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CASE REPORT

The intensity and match load comparison between high spinal cord injury and non-spinal cord injury wheelchair basketball players: a case report

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INTRODUCTION: This is a comparative case study between one high spinal cord injury (SCI) and two non-SCI players during an official wheelchair basketball (WB) match. The aim of the study was to calculate the differences in the absolute and relative HR responses and in the match load among one SCI and two non-SCI players in the same WB match.
CASE PRESENTATION: The study was conducted with first-division WB players in Vitoria-Gasteiz, Spain (2014). All of the participants had played the whole official WB match. Absolute heart rate (HR) in the test (10 m Yo-Yo Intermittent Recovery Test Level 1, YYIR1 10 m) as well as absolute and relative HR and match load (ML) were recorded for these three players in an official WB match.
DISCUSSION: The HRpeak and mean during the YYIR1 10 m test and the whole WB match were lower for the SCI player than the non-SCI players. However, as opposed to absolute HR values, relative HR values and ML reported very similar responses among SCI and non-SCI values. Moreover, in the high-intensity HR zone the values were similar among the three players but not in the low ($<$75% of HRpeak), moderate (75–85% of HRpeak) and maximal ($>$95% of HRpeak) HR zones. Although the absolute HR values were lower for the SCI player, the relative values and the ML were similar for all the players. Therefore, it could be necessary to use relative HR values to quantify the intensity of efforts in the WB matches.

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INTRODUCTION

Heart rate (HR) is normally determined by the pacemaker activity of the sinoatrial (SA) node located in the posterior wall of the right atrium.[1] HR can decrease or increase the intrinsic rate primarily by activation of the vagus or sympathetic nerve innervating the SA node.[1] In individuals with high spinal cord injury (SCI), the autonomic innervation of the heart is impaired, resulting in lowered maximal HR (HRmax).[2,3] Moreover, the increase in HR during exercise in these persons is mostly due to withdrawal of vagal parasympathetic stimulation.[4] The parasympathetic stimulation may, as a consequence of the disturbed sympathetic innervation, give rise to autonomic dysreflexia in individuals with high SCI.[4] In conjunction with factors such as reduced sympathetic nervous system, innervation and cardiovascular function, maximal exercise capacity is reduced when compared with able-bodied individuals.[5]

With the aim of analyzing the utility of the HR in high SCI players, some studies reported HR responses in laboratory environments along with oxygen consumption[4] and rating of perceived exertion methods (RPE).[6] In this sense, Valent *et al*[4] reported that the HR–VO_2 relationship appeared linear in only eight out of 18 high SCI participants, so that these authors question the use of HR monitors in this population when prescribing training intensity. Moreover, Lewis *et al*[6] observed an absence of associations among HR, VO_2 and RPE in motor complete SCI. However, all these studies have been realized in laboratory environments. Despite the results reported in this area, with the increasing professionalism of Paralympic sport, one of the main tools to measure the objective internal load are HR monitors in WB[7–9] where some participants are high SCI players. Probably, if only the absolute HR values are taken into account, the difference between high SCI and non-SCI players would be high due to the reasons previously described. However, the proposal made by some authors[10,11] to calculate the training load (TL) or match load (ML) based on the relative intensities of maximum HR could provide better information.

Therefore, the aim of this study was to describe the absolute and relative HR responses and match load of a complete high SCI player during a wheelchair basketball (WB) match. The second aim of the study was to calculate the differences in the absolute and relative HR responses and in the match load among this player and two non-SCI players in the same WB match.

METHODS

Participants

Three Spanish first-division male WB players volunteered to participate in the study (Table 1). All of the participants were the only ones who played the whole official WB match. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF). This study was approved by the institutional Research Ethics Committee for Human Research (CEISH) of the University of the Basque Country (UPV/EHU). All participants provided written informed consent as outlined in the Declaration of Helsinki (2013).

Procedures

To obtain individual peak HR (HRpeak), a 10 m Yo-Yo Intermittent Recovery Test Level 1 (YYIR1 10 m) as described by Iturricastillo

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Table 1. Wheelchair basketball player's characteristics

Player	*Injury type*	*IWBF Classification*	*Age (years)*	*Injury time (years)*	*Training experience (years)*
SCI-1	SCI (T1-T2 complete)	1	36	34	20
Non-SCI-1	Osteoartritis congenital	4	40	40	21
Non-SCI-2	Double below-knee amputation	4	35	28	15

Abbreviations: IWBF, International wheelchair basketball federation; SCI, spinal cord injury; Non-SCI-1, player 1 with Non-spinal cord injury; player 2 with Non-spinal cord injury.

Table 2. The absolute heart rate (HR) responses during the 10 m Yo-Yo Intermittent Recovery Test Level 1 (YYIR1 10 m) and match

Players	*HRpeak in YYIR1 10 m (beat·per min)*	*Δ% (CV) with respect to SCI-1*	*HRpeak in the match (beat·per min)*	*Δ% (CV) with respect to SCI-1*	*HRmean in the match (beat·per min)*	*Δ% (CV) with respect to SCI-1*
SCI-1	154	—	159	—	141	—
Non-SCI-1	182	18.2 (11.8)	180	13.2 (8.8)	151	7.1 (4.9)
Non-SCI-2	193	25.3 (15.9)	195	22.6 (14.4)	163	15.6 (10.3)
Total	176.3 ± 20.1	—	178.0 ± 18.1	—	151.7 ± 11.0	—

Abbreviations: CV, coefficient of variation; HRmean,mean heart rate; HRpeak, peak heart rate; Non-SCI, non spinal cord injury; SCI, spinal cord injury; Δ%, percentage of change.

et al[11] was completed 1 week before the official match. This endurance test has been verified using WB players and has shown good reproducibility (ICC = 0.83–0.94).[12] The players were familiar with this test as it had been part of their usual fitness-assessment programme. During the test, HR was continuously monitored at 1 s intervals by telemetry (Polar Team Sport System, Polar Electro Oy, Kempele, Finland). One week after completing the YYIR1 10 m test, players performed in one official match. Moreover, during the match, the HR also was continuously monitored at 1 s intervals by telemetry. The total duration of the match was 92 min. The highest HRpeak value from the YYIR1 was at 10 m, or the match was used to determine the ML and HR zones 'see below'.

Determination of match load (ML). The match internal load of the player was evaluated by means of objective methods as previously used in WB.[11] The objective methods included absolute (that is, HRmean, HRpeak) and relative HR (%HRmean and %HRpeak of the HRpeak), and the calculation of Edwards' ML[13] and Stagno's ($TRIMP_{MOD}$ ML) ML[14] summarized HR zones. The weighting factor is different for Edwards' (90–100% HRpeak = 5, 80–90% HRpeak = 4, 70–80% HRpeak = 3, 60–70% HRpeak = 2, 50–60% HRpeak = 1) and $TRIMP_{MOD}$ (93–100% HRpeak = 5.16, 86–92% HRpeak = 3.61, 79–85% HRpeak = 2.54, 72–78% HRpeak = 1.71, 65–71% HRpeak = 1.25). Both methods provide the summation of the results to obtain the ML value (in arbitrary units, AU) and these AU were set for statistical analysis.

Determination of the percentage of time spent in each HR zone. Four HR zones were established, and the time and the percentage of time spent in each zone during the match were calculated. The HR zones were defined as low (< 75% of HRpeak), moderate (75–85% of HRpeak), high (85–95% of HRpeak) and maximal (> 95% of HRpeak), according to previously established criteria in basketball[15,16] and in WB players.[8]

Statistical analysis

The total values are means ± s.d. The delta value (Δ%) between SCI-1 and non-SCI players was calculated using the formula: Δ% = ((non-SCI-1 or non-SCI-2 − SCI-1)/SCI-1) × 100. The coefficient of variation (CV): [(s.d./mean) × 100] was used[17] to assess the total HR responses values among the SCI and non-SCI players.

RESULTS

The absolute HR responses of the YYIR1 10 m and the match load are presented in Table 2. The SCI player obtained lower absolute HRpeak responses in YYIR1 10 m than the non-SCI players (Δ% = 18.2–25.3%; CV = 11.8–15.9%). The differences in the absolute HRpeak reached during the match between SCI and non-SCI players (Δ% = 13.2–22.6; CV = 8.8–14.4%) were similar to those in YYIR1 10 m. Similarly, the differences also were observed in match absolute HRmean between SCI and non-SCI players (Δ% = 7.1–15.6%; CV = 4.9–10.3%).

The %HRmean and %HRpeak as well as the ML are presented in Table 3. As opposed to absolute HR values, relative HR values reported very similar responses among SCI and non-SCI values (Δ% = − 6.0 to − 6.4%; CV = 4.4 to 4.7%).

The time and the percentage of the total time spent in each HR zone are presented in Table 4. These relative HR values were similar in low, moderate and high zones between SCI-1 and non-SCI-1 players (Δ% = − 5.3 to 8.9%; CV = 1.6 to 6.1%) and quite similar in the maximal zone (Δ% = − 13.3%; CV = 10.7%). However, the differences between SCI-1 and non-SCI-2 were considerably different in the low, moderate and maximal intensities (Δ% > − 18.3%; CV > 14.5%), while in the high intensity zone, the values were similar (Δ% = − 8.9%; CV = 6.1%).

DISCUSSION

Previous studies determined the questionable use of HR monitoring for exercise intensity quantification in persons with a high-level SCI,[4,6] as these players could have an altered HR response. However, in the last years various studies have used HR methods to quantify physiological responses or the ML in WB matches,[7,8] both for SCI and for non-SCI players. Identifying the absolute and relative HR responses in WB players could help coaches and physical trainers to understand how the level of injury may condition the physiological responses of the high SCI players. In this sense, the aim of this study was to describe the absolute and relative HR responses and the ML of a complete SCI player (T1–T2) during a WB match in order to compare with two non-SCI players.

The results of our study reported that, in absolute values the HRpeak and HRmean was lower in the SCI player than in the non-SCI players, both in YYIR1 and in the match. These results were in line with those of other.[2,3] It is well determined that the impairment of the high SCI player could affect the HR responses

Table 3. The relative match heart rate (HR) responses and match load (ML)

Players	*%HRmean*	*Δ% (CV) with respect to SCI-1*	*%HRpeak*	*Δ% (CV) with respect to SCI-1*	*Edwards ML (AU)*	*Δ% (CV) with respect to SCI-1*	*$TRIMP_{MOD}$ ML (AU)*	*Δ% (CV) with respect to SCI-1*
SCI-1	88.7	—	103.3	—	340.2	—	249.6	—
Non-SCI-1	83.0	−6.4 (4.7)	99.0	−4.3 (3.1)	349.7	2.8 (1.9)	257.5	3.1 (2.2)
Non-SCI-2	83.4	−6.0 (4.4)	101.0	−2.2 (1.6)	326.9	−4.1 (2.8)	241.1	−3.5 (2.4)
Total	85.0 ± 3.2	—	101.1 ± 2.2	—	338.9 ± 11.5	—	249.4 ± 8.2	—

Abbreviations: AU, arbitrary unit; CV, coefficient of variation; Edwards ML, Edwards match load; %HRmean, percentage of heart rate mean; %HRpeak, percentage of heart rate peak; Non-SCI, non spinal cord injury; SCI, spinal cord injury; $TRIMP_{MOD}$, stagno modified match load; Δ%, percentage of change.

Table 4. The time and the percentage of the total time (%) spent in different heart rate (HR) zones during wheelchair basketball matches

Player	*Time at < 75% of HRpeak (%)*	*Δ% (CV) with respect to SCI-1*	*Time at 75–85% of HRpeak (%)*	*Δ% (CV) with respect to SCI-1*	*Time at 85–95% of HRpeak (%)*	*Δ% (CV) with respect to SCI-1*	*Time at > 95% of HRpeak (%)*	*Δ% (CV) with respect to SCI-1*
SCI-1	24.5 (22.5)	—	38.2 (35.1)	—	31.5 (29.0)	—	6.0 (5.5)	—
Non-SCI-1	23.2 (21.3)	−5.3 (3.8)	37.3 (34.3)	−2.4 (1.6)	34.3 (31.6)	8.9 (6.1)	5.2 (4.8)	−13.3 (10.7)
Non-SCI-2	30.4 (28.0)	24.1 (15.3)	30.3 (27.9)	−20.7 (16.3)	34.3 (31.6)	8.9 (6.1)	4.9 (4.5)	−18.3 (14.5)
Total	26.0 ± 3.8	—	35.4 ± 4.3	—	33.4 ± 1.6	—	5.4 ± 0.6	—

Abbreviations: CV, coefficient of variation; HRpeak, peak heart rate; SCI, spinal cord injury; Non-SCI, non spinal cord injury; Δ%, percentage of change.

due to an impairment in the autonomic innervation of the heart, preventing the high SCI players achieving the theoretical maximum or peak HR values,[4] as it happened with the high SCI player. However, although the absolute HR could be different between high SCI and non-SCI players, in our study, the high SCI player could have obtained very similar relative HR (%HRmean and %HRpeak) and ML (Edwards' ML and $TRIMP_{MOD}$) values compared with non-SCI players in the official WB match. The impairment in the autonomic innervation of the heart could lead not to reach the peak HR, however, in this case, this impairment did not affect the relative HR values. This aspect shows that for the quantification of ML in WB might be necessary to relativize the data, as absolute HR values could distort the results.

Regarding the intensity zones, the results showed that the differences between SCI-1 and non-SCI-1 were distinct from the difference between SCI-1 and non-SCI-2 in the low, moderate and maximal intensities. The time and the percentage of the time spent in the high-intensity zone (85–95%) were similar in all the players. Therefore, when relativizing the HR, the differences in each intensity zone may not be due to the impairment but the game characteristics, the tactical and strategic aspects or the position in the court of the players.[15]

CONCLUSIONS

The authors are conscious that this study is a case report. Nevertheless, it could be that high SCI players even with a lowered maximum HR obtain very similar relative HR and ML values compared with non-SCI players in the same match. It is obvious that more studies should carry on in this line to verify if high SCI players have the same or similar relative HR responses than non-SCI players for the same training sessions, training tasks or matches in WB. However, although the level of spinal lesion determines the level of physiological system impairment, it seems that relative HR values may be very similar to non-SCI players. Thus, the same methods of quantifying relative HR responses and ML might be used for high SCI players and non-SCI players.

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COMPETING INTERESTS

The authors declare no conflict of interest.

REFERENCES

1 Klabunde RE. *Cardiovascular Physiology Concepts*. (Lippincott Williams & Wilkins, Philadelphia, PA, USA, 2011).
2 Goosey-Tolfrey VL, Leicht CA. Field-based physiological testing of wheelchair athletes. *Sports Med* 2013; **43**: 77–91.
3 Jacobs PL, Nash MS. Exercise recommendations for individuals with spinal cord injury. *Sports Med* 2004; **34**: 727–751.
4 Valent LJ, Dallmeijer AJ, Houdijk H, Slootman J, Janssen TW, Hollander AP *et al.* The individual relationship between heart rate and oxygen uptake in people with a tetraplegia during exercise. *Spinal Cord* 2007; **45**: 104–111.
5 Price M. Energy expenditure and metabolism during exercise in persons with a spinal cord injury. *Sports Med* 2010; **40**: 681–696.
6 Lewis JE, Nash MS, Hamm LF, Martins SC, Groah SL. The relationship between perceived exertion and physiologic indicators of stress during graded arm exercise in persons with spinal cord injuries. *Arch Phys Med Rehabil* 2007; **88**: 1205–1211.
7 Croft L, Dybrus S, Lenton JP, Goosey-Tolfrey VL. A comparison of the physiological demands of wheelchair basketball and wheelchair tennis. *Int J Sports Physiol Perform* 2010; **5**: 301–315.
8 Iturricastillo A, Yanci J, Barrenetxea I, Granados C. Game intensity analysis of wheelchair basketball players during play-off matches. *Retos* 2016; **30**: 54–58.
9 Sanchez-Pay A, Torres-Luque G, Sanz-Rivas D. Match activity and physiological load in wheelchair tennis players: a pilot study. *Spinal Cord* 2016; **54**: 229–233.
10 Paulson TAW, Mason B, Rhodes J, Goosey-Tolfrey VL. Individualized internal and external training load relationships in elite wheelchair rugby players. *Front Physiol* 2015; **6**: 388.
11 Iturricastillo A, Yanci J, Granados C, Goosey-Tolfrey VL. Quantifying wheelchair basketball match load: a comparison of heart rate and perceived exertion methods. *Int J Sports Physiol Perform* 2016; **11**: 508–514.
12 Yanci J, Granados C, Otero M, Badiola A, Olasagasti J, Bidaurrazaga-Letona I *et al.* Sprint, agility, strength and endurance capacity in wheelchair basketball players. *Biol Sport.* 2015; **32**: 71–78.

13 Edwards S. *The Heart Rate Monitor Book*. Fleet Feet Press: sacramento, CA, USA, 1993.
14 Stagno KM, Thatcher R, Van Someren KA. A modified TRIMP to quantify the in-season training load of team sport players. *J Sports Sci* 2007; **25**: 629–634.
15 Delextrat A, Kraiem S. Heart-rate responses by playing position during ball drills in basketball. *Int J Sports Physiol Perform* 2013; **8**: 410–418.
16 Ben Abdelkrim N, El Fazaa S, El Ati J. Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med* 2007; **41**: 69–75.
17 Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med* 1998; **26**: 217–238.