



# CAN WE IDENTIFY THE HEART RATE DEFLECTION POINT AND RATING OF PERCEIVED EXERTION THRESHOLD DURING THE YO-YO INTERMITTENT RECOVERY TEST LEVEL 1 IN UNIVERSITY BASKETBALL PLAYERS? A PILOT STUDY

doi: 10.1515/humo-2016-0029

JUAN HENRIQUE SZYMCZAK CONDE\*, GISLAINE CRISTINA DE SOUZA, POLIANA DE LIMA COSTA, LUIZ FERNANDO NOVACK, RAUL OSIECKI

Department of Physical Education, Federal University of Parana, Curitiba, Brazil

## ABSTRACT

**Purpose.** The aim of the study was to identify the heart rate deflection point (HRDP) and the rating of perceived exertion (RPE) threshold ( $D_{\max}$ RPE) during the Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1) in university basketball players. **Methods.** Eleven male university basketball athletes performed two incremental tests, interspersed by seven days, in a random crossover pattern: (1) the treadmill test with the initial velocity of  $6 \text{ km} \cdot \text{h}^{-1}$ , increments of  $1 \text{ km} \cdot \text{h}^{-1}$  each 2 minutes, and pauses of 15 seconds between the stages; (2) the Yo-Yo IR1. **Results.** During the Yo-Yo IR1, the HRDP and the  $D_{\max}$ RPE were identified only in six and seven subjects, respectively. In the treadmill test, the HRDP and the  $D_{\max}$ RPE were found in 11 and 10 individuals, respectively. Additionally, there were no differences between the velocity of occurrence of the HRDP and the  $D_{\max}$ RPE recognized in the treadmill test and in the Yo-Yo IR1 ( $p > 0.05$ ). **Conclusions.** The results suggest that if the goal is to determine aerobic capacity by the HRDP and the  $D_{\max}$ RPE, Yo-Yo IR1 should not be used. Instead, the treadmill test is a reliable tool.

**Key words:** incremental test, perceived exertion, aerobic capacity

## Introduction

Basketball is defined as an interval and intermittent sport, once the technical and tactical actions involve sudden and repeated changes of direction, and high intensity effort with short duration (e.g. shooting, blocking, rebounding, and fast offense-defence transitions). In addition, basketball is a predominantly aerobic sport; however, actions that determine the success in a match depend on anaerobic metabolism [1]. On the other hand, it is advantageous for team sports athletes to have an increased aerobic metabolism, since it allows them to recover faster from brief and intense efforts [2] and perform repeated sprints with less fatigue [3].

The anaerobic threshold (AnT) is a widely used methodology for the evaluation of aerobic fitness in athletes [4]. Some authors have suggested that the velocity/load of AnT occurrence is associated with performance in team sports and repeated sprint ability [5]. It has been demonstrated that AnT can be identified by the heart rate deflection point (HRDP), which is found at similar intensities to the lactate threshold (LT) [6]. Another proxy for AnT is the rating of perceived exertion (RPE) threshold ( $D_{\max}$ RPE). This method has been recently demonstrated in literature by Fabre et al. [7], who applied the  $D_{\max}$  mathematical model to the RPE curve during a progressive test in a cycle ergometer and found it in the same intensity of occurrence as LT.

In the current sports context, it is necessary to evaluate the aerobic fitness by tests that take into account the interval and intermittent nature of basketball. In

this regard, Castagna et al. [8] validated the Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1) to measure the aerobic power in basketball athletes. However, the literature still lacks information about the possibility to identify the HRDP and  $D_{\max}$ RPE during this test.

Therefore, the aim of the present study was to verify the possibility to determine the HRDP and the  $D_{\max}$ RPE during the Yo-Yo IR1.

## Material and methods

### Sample

The participants of the study were 11 male university basketball athletes (age,  $20.6 \pm 2.3$  years; height,  $185.2 \pm 9.4$  cm; body mass,  $84.7 \pm 18$  kg; body fat,  $13.2 \pm 7.7\%$ ). Individuals were informed about the possible risks and provided a signed consent to take part in the study. The ethics committee on human research at the State University approved the study procedures (CAAE: 33221414.3.0000.0106). The participants were instructed to refrain from alcohol and caffeine for 24 hours before the test.

### Experimental design

The study was composed of two evaluation sessions: (1) laboratory treadmill (Greenmaster model x-fit7, São Paulo, Brazil) test; (2) intermittent field test (Yo-Yo IR1). These were carried out in a random crossover pattern, interspersed by seven days for washout. The heart rate (HR) was monitored with the use of a cardiofrequency FirstBeat® (Jyväskylä, Finland) and the RPE with the CR-10 Borg Scale [9]. The tests were performed in the afternoon and in the evening; the data were collected

\* Corresponding author.

between November 27<sup>th</sup> and October 13<sup>th</sup>, 2015 (temperatures ranged between ca. 23–25°C in the laboratory and ca. 26–29°C in the gym), at the beginning of the off-season.

#### Laboratory treadmill test protocol

The test was characterized by the initial speed of 6 km · h<sup>-1</sup>, increments of 1 km · h<sup>-1</sup> each 2 minutes, and pauses of 15 seconds between the stages [10]. The peak velocity (PV) was determined by the equation proposed by Kuipers et al. [11]:

$$PV = V + \frac{t}{120}$$

where V is the velocity in the last complete stage, t is the time (s) of the incomplete stage, and 120 is the duration (s) of a complete stage. Verbal stimuli were given to individuals to reach to their maximum. The first treadmill test velocities were low, thus a previous warm-up was not necessary.

#### Yo-Yo Intermittent Recovery Test level 1

Before the Yo-Yo IR1, the subjects performed a standard warm-up, consisting of running around the court for 5 minutes. The test consisted in 40 m (2 × 20 m) shuttle runs, signalled by a beep, interspersed by 10 seconds of active recovery. The initial velocity was 10 km · h<sup>-1</sup>, then it increased to 12 km · h<sup>-1</sup>, in the third stage it increased to 13 km · h<sup>-1</sup>, and from the fourth stage on it incremented by 0.5 km · h<sup>-1</sup> at each stage. The test was finished by volitional exhaustion or when the subject could not twice keep the pace signalled by the beep, considering a delay, when it was bigger than the 2 m of tolerance. The Yo-Yo IR1 was validated for basketball athletes [8]. Figure 1 illustrates the course of the test.

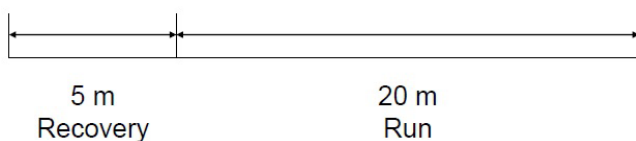


Figure 1. A preview of the Yo-Yo Intermittent Recovery Test Level 1

Table 1. Perceptive responses and the velocity of the physiological transition points occurrence expressed by HR (beats · min<sup>-1</sup>), %PV, and %HR<sub>max</sub>

	HRDP		D <sub>max</sub> RPE	
	Yo-Yo IR 1 (n = 6)	Treadmill (n = 11)	Yo-Yo IR 1 (n = 7)	Treadmill (n = 10)
Velocity (km·h <sup>-1</sup> )	13.5 ± 1	10.3 ± 1.2	13.2 ± 0.3	10.1 ± 1.1
RPE	3.3 ± 2.5	5.2 ± 1.7	2.3 ± 1†	5.1 ± 2.2
HR (beats·min <sup>-1</sup> )	166 ± 12	176 ± 10	167 ± 12	174 ± 14
%PV	87.7 ± 5.1†*	75.9 ± 7.9	88.7 ± 2†*	74.8 ± 7.9
%HR <sub>max</sub>	86.7 ± 8	89.7 ± 4	86 ± 6	89.1 ± 5.1

† Significantly different from the HRDP in the treadmill test.

\* Significantly different from the D<sub>max</sub>RPE in treadmill test. Significance at *p* < 0.05.

#### Determination of the Heart Rate Deflection Point

The HR values equal or greater than 140 beats · min<sup>-1</sup> were plotted at each stage versus the running speed. A linear fit between both HR curve extremes (i.e. the first and last value), and the 3<sup>rd</sup> degree polynomial fit through all the curve points were applied. The HRDP was obtained in the highest distance between the linear and the 3<sup>rd</sup> degree polynomial fit [12].

#### Determination of the rating of perceived exertion threshold

The D<sub>max</sub>RPE was obtained in the highest distance between the linear fit between both curve extremes and the 3<sup>rd</sup> degree polynomial fit through all curve points [7].

#### Statistical analyses

Initially, data normality was tested with the Shapiro-Wilk test. The only data set considered non-parametric was the HRDP velocity relative to the HR<sub>max</sub> (%HR<sub>max</sub>) in the Yo-Yo IR1. Thus, the Kruskal-Wallis test was applied to compare the %HR<sub>max</sub> of the thresholds. The parametric data were compared with the use of one-way ANOVA and Tukey's post hoc tests. Furthermore, owing to the small sample size, possible associations between the data were tested with the Spearman's rank correlation. The significance was set at the value of *p* < 0.05. Statistical analyses were carried out with the Statistica 7.0 software (Oklahoma, USA).

#### Results

Table 1 presents the number of subjects in which it was possible to identify the thresholds, as well as the velocities of occurrence of the HRDP and the D<sub>max</sub>RPE during the Yo-Yo IR1 and during the treadmill test. During the Yo-Yo IR1, the HRDP was found in 6 of the 11 subjects only, whereas in the treadmill test, it was established in all the participants. The D<sub>max</sub>RPE was identified in 7 of 10 subjects in the Yo-Yo IR1 and in 10 of 11 participants in the treadmill test. When the data were expressed relative to the peak of velocity (%PV),

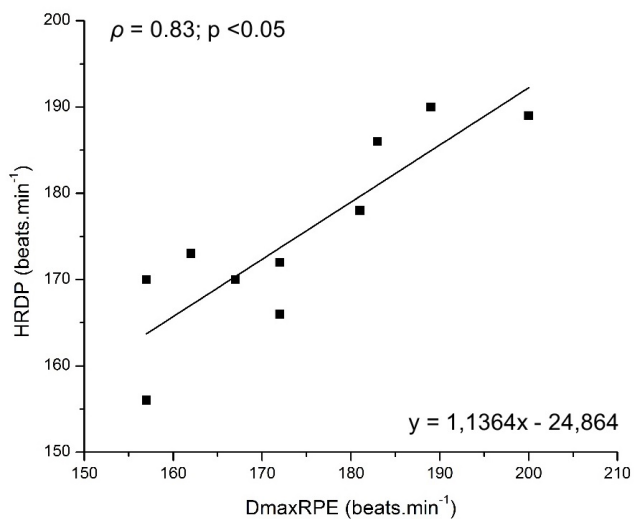


Figure 2. Association between the absolute HR at the HRDP and the  $D_{max}RPE$  in the treadmill test ( $\rho = 0.83$ ;  $p < 0.05$ )

the comparison of the thresholds in the Yo-Yo IR1 and in the treadmill test showed a statistical difference ( $p < 0.05$ ). However, when the HRDP and the  $D_{max}RPE$  were compared, there was no significant difference ( $p > 0.05$ ). Similarly, when the thresholds were expressed by  $\%HR_{max}$  and by the absolute HR (beats  $\cdot$  min $^{-1}$ ), no statistically differences were found ( $p > 0.05$ ). Moreover, the RPE values obtained in the  $D_{max}RPE$  during the Yo-Yo IR1 were significantly lower than the experienced ones in the HRDP identified in the treadmill test ( $p < 0.05$ ).

Significant associations were found between the HRDP and the  $D_{max}RPE$  identified in the treadmill test when they were expressed by the absolute HR ( $\rho = 0.83$ ) (Figure 2). The correlations between HRDP and  $D_{max}RPE$  in the treadmill test expressed by  $\%HR_{max}$  and  $\%PV$  were  $\rho = 0.62$  and  $\rho = 0.39$ , respectively; however, they did not approach significance. No significant associations were established between the HRDP and the  $D_{max}RPE$  during the Yo-Yo IR1 in  $\%PV$  ( $\rho = -0.50$ ),  $\%HR_{max}$  ( $\rho = 0.50$ ), or HR ( $\rho = -0.23$ ).

Figures 3 and 4 represent, respectively, the  $D_{max}RPE$  and HRDP calculation for one representative individual from the sample during the treadmill test (A) and the Yo-Yo IR1 (B).

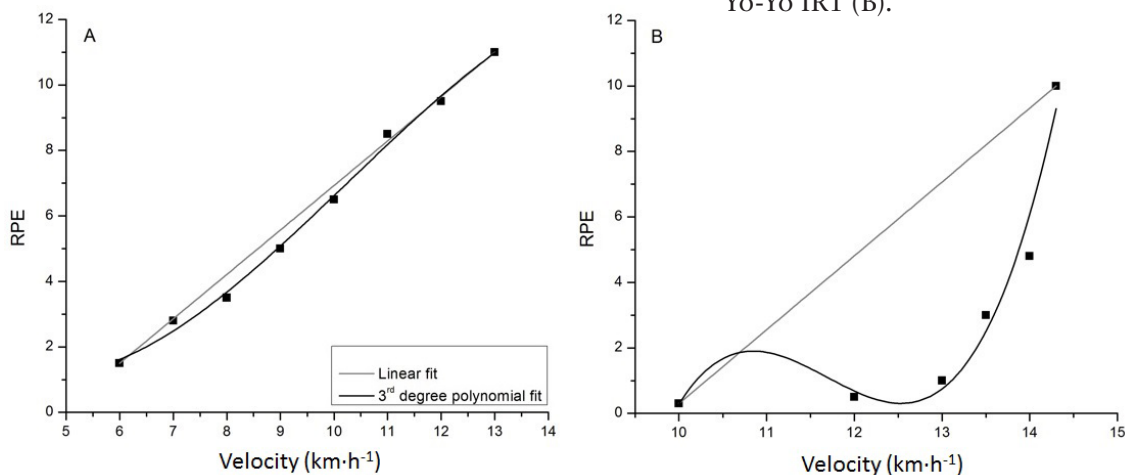


Figure 3. The  $D_{max}RPE$  identified during the treadmill test (A) and during the Yo-Yo IR1 (B) in one subject of the sample

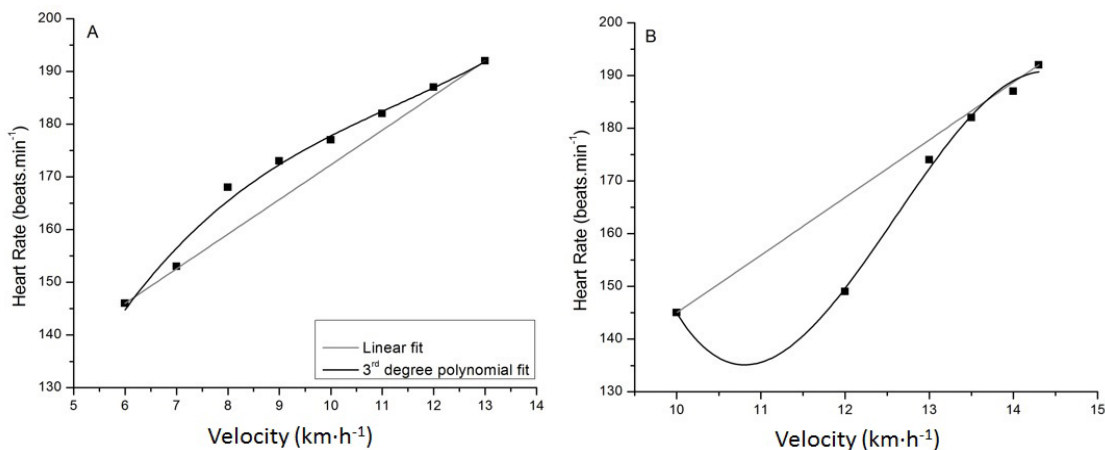


Figure 4. The HRDP identified during the treadmill test (A) and during the Yo-Yo IR 1 (B) in one subject of the sample

## Discussion

The main finding of the study was that the HRDP and the  $D_{\max}$ RPE were not identified in all subjects during the Yo-Yo IR1: only in 6 (54%) and 7 (63%) of the 11 individuals, respectively. In contrast, during the treadmill test, the HRDP was found in all and the  $D_{\max}$ RPE in 10 (91%) of the 11 subjects.

Dittrich et al. [13] found the HRDP in all individuals submitted to an intermittent field test in which the velocity increased linearly (Carminatti's Test, TCar). In the present study, however, the HRDP could not be assessed in subjects whose HR values equal or higher than  $140 \text{ beats} \cdot \text{min}^{-1}$  were achieved at intensities lower than  $13 \text{ km} \cdot \text{h}^{-1}$ . The impossibility to calculate the HRDP during the Yo-Yo IR1 may be due to the non-linear increasing of the speed [8], causing the 3<sup>rd</sup> degree polynomial trend line to permeate the values the subjects did not reach during the test (Figure 4B). Once the threshold is obtained in the higher distance between the 3<sup>rd</sup> degree polynomial fit through all the curve points and a linear fit between the curve extremes, owing to the nonlinear increasing of the speed, the threshold for these individuals would have occurred at very low velocities.

Similarly, the  $D_{\max}$ RPE was not identified in all subjects as the 3<sup>rd</sup> degree polynomial trend lines permeated unreal values, not reached by the individuals. Besides, when the  $D_{\max}$ RPE could be identified, the velocity of occurrence was close to  $13 \text{ km} \cdot \text{h}^{-1}$  for all individuals, which possibly does not represent the real value of the threshold. Like the pattern of the velocity increments, the number of shuttle runs to be held during the stages, which increases nonlinearly, apparently plays an important role. In the Yo-Yo IR1, athletes had to hold two shuttle runs at  $13 \text{ km} \cdot \text{h}^{-1}$ ; in the next stage, they had to face three shuttle runs at  $13.5 \text{ km} \cdot \text{h}^{-1}$ , which led to an abrupt increase in the RPE (Figure 3B). This hypothesis is supported by the results obtained by Kuipers et al. [14], who observed that the velocity of the LT occurrence was lower in 6-minute stages compared with 3-minute stages, suggesting an effect of the time at which the velocity is sustained.

On the other hand, in the treadmill test, the HRDP was identified in all subjects and the  $D_{\max}$ RPE in 10 of the 11 individuals. The HRDP is often found at intensities close to the LT [15]. Accordingly, our results corroborate the observations by Conde et al. [16] and Dittrich et al. [13], who found the HRDP at  $91.8 \pm 3.9 \%HR_{\max}$  and  $91.6 \%HR_{\max}$ , respectively, whilst we established it at  $89.7 \pm 4 \%HR_{\max}$ .

Not significant differences were found between the intensity of occurrence of the  $D_{\max}$ RPE ( $89.1 \pm 5.1 \%HR_{\max}$ ) and the HRDP ( $89.7 \pm 4 \%HR_{\max}$ ). These results are supported by those obtained by Conde et al. [16], who identified the  $D_{\max}$ RPE and the HRDP in similar intensities ( $89.7 \pm 7.6 \%HR_{\max}$  and  $91.8 \pm 3.9 \%HR_{\max}$ , respectively). However, in the present study, a strong signifi-

cant correlation was discovered between the intensity of occurrence of both thresholds when they were expressed by absolute HR ( $\rho = 0.83$ ;  $p < 0.05$ ) (Figure 2). Fabre et al. [7] found the  $D_{\max}$ RPE at the same intensity as the LT. Similarly, Ferreira et al. [17] observed that the intensity of occurrence of the  $D_{\max}$ RPE and the LT was the same, independently of the pre-exercise carbohydrate availability, which suggests that the AnT can be estimated by the RPE scale alone.

As a limitation, the sample of the present study was small, which reduces the statistical power of the research. On the other hand, the HRDP and the  $D_{\max}$ RPE were identified in only 54% and 63% of the individuals during the Yo-Yo IR1, which is an important outcome. A coach would not use an improper test for his goal. Thus, if the goal is to determine aerobic capacity by the HRDP and  $D_{\max}$ RPE, Yo-Yo IR1 should not be used. Further research demonstrating the identification of the HRDP and  $D_{\max}$ RPE in other field tests, using larger samples, is encouraged.

## Conclusions

The  $D_{\max}$ RPE and the HRDP were found at similar velocities in the treadmill test and in the Yo-Yo IR1, which supports the usage of the RPE scale as a proxy of aerobic capacity. However, during the Yo-Yo IR1, the HRDP and the  $D_{\max}$ RPE were identified only in 54% and 63% of the individuals, respectively. Therefore, Yo-Yo IR1 should not be applied to determine aerobic capacity by the HR and RPE curves in university basketball athletes.

## References

1. Ziv G., Lidor R., Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. *Sports Med*, 2009, 39 (7), 547–568, doi: 10.2165/00007256-200939070-00003.
2. Spencer M., Bishop D., Dawson B., Goodman C., Physiological and metabolic responses of repeated-sprint activities specific to field-based team sports. *Sports Med*, 2005, 35 (12), 1025–1044, doi: 10.2165/00007256-200535120-00003.
3. Bogdanis G.C., Nevill M.E., Boobis L.H., Lakomy H.K., Contribution of phosphocreatine and aerobic metabolism to energy supply during repeated sprint exercise. *J App Physiol*, 1996, 80 (3), 876–884.
4. Midgley A.W., McNaughton L.R., Jones A.M., Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Med*, 2007, 37 (10), 857–880, doi: 10.2165/00007256-200737100-00003.
5. Bishop D., Girard O., Mendez-Villanueva A., Repeated-sprint ability – part II. *Sports Med*, 2011, 41 (9), 741–756, doi 10.2165/11590560-000000000-00000.
6. Erdogan A., Cetin C., Karatosun H., Baydar M.L., Non-invasive indices for the estimation of the anaerobic threshold of oarsmen. *J Int Med Res*, 2010, 38 (3), 901–915, doi: 10.1177/147323001003800316.



7. Fabre N., Mourot L., Zerbini L., Pellegrini B., Bortolan L., Schena F., A novel approach for lactate threshold assessment based on rating of perceived exertion. *Int J Sports Physiol Perform*, 2013, 8 (3), 263–270, doi: 10.1123/ijspp.8.3.263.
8. Castagna C., Impellizzeri F.M., Rampinini E., D'Ottavio S., Manzi V., The Yo-Yo Intermittent Recovery Test in basketball players. *J Sci Med Sport*, 2008, 11 (2), 202–208, doi: 10.1016/j.jsams.2007.02.013.
9. Borg G., The Borg CR10 Scale. In: Borg G., Borg's perceived exertion and pain scales. Human Kinetics, Champaign 1998, 39–43.
10. Rocha C., Canellas A., Monteiro D., Antoniazzi M., Azevedo P.H., Changes in individual glucose threshold during military training. *Int J Sports Med*, 2010, 31 (7), 482–485, doi: 10.1055/s-0030-1248284.
11. Kuipers H., Verstappen F.T., Keizer H.A., Geurten P., van Kranenburg G., Variability of aerobic performance in the laboratory and its physiologic correlates. *Int J Sports Med*, 1985, 6 (4), 197–201, doi: 10.1055/s-2008-1025839.
12. Kara M., Gökbel H., Bediz C., Ergene N., Uçok K., Uysal H., Determination of the heart rate deflection point by the  $D_{max}$  method. *J Sports Med Phys Fitness*, 1996, 36 (1), 31–34.
13. Dittrich N., da Silva J.F., Castagna C., de Lucas R.D., Guglielmo L.G.A., Validity of Carminatti's test to determine physiological indices of aerobic power and capacity in soccer and futsal players. *J Strength Cond Res*, 2011, 25(11), 3099–3106, doi: 10.1519/JSC.0b013e3182132ce7.
14. Kuipers H., Rietjens G., Verstappen F., Schoenmakers H., Hofman G., Effects of stage duration in incremental running tests on physiological variables. *Int J Sports Med*, 2003, 24 (7), 486–491, doi: 10.1055/s-2003-42020.
15. Bodner M.E., Rhodes E.C., A review of the concept of the heart rate deflection point. *Sports Med*, 2000, 30 (1), 31–46, doi: 10.2165/00007256-200030010-00004.
16. Conde J.H.S., Rubio T.B.G., Ferreira G.A., Coelho R.L., de Oliveira F.R., Osiecki R., Identification of the lactate threshold and the heart rate deflection point by the perceived exertion curve. *J Exerc Physiol Online*, 2014, 17 (3), 32–38.
17. Ferreira G.A., Osiecki R., Lima-Silva A.E., Angelis-Pereira M.C., De-Oliveira F.R., Effect of a reduced-CHO diet on the rate of perceived exertion curve during an incremental test. *Int J Sport Nutr Exerc Metab*, 2014, 24 (5), 532–542, doi: 10.1123/ijsnem.2013-0248.

Paper received by the Editor: April 7, 2016

Paper accepted for publication: November 24, 2016

*Correspondence address*

Juan Henrique Szymczak Conde  
Department of Physical Education  
Federal University of Parana  
Coração de Maria Street, 92  
Jardim Botânico, Curitiba, Paraná,  
Brazil 80210-132  
e-mail: juanufpr@gmail.com