Article Title: Quantifying Wheelchair Basketball Match Load: A Comparison of Heart Rate and Perceived Exertion Methods

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Title of the article

Quantifying wheelchair basketball match load: a comparison of heart rate and perceived exertion methods

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Running Head: wheelchair basketball match load quantification

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Abstract

Purpose: The aim of this study was to describe the objective and subjective match load (ML) of wheelchair basketball (WB) and to determine the relationship between session heart rate-based ML (HR-based ML) and perceived exertion-based ML (RPE-based ML) methods. **Methods:** HR-based measurements of ML included Edward's ML and Stagno training

impulses ($TRIMP_{MOD}$) whilst RPE-based ML measurements included respiratory (sRPEres ML) and muscular (sRPEmus ML). Data were collected from ten WB players during a whole competitive season. **Results:** Edward’s ML and $TRIMP_{MOD}$ averaged across 16 matches were 255.3 ± 66.3 and 167.9 ± 67.1 AU respectively. In contrast, sRPEres ML and sRPEmus ML were found to be higher (521.9 ± 188.7 and 536.9 ± 185.8 AU respectively). Moderate correlations ($r = .629 – .648$, $P < .001$) between Edward’s ML and RPE-based ML methods were found. Moreover, similar significant correlations were also shown between the $TRIMP_{MOD}$ and RPE-based ML methods ($r = .627 – .668$, $P < .001$). That said, only ≥40% of variance in HR-based ML was explained by RPE-based ML which could be explained by the heterogeneity of physical impairment type. **Conclusion:** results suggest that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players.

Key words: match activity, RPE, TRIMP, training load, Paralympic.

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Introduction

To evaluate the success of training, coaches need to systematically monitor athletes' internal training load (TL).[1] Understanding TL's will allow coaches to monitor the effectiveness of training and competitive stimuli in provision of a successive training plan.[2] Consequently, TL has been analyzed in many able-bodied team sports during training[2-6] and competitive match play.[7-9] Monitoring TL or match load (ML) helps the coach individualize training with respect to simulating game play via certain drills in training or indeed individualizing the physical load due to the player's positional requirements. Thus, methods based on the analysis of heart rate (HR) as the measurement of Banister's training impulses,[10] Edward's method[11] or modified Stagno's $TRIMP_{MOD}$[12] have been used to quantify TL in many sports such as soccer, [3,9,13-15] Australian football[16,17] and water-polo.[2]

Evidently, not only the analysis of HR have been used to quantify TL, since over the last decade researchers are combining other objective measures of TL such as athlete's perceived exertion (RPE). For example, several authors have successfully verified the quantification of TL or ML by multiplying an athlete's RPE for the total duration (min) of the training or match play in team sports.[2,5,15,17,18] Extending this further, recent work has differentiated between the subjective measure of RPE and noted RPE as scores relating to 'overall' or 'respiratory' RPE (RPEres) and 'muscular' RPE (RPEmus).[14,19] This may be pertinent when working in adaptive sports such as wheelchair basketball (WB) since wheelchair propulsion involves exercise of the upper extremities which are prone to peripheral fatigue.[20]

With the increasing professionalism of Paralympic Sport, it is surprising to see that little is known about the competitive conditions that are faced by the wheelchair sportsperson.[21-25] There is a paucity of data that quantifies the physiological responses during

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WB game play[21,26-28] or mobility performance via tracking distances covered, like those reported in the wheelchair sports of tennis and rugby.[23,25] To our knowledge there are no studies examining the HR-based method in quantifying TL in wheelchair sports despite our anecdotal observations that many coaches have access to these methods (e.g., HR monitors). An alternative low cost and practical strategy to quantify ML is session-RPE,[18] which has been extensively shown as a valid and reliable load-monitoring tool in many able-bodied team sports[15,18] Moreover, monitoring internal loads using session-RPE and hormonal responses has been identified in simulations and official basketball competitive outputs,[29] but yet to be proven a viable option to consider within wheelchair sports. Because the disability type influences the heart rate response to wheelchair sport[30] may be necessary to meet ML by HR-based method and RPE-based methods specifically in WB players.

Therefore, the purpose of this study was to describe the objective and subjective ML of WB game play and to investigate the relationship between HR-based ML and RPE-based ML methods across a competitive WB season.

Methods

Participants

Ten Spanish First Division male WB players (age 34 ± 8 years, time since injury 24 ± 12 years, WB training experience 11 ± 7 years and 4-6 training hours per week) volunteered to participate in the study. The participants were classified according to the Classification Committee of the International Wheelchair Basketball Federation (IWBF) (Table 1). This study was approved by the institutional research ethics committee and all participants provided written informed as outlined in the Declaration of Helsinki (2013).

Data Collection Period

Data were collected over a 6 month competitive season during the squad's build up to end of season game play in March. During this period players undertook two training sessions and one match per week. Data from 16 matches were collected from the competitive match play as HR-based ML and RPE-based ML. At least all players completed 4 matches and in this sense, a minimum of 4 full observations was considered for the analysis. Thus, a total of 111 individual observations met all requirements and were included in the analysis.

Endurance test

In order to obtain individual maximal heart rates (HRmax), a 10m Yo-Yo intermittent recovery test level 1 (YYIR1) as described by Yanci et al[31] were completed by all players one week before the competition period. This endurance test has been verified using WB players and has shown good reproducibility (ICC = .83-.94). Importantly, all players were familiar with this test as it had been part of their usual fitness assessment program. During the test, HR was continuously monitored at 1s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland). The maximum HR was determined from the highest value from either the YYIR1 or game play.

Determination of match load (ML)

The ML for each player was determined during each match by four different methods; Edward's ML[11] and $TRIMP_{MOD,}$[12] and other two RPE-based methods described later were used in order to quantify ML. The HR was continuously monitored throughout the matches at 1s intervals by telemetry (Polar Team Sport System™, Polar Electro Oy, Kempele, Finland).

For ease of data collection, the whole match time (the rest time and substitution time on the bench) was reported for the analysis. Collection was only paused during any periods of extended stoppages (time-outs, equipment calls) throughout the match since WB players also remain active during the stopped game clock.

Edwards' ML method. Match load calculation was performed as proposed by Edwards[11], in brief this included the total volume of match intensity which considers 5 zones of different intensity. The calculation was performed for each session by multiplying the accumulated duration each HR zone (min) for a value assigned to each intensity zone (90-100% HRmax = 5, 80-90% HRmax = 4, 70-80% HRmax = 3, 60-70% HRmax = 2, 50-60% HRmax = 1), and finally summarizing the results.[5,6]

$TRIMP_{MOD}$ method. Calculations of TRIMP were also performed as described by Stagno et al[12]. For this calculation, the ML is determined by calculating the result of multiplying the match duration (min) at each of the current zones for the weighting factor for each zone (93-100% HRmax = 5.16; 86-92% HRmax = 3.61; 79-85% HRmax = 2.54; 72-78% HRmax = 1.71; 65-71% HRmax = 1.25), and performs the summation of the results.[3,12]

Rating of Perceived Effort (RPE) based methods. RPE using the 0-10 point scale[18] was recalled by each player at the end of each match. Participants differentiated between the overall or respiratory RPE (RPEres) and the arm muscle RPE (RPEmus) as previously noted for wheelchair ambulation.[20,32] In accordance to the work of Foster et al[18] to estimate the RPE-derived ML (sRPEres ML and sRPEmus ML), the RPEres and RPEmus values were multiplied by the total duration of the match (min). Players were fully familiarized with the 0-10 point scale before the data collection since these methods had been used previously during the pre-season.

Data analysis

Data analysis was performed using the Statistical Package for Social Sciences (version 20.0 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used for the calculation of the mean and standard deviations (SD). Data were screened for normality of distribution. The relationships between HR-based ML methods and RPE-based ML scores were assessed using Pearson’s product moment correlation (r), as well as the coefficient of determination (R^2). The $P < .05$ criterion was used for establishing statistical significance.

Results

As shown in Table 1, game play elicited greater mean HRmax values than that found in the YYIR1 (188 ± 13 vs. 178 ± 12 beat·min^{-1} respectively, P < .001) and so thereafter these HR values obtained from game play were used for the following calculations.

The ML of each match across the 16 matches is shown in the Figure 1. The mean value utilizing the methods of Edward’s ML was 255.3 ± 66.3 AU and for $TRIMP_{MOD}$ was 167.9 ± 67.1 AU. Moreover, the means for subjective ML were 521.9 ± 188.7 AU and 536.9 ± 185.8 AU, sRPEres and sRPEmus, respectively.

According to the whole team values, moderate correlations were found between RPE-based ML methods and Edwards’s ML (sRPEres ML, r = .629, R^2 = .40, P < .001 and sRPEmus ML, r = .648, R^2 = .42, P < .001) and $TRIMP_{MOD}$ (sRPEres ML, r = .627, R^2 = .39, P < .001 and sRPEmus ML, r = .668, R^2 = .45, P < .001) methods (Figure 2). Nevertheless, there were not significant correlations in all individuals between HR-based ML and RPE-based ML methods (Table 2).

The correlations between objective and subjective methods with the mean values of each match were moderate (r = .511 – .609; R^2 = .261 – .371; P < .05). As was expected high correlations were observed between Edward’s ML and $TRIMP_{MOD}$ methods (r = .959; R^2 = .920; P < .001) and sRPEres ML and sRPEmus ML methods (r = .919; R^2 = .842; P < .001).

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Discussion

The RPE-based TL method has been widely correlated with stress responses[29] and the HR-based TL score in many able-bodied sports.[2,15,18,33] However, to date it is unknown how transferable these methods are to the sport of WB that involves wheelchair propulsion of persons with a physical impairment. Thus, the current study described the ML and investigated the HR-based ML and RPE-based ML methods in WB players during a whole competitive basketball season. The results revealed that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players with some cautionary attention due to RPE-based ML should not be seen as a substitute of HR-based ML. With accordance to the individual correlations between subjective and objective methods there were not a significant relation in all the players, thus, both the large heterogeneity of physical impairment types and a reduced number of cases for each individual could condition the relation between both methods.

The current study found that when using the HR-based methods adopted by Edward’s that the ML values were higher than utilizing the $TRIMP_{MOD}$ (255.3 ± 66.3 AU vs. 167.9 ± 67.1 AU). That said, both these values were found to be lower than those reported for non-disabled basketball practices and/or games (652 ± 59 AU, Edward’s ML).[18] Moreover, whilst using the subjective methods for quantifying ML was found to be similar between methods for the WB players (521.9 ± 188.7 AU vs. 536.9 ± 185.8 AU; sRPEres for sRPEmus, respectively). Similar to above, Foster et al[18] found higher sRPE values (744 ± 84 AU) during basketball games. Obviously, this comparison must be done with caution since a complete spinal cord injury (SCI) results in paralysis of the voluntary muscles below the

level of lesion.[34] Consequently, a reduced muscle mass is available for exercise. In conjunction with factors such as reduced sympathetic nervous system innervation and

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cardiovascular function, maximal exercise capacity is reduced when compared with able-bodied individuals.[34] The difference between our findings and those reported by Foster et al[18] were 29.9% for sPREres and 27.8% for sRPEmus in AU units. These lower values could be due to the muscle mass differences between modalities and for the different consequences of a SCI as previously mentioned.

The relationship between objective and subjective methods has been widely analyzed in training tasks[5,6] and competition[8,9] in team sports. In our study, the relationship between RPE-based ML and HR-based ML methods was moderate (r = .627 for sRPEres ML and r = .668 for sRPEmus ML). Such findings are consistent with previous studies involving other team sports.[8,9] In the same way, very high correlations were found between sRPEres ML and sRPEmus ML (r = .919). The relationship between HR-based ML and RPE-based ML in the studies previously referred above were moderate between objective and subjective methods (r range = .60 - .61; $P < .05$) in soccer players and soccer referees.[8,9] As Imperizelli et al[15], we suggest that the RPE-based ML score cannot yet replace the HR-based ML methods as a valid measure of exercise intensity, as sRPEres ML and sRPEmus ML could only explain 40% of the variation measured by HR, or even less in some cases. This could be due to the intermittent exercise nature of team sports (aerobic and anaerobic sources) reducing the grade of correlations between RPE-based TL and Edward’s HR-based TL method. In addition, Bridge et al[7] have reported that under certain training and competitive conditions, athletes tend to report lower RPE-based TL than their actual HR responses. Other authors, such as Lupo et al[2] inferred that the game may tend to make less reliable the RPE values because of a high grade of involvement and good time during the practice, therefore, underestimating their efforts. For this reason, Borresen et al[33] attempted to identify characteristics that may explain the variance not accounted for in the relationship between the objective (HR-based TL) and subjective (RPE-based TL) methods of quantifying training load. Rhodes et al[23] clearly

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showed the intermittent nature of match play during wheelchair rugby which is a similar wheelchair sport to that of WB. Of interest were the noted differences in high intensity activities among the functional classification during a wheelchair rugby match. This could be attributed to the superior trunk function associated with higher classification groups. For this reason, similar situations may come about in WB so the athletes who spent a greater percentage of their training time doing high-intensity exercise, the objective (HR-based TL) equations may overestimate training load compared with the subjective (RPE-based TL) method.[33]

According to the individual correlations there were significant correlations between both HR-based ML and RPE-based ML in most of the cases, nevertheless, no correlations were found in several cases concerning different disabilities. Lupo et al[2] reported high individual correlations (r = .76 – .98, R^2 = .58 – .97, $P < .05$) in water polo training tasks. Impellizzeri et al[15] found moderate correlations (r = 0.50 to 0.85 for individuals) between training loads calculated using the RPE-based TL and the HR-based TL for members of a club soccer team. These individual high correlations also were observed in basketball training tasks between Edward’s TL and RPE-based TL methods (r = .69 to .85 for individuals).[5] In the study of Scanlan et al[6] the sRPE TL model was significantly correlated with the Banisters’ training impulse model (r = .80, P < .05) and Edwards’ TL model (r = .89, P < .05) across all sessions. Generally, our results are lower than those observed by these authors.[2,5,6,15] However, in this study, as we mention above, not all of WB players obtained significant correlations.

In the recent literature regarding different disabilities, some studies corroborated the relationship between RPE and other physiological markers in laboratory environments, but not in a real game situation, nor in training sessions in WB.[32,35-37] Paulson et al[32] reported strong linear relationships between VO_2 and local (r = .91), central (r = .88) and overall RPE (r = .90) in eight male wheelchair dependent participants with a cervical SCI at C5/6. Although these laboratory studies support the use of RPE as a tool to self regulate the intensity of wheelchair propulsive exercise, more studies are necessary in an intermittent exercise situation in WB to determine the validity of a subjective method to quantify the match load. As we explained above, even if the whole team obtained moderate correlation between RPE-based ML and HR-based ML methods, not all of WB players obtained significant correlations, for this reason, it would be interesting to pursue this issue and determine which injury type correlates better. Thus, we could improve current training methods and optimize sport-specific training.

Conclusions

Our results suggest that RPE-based ML methods could be used as an indicator of global internal ML in highly trained WB players. This method is cost effective and a practical tool that any coach could administer as long as they were confident that the players had been familiarized to the 0-10 RPE scale. That said, since only ≥40% of variance in HR-based ML was explained by RPE-based ML then although RPE could be considered a proxy measure of ML it should not be seen as a substitute of HR. This may be explained by the sample recruited, since large heterogeneity of physical impairment types existed which is typical to the make-up of a WB team. This is likely to have influenced the subjective methods of quantifying ML. This warrants further attention and future studies should explore whether there are different RPE responses of players with a spinal cord injury compared to those with a non-spinal injury so that match play and training quantification can be accurately reported via subjective measures.

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References

1. Alexandre D, da Silva CD, Hill-Haas S, Wong del P, Natali AJ, De Lima JR, Bara Filho MG, Marins JJ, Garcia ES, Karim C. Heart rate monitoring in soccer: interest and limits during competitive match play and training, practical application. *J Strength Cond Res.* 2012;26(10):2890–906.

2. Lupo C, Capranica L, Tessitore A. The Validity of the Session-RPE Method for Quantifying Training Load in Water Polo. *Int J Sports Physiol Perform.* 2014;9:656–660.

3. Campos-Vazquez MA, Mendez-Villanueva A, Gonzalez-Jurado JA, León-Prados JA, Santalla A, Suarez-Arrones L. Relationships between RPE- and HR-derived measures of internal training load in professional soccer players: a comparison of on-field integrated training sessions. *Int J Sports Physiol Perform. In press*.

4. Fanchini M, Ghielmetti R, Coutts AJ, Schena F, Impellizzeri FM. Effect of Training Session Intensity Distribution on Session-RPE in Soccer Players. *Int J Sports Physiol Perform. In press*.

5. Manzi V, D'Ottavio S, Impellizzeri F, Chaouachi A, Chamari K, Castagna C. Profile of weekly training load in elite male professional basketball players. *J Strength Cond Res.* 2010;24(5):1399–1406.

6. Scanlan AT, Wen N, Tucker PS, Borges NR, Dalbo VJ. Training Mode's Influence on the Relationships Between Training-Load Models During Basketball Conditioning. *Int J Sports Physiol Perform*. 2014;9:851–856.

7. Bridge CA, Jones M, Drust B. Physiological responses and perceived exertion during international taekwondo competition. *Int J Sports Physiol Perform.* 2009;4(4):485 – 493.

8. Costa EC, Vieira CMA, Moreira A, Ugrinowitsch C, Castagna C, Aoki MS. Monitoring External and Internal Loads of Brazilian Soccer Referees during Official Matches. *J Sports Sci Med*. 2013;12:559–564.

9. Rebelo A, Brito J, Seabra A, Oliveira J, Drust B, Krustrup P. A New Tool to Measure Training Load in Soccer Training and Match Play. *Int J Sports Med.* 2012;33:297–304.

10. Banister E. (1991). Modeling elite athletic performance. In:GreenH, McDougal J, Wegner H, eds. *Physiological Testing of the High-Performance Athlete*. Champaign, IL: Human Kinetics, 403–424.

11. Edwards S. (1993). The Heart Rate Monitor Book. Sacramento, CA: Fleet Feet Press.

12. 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(6):629–34.

13. Alexiou H, Coutts A. A comparison of methods used for quantifying internal training load in women soccer players. *Int J Sports Physiol Perform.* 2008;3(3):320–330.

14. Los Arcos A, Yanci J, Martín J, Castagna C. Variability of objective and subjective intensities during ball drills in youth soccer players. *J Strength Cond Res.* 2014;28(3):752–7.

15. Impellizzeri FM, Rampinini E, Coutts AJ, Sassi A, Marcora SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc*. 2004;36(6):1042–1047.

16. Moreira A, Bilsborough JC, Sullivan JC, Ciancosi M, Aoki MS, Coutts AJ. The Training Periodization of Professional Australian Football Players During an Entire AFL Season. *Int J Sports Physiol Perform.* In press.

17. Scott TJ, Black C, Quinn J, Coutts A. Validity and reliability of the session-RPE method for quantifying training in Australian football: a comparison of the CR10 and CR100 scales. *J Strength Cond Res.* 2013;27(1):270–276.

18. Foster C, Florhaug J, Franklin J, Gottschall L, Hrovatin LA, Parker Z, Doleshal P, Dodge C. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001;15(1):109–115.

19. Weston M, Siegler J, Bahnert A, McBrien J, Lovell R. The application of differential ratings of perceived exertion to Australian Football League matches. *J Sci Med Sport.* In press.

20. Lenton JP, Fowler NE, Van der Woude LHV, Goosey-Tolfrey VL. Wheelchair propulsion: effects of experience and propulsion strategy on efficiency and perceived exertion. *Appl Physiol Nut Metab.* 2008;33(5):870–879.

21. Croft L, Dybrus S, Lenton J, Goosey-Tolfrey V. A comparison of the physiological demands of wheelchair basketball and wheelchair tennis. *Int J Sports Physiol Perform.* 2010;5(3):301–315.

22. Gómez MA, Pérez J, Molik B, Szyman RJ, Sampaio J. Performance analysis of elite men’s and women’s wheelchair basketball teams. *J Sports Sci*. 2014;32(11):1066–75.

23. Rhodes JM, Mason BS, Perrat B, Smith MJ, Malone NA, Goosey-Tolfrey VL. Activity Profiles of Elite Wheelchair Rugby Players During Competition. *Int J Sports Physiol Perform.* 2015;10: 318-324.

24. Roy JLP, Menear KS, Schmid MMA, Hunter GR, Malone LA. Physiological responses of skilled players during a competitive wheelchair tennis match. *J Strength Cond Res.* 2006;20(3):665–671.

25. Sindall P, Lenton J, Tolfrey KCR, Oyster M, Goosey-Tolfrey VL. Wheelchair tennis match-play demands: effect of player rank and result. *Int J Sports Physiol Perform*. 2013;8(1):28–37.

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26. Bloxham LA, Bell GJ, Bhambhani Y, Steadward RD. Time motion analysis and physiological profile of canadian world cup wheelchair basketball players. *Sports Med.* 2001;10(3):183–198.

27. Coutts KD. Heart rates of participants in Wheelchair Sports. *Paraplegia*. 1988;26:43–49.

28. Schmid A, Huonker M, Stober P, Barturen JM. Schimdt-Trucksäss A, Dürr H, Völpel HJ, Keul J. Physical performance and cardiovascular and metabolic adaptation of elite female wheelchair basketball players in wheelchair ergometry and in competition. *Am J Phys Med Rehabil*. 1998;77:527–533.

29. Moreira AL, Mcguigan MR, Arruda AFS, Freitas CG, Aoki MS. Monitoring internal load parameters during. simulated and official basketball matches. *J Strength Cond Res.* 2012;26(3):861–866.

30. Barfield JP, Malone LA, Collins JM, Ruble SB. Disability type influences heart rate response during power wheelchair sport. *Med Sci Sports Exerc*. 2005;37(5):718–723.

31. Yanci J, Granados C, Otero M, Badiola A, Olasagasti J, Bidaurrazaga I, Iturricastillo A, Gil SM. Sprint, agility, strength and endurance capacity in wheelchair basketball players. *Biology of Sport*. 2015;32:71–78.

32. Paulson TAW, Bishop NC, Leicht CA, Goosey-Tolfrey VL. Perceived exertion as a tool to self-regulate exercise in individuals with tetraplegia. *Eur J Appl Physiol*. 2013;113:201–209.

33. Borresen J, Lambert M. Quantifying training load: a comparison of subjective and objective methods. *Int J Sports Physiol Perform.* 2008;3(1):16–30.

34. Price M. Energy Expenditure and Metabolism during Exercise in Persons with a Spinal Cord Injury. *Sports Med*. 2010;40(8):681–691.

35. Al-Rahamneh H, Faulkner J, Byrne C, Eston R. Relationship between perceived exertion and physiologic markers during arm exercise with able-bodied participants and participants with poliomyelitis. *Arch Phys Med Rehabil.* 2010;91(2):273–277.

36. Al-Rahamned H, Eston R. Rating of perceived exertion during two different constant-load exercise intensities during arm cranking in paraplegic and able-bodied participants. *Eur J Appl Physiol.* 2011;111(6):1055–1062.

37. Goosey-Tolfrey V, Lenton J, Goddard J, Oldfield V, Tolfrey K, Eston R. Regulating intensity using perceived exertion in spinal cord injured participants. *Med Sci Sports Exerc*. 2010;42:608–613.

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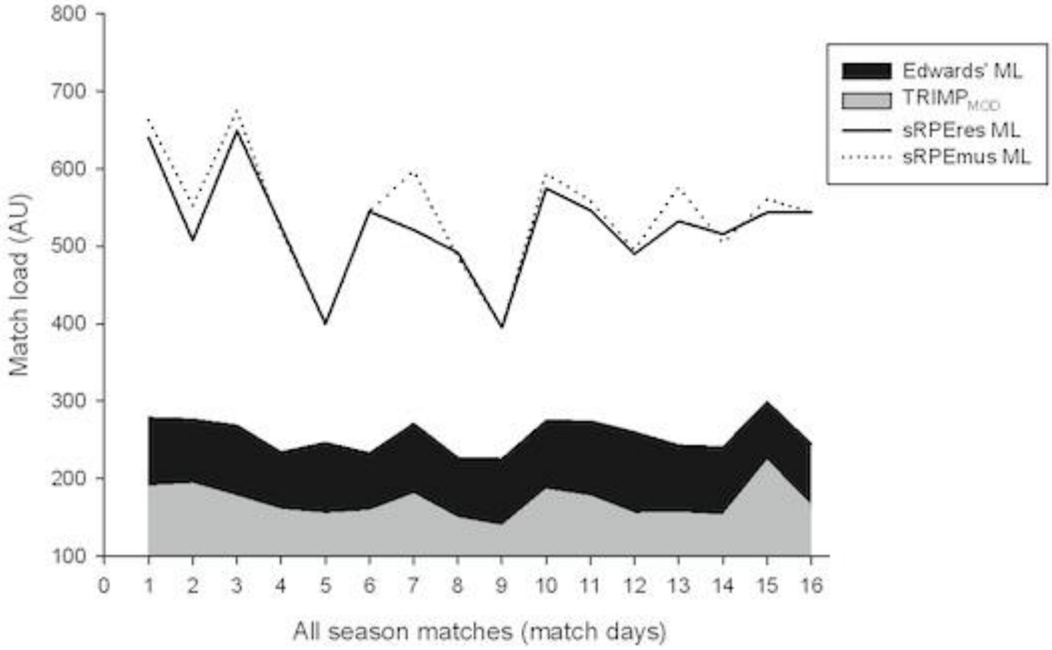
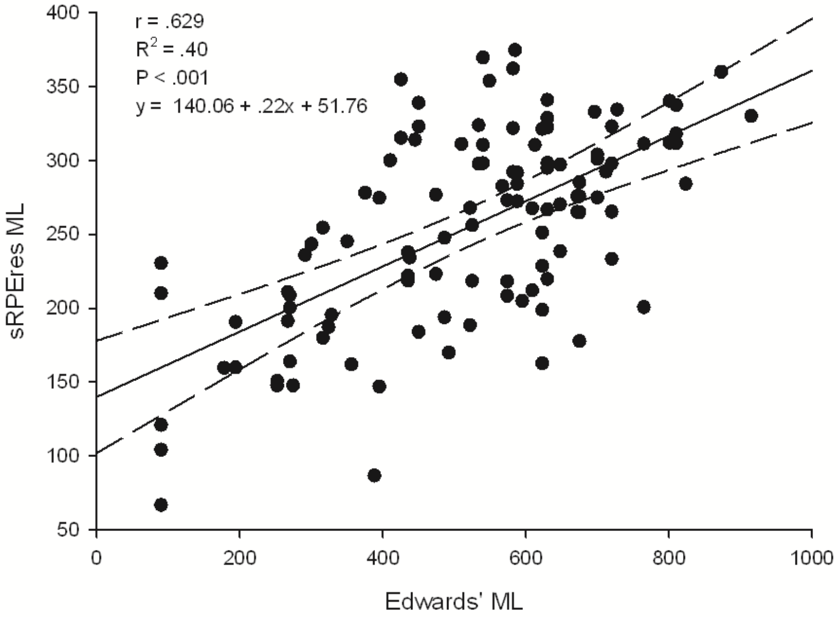
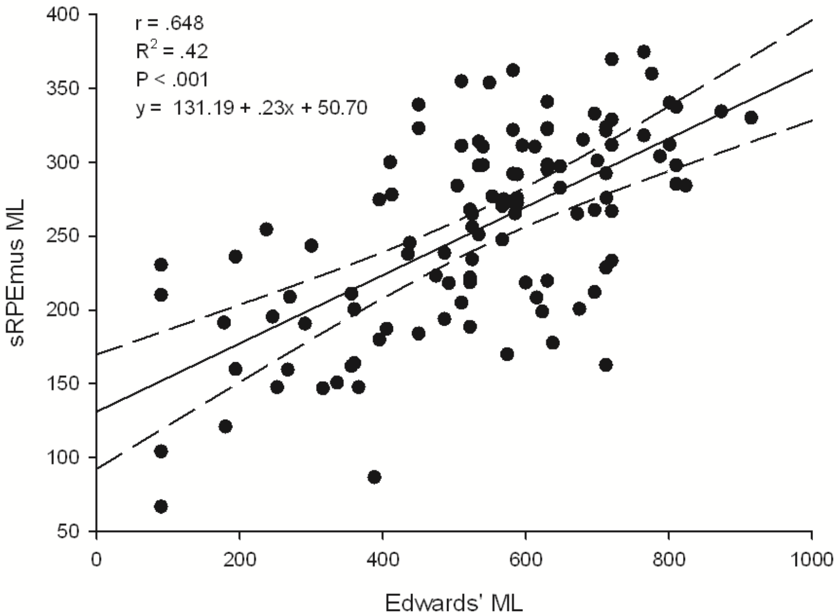


Figure 1 Edward’s match load (Edward’s ML), Stagnos’ modified TRIMP (TRIMP$_{MOD}$) and respiratory and muscular rating of perceived exertion based match load (sRPEres ML and sRPEmus ML) for the whole team during the 16 wheelchair basketball matches.
AU = arbitrary units; Edward’s ML = Edward’s match load; TRIMP$_{MOD}$ = Stagnos’ modified training impulse; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load.

2A)


r = .629
R2 = .40
P < .001
y = 140.06 + .22x + 51.76
sRPEres ML
Edwards' ML
400
350
300
250
200
150
100
50
0
200
400
600
800
1000

2B)


r = .648
R2 = .42
P < .001
y = 131.19 + .23x + 50.70
sRPEmus ML
Edwards' ML
400
350
300
250
200
150
100
50
0
200
400
600
800
1000

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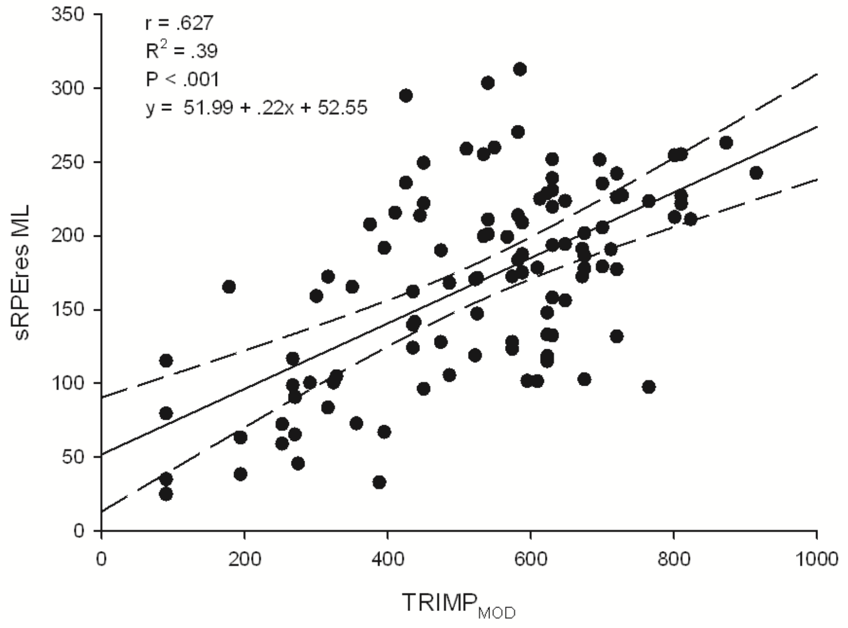
2C)



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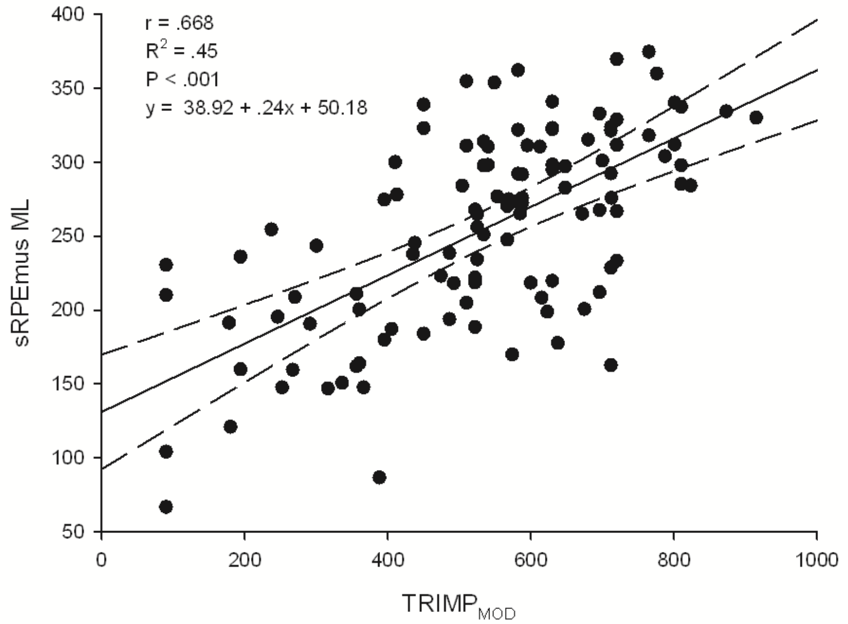

Figure 2 Correlation between overall HR-based ML (Edward's ML and TRIMP$_{MOD}$) and sRPE-based match load (sRPEres ML and sRPEmus ML) of 111 observations. Confidence interval (CI) 90%.

HR-based ML = heart rate based match load; Edward's ML = Edward's match load; TRIMP$_{MOD}$ = Stagnos' modified training impulse; sRPE ML = session rating of perceived exertion match load; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load.

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Table 1 Wheelchair basketball players’ characteristics.

Player	Physical Impairment	IWBF Classification	Age (years)	Injury time (years)	Training experience (years)	Modified YYIR1 (beat·min^{-1})	Match (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	Osteoarthritis congenital	4	40	40	21	179	183
8	Double amputation below knee	4	35	28	15	185	201
9	Knee injury	4.5	41	9	9	169	187
10	Knee injury	4.5	25	5	2	182	184
Sample (n = 10)		-	34 ± 8	24 ± 12	11 ± 7	178 ± 12	188 ± 13

Results are mean ± SD; YYIR1 = Yo-Yo intermittent recovery level 1 test; IWBF = International wheelchair basketball federation.

Table 2 Individual correlations between HR-based ML (Edward's ML and $TRIMP_{MOD}$) and RPE-based ML (sRPEres ML and sRPEmus ML).

	Edward's ML						$TRIMP_{MOD}$					
	sRPEres ML			sRPEmus ML			sRPEres ML			sRPEmus ML		
Player	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**	***r***	**CI (95%)**	**R^2**
1	.63*	.15-1.12	.40	.69**	.24-1.15	.48	.66*	.18-0.13	.43	.69**	.23-1.15	.47
2	.65**	.20-1.11	.43	.59*	.11-1.08	.35	.78**	.40-1.15	.60	.70**	.27-1.13	.49
3	.48	-.40-1.36	.23	.69	-.03-1.41	.48	.36	-.57-1.30	.13	.66	-.09-1.41	.43
4	.92	-.24-2.09	.85	.92	-.24-2.09	.85	.98*	.31-1.64	.95	.98*	.31-1.64	.95
5	.71**	.21-1.21	.50	.72**	.22-1.21	.51	.68*	.14-1.24	.47	.68*	.13-1.24	.46
6	.47	-.15-1.09	.22	.41	-.23-1.05	.17	.61*	.05-1.17	.37	.55	-.04-1.14	.30
7	.62*	.02-1.04	.38	.67*	.01-1.03	.45	.67*	.01-1.03	.44	.64*	.10-1.07	.41
8	.71**	.26-1.15	.50	.52	-.01-1.06	.27	.61*	.11-1.11	.37	.46	-.09-1.02	.22
9	.53*	.06-1.17	.28	.52*	.15-1.19	.28	.52*	.14-1.19	.27	.59*	.10-1.18	.35
10	.89*	.07-1.72	.80	.85	-.13-1.83	.72	.85	-.13-1.82	.72	.82	-.25-1.88	.67
Min	.47	-	.22	.41	-	.17	.364	-	.13	.46	-	.22
Max	.92	-	.85	.92	-	.85	.976	-	.95	.98	-	.95
Mean	.66 ± .16		.46 ± .22	.66 ± .15		.46 ± .21	.67 ± .17		.48 ± .23	.68 ± .14		.48 ± .21

*r = coefficient; CI = 95% confidence interval; R^2 = coefficient of determination; Min = minimum value; Max = maximum value; HR-based ML = heart rate based match load; Edward's ML = Edward's match load; $TRIMP_{MOD}$ = Stagnos' modified training impulse; sRPE ML = session rating of perceived exertion match load; sRPEres ML = respiratory session rating of perceived exertion match load; sRPEmus ML = muscular session rating of perceived exertion match load; *P < .05 and **P < .01: significant correlations between RPE-based TL and HR-based TL methods.*