled standard deviation were also calculated. The magnitude of the effect size was classed as trivial (< 0.2), small (≥ 0.2-0.6), moderate (≥ 0.6-1.2), large (≥ 1.2-2.0), and very large (≥ 2.0) based on previous guidelines.[21]

Results

Activity profiles during complete quarters of wheelchair rugby

Functional classification significantly influenced the total distance, relative distance, mean speed and peak speed achieved during complete quarters of WCR ($P < 0.001$). As demonstrated in Table 2, significant increases in total distance, relative distance and mean speed were revealed with an increase in functional classification, except for groups III and IV ($P \geq 0.704$; ES ≤ 0.1). Alternatively, peak speed was significantly higher as classification increased across all groups (Table 2).

INSERT TABLE 2 HERE

Arbitrary speed zones. The 'mean' peak speed values displayed (Table 2) established arbitrary speed zones specific to each classification group (Table 3). In general, WCR players spent 31% of a typical quarter in the very low speed zone, with the majority of time spent in the low speed zone (47%). The moderate speed zone accounted for 20% of the quarter duration, with 1.5% and 0.5% spent in the high and very high zones respectively. As illustrated in Figure 1, classification had no significant effect on the times spent in the moderate ($P = 0.099$), high ($P = 0.081$) and very high ($P = 0.636$) speed zones. However the time spent in the very low and low speed zones was influenced by classification ($P < 0.001$). Groups I and II spent a significantly greater time in the very low speed zone than groups III and IV ($P < 0.001$; ES = 0.7 - 1.1). Alternatively, groups III and IV spent a significantly greater time in the low speed zone, compared to groups I and II ($P < 0.001$; ES = 0.8 - 1.4).

INSERT TABLE 3 HERE

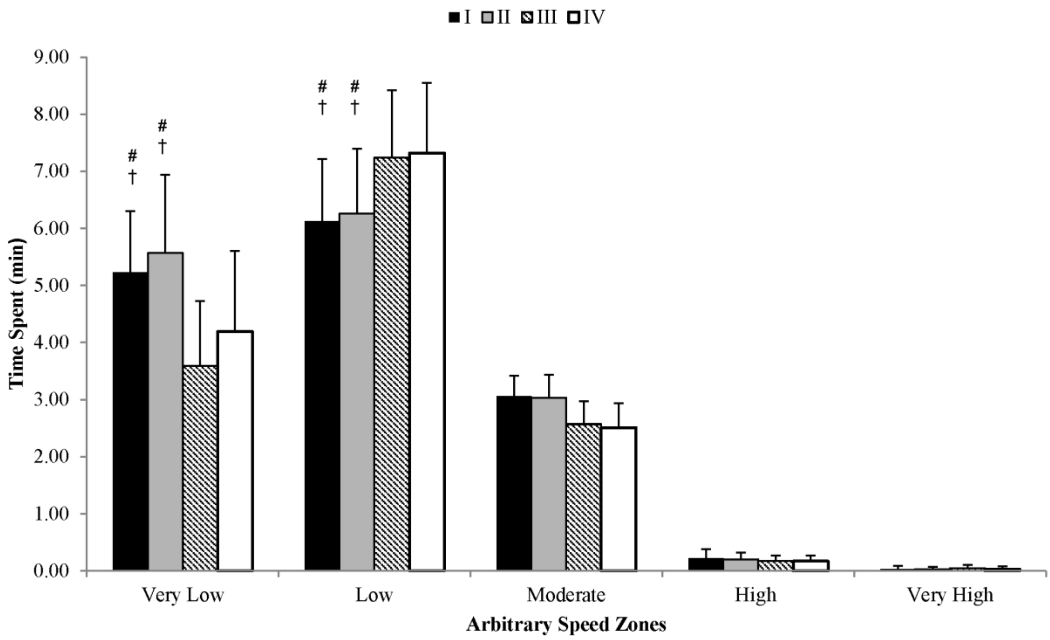

Figure 1 – Time spent (min) within five arbitrary speed zones between classification groups during a typical WCR quarter. #Significantly different to group III. †Significantly different to group IV. Data presented as means ± SD.

High-intensity activities. The number of HI activities differed between classifications (P = 0.005). As highlighted in Table 4, group I performed more HI activities than groups III (P = 0.005; ES = 0.6) and IV (P = 0.004; ES = 0.6). Classification had no significant effect on the mean (P = 0.347) and maximum (P = 0.629) duration of HI activities. However a significant main effect for the mean (P < 0.001) and maximum (P = 0.031) distance of each HI activity was revealed. The mean distance of each HI activity was significantly greater for groups III and IV compared to I and II (Table 4). Despite this, pairwise comparisons failed to reach statistical significance between all classification groups for maximum distance ($P \geq 0.009$; ES ≤ 0.5).

INSERT TABLE 4 HERE

Activity profiles during full matches of wheelchair rugby

Total distance ($P \geq 0.827$), relative distance ($P \geq 0.963$), mean speed ($P \geq 0.946$) and peak speed ($P \geq 0.944$) did not differ across quarters or halves (Figure 2). No significant changes in the number ($P \geq 0.964$), mean duration ($P \geq 0.990$) maximum duration ($P \geq 0.641$), mean distance ($P \geq 0.998$) or maximum distance ($P \geq 0.592$) of HI activities performed were identified across quarters and halves. Moreover, no interactions existed for any movement parameter between classification group and quarters and match-half ($P \geq 0.545$).

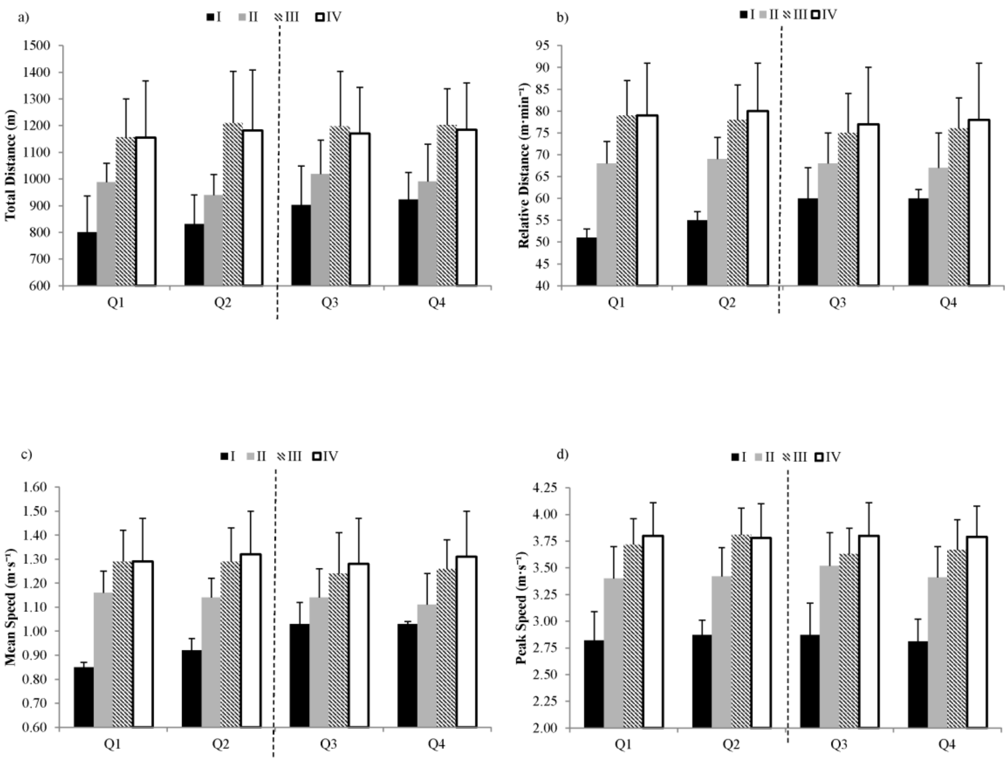

Figure 2 – Total distance (a), relative distance (b), mean speed (c) and peak speed (d) values of each classification group during each of the four quarters in full matches of WCR. Data presented as means ± SD.

Discussion

The results of the current study revealed that functional classification is closely associated with the volume of activity elicited over typical quarters of WCR match-play. In addition, the ability to perform greater peak speeds increased with functional classification. Whilst the current study was the first to establish arbitrary speed zones for WCR, results revealed that match-play intensity was also influenced by functional classification, particularly during low speeds, which has practical implications on classification-specific training prescription. Furthermore, comparison of activity profiles across full WCR matches indicated no deterioration of physical performance was evident, regardless of functional classification.

The present study demonstrated that total distance, relative distance and mean speed values increased in association with higher functional classification across a typical quarter, yet no significant difference between classification groups III (2.0-2.5) and IV (3.0-3.5) was observed. Such findings are consistent with previous WCR match-play research, in which game efficiency patterns did not significantly differ between these classification groups.[19] Practical implications of these findings may impact upon team selection, in which group III players (2.0-2.5) do not seemingly restrict the functional ability of the team, whilst subsequently reducing the total on-court classification points (8.0 points permitted at any one time). This could partially explain why the present study observed a wider number of participants within group III (*n* = 28) than in group IV (*n* = 13). Despite this, sprint performance differed across all classification groups, with group IV capable of reaching significantly higher peak speeds (3.82 ± 0.31 $m \cdot s^{-1}$) than groups I (2.99 ± 0.28 $m \cdot s^{-1}$), II (3.44 ± 0.26 $m \cdot s^{-1}$), and III (3.67 ± 0.32 $m \cdot s^{-1}$). This could, however, be attributed to the superior trunk function associated with higher classification groups.[22] While the ability to apply force to the hand-rim is a prerequisite for successful sprint performance, trunk function has previously been established as an important determinant of hand-rim force.[22,23] Subsequently, improved trunk function was likely to attribute to an increase in applied hand-rim force and, as such, greater peak speeds can be expected in higher functional players.[23] Nevertheless, the volume of activity along with the peak speeds performed during WCR match-play advocates the need for classification-specific training drills.

Given that peak speeds are influenced by functional classification, the use of arbitrary speed zones for all classification groups was likely to misrepresent individual intensity profiles. Thus, the creation of arbitrary zones specific to each classification group was an important outcome of the current study. Accordingly, the data suggested that elite WCR match-play is typically played at low speeds, with at least 75% of a typical quarter spent within the very low and low speed zones (≤ 50% Vmax) regardless of functional classification. Specifically, groups I and II spent a significantly greater amount of time within the very low zone compared to groups III and IV. Such a finding may be attributed to the varying on-court roles, in which groups I and II (0-1.5) have previously been identified as low point players who predominantly occupy defensive roles, whereas groups III and IV (2.0-3.5) have been identified as high point players occupying offensive roles.[24,25] These on-court roles require low point players to 'pick' the opposition (block and trap opponents), which may account for the longer durations of static/very low speed activity. Alternatively, groups III and IV (2.0-3.5) spent significantly more time within the low speed zone, equating to 54% and 52% of the total quarter duration respectively, as opposed to groups I (39%) and II (41%). These findings indicate the contrasting intermittent match intensities between low and high point players, suggesting the need for role specific training drills.

The present data also indicated that HI activities were influenced by on-court roles during a typical WCR quarter. The significantly greater number of HI activities exhibited by low point (I & II) compared to high point players (III & IV) indicate that this is a key requirement for the defensive on-court role. The rationale for such a finding may be attributed to the fact that low point players do not possess the physical function of high point players,[26] and therefore must perform high intensity activities more frequently to compete with more functionally able opponents. Furthermore, typical HI durations of 1.7 to 1.9 seconds were observed, with no significant differences across classification groups. This could be partly attributed to opposing players and court dimensions, preventing the capacity to generate prolonged durations of HI activities. Despite this, the higher speeds attained by high point players are likely to have attributed to the significant differences found in the mean distance of HI activities. Nevertheless, these findings further emphasize that on-court roles seem to dictate the intensity of activity profiles in WCR, highlighting the necessity for role specific training drills, in addition to classification-specific drills required for the volume of activity.

As part of the largest study to monitor activity profiles across full WCR matches, our results revealed elite WCR players covered approximately 4213 ± 626 m at a mean speed of

1.17 ± 0.14 $m \cdot s^{-1}$. These results were in accordance with the total distance (4540 ± 817 m) and mean speed values (1.14 ± 0.21 $m \cdot s^{-1}$) previously reported by Sarro et al.[8] However, in contrast to Sarro et al.,[8] the present study revealed that activity profiles did not seem to deviate significantly across full WCR matches, suggesting match-play activity was not influenced by fatigue. Sarro et al.[8] further suggested that this decline was greater within low point players (distance - 9.9%; mean speed - 19.1%) than high point players (distance - 4.2%; mean speed – 10.1%). This would appear to suggest that WCR players now display far superior physical capabilities than the previous data from match-play collected in 2008.[8] Indeed, the advancement of sport science support and the development of conditioning strategies may partly explain these contrasting findings. The continuous roll-on substitutions in WCR may also attribute to these results, whereby if activity was perceived to be deteriorating then the likelihood is they would be substituted. Despite this, future analysis of game efficiency (e.g. ball-handling skills) across full matches may further contribute to the current understandings of fatigue during WCR match-play.

Practical Applications

In order to facilitate the development of WCR training programmes a better understanding of the match-play demands are required to improve the key training principles; specificity and individualisation of training. The current findings suggest that training programmes should be classification specific when related to activity volume, and designed to elicit the levels of aerobic demands sufficient to cope with match distances of up to ~4,600 m, combined with the anaerobic demands required for ~38 high-intensity bouts per match. Such programmes should also be extended to accommodate the various intensities attributed to the specific on-court roles of low (0-1.5) and high point players (2.0-3.5).

As identified in previous work, the ability to accelerate from a standstill is a key indicator of performance in WCR.[27,28] Yet owing to the sensitivity of the ITS when sampling at 8 Hz, a limitation of the current study was the inability to accurately measure acceleration values. Further work utilising the ITS alongside accelerometry technology may provide a more in-depth insight into the activity profiles during WCR match-play. However, as acceleration values over the first two pushes have previously been shown to range between 1.69 and 1.81 $m \cdot s^{-2}$ in elite WCR athletes,[24] such values would not have registered as HI activities within the present study, and as a consequent the true HI activities seen during match-play may be underestimated. Whilst the dynamic nature of WCR match-play has been explored in the present study, it is recommended that future research investigates the effect of situational variables (e.g. team rank, match outcome) on WCR activity profiles as seen in AB sports[2,3,29] to establish which measures of performance are associated with successful performance.

Conclusions

The present investigation demonstrated notable differences in the volume of activity profiles across functional classification during elite WCR match-play. Additionally, the use of individualised peak speeds in determining arbitrary speed zones provided new insights into the classification-specific differences in match-play intensity. However, these differences were exacerbated between groups I and II (0-1.5) compared with groups III and IV (2.0-3.5). Such differences can be attributed to the varying on-court roles of defensive (I and II) and offensive (III and IV) players. Furthermore, as opposed to previous reports, the match-play activities monitored in the current study were not shown to be associated with a physical decline across full WCR matches. The current results highlight the importance of both classification and role-specific training drills in WCR.

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Table 1. A breakdown of classification profiles, datasets and sample size.

Group	IWRF Classification	Full Quarters	Participants (*n*)	Full Matches	Participants (*n*)
I	0-0.5	38	12	2	2
II	1.0-1.5	138	22	12	9
III	2.0-2.5	122	28	9	8
IV	3.0-3.5	108	13	12	6
	Total	**406**	**75**	**35**	**25**

Table 2. Descriptive statistics (mean ± SD) for movement variables during a typical WCR quarter

	I (n = 38)		**II** (n = 138)		**III** (n = 122)		**IV** (n = 108)	
Variables	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Total distance (m)	881*#†	137	1011#†	142	1155	196	1153	172
Relative distance ($m \cdot min^{-1}$)	59.9*#†	6.5	69.7#†	8.4	77.1	7.4	78.4	10.1
Mean speed ($m \cdot s^{-1}$)	1.01*#†	0.11	1.15#†	0.13	1.27	0.13	1.29	0.16
Peak speed ($m \cdot s^{-1}$)	2.99*#†	0.28	3.44#†	0.26	3.67†	0.32	3.82	0.31

Note: n = number of datasets per classification group. *Significant to group II (P < 0.05); #Significant to group III (P < 0.05); †Significant to group IV (P < 0.05).

Table 3. Arbitrary speed zones ($m \cdot s^{-1}$) as proposed for use within WCR

Zones		**I** (*n* = 38)	**II** (*n* = 138)	**III** (*n* = 122)	**IV** (*n* = 108)
Very low	*≤ 20% Vmax*	≤ 0.60	≤ 0.69	≤ 0.73	≤ 0.76
Low	*21-50% Vmax*	0.61-1.50	0.70-1.72	0.74-1.84	0.77-1.91
Moderate	*51-80% Vmax*	1.51-2.39	1.73-2.75	1.85-2.94	1.92-3.06
High	*81-95% Vmax*	2.40-2.84	2.76-3.27	2.95-3.49	3.07-3.63
Very High	*> 95% Vmax*	> 2.84	> 3.27	> 3.49	> 3.63

Table 4. Descriptive statistics (mean ± SD) for HI activities performed during a typical WCR quarter

	I (*n* = 38)		**II** (*n* = 138)		**III** (*n* = 122)		**IV** (*n* = 108)	
HI activities	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Number	13[#†]	7	11	6	9	5	9	6
Mean duration (s)	1.7	0.8	1.7	0.7	1.8	0.8	1.9	0.8
Max duration (s)	4.3	1.9	4.2	1.9	4.4	2.3	4.0	1.8
Mean distance (m)	4.7[#†]	2.3	5.4[#†]	2.1	6.3	2.6	6.4	2.8
Max distance (m)	11.7	5.2	13.5	6.2	15.4	8.4	14.8	6.6

Note: *n* = number of datasets per classification group. [#]Significant to group III ($P < 0.05$); †Significant to group IV ($P < 0.05$).