# DIFFERENT APPROACHES TO DETERMINE PHYSIOLOGICAL THRESHOLDS IN HANDCYCLING ATHLETES

**Diego Antunes**[1]
*diegoantunestreinador@gmail.com*

**Eduardo Marcel Fernandes Nascimento**[1]
*eduardomarcel@usp.br*

**Alexandre Tremel**[1]
*atremel@gmail.com*

**Paulo Cesar do Nascimento Salvador**[1]
*nascimentosalvadorpc@gmail.com*

**Gabriela Fischer**[1]
*g.fischer@ufsc.br*

**Ricardo Dantas de Lucas**[1]
*ricardo.dantas@ufsc.br*

**Gary Brickley**[2]
*g.brickley@bton.ac.ul*

**[1]Universidade Federal de Santa Catarina (UFSC)**

**[2]University of Brighton**

## ABSTRACT

The aim of this study was to assess the relationship between physiological thresholds in handcycling athletes (HA) on treadmill tests. Eight HA with spinal cord injury (C5-T11) performed a maximal incremental handcycle test, plus three tests to exhaustion to determine critical speed (CS). The three methods (second ventilatory threshold, heart rate deflection point and CS) did not differ significantly from each other. In conclusion, the different methods were found at the same intensity for HA.

## KEYWORDS

*handcyling; physiological theresholds; paralympic sports*

## INTRODUCTION

Handcycling started to consolidate in the sports field when it was added as a modality of Paracycling in the World Championship in 1998. Also, the inclusion in 2004 Paralympic Games increase the visibility of this modality (Hettinga *et al*., 2010, p. 128). The majority of participants present spinal cord injury (SCI). The training prescription for this population is often based on empirical knowledge, due to specific characteristics of athletes and difficulty for perform laboratorial assessments.

Besides, the individuality of impairment leads to different physiological responses such as less activation of muscle groups during exercise, reduction of stroke volume, disruption of autonomic control, level and extension of SCI (complete or incomplete) (Baumgart *et al*., 2018. p. 19 and West *et al*., 2014. p.65). Thus, these specificities can lead a doubt which methods to use when assessing the submaximal aerobic function, such as physiological thresholds (PTs).

The identification of the metabolic transition zones are very important in handcycling for accuracy in prescription and determination of training intensity. (De Groot *et al*., 2014. p.459). The majority of studies comprise gas exchange measurements for determination of PTs (Fischer *et al*., 2015. p.970; Groot *et al*., 2018. p.3 e Lovell *et al*., 2012. p.3434). However, the determination of ventilatory thresholds (VTs) require sophisticated and expensive equipment, making it difficult to use these evaluation over season by the coaches.

Therefore, it is important to verify alternative and practical methods in disabled people during handcycling to determine PTs. The Heart Rate deflection point (HRDP) can be identified by the Dmax method and approximates to the onset of blood lactate accumulation (Cheng *et al*. 1992. p. 518). In this sense, the "critical speed" (CS; equivalent to critical power, CP) recognized as an important fatigue threshold in exercise physiology (Poole *et al*., 2016. p.16)D. C., M. BURNLEY, A. VANHATALO, H. B. ROSSITER, and A. M. JONES. Critical Power: An Important Fatigue Threshold in Exercise Physiology. Med. Sci. Sports Exerc., Vol. 48, No. 11, pp. 00–00, 2016. The hyperbolic form of the power–duration relationship is rigorous and highly conserved across species, forms of exercise, and individual muscles/muscle groups. For modalities such as cycling, the relationship resolves to two parameters, the asymptote for power (critical power [CP] appears as a low-cost alternative to identify the non-steady state intensity zone. Therefore, the purpose of this study was to assess the agreement among $VT_2$, HRDP and CS in handcycling athletes during treadmill handcycle tests.

## METHODS

### *Participants*

Six male and two female handcycling with SCI (34.5±4.6 years, 69.6±9.4 kg, injury level C5-T11) participate in this study. They signed an informed consent form approved by the ethical committee of the Federal University of Santa Catarina (protocol nº 94905118.5.0000.0121).

### *Experimental design*

Testing was performed on an oversized treadmill (Cosmo HP 300/100r, Germany), using the athlete's own handcycle. Each subject performed a maximal incremental handcycling test (MIHT), plus three tests until exhaustion at constant speed between 90-105% of the incremental peak speed for modeling CS, Before testing, all participants completed a questionnaire with information about health, training and level of disability. The oxygen uptake ($VO_2$) was measured breath-by-breath throughout the tests using a portable gas analyzer Cosmed K5 (Cosmed, Rome, Italy). Calibration of the device was performed according to manufacturer specification. HR was measured during the test with a HR monitor (S810, Polar Electro Oy, Kempele, Finland).

### *Maximal Incremental handcycle test*

After 5 to 10 min warm-up at a low speed and familiarization, the MIHT was started a speed between 9.0 and 28 $km.h^{-1}$ and was chosen according to athlete's previous race results. The speed was increased by 1 km.h$^{-1}$ every 3 min until the participants arrived their rating of perceived exertion (RPE) around 4-5 point in 10-point scale (Borg, 1998). Subsequently, the speed was increased by 1.0 km.h$^{-1}$ every 1 min, until exhaustion. A constant 1.0 % gradient was used throughout the test.

### *Determination of PTs*

*$VT_2$*. Breath by breath data were averaged to provide a data point for each 15-s period. For $VT_2$, the lowest value of the $VCO_2$ equivalent ($VE/VCO_2$) was used, before progressive increase. If the $VE/VO_2$ and $VE/VCO_2$ data did not show satisfactory sharpness, the expired oxygen and dioxide fractions were used in association, respectively (Meyer *et al*., 2005). *HRDP.* The Dmax method was applied to exclude mainly the subjectivity of the visual identification, as well as, the previous experience of the researcher (Cheng *et al*., 1992). This method consists of determining the point on the curve adjusted by the HR exercise intensity, at which the furthest perpendicular distance to the line drawn connecting the first and last point of the curve occurs $HRD_{MAX}$.

*CS.* The three speeds were selected to induce the exhaustion between 2-15 minutes. CS was determined using three mathematical models: the hyperbolic speed-time (Non-2) model, the linear inverse-of-time (Lin-S) and the linear distance-time (Lin-TD). The Lin-TD presented the best fit and was used for analysis. All the PTs, $HRD_{MAX}$, $VT_2$, and CS were expressed in absolute and relative values of speed (km.h$^{-1}$), $VO_2$ (ml. kg.min$^{-1}$) and HR (bpm).

### *Statistics*

Values were expressed as mean and standard deviation (± SD). After ensuring Gaussian data distribution (normality and homoscedasticity), a one-way ANOVA with Scheffe post-hoc test was used to verify possible differences among different thresholds. The Bland and Altman plot further provided a visual analysis of the data set bias (Bland and Altman, 1986). All analyzes were performed with SPSS (21.0). Results were interpreted as significant when P was $< 0.05$.

## RESULTS

The peak values obtained during the MIHT were 37.0 ± 9.3 km.h$^{-1}$ for speed, $VO_{2PEAK}$ = 45.6±9.5 ml.kg. min$^{-1}$, $HR_{MAX}$ = 178 ± 17 bpm and RPE (9 – 10 points). Values of speed, $VO_2$ and HR corresponding to $VT_2$, HRDP and CS are presented in Table 1. All the variables did not present significantly difference among methods. The Bland-Altman plot between each pair of methods was depicted in Figure 1, and revealed the agreement between speeds obtained from the three approaches.

**Table 1.** Physiological Thresholds expressed in absolute and relative speed, oxygen uptake and heart rate during treadmill handcycling test.

| | Speed | | $VO_2$ | | HR | |
|---|---|---|---|---|---|---|
| | **(km.h$^{-1}$)** | **%Peak speed** | **(ml.kg.min$^{-1}$)** | **%$VO_{2peak}$** | **(bpm)** | **%$HR_{max}$** |
| **$VT_2$** | 30.9 ± 8.3 | 84.7 ± 4.0 | 33.1 ± 11.7 | 74.1 ± 10.3 | 164 ± 22 | 93.5 ± 2.6 |
| **HRDP** | 30.0 ± 9.2 | 81.8 ± 8.2 | 31.8 ± 11.6 | 70.2 ± 8.9 | 162 ± 24 | 92.0 ± 4.5 |
| **CS** | 32.5 ± 7.5 | 89.8 ± 2.6 | 32.9 ± 11.1 | 73.8 ± 8.7 | 160 ± 24 | 94.8 ± 2.5 |

**Table 2.** Pearson Correlation expressed for absolute and relative speed, oxygen uptake and heart rate during treadmill handcycling test.

| | Speed | | | $VO_2$ | | | HR | | |
|---|---|---|---|---|---|---|---|---|---|
| | **$VT_2$** | **HRDP** | **CS** | **$VT_2$** | **HRDP** | **CS** | **$VT_2$** | **HRDP** | **CS** |
| **$VT_2$** | | .970** | .980** | | .975** | .987** | | .962** | .996** |
| **HRDP** | -.024 | | .951** | .576 | | .957** | .521 | | .955** |
| **CS** | -.789* | -.010 | | .737* | .629 | | .716* | .360 | |

***** $p < 0.05$.
****** $p < 0.01$.

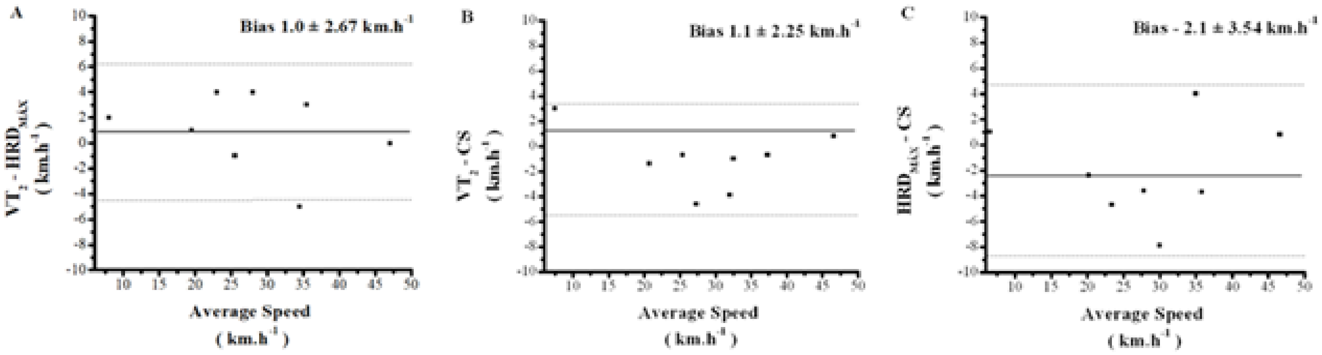


**Figure 1.** Bland and Altman Plot for the agreement between $VT_2$ and HRDP (A), $VT_2$ and CS (B), and between HRDP and CS (C) methods. Bias ± 95% of Level of Agreement are shown at the top of each panel.

## DISCUSSION

The principal finding of this investigation indicates that $VT_2$, HRDP and CS occurred at the same intensity zone in HA during treadmill testing (70.2 - 74.1 % $VO_{2PEAK}$). Most studies have been identified $VT_2$ in HA during incremental tests. Similar values of $VT_2$ to the present study (74.0 ± 10.3 % $VO_{2PEAK}$) were found in the study of Lovell *et al*. (2012 p.3434) for trained HA (74.1 ± 6.4 % $VO_{2PEAK}$), altought Fischer *et al*. (2015. p.970) reported higher values (93 % $VO_{2PEAK}$). These differences could be related to the testing protocol and the sample size. The endurance performance in wheelchair sports occurred close to of $VT_2$ intensity (Bernardi *et al*., 2010. p.1256)n = 5.

The HRDP is other alternative non-invasive method to determine PTs, in able-bodied cyclist. HRDP showed reliable and reproducible for detecting ventilatory and lactate thresholds (Cheng *et al*. 1992. p. 518). In this sense, the CS is also an endurance index representing some agreement to PTs. However, it is not known about its applicability in paralympic sports. Similarly with our findings, in the study of Dekerle *et al*., 2003. p.287 assessing able-bodied subjects during cycling, the CP and $VT_2$ did not show differences, despite that were higher than maximal lactate steady state Furthermore, in athletes with paraplegia and tetraplegia, the [La] showed a practical advantage over ventilatory data collection (Leicht *et al*., 2014. p.1641)the ventilatory threshold and the respiratory compensation point (RCP. However, the invasive methods are hardly applied in practice by coaches.

In conclusion, the different methods analyzed herein ($VT_2$, HRDP and CS) present good agreement between them and might be useful for identifying PTs in HA. Thus, it might be a valuable tool for coaches prescribing trainings. Further research is necessary to explain the physiological significance and applicability of the PTs in HA.

### DIFERENTES ABORDAGENS PARA DETERMINAR LIMIARES FISIOLÓGICOS EM ATLETAS DE HANDCYCLING

### RESUMO

O objetivo desse estudo foi avaliar a relação entre limiares fisiológicos em atletas de handcycle (HA) durante testes na esteira. Oito AH com lesão medular (C5-T11) realizaram um teste incremental máximo, mais três testes de exaustão para determinar a velocidade crítica (VC). Os três métodos (segundo limiar ventilatório, ponto de deflexão cardíaca e VC) não apresentaram diferença significativas entre eles. Concluímos que os diferentes métodos foram encontrados na mesma intensidade para HA.

**PALAVRAS-CHAVE:** *handcycling; limiares fisiológicos; esportes paralímpico*

## DIFERENTES ENFOQUES DE DETERMINACIÓN DE LOS LIMIARES FISIOLÓGICOS EN ATLETAS DE HANDCYCLING

**RESUMEN**

El objetivo de este estudio fue evaluar la relación entre umbrales fisiológicos en atletas de handcycle (HA) durante pruebas en la estera. Ocho AH con lesión medular (C5-T11) realizaron una prueba incremental máxima, más tres pruebas de agotamiento para determinar velocidad crítica(VC). Los tres métodos (segundo umbral ventilatorio, punto de deflexión cardíaca y VC) no presentaron diferencias significativas. Concluimos que los diferentes métodos fueron encontrados en la misma intensidad para HA.

**PALABRAS CLAVES:** *handcycling; limiares fisiológicos; desporte paralímpico*

### REFERENCES

BAUMGART, J. K.; BRUROK, B.; SANDBAKK, Ø. Peak oxygen uptake in Paralympic sitting sports: A systematic literature review, meta- and pooled-data analysis. *PLoS ONE*, v. 13, n. 2, p. 1–25, 2018.

BERNARDI, M.; DI GIACINTO, B.; CASTELLANO, V.; *et al*. Field Evaluation of Paralympic Athletes in Selected Sports. *Medicine & Science in Sports & Exercise*, v. 42, n. 6, p. 1, 2010.

CHENG B *et al*. A new approach for the determination of ventilatory and lactate thresholds. *Int J Sports Med*. 1992;13(7):518–22

CONCONI, F *et al*. Determination of the anaerobic threshold by a noninvasive field test in runners. *Journal of Applied Physiology*, Bethesda, v. 52, n. 4, p. 869-73, 1982.

DE GROOT, S T *et al*. Mountain time trial in handcycling: Exercise intensity and predictors of race time in people with spinal cord injury. *Spinal Cord*, v. 52, n. 6, p. 455–461, 2014. Nature Publishing Group.

DE GROOT, S.; HOEKSTRA, S.; COMTESSE, P.; KOUWIJZER, I.; VALENT, L. Relationships between internal and external handcycle training load in people with spinal cord injury training for the handbikebattle. *Journal of Rehabilitation Medicine*, v. 50, n. 3, p. 261–268, 2018.

DEKERLE, J T *et al*. Maximal lactate steady state, respiratory compensation threshold and critical power. European *Journal of Applied Physiology*, v. 89, n. 3–4, p. 281–288, 2003.

FISCHER, G.; FIGUEIREDO, P.; ARDIGÒ, L. P. Physiological Performance Determinants of a 22 km Handbiking Time Trial. *International journal of sports physiology and performance*, n. April 2016, p. 965–971, 2015.

HETTINGA, F. J T *et al*. Hand-Cycling: An Active Form of Wheeled Mobility, Recreation, and Sports. *Physical Medicine and Rehabilitation Clinics of North America*, v. 21, n. 1, p. 127–140, 2010.

LEICHT, C. A *et al*. Blood lactate and ventilatory thresholds in wheelchair athletes with tetraplegia and paraplegia. *European Journal of Applied Physiology*, v. 114, n. 8, p. 1635–1643, 2014.

LOVELL, D. *et al*. The aerobic performance of trained and untrained handcyclists with spinal cord injury. *European Journal of Applied Physiology*, v. 112, n. 9, p. 3431–3437, 2012.

MEYER, T *et al*. A conceptual Framework for Performance Diagnosis and Training Prescription from Submaximal Gas Exchange Parameters – Theory and Application. International *Journal of Sports Medicine*, Stuttgard, v. 26, p.S38-S48, 2005.

POOLE, D. C *et al*. Critical power: An important fatigue threshold in exercise physiology. *Medicine and Science in Sports and Exercise*, v. 48, n. 11, p. 2320–2334, 2016.

WEST, C. R.; WONG, S. C.; KRASSIOUKOV, A. V. Autonomic cardiovascular control in paralympic athletes with spinal cord injury. *Medicine and Science in Sports and Exercise*, v. 46, n. 1, p. 60–68, 2014.