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Differences in physiological responses during wheelchair basketball according to playing time and competition

Abstract

Purpose: The main purpose of the present study was to determine physiological responses in wheelchair basketball (WB) matches, in relation to heart rate (HR), match load (ML), differentiated perceived exertion (dRPE), lactate concentrations (LA) and tympanic temperature (TEMP), specifying the individual player's playing time during different types of matches. **Method:** Nine Spanish First Division WB players participated in the study. Three groups were determined for each observation (i.e., HR, ML, dRPE, LA and TEMP) according to the minutes played by the WB players; players who had played 30-40 minutes (WB_{30-40}), 20-30 minutes (WB_{20-30}) and 0-20 minutes (WB_{0-20}). **Results:** The WB_{30-40} group attained statistically significant higher results in HRmean than the other groups in League and Play-off matches (p<0.05; Δ%>-25.73%; ES>-1.31, large). With regard to the difference in each variable between League and Play-off matches, the differences were highlighted in the WB_{30-40} group according to ML (Edwards: p<0.05; Δ%=-11.14%, ES=-0.87, large; $TRIMP_{MOD}$: p<0.05; Δ%=-16.95, ES=-0.77, large). TEMP also reached higher values in Play-off matches than League matches in WB_{30-40} (p<0.05; Δ%=1.1%; ES=0.67, moderate) but not in LA values. **Conclusions:** Coaches should take into account that Play-off matches were more demanding than League matches, thus, forcing coaches to try to peak WB players' physical performance for the former.

Keywords: match analysis, heart rate, perceived exertion, physiological demands

Several papers have been published recently concerning physiological responses in para-sports in competition (Iturricastillo, Yanci, Granados, & Goosey-Tolfrey, 2016a; Paulson, Mason, Rhodes, & Goosey-Tolfrey, 2015; Sánchez-Pay, Torres-Luque, & Sanz-Rivas, 2016). Many researchers are aware of the importance of studying the physiological responses during the match to understand the physiological requirements and to improve training programs. To this end the internal and external load methods have been analyzed in wheelchair tennis (Sánchez-Pay et al., 2016; Sindall, Lenton, Tolfrey, Oyster, & Goosey-Tolfrey, 2013), wheelchair rugby (Paulson et al., 2015; Rhodes, Mason, Perrat, Smith, Malone, & Goosey-Tolfrey, 2015) and especially wheelchair basketball (WB) (Bloxham, Bell, Bhambhani, & Steadward, 2001; Coutts, 1988; Croft, Dybrus, Lenton, & Goosey-Tolfrey, 2010), but not during different types of matches (i.e., League and Play-offs). Possibly, the fact that WB is an intermittent sport characterized by short and high intensity accelerations/decelerations combining anaerobic and aerobic efforts (Weissland, Faupin, Borel, & Leprêtre, 2015), sports performance depends largely on physical performance, so researchers have focused their efforts on understanding the match from the physiological point of view, an issue that has received special attention.

Similarly, WB physiological match responses have been analyzed by means of the internal (Bloxham et al., 2001; Coutts et al., 1988; Croft et al., 2010) and external load (De Witte, Hoozemans, Verger, Van der Woude, & Veeger, 2015; Gómez, Pérez, Molik, Szyman, & Sampaio, 2014; Paulson et al., 2015). The external load may be expressed in terms of physical demands, i.e., total distance covered, distance at certain velocities, and accelerations (Bradley et al., 2013). The internal load, on the other hand, could be analyzed with objective methods such as heart rate (HR) monitors (Croft et al., 2010) or subjective methods separating respiratory and muscular perceived exertion (Iturricastillo et al., 2016a), which might be pertinent when working with the upper extremities in WB due to the need to propel the wheelchair which entails peripheral fatigue (Lenton, Fowler, Van der Woude, & Goosey-Tolfrey, 2008). Coutts (1988) was the first to study WB physiological responses by monitoring HR, however, the author reported only the absolute HR values. Since then, a few studies have reported relative HR values during WB matches (Bloxham et al., 2001; Croft et al., 2010), but to our knowledge only one study has used other subjective methods (Iturricastillo et al., 2016a).

Other physiological responses have also been analyzed in para-sport during matches such as blood lactate concentration (LA) (Sanchez-Pay et al., 2016; Schmid et al., 1998) and body temperature (TEMP) (Girard, 2015; Griggs, Leicht, Price, & Goosey-Tolfrey, 2015; Trbovich, Ortega, Schroeder, & Fredrickson, 2014). However, there are few studies that determine the values of LA (Schmid et al., 1998) and TEMP during WB official matches. The LA and TEMP during matches could be particularly important as some WB players may have impaired thermoregulation, such as high spinal cord injury players (Griggs et al., 2015; Price & Goosey-Tolfrey, 2008). Since a lack of sympathetic vasomotor adjustments and reduced sweating capacity below the lesion level may hamper appropriate blood redistribution and limit cooling efficiency (Theisen & Vanlandewijck, 2002), these players could be at greater risk of heat strain and heat injury than non-spinal cord injury players (Bhambani, 2002). As there is minimal information about the physiological demands during a WB match (Iturricastillo, Yanci, Barrenetxea, & Granados, 2016b), this study might provide coaches and physical fitness trainers with knowledge about reliance on anaerobic glycolysis and thermoregulatory needs during different matches according to competition type.

Traditionally, the HR, differentiated perceived exertion (dRPE), LA concentration and tympanic TEMP values have been analyzed providing all players' data (Croft et al., 2010; Schmid et al., 1998), without considering the minutes played, when not all players play the same time in matches. It would be pertinent therefore for coaches and physical trainers to carry on studying not only all players' values, considering the same playing time for all of them, but specifying the individual playing time and the different competition types, to provide a better understanding of the match load (ML). Moreover, as we have not found any study that has analyzed the differences in the physiological responses among different types of WB matches, it would be interesting to compare those variables between League and Play-off matches, in order to know if the type of competition may affect these physiological responses.

Therefore, the main purpose of the present study was to determine wheelchair basketball physiological responses, in relation to heart rate, differentiated perceived exertion, blood lactate concentration and tympanic temperature specifying the individual wheelchair basketball player's playing time during different types of matches (i.e., League and Play-offs).

Methods

Participants

Spanish First Division league WB players (n = 9) participated in the study (Table 1). Two training sessions and one match per week were undertaken by all the players. Each player was classified according to the classification rules of the International Wheelchair Basketball Federation (IWBF) by WB officials from the Spanish classification committee. All the players were informed about all the tests and possible risks involved, and they provided written informed consent before testing. Thus, all the participants involved in the study were treated all the time according to the Declaration of Helsinki (2013). The participants had the option to voluntarily withdraw from the study at any time. The study was approved by the Ethics Committee of the University of the Basque Country.

****Table 1 near here please****

Procedures

The last five matches of the League competition (January - February) and five matches of the Play-offs (March - April) were analyzed in the same team and with the same players. All participants performed the matches with their usual sports chair. According to the minutes played by the WB players, three groups were determined for each observation; players who had played 30-40 minutes (WB_{30-40}, n=47 occurrences), players who had played 20-30 minutes (WB_{20-30}, n=12 occurrences) and players who had played 0-20 minutes (WB_{0-20}, n=10 occurrences). Finally, a total of 69 individual observations (occurrences) were included in the analysis. One week before the competition period, the individual peak HR (HRpeak) of each player (HR monitored by telemetry) was obtained by means of a modified (10 m) Yo-Yo intermittent recovery test level 1 (YYIR1 10 m), previously described by Yanci et al., (2015). The HRpeak of the moment (obtained in the test or match) was considered in order to set the individual training intensity zones more precisely.

Measures

Heart rate. Heart rate (HR) was recorded continuously by a HR monitor

(Polar Team Sport System™, Polar Electro Oy, Finland). The absolute HRmean and HRpeak were recorded for all the matches. Moreover, the match load (ML) was calculated as proposed by Edwards ML (Edwards, 1993) and using Stagno's TRIMP$_{MOD}$ (Stagno, Thatcher, & Van Someren, 2007), as has been previously used in wheelchair rugby and WB by different authors (Iturricastillo et al., 2016a; Paulson et al., 2015). In brief, these methods included 5 different HR intensity zones of the total volume of match intensity. In order to calculate the ML, the match duration (min) in each of the current zones was multiplied by the weighting factor for each zone. The weighting factor is different for Edwards ML (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). The ML in AU was used for the statistical analysis.

Differentiated perceived exertion (dRPE). The 0-10 point scale proposed by Iturricastillo et al. (2016a) for WB players was recalled by each player at the end of each match. Players responded separately about their respiratory perceived exertion (RPEres) and arm muscle perceived exertion (RPEmus) as previously described in other WB and wheelchair rugby studies (Iturricastillo et al., 2016a; Paulson et al., 2015). During all the matches, the same investigator collected the dRPE values. The absolute values of RPEres and RPEmus were used for the statistical analysis.

Blood lactate (LA) and tympanic temperature (TEMP). Capillary blood samples were obtained from the earlobe to determine LA concentrations (Lactate Plus™, Nova Biomedical) (Granados et al., 2015). Tympanic TEMP was also measured (ThermoScan™5 IRT 4520, Braun GmbH, Kronberg, Germany) (Price et al., 2008; Yanci, Iturricastillo, & Granados, 2014). Data were obtained 10 min before warm-up (Pre) and immediately after finishing the match (Post) by the same investigator on all occasions. The absolute values of LA samples and tympanic TEMP were used for the statistical analysis. The delta value (Δ%, between Pre and Post match) was calculated using the formula: Δ% = [(Post-Pre)/Pre] x 100.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS™ Inc, version 20.0 Chicago, IL, USA) was used for the main statistical analysis. Results are presented as mean ± standard deviation (SD). All the variables showed a normal distribution and homogeneity of variances according to the Kolmogorov-Smirnov and Levene tests. To analyze the differences among the three groups (WB_{30-40}, WB_{20-30} and WB_{0-20}), in terms of HRpeak and HRmean values as well as ML, dRPE, LA concentration and tympanic TEMP, in both League and Play-off matches, a one-way ANOVA was used with the corresponding Bonferroni post hoc test. Student's t-test for independent samples was used in an independent way to determine the differences between League and Play-off matches in HR ML, dRPE, LA concentration and tympanic TEMP measurements in each group (i.e., WB_{30-40}, WB_{20-30} and WB_{0-20}). Cohen's (1988) effect sizes (ES), lower than 0.2, between 0.2-0.5, between 0.5-0.8 or greater than 0.8 were considered trivial, small, moderate, or large, respectively. The delta value (Δ%) between groups according to the playing time or between competition types was calculated using the formula: Δ% = [(mean 2 - mean 1)/mean 1] x 100. The $p<0.05$ criterion was used in order to establish statistical significance.

Results

Heart rate

The HRmean, HRpeak, as well as the ML of League and Play-off matches are presented in Table 2. The differences among groups (i.e., $WB_{30\text{-}40}$, $WB_{20\text{-}30}$ and $WB_{0\text{-}20}$) in League matches were observed in HR mean between $WB_{30\text{-}40}$ and the other groups ($WB_{20\text{-}30}$: $p<0.05$; $\Delta\% = -12.1\%$; ES = -1.40, large; and $WB_{0\text{-}20}$: $\Delta\% = -17.6\%$; ES = -2.02, large) but not in HRpeak ($p>0.05$; $\Delta\% < -3.95\%$; ES < -0.71, moderate). According to ML (Edwards and $TRIMP_{MOD}$), the $WB_{30\text{-}40}$ group obtained higher results than the other two groups in League and Play-off matches ($p<0.05$; $\Delta\% > -25.73\%$; ES > -1.31, large). However, only Play-off matches showed higher results in $WB_{20\text{-}30}$ than $WB_{0\text{-}20}$ for Edwards ML and $TRIMP_{MOD}$ ($p<0.05$; $\Delta\% = 22.9$ and -45.6%; ES = -1.28 and -1.70, large, respectively).

According to the difference in each variable between League and Play-off matches, the differences were highlighted in the $WB_{30\text{-}40}$ group according to ML (Edwards: $p<0.05$; $\Delta\% = -11.14\%$, ES = -0.87, large and $TRIMP_{MOD}$: $p<0.05$; $\Delta\% = -16.95$, ES = -0.77, large), but not in HRmean and HRpeak. In the other groups, no differences were observed according to competition type.

****Table 2 near here please****

Differentiated Perceived Exertion (dRPE)

The dRPE values for each group are presented in the Table 2. The RPEres and RPEmus values in League matches were statistically significant higher for RPEres and RPEmus in the $WB_{30\text{-}40}$ than the $WB_{20\text{-}30}$ group ($p<0.05$; $\Delta\% = -31.64$ and -27.32%; ES = -1.34 and -1.12, large, respectively). However, in spite of the fact that there were not significant differences in dRPE between the $WB_{30\text{-}40}$ and $WB_{0\text{-}20}$ group, there was a large tendency to obtain greater values than in WB_{0-20} ($p>0.05$; Δ% = -30.56 and -32.64%; ES = -1.29 and -1.24, large, for RPEres and RPEmus). In Play-off matches, there were not significant differences in RPEres and RPEmus between the WB_{30-40} and WB_{20-30} groups although WB_{0-20} group values were statistically significant lower than the WB_{30-40} ($p<0.05$; Δ% = -57.77 and -55.29%; ES = -3.15 and -3.49, large, for RPEres and RPEmus) and WB_{20-30} groups ($p<0.05$; Δ% = -53.55 and -51.09%; ES = -3.95 and -3.67, large, for RPEres and RPEmus).

In relation to the dRPE between different types of matches, there were not significant differences in the WB_{30-40} group, but significant higher values were visible in Play-off than in League matches in the WB_{20-30} group ($p<0.05$; Δ% = 35.88%; ES = 1.06, large). Moreover, during Play-offs the WB_{20-30} group showed a higher RPEres ($p>0.05$; Δ% = 39.95%; ES = 1.03, large). On the contrary, the WB_{0-20} group (Play-off) reported significant lower values in RPEres than in League matches ($p<0.05$; Δ% = -36.00%; ES = -2.28, large) but not in RPEmus.

Physiological markers

Table 3 shows capillary blood LA and tympanic TEMP values. During League matches no significant differences were observed among groups in Post LA concentrations and TEMP values ($p<0.05$; Δ% = 6.0 and -20.0%, ES = 0.09 and -0.31, trivial and small, for WB_{20-30} and WB_{0-20}). However, in Play-off matches WB_{30-40} obtained statistically significant higher Post LA concentration values than WB_{20-30} ($p<0.05$; Δ% = -51.2%; ES = -1.24, large) and WB_{0-20} ($p<0.05$; Δ% = -41.5%; ES = -1.00, large). Thus, the WB_{0-20} group also reported statistically significant lower TEMP values than WB_{30-40} ($p<0.05$; Δ% = -1.3, ES = -1.25, large).

According to the differences between League and Play-off matches, no significant differences were observed among groups in Post LA values, but the Δ% Pre – Post LA was statistically significant higher in League matches than in Play-off matches (p<0.05; ES = -0.46, small). As opposed to the LA development, the WB_{30-40} group in Play-off matches obtained higher tympanic TEMP values than in League matches (p<0.05; Δ% = 1.1%; ES = 0.67, moderate) but the Δ% Pre – Post tympanic TEMP was similar. However, there were no differences in the WB_{20-30} and WB_{0-20} groups.

****Table 3 near here please***

Discussion

Only two studies have analyzed the physiological responses of WB players during matches (Croft et al, 2010; Iturricastillo et al., 2016a). However, they did not consider either the playing time of the WB players, or the competition type of the match as confounding variables of the physiological responses. The present study was carried out to provide a better understanding of the physiological responses (i.e., HR, ML, dRPE, LA and tympanic TEMP) of WB players according to playing time (i.e.,WB_{30-40}, WB_{20-30}, WB_{0-20}) and competition type (i.e., League and Play-off). During League matches the objective and subjective internal load was greater in WB_{30-40} than in the other groups while, Post LA and TEMP values did not reveal differences among groups. In Play-off matches, similar results were obtained according to ML, but Post LA and TEMP values were greater in WB_{30-40} than in WB_{0-20}. In relation to the differences in physiological responses according to competition type (i.e., League and Play-off), the main differences were observed in ML and tympanic TEMP in WB_{30-40} due to Play-off matches obtaining higher values, determining greater physiological requirements.

Several studies have analyzed the physiological responses of WB players during match and field tests (Bloxham et al., 2001; Coutts, 1988; Croft el al., 2010). Nevertheless, assessing the HR and dRPE according to the playing time and the competition type could provide WB coaches with a better understanding of the physiological responses. The WB_{30-40} group elicited higher HRmean, ML and dRPE values than the other groups in both competition types. As regards the League and Play-off differences, the players who spent more time playing (i.e.,WB_{30-40}) elicited greater ML values during the Play-off matches. Likewise, the WB_{20-30} group showed higher RPEmus values during the Play-offs. These results indicate that in players who played more (WB_{30-40} and WB_{20-30}) the intensity measured by HR, ML or dRPE during WB matches was higher in Play-off matches. In a previous study (Klusemann, Pyne, Hopkins, & Drinkwater, 2013), it was observed that official matches were more physically demanding than friendly tournaments in conventional basketball players. Specifically, it was reported that during official matches players spent 7% more time in the 80-89% of HRmax than during friendly tournaments. Therefore, it seems that both the competition type and the playing time could influence physiological responses, among other variables. The higher intensity observed during the Play-offs could be due to the relevance of this competition for category promotion and demotion. Thus coaches should not overlook the physical fitness of WB players and specifically when Play-off matches are being played.

Results obtained from the LA concentration should be viewed with caution, since such values may be directly influenced by the actions occurring just before the taking of the sample (Ben Abdelkrim, Castagna, Jabri, Battikh, El Fazaa, & El Atli, 2010). However, this physiological marker has been widely used in both basketball players (Ben Abdelkrim, El Fazaa, & El Atli, 2007; Matthew & Delextrat, 2009), and WB players (Granados et al., 2015; Weissland et al., 2015). In our study, although no differences in Post LA values among playing time groups in League matches were observed during Play-off matches, the group that played the most time reported the highest Post LA values. These results suggest that in WB not only the glycolytic pathway might be important in terms of performance, but also a good aerobic fitness could help players to improve LA clearance during recovery (Matthew & Delextrat, 2009). Moreover, the WB_{30-40} group elicited both higher Post LA values and higher increases of LA values after the match during League matches than during Play-offs in spite of the lower HR, ML and dRPE. The greater Post LA values during League matches is indicative of the higher involvement of the glycolytic pathway during this competition type. The differences in the LA concentration across different competition types could have been influenced by the coaching tactics adopted across matches (Scanlan, Dascombe, Reaburn, & Dalbo, 2012). Nevertheless, considering that LA measurements could be influenced by the high intensity activity performed in the last 5-minutes (Ben Abdelkrim et al. 2007), the differences in LA concentration could have been influenced by the actions performed during matches by WB players prior to blood withdrawal, as a result, data from blood lactate concentration should be taken with caution.

It has been previously observed that body TEMP plays an important role in physical performance, as its increase has been associated with fatigue in athletes (West, Cook, Beaven, & Kilduff, 2014). Moreover, due to the impaired thermoregulatory capacity of some WB players with spinal cord injury, body TEMP becomes a limiting factor of performance (Price et al., 2008; Theisen &

Vanlandewijck, 2002). In our study, during League matches, both the Post TEMP and the body TEMP increases during matches did not differ among playing time groups. Nevertheless, in Play-off matches, the $WB_{30\text{-}40}$ group obtained higher Post tympanic TEMP than the $WB_{20\text{-}30}$ group ($p<0.05$, Δ% = -51.2%; ES = -1.24, large) and the $WB_{0\text{-}20}$ group ($p<0.05$; Δ% = -41.5%; ES = -1.00, large). Thus, it seems that the time spent at high intensities seems to influence Post tympanic TEMP values; this coincides with the greater intensity observed in Play-offs (i.e., higher HRmean and ML). In previous research, it was observed that after 16 minutes of training tasks there was an increase in tympanic TEMP but not after 12 minutes of a real game (Yanci, Iturricastillo, & Granados, 2014). On the other hand, (Pliagua et al., 2015) reported an increase in body TEMP (37.8 to 39.4ºC) after 40 minutes of a basketball match. An increase in body TEMP has been associated with fatigue (West et al., 2014) and dehydration is one of the factors causing an increase in body TEMP (Linseman, Palmer, Sprenger, & Spriet, 2014). Nevertheless, we did not control either hydration or the ergogenic aids of the WB players in spite of their influence on thermal and cardiovascular strain (Girard, 2015). The influence of hydration in WB players during basketball matches could be the focus for future studies.

The results obtained should be interpreted with caution due to some important limitations of the study. Moreover, due to the sample size of this study the authors could not draw generalizations regarding the population of WB. On the other hand, the level of the players, the training experience, injury time and the time of the season where the games were played could have affected the results obtained. Therefore, further studies are needed to analyze the physiological responses of WB official matches.

Conclusion

Quantifying physiological responses during official matches in WB provides coaches with interesting information however, when analyzing physiological responses according to individual WB player's playing time during different types of matches the data become more specific. The WB_{30-40} group reported greater HRmean, ML, and dRPE values than the other groups in League and in Play-off matches. However, Play-off matches were more demanding than League matches, thus, coaches should take into account that Play-off matches were more demanding than League matches, thus, forcing coaches to try to peak WB players' physical performance for the former. In relation to physiological markers, Post LA values suggested that the glycolytic pathway might be important in WB, especially for WB_{30-40}. Nevertheless, these values should be viewed with caution due to the fact that high intensity activity performed in the last 5 minutes could have influenced the results obtained in the study. As in ML, TEMP values reflected higher values in Play-off matches than in League matches (WB_{30-40}), possibly associated with more time spent in high or maximal HR zones.

What Does This Article Add?

Coaches should consider this information when planning the season and the rest periods after match sessions to individualize, as much as possible, post match training sessions. Moreover, if different types of competition are included in the season, coaches should try to peak physical fitness for the most important matches.

References

Ben Abdelkrim, N., El Fazaa, S., & El Atli, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine, 41*, 69-75.

Ben Abdelkrim, N., Castagna, C., Jabri, I., Battikh, T., El Fazaa, S., & El Atli, J. (2010). Activity profile and physiological requirements of junior elite basketball players in relation to aerobic-anaerobic fitness. *Journal of Strength and Conditioning Research, 24*, 2330-2342. doi:10.1519/JSC.0b013e3181e381c1

Bhambhani Y. (2002) Physiology of wheelchair racing in athletes with spinal cord injury. *Sports Medicine*, 32, 23-51.

Bloxham, L. A., Bell, G. J., Bhambhani, Y., & Steadward, R. D. (2001). Time motion analysis and physiological profile of Canadian world cup wheelchair basketball players. *Sports Medicine*, *10*, 183-198. doi:10.1080/10578310210398.

Bradley P. S., Carling C., Gomez Diaz A., Hood P., Barnes C., Ade J., Boddy M., Krustrup P., Mohr M. (2013). Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Human Movement Science*, 32, 808–821.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. New York: Academic Press.

Coutts, K. D. (1988). Heart rates of participants in wheelchair sports. *Paraplegia, 26,* 43-49.

Croft, L., Dybrus, S., Lenton, J., & Goosey-Tolfrey, V. L. (2010). A comparison of the physiological demands of wheelchair basketball and wheelchair tennis. *International Journal of Sports Physiology and Performance, 5,* 301-315.

De Witte, A. M. H., Hoozemans, M. J. M., Verger, M. A. M., Van der Woude, L. H. V., & Veeger, D. (2015). Do field position and playing standard influence athlete performance in wheelchair basketball? *Journal of Sports Sciences, 29,* 1-10. doi:10.1080/02640414.2015.1072641

Edwards, S. (1993). *The heart rate monitor book.* Sacramento, CA: Fleet Feet Press.

Girard, O. (2015). Thermoregulation in wheelchair tennis - How to manage heat stress? *Frontiers in Physiology, 6,* 175. doi:10.3389/fphys.2015.00175

Gómez, M. A., Pérez, J., Molik, B., Szyman, R. J., & Sampaio, J. (2014). Performance analysis of elite men's and women's wheelchair basketball teams. *Journal of Sports Sciences, 32,* 1066–1075.

Griggs, K. E., Leicht, C. A., Price, M. J., & Goosey-Tolfrey, V. L. (2015). Thermoregulation during intermittent exercise in athletes with a spinal cord injury. *International Journal of Sports Physiology and Performance, 10,* 469-475. doi:10.1123/ijspp.2014-0361

Granados, C., Yanci, J., Badiola, A., Iturricastillo, A., Otero, M., Olasagasti, J., … & Gil, S. M. (2015). Anthropometry and performance in wheelchair basketball. *Journal of Strength and Conditioning Research, 29,* 1812-1820. doi:10.1519/JSC.0000000000000817

Iturricastillo, A., Yanci, J., Granados, C., & Goosey-Tolfrey, V. L. (2016a). Quantifying wheelchair basketball match load: A comparison of heart rate and perceived exertion methods. *International Journal of Sports Physiology and Performance, 11,* 508-514. doi:10.1123/ijspp.2015-0257

Iturricastillo, A., Yanci, J., Barrenetxea, I., & Granados, C. (2016b). Game intensity analysis of wheelchair basketball players during play-off matches. *Retos, 30,* 54-58.

Klusemann, M. J., Pyne, D. B., Hopkins, W. G., & Drinkwater, E. J. (2013). Activity profiles and demands of seasonal and tournament basketball competition. *International Journal of Sports Physiology and Performance, 8,* 623-629.

Lenton, J. P., Fowler, N. E., Van der Woude, L. H. V., & Goosey-Tolfrey, V. L. (2008). Wheelchair propulsion: effects of experience and propulsion strategy on efficiency and perceived exertion. *Applied Physiology, Nutrition, and Metabolism, 33,* 870-879. doi:10.1139/H08-072

Linseman, M. E., Palmer, M. S., Sprenger, H. M., & Spriet, L. L. (2014). Maintaining hydration with a carbohydrate–electrolyte solution improves performance, thermoregulation, and fatigue during an ice hockey scrimmage. *Applied Physiology, Nutrition, and Metabolism, 39,* 1214-1221. doi:10.1139/apnm-2014-0091

Matthew, D., & Delextrat, A. (2009). Heart rate, blood lactate concentration, and time-motion analysis of female basketball players during competition. *Journal of Sports Sciences, 27,* 813-821. doi:10.1080/02640410902926420

Paulson, T. A. W., Mason, B., Rhodes, J., & Goosey-Tolfrey, V. L. (2015). Individualized internal and external training load relationships in elite wheelchair rugby players. *Frontiers in Physiology, 6,* 388. doi:10.3389/fphys.2015.00388

Pliagua, V., Kamandulis, S., Dargevièiûtë, G., Jaszczanin, J., Klizienë, I., Stanislovaitienè, J., & Stanislovaitiss, A. (2015). The effect of a simulated basketball game on players' sprint and jump performance, temperature and muscle. *Journal of Human Kinetics, 27,* 167-175. doi:10.1515/hukin-2015-0045

Price, M., & Goosey-Tolfrey, V. L. (2008). Heat flow of the paraplegic and able-bodied lower limb during resting heat exposure. *Journal of Thermal Biology, 33,* 255-260. doi:10.1016/j.jtherbio.2008.02.004

Rhodes, J. M., Mason, B. S., Perrat, B., Smith, M. J., Malone, N. A., & Goosey-Tolfrey, V. L. (2015). Activity profiles of elite wheelchair rugby players during competition. *International Journal of Sports Physiology and Performance, 10,* 318-324. doi:10.1123/ijspp.2014-0203

Sánchez-Pay, A., Torres-Luque, G., & Sanz-Rivas, D. (2016). Match activity and physiological load in wheelchair tennis players: a pilot study. *Spinal Cord, 54(3),* 229-233. doi:10.1038/sc.2015.107

Scanlan, A. T., Dascombe, B. J., Reaburn, P., & Dalbo, V. J. (2012). The physiological and activity demands experienced by Australian female basketball players during competition. *Journal of Science and Medicine in Sport, 15,* 341-347. doi:10.1016/j.jsams.2011.12.008

Schmid, A., Huonker, M., Stober, P., Barturen, J. M., Schimdt-Trucksäss, A., Dürr, H., … & Keul, J. (1998). Physical performance and cardiovascular and metabolic adaptation of elite female wheelchair basketball players in wheelchair ergometry and in competition. *American Journal of Physical Medicine & Rehabilitation, 77,* 527-533.

Sindall, P., Lenton, J., Tolfrey, K. C. R., Oyster, M., & Goosey-Tolfrey, V. L. (2013). Wheelchair tennis match-play demands: effect of player rank and result. *International Journal of Sports Physiology and Performance, 8,* 28-37.

Stagno, K.M., Thatcher, R., & Van Someren, K.A. (2007). A modified TRIMP to quantify the in-season training load of team sport players. *Journal of Sports Science*, *25,* 629–634. doi:10.1080/02640410600811817

Theisen, D., & Vanlandewijck, Y. (2002). Cardiovascular responses and thermoregulation in individuals with spinal cord injury. *European Bulletin of Adapted Physical Activity*, volume *1, issue 1.*

Trbovich, M., Ortega, C., Schroeder, J., & Fredrickson, M. (2014). Effect of a cooling vest on core temperature in athletes with and without spinal cord injury. *Top Spinal Cord Injury Rehabilitation, 20,* 70-80. doi:10.1310/sci2001-70

West, D. J., Cook, C. J., Beaven, M., & Kilduff, L. P. (2014). The influence of the time of day on core temperature and lower body power output in elite rugby union sevens players. *Journal of Strength and Conditioning Research, 28,* 1524-1528. doi:10.1519/JSC.0000000000000301

Weissland, T., Faupin, A., Borel, B., & Leprêtre, P. M. (2015a). Comparison between 30-15 intermittent fitness test and multistage field test on physiological responses in wheelchair basketball players. *Frontiers in Physiology, 6,* 380. doi:10.3389/fphys.2015.00380

Yanci, J., Granados, C., Otero, M., Badiola, A., Olasagasti, J., Bidaurrazaga-Letona, I. … & Gil, S. M. (2015). Sprint, agility, strength and endurance capacity in wheelchair basketball players. *Biology of Sport, 32,* 71-78. doi:10.5604/20831862.1127285

Yanci, J., Iturricastillo, A., & Granados, C. (2014). Heart rate and body temperature response of wheelchair basketball players in small-sided games. *International Journal of Performance Analysis in Sport, 14,* 535-544.

Table 1

Wheelchair basketball players' characteristics

Player	**Physical Impairment**	**IWBF Classification**	**Age (years)**	**Injury time (years)**	**Training experience (years)**	**Modified YYIR1 HRpeak (beat·min^{-1})**	**Match HRpeak (beat·min^{-1})**
1	Spinal Cord Injury (T12-L3)	1	42	18	7	191	196
2	Spina Bífida (L1)	1	16	16	2	180	195
3	Spinal Cord Injury (T1-T2)	1	36	34	20	154	160
4	Viral Disease (polio)	2	35	33	4	198	204
5	Spinal Cord Injury (incomplete C5-C6)	3	35	30	18	169	182
6	Viral Disease (polio)	3.5	33	31	14	176	189
7	Congenital osteoarthritis	4	40	40	21	179	183
8	Double amputation below knee	4	35	28	15	185	201
9	Knee impairment	4.5	25	5	2	182	184
Sample (n = 9)		-	33 ± 8	26 ± 11	11 ± 8	179 ± 13	188 ± 13

IWBF = International wheelchair basketball federation; YYIR1 = Yo-Yo intermittent recovery level 1 test; HRpeak = peak heart rate.

Table 2

Heart rate (HR), match load (ML) and differentiated rating of perceived exertion (dRPE) responses of wheelchair basketball players (WB) during matches according to the time they had played in League and Play-off matches

	WB$_{30\text{-}40}$ (n = 47)		**WB$_{20\text{-}30}$** (n = 12)		**WB$_{0\text{-}20}$** (n = 10)		**Total** (n = 69)	
	League	Play-off	League	Play-off	League	Play-off	League	Play-off
HRmean (beats·min^{-1})	142.6 ± 12.4	146.5 ± 10.4	125.3 ± 10.1†	124.6 ± 10.4†	117.5 ± 3.5†	115.4 ± 7.5†	137.5 ± 14.3	136.3 ± 16.8
HRpeak beats·min^{-1})	184.8 ± 10.3	183.2 ± 11.9	182.0 ± 9.7	173.2 ± 26.6	177.5 ± 16.3	178.8 ± 13.0	183.8 ± 10.3	180.8 ± 14.8
Edwards ML (AU)	268.2 ± 48.9	301.6 ± 38.3*	197.8 ± 28.6†	224.0 ± 40.1†	163.5 ± 23.3†	172.7 ± 46.4$^{\dagger\,\Psi}$	247.6 ± 56.4	261.1 ± 68.1
TRIMP$_{MOD}$ (AU)	182.9 ± 44.9	213.9 ± 40.5*	123.2 ± 29.3†	126.0 ± 33.8†	75.3 ± 11.8†	68.6 ± 24.8$^{\dagger\,\Psi}$	163.7 ± 52.3	168.1 ± 72.3
RPEres	6.48 ± 1.53	6.82 ± 1.25	4.43 ± 1.72†	6.20 ± 0.84	4.50 ± 0.71	2.88 ± 0.64$^{\dagger\,\Psi *}$	5.94 ± 1.76	5.83 ± 1.96
RPEmus	6.68 ± 1.76	7.00 ± 1.11	4.71 ± 1.60†	6.40 ± 0.89*	4.50 ± 0.71	3.13 ± 0.83$^{\dagger\,\Psi}$	6.12 ± 1.88	6.03 ± 1.90

Values are means (± SD), Edwards ML = Edwards match load; TRIMP$_{MOD}$ = Stagno's match load; AU = arbitrary units; RPEres = respiratory rating of perceived exertion; RPEmus = muscular rating of perceived exertion. WB$_{30\text{-}40}$ = Wheelchair basketball players who played 30-40 minutes, WB$_{20\text{-}30}$ = wheelchair basketball players who played 20-30 minutes, WB$_{0\text{-}20}$ = wheelchair basketball players who played 0-20 minutes. † $p < 0.05$ statistically significant differences with respect to WB$_{30\text{-}40}$. $^{\Psi}$ $p < 0.05$ statistically significant differences with respect to WB$_{20\text{-}30}$. * $p < 0.05$ statistically significant differences between League and Play-off matches.

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Table 3

Lactate concentrations (LA) and tympanic temperature (TEMP) and of wheelchair basketball players (WB) before (Pre) and after (Post) matches according to the time played in League and Play-off matches

	WB$_{30-40}$ (n = 47)		**WB$_{20-30}$** (n = 12)		**WB$_{0-20}$** (n = 10)		**Total** (n = 69)	
	League	Play-off	League	Play-off	League	Play-off	League	Play-off
Pre LA (mmol·l^{-1})	1.6 ± 0.7	1.9 ± 1.2	1.8 ± 0.5	1.3 ± 0.3	1.7 ± 0.6	1.5 ± 0.5	1.6 ± 0.6	1.7 ± 1.0
Post LA (mmol·l^{-1})	5.0 ± 3.2	4.1 ± 1.7	5.3 ± 3.3	2.0 ± 0.7†	4.0 ± 0.7	2.4 ± 1.1†	5.0 ± 3.1	3.4 ± 1.7*
Δ% LA Pre – Post (%)	296.0 ± 347.8	136.6 ± 101.3*	184.7 ± 125.2	53.0 ± 48.3	141.8 ± 38.8	62.8 ± 64.6	265.5 ± 308.7	110.0 ± 95.2*
Pre TEMP (ºC)	36.5 ± 0.4	36.6 ± 0.5	36.3 ± 0.3	36.5 ± 0.5	36.5 ± 0.6	36.5 ± 0.3	36.5 ± 0.5	36.6 ± 0.5
Post TEMP (ºC)	37.1 ± 0.6	37.5 ± 0.4*	37.0 ± 0.4	37.2 ± 0.7	37.0 ± 0.2	37.0 ± 0.4†	37.1 ± 0.5	37.3 ± 0.4
Δ% TEMP Pre – Post (%)	1.7 ± 1.3	2.3 ± 1.5	2.0 ± 1.8	1.7 ± 0.8	1.2 ± 1.0	1.4 ± 0.8	1.8 ± 1.4	2.0 ± 1.3

Values are means (± SD), Δ% = percentage of difference, WB$_{30-40}$ = wheelchair basketball players who played 30-40 minutes, WB$_{20-30}$ = wheelchair basketball players who played 20-30 minutes, WB$_{0-20}$ = wheelchair basketball players who played 0-20 minutes. † $p < 0.05$ statistically significant differences with respect to WB$_{30-40}$. * $p < 0.05$ statistically significant differences between League and Play-off matches.