Original article

Validity of the RAST for evaluating anaerobic power performance as compared to Wingate test in cycling athletes

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Abstract—The validity of the Running-based Anaerobic Sprint Test (RAST) was investigated to evaluate the anaerobic power performance in comparison to Wingate test in cycling athletes. Ten mountain-bike male cyclists (28.0±7.3 years) randomly performed Wingate Test and RAST with two trials each. After several anthropometric measurements, peak power (PP), mean power (MP) and fatigue index (FI) for RAST and Wingate Test were analyzed using Student's paired *t*-test, Pearson's linear correlation test (*r*) and Bland and Altman's plots. Results showed that, with the exception of FI (33.8±4.6% vs. 37.8±7.9%; *r*=0.172), significant differences were detected between the Wingate and RAST tests with regard to PP and MP. Although there was a strong correlation for PP and MP, or rather, 0.831 and 0.714 respectively, agreement of analysis between Wingate and RAST protocols was low. The above suggested that RAST was not appropriate to evaluate the performance of anaerobic power by Wingate test in cycling athletes.

Keywords: cyclists, mountain bike, running-based anaerobic sprint test, running test

Resumo—"Validade do RAST para avaliar o desempenho da potência anaeróbia em relação ao teste Wingate em ciclistas." O objetivo foi investigar a validade do teste de RAST (Running-based Anaerobic Sprint Test) em avaliar o desempenho da potência anaeróbia a partir do teste de Wingate em ciclistas treinados. Participaram do estudo 10 ciclistas do sexo masculino (28,0±7,3 anos) da modalidade de Mountain bike. Após a mensuração das variáveis antropométricas, a potência pico (PP), média (PM) e o índice de fadiga (IF) foram determinados randomicamente a partir de dois testes de Wingate e dois testes de RAST. Foram utilizados o teste *t* independente de Student, a análise de correlação linear de Pearson (*r*) e o teste de Bland-Altman. Os resultados demonstraram, exceto para o IF (33.8±4.6% vs. 37.8±7.9%; *r*=0.172), diferenças significativas entre o teste de Wingate e o RAST para PP e PM (W.kg-1 e W). Embora os valores de correlação para a PP e PM (W) tenham sido fortes (0.831 e 0.714, respectivamente) a concordância entre os protocolos de Wingate e RAST foi baixa, sugerindo que o teste de RAST não é válido para avaliar o desempenho da potência anaeróbica a partir do teste de Wingate em ciclistas.

Palavras-chaves: ciclistas, *mountain bike*, RAST, testes de corrida

Resumen—"Validad del RAST para evaluar el rendimiento de potencia anaeróbica en comparación con el test de Wingate en los atletas de ciclismo." El objetivo fue investigar la validad del teste de RAST (Running-based Anaerobic Sprint Test) en evaluar el desempeño de la potencia anaeróbica través del uso del teste de Wingate en ciclistas trenados. Participaron del estudio 10 ciclistas masculinos (28,0±7,3 años) de la modalidad de Mountain bike. Después de la mensuración de las variables antropométricas, la potencia pico (PP), media (PM) y el índice de fatiga (IF) fueron determinados al acaso a partir de dos testes de Wingate y de dos testes de RAST. Fueron utilizados el test *t* independiente de Student, el análisis de correlación linear de Pearson (*r*) y el test de Bland-Altman. Los resultados demostraron, contrariamente al IF (33.8±4.6% vs. 37.8±7.9%; *r*=0.172), diferencias significativas entre el teste de Wingate y el RAST para PP y PM (W.kg-1 e W). Mismo que los valores de correlación de PP e PM (W) tengan sido fortes (0,831 e 0,714, respectivamente), la concordancia entre los protocolos de Wingate y RAST fue baja, sugiriendo que el teste de RAST no es válido para evaluar el desempeño de la potencia anaeróbica a partir del teste de Wingate en este grupo.

Palabras claves: ciclista, *mountain bike*, RAST, testes de corrida

Introduction

Bicycles are some of the most popular vehicles for competitions, sports and transport. In sports competitions, cycling has been extremely popular on the track, road, BMX, in the Paralympic games and several mountain-bike modalities. Although duration of sports competitions affects aerobic metabolism, anaerobic pathways have great influence during certain periods of cycling. While taking into consideration the constant changes in land relief where competitions are carried out, power and speed are required during start, speeding, uphill, flights and final sprint (Sadoyama, Masuda, Miyata & Katsuda, 1988). Anaerobic ability is important for performance in competitions since adenosine triphosphate re-synthesis speed becomes a variable of great relevance during critical moments when maximum and intense power is required (Nummela, Alberts, Rijntjes, Luhtanen, & Rusko, 1996).

Since anaerobic capacity in cycling athletes is highly important, the development of tools and alternative methodologies for its estimate are required (Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985). The literature abounds with a wide variety of protocols for cycling ergometer and running test to evaluate anaerobic performance. The Wingate test is considered the most common test to evaluate anaerobic cycling performance (Bar-Or, 1987) and many studies have used the Wingate test to assess the anaerobic metabolism of multi-sprint sports athletes (Bencke et al., 2002; Davis, Brewer, & Atkin, 1992). The test provides data on anaerobic power, such as peak power (PP), mean power (MP) and fatigue index (FI), that correspond to the mechanical power developed by the recruited muscular group. Within the Wingate test protocol, PP represents the highest average power output over a 3- to 5-second period, MP is the average power maintained throughout the six 5 s segments and FI is the amount of the decline in power during the test, expressed as a percentage of peak power (Beneke, Pollmann, Bleif, Leithauser, & Hutker, 2002).

In spite of the advantages in Wingate test for cyclists, its usage demands a properly equipped laboratory (Adamczyk, 2011). When the acquisition of instruments for the above methodologies is limited, anaerobic capacity is hard to determine. In fact, tools whose utilization is not conditioned by access to specialized equipments or laboratories have their special value. Indirect evaluations, such as running tests, may be useful, mainly because of their practicality and low costs (Bar-Or, 1987; Reza & Rastegar, 2012). Several running tests, such as maximal anaerobic running test (MART) (Bar-Or, 1987; Nummela et al., 1996) and running-based anaerobic sprint test (RAST), have been adopted to measure anaerobic performance (Adamczyk, 2011).

The field test RAST may be employed to assess anaerobic power and capacity since it measures the PP, MP, and FI variables (Zacharogiannis, Paradisis & Tziortzis, 2004). Similar to the Wingate test, it evaluates the anaerobic performance of the sports modalities which feature intense and intermittent rhythms, such as basketball, team handball and performance on 100m, 200m and 400m sprint in track and field (Balciûnas, Stonkus, Abrantes, & Sampaio, 2006; Paradisis, Tziortzis, Zacharogiannis, Smirniotou, & Karatzanos, 2005; Roseguini, Ramos da Silva & Gobatto, 2008). RAST has the same advantages as the Wingate test albeit without high cost equipments. It has been reported that the RAST-obtained anaerobic performance is significantly correlated to the Wingate test (Zacharogiannis et al., 2004; Zagatto, Beck, & Gobatto, 2009).

Several studies, which have demonstrated strong correlations between performance in the Wingate test and that in sprint speed (Tharp et al., 1985; Almuzaini, 2000; Nummela et al., 1996; Denadai, Gugliemo, & Denadai, 1997), suggest that the former test may be a good predictor of sprinting ability. However, there is no information whether the results of sprint tests foresee the performance on a cycloergometer. Although previous studies show a correlation between RAST and Wingate tests (Zacharogiannis et al., 2004; Zagatto et al., 2009), the literature does not provide any comparisons of protocols in cyclists.

The hypothesis of the study was that performing a speed test (i..e, RAST) can replace the power performance in anaerobic cycle ergometer (i.e., Wingate test) in a sample of cycling athletes. The purpose of this investigation was to investigate the validity of RAST to evaluate anaerobic power performance in Wingate test in cycling athletes.

Methods

Ten male mountain-bike cyclists (28.0±7.3 years, 70.6±9.9 kg, 172.0± 11.1 cm), with a 3.2±1.1 weekly training and 6.5±5.6 years' experience, from Guarapuava, Paraná, Brazil, participated in the current study. The participants were previously informed about the procedures and all signed a consent form for human experiment. The study was approved by the Ethics Committee in Research of the Midwestern State University of Paraná.

Body mass was assessed by a 100g-precision anthropometric scale (Welmy®) and height by a wood stadiometer with scales 0.1 cm. Anaerobic performance was determined using Wingate and RAST protocols. Two tests per protocol were randomly undertaken at a minimum interval of 48 hours to minimize learning effects. Mean rate of the two tests was used for the analysis of results. Intraclass correlation coefficient (ICC) showed high test reproducibility (>0.87) (data not depicted). The athletes were instructed not to practice 24 hours prior taken the tests. Verbal incentives were provided in all tests for maximum effort.

The Wingate test was undertaken using a cycle ergometer (MAXX®) and peak power (PP), mean power (PM) and fatigue index (FI) were calculated using MCE 5.1. The test required maximum effort for 30 seconds, with individual loads of 10% of the body weight, as suggested for trained athletes (Bar-Or, 1987). Each athlete adjusted the bicycle seat according to individual parameters and used his own training equipment (e.g., shoes and specific pedals). Prior to starting the test, the cyclists warmed up for 10 min running 3 or 4 sprints of approximately 5 seconds each, with gradual intensity until meeting the test load protocol. Sprints have 2-min intervals during which participants pedaled without resistance.

After the warming up phase, test instructions were given to participants, such as: to keep the trunk straight while sitting on the seat; to give their maximum effort, and to slow down their effort when required. The athletes started to pedal at high speed and at a signal trigger in a computer monitor by one of the researchers, the cycle ergometer cage was released with the experimental load. When the test ended, the athletes were instructed to keep cycling for another two minutes with a load of 30 kp. They were then instructed to sit on a chair for passive recovery and continue the post-test evaluations that included heart rate (HR) monitoring and blood collection, which were used for lactate concentration analysis.

The RAST test was conducted on a 46-m distance runway in a poly sports circuit, and the 35 m sprint test was delimited by a straight line with 5.5 m at each endpoint for escape. The test consisted of 6 sprints at maximum speed covering a distance of 35 meters, with a 10-second pause between each trial. Prior the start of the test, athletes warmed up during approximately 10 minutes with stretching exercises and specific training routines (sprints and light running). Time was manually timed by a researcher (the same for all the tests). Two other researchers were positioned at each extremity of the test area to control recovery time (10 sec). After finishing the test, each cyclist was instructed to keep walking for 2 min for active recovery and then to sit on a chair for post-training evaluations, such as HR and blood collection to analyze lactate concentration. The PP and MP in absolute units (W) and relative to body mass ($W.kg^{-1}$), fatigue index in watts per second ($W.seg^{-1}$) and in relative rates (%) were assessed from the RAST results, following instructions by Draper and Whyte (Draper & Whyte, 1997).

A Polar S810i heart rate recorder measured HR during the resting phase (HRrest) and after a 10-min period sitting. Athletes continued wearing the frequency meter during the test and furthermore for 12 min. HR was registered during the resting phase (HR_{rest}), maximum effort (HR_{max}) and at 3, 6, 9 and 12 minutes after tests's completion ($HR_{recovery}$). Ear lobule was sterilized and punctured with a sterile micro-lancet (Embramed®). One or two blood drops were deposited on a strip (BM-lactate Cobas® - Roche) to analyze lactate concentration (Lactimeter Cobas® - Accytrend Plus®). Blood collection was collected during resting phase (pre-tests) and at 4, 8 and 12 minutes after the Wingate and RAST tests were completed.

Shapiro-Wilk test measured the data normality and results were reported using means and standard deviations. Student´s paired t test was employed to compare maximum and mean power rates and fatigue index obtained by Wingate test and RAST. Pearson coefficient correlation and Bland-Altman plots (Bland & Altman, 1986) established the relationship and agreement between power rates obtained from the tests. Significance level at 0.05 was used in all tests.

Results

Table 1 compares anaerobic power performance and correlation rates between Wingate test and RAST. There was a strong correlation between Wingate test and RAST for PP and MP in power units (W). However, weak correlation was found when anaerobic performance was corrected using the athletes' body mass ($W.kg^{-1}$). In spite of significant and positive correlation, significantly lower rates from RAST were observed in all power performance variables.

Table 1. Descriptive results (mean ± standard deviation) for peak power, mean power and fatigue index from Wingate test and RAST.

Variables	**Wingate**	**RAST**	***r***
Peak Power ($W \cdot kg^{-1}$)	12.8±0.9	8.1±0.6*	0.107
Peak Power (W)	907.3±150.5	575.0±96.6*	0.831**
Mean Power ($W \cdot kg^{-1}$)	9.1±1.7	6.4±0.5*	-0.054
Mean Power (W)	649.8±200.1	448.6±65.4*	0.714**
Fatigue Index (%)	33.8±4.6	37.8±7.9	0.172

p: paired *t* test Wingate vs RAST; *r*: correlation between results; $W \cdot kg^{-1}$: power corrected by body mass; *$p<0.05$; **$p<0.01$

Figure 1 shows Bland-Altman plots with agreement rates between test results (Wingate vs RAST). Significant differences were found for all the variables (PP, MP and FI). The above result was corroborated by differences between the mean paired results from Wingate test and RAST which were different from zero (0) and by the agreement limits (great mean difference).

Blood lactate and HR were obtained during the resting phase and recovery so that effort intensity during the tests could be controlled. Table 2 shows blood lactate concentration during resting, and at 4, 8, 12 min; and HR

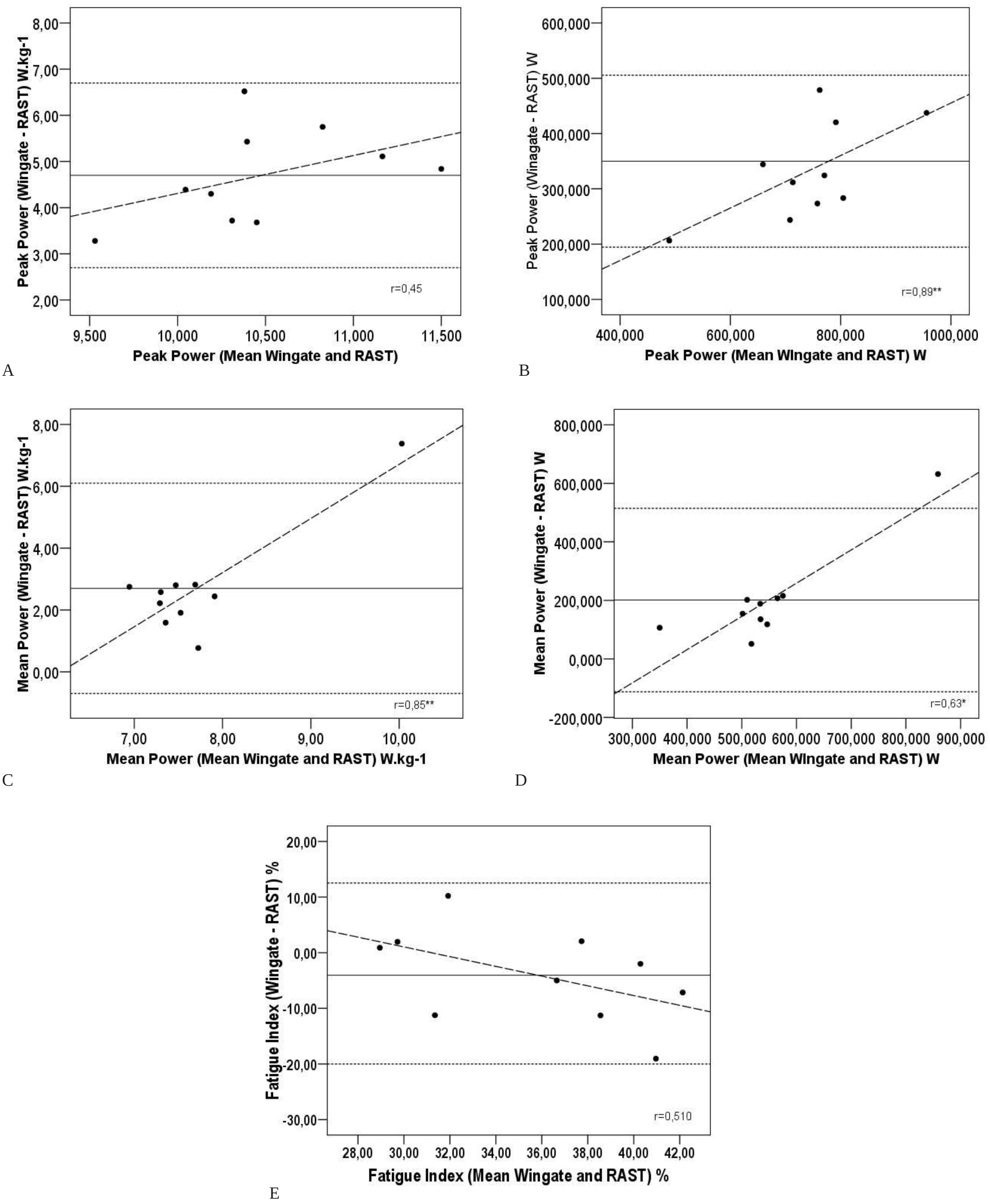

Figure 1. Bias plotting (mean differences) between Wingate test and RAST, respectively for: peak power, A ($W.kg^{-1}$) and B (W), mean power, C ($W.kg^{-1}$) and D (W) and fatigue index, E (%), according to procedures by Bland-Altman (n=10).

Table 2. Descriptive results (mean ± standard deviation) of blood lactate concentration and heart rate of cyclists for Wingate and RAST tests.

		Wingate	RAST	r
Lactate (mml·l^{-1})	Rest	2.2±0.6	2.1±0.4	0.688*
	Recovery 4 min	9.1±3.5	6.2±1.6*	0.153
	Recovery 8 min	9.5±2.4	8.0±1.9	0.018
	Recovery 12 min	8.7±2.8	7.7±1.9	-0.146
Heart rate (b/min)	HR rest	72.2±11.1	71.7±9.9	0.735*
	HR maximum	185.9±14.6	188.6±12.6	0.938*
	HR recovery 3 min	123.7±15.3	113.4±21.3*	0.911*
	HR recovery 6 min	108.1±12.0	107.6±13.7	0.938*
	HR recovery 9 min	106.4±9.5	108.0±12.7	0.906*
	HR recovery 12 min	102.6±13.7	105.0±14.4	0.516

p: paired *t* test Wingate vs RAST, comparison between mean rates; *r*: Pearson correlation coefficient between tests; b/min: beats per minute; *$p<0.05$.

(b/min) during resting (HR_{rest}) and maximum effort (HR_{max}), after Wingate test, and RAST ($HR_{recovery}$). Significantly positive correlation for lactate was reported only during the resting phase, whereas lactate concentration was significantly lower in RAST at the 4th minute of recovery. In both tests blood lactate peak was obtained at the 8th minute after recovery.

With the exception of the 12th minute after recovery, a significantly positive correlation in HR between measurements in both tests was reported. When mean rates were compared, significant differences in HR for Wingate test and RAST were reported only at the 3rd minute of recovery (Table 2).

Discussion

One of the main goals in administering tests to predict the performance of physical capacities is when laboratory procedures and high cost equipments are unavailable. Although Wingate test is easily applied and interpreted, it requires a set of resources, such as a cycle ergometer, computer and specific software that would detect the bicycle signal and, consequently, the analysis of results. The performance of anaerobic power by Wingate test and RAST was compared to investigate RAST validity in assessing anaerobic power performance in the Wingate test in mountain-bike cyclists.

Our results did not confirm our hypothesis. Performance rates for PP and MP (W or W.kg^{-1}) in Wingate test were significantly higher than those obtained by RAST. Since FI was the product of PP and minimum power, results among the protocols also differed. However, higher power rates by Wingate test may be explained by the specific mechanical act of pedaling when compared to that of running (Zacharogiannis et al., 2004). This fact was more relevant with cycling athletes who did not run as a form of physical preparation.

Although the correlation coefficient showed a strong positive relationship between Wingate test and RAST for PP and PM in power units (W), such relationship was not observed when data were corrected using the body mass (W.kg^{-1}). The above fact showed variability in the participants´ body mass rates (70.6±9.9 kg) and, perhaps crucially, the cyclist failed to sustain his body weight.

Analysis of agreement produced by the Bland-Altman´s test showed a greater variability between the Wingate test and RAST for the anaerobic power parameters. Bias was different from zero for all the variables (PP, MP and FI) and revealed that measurements obtained by tests failed to meet the expected agreement. Furthermore, precision given by the agreement limits was low as measurement error was identified (Figure 1). The above result suggested that RAST provided imprecise data prediction for PP, MP and FI in cyclists.

The usefulness of the Wingate test in determining the anaerobic capacity of prolonged sprint competitors was confirmed by the relationship between test results and 100 - 400-meter-distance results (Tharp et al., 1985; Nesser, Latin, Berg, & Prentice 1996; Almuzaini, 2000). However, in other studies, the cycling mode employed in the Wingate test limited the transference of results to running (Aziz & Chuan, 2004) and vertical jump activities (Sands et al., 2004).

The anaerobic performance in 50- and 200-meter sprints was investigated with basketball players. MP (*r*=-0.83) and PP (*r*=-0.83) showed significant correlations, respectively, with the 200- and 50-meter running time (Denadai et al., 1997). These authors concluded that Wingate test measured the anaerobic performance of a basketball team during running. It was also reported that RAST had validity and reproducibility with the Wingate test when applied to race athletes and football players (Roseguini, 2010). Emphasis should be given to the fact that the Wingate test is often used to evaluate the anaerobic performance in races (Millet, Vleck, & Bentley, 2009) and in court and field sports (Balga & Moraes, 2007). However, the lack of an inverse association from cycling to racing, as found in the present study, may be explained by a greater transference of effects on physiological parameters from the race training to the cycling, than from the cycling to the race training (Balciûnas et al., 2006).

If mechanical differences between pedaling and cycling were not taken into consideration, the slight variation in lactate concentration between the two protocols might suggest a similar activation of the anaerobic metabolism. Another type of information referred to the lactate peak which was obtained at the 8th minute of recovery in the two protocols. This fact corroborated studies that used these tests to induce hyperlactemia (Granier, Mercier, Mercier, Anselme & Prefaut, 1995; Millet & Lepers, 2004). There is evidence that maximum HR response is higher in field tests than in laboratory tests (Reza & Rastegar, 2012). The HRmax in the current analysis did not differ between the test protocols or at the 6th and 9th minute of recovery. However, mean HRmax in RAST (188.6±12.6) was slightly higher than that found in the Wingate test (185.9±14.6). Since this result showed similarity in the intensity effort employed in both tests by the cyclists, it may be speculated that the tests were based on approximate metabolic processes (Adamczyk, 2011).

A significant difference between Wingate test and RAST occurred for the lactate concentration and the HR in a single measurement of each variable, that is, on the 4th (lactate) and 3rd (HR) minute of recovery. This was likely due to differences in the execution of specific physical activities of post-test recovery. Procedures were identical: immediately after the end of the test, i.e., the athletes performed active recovery for two minutes. The 30 kp load in the Wingate test was maintained and the cyclists kept pedaling, whereas at the end of RAST the recovery was done by walking. After this period, the cyclists, in both protocols, sat down comfortably on a chair until the termination of data collection (12 minutes). Since there was a fast decrease in HR, and lactate concentration was lower in RAST than in the Wingate test, it might be suggested that recovery in RAST was more effective in HR reduction and in lactate concentration than that in the Wingate test. However, lactate and HR did not differ when the athletes remained sitting.

It is highly important to discuss limitations that may have interfered in the results of current study. Sample size (n=10) may have been a limitation. However, the participants performed randomly two tests for each protocol at their best. Moreover, it is also relevant to mention that the known number of athletes that practice mountain-bike cycling in the region is not higher than ten. Another limitation may have been the participants´ motor specificity that likely would create an advantage for the Wingate test. The study's actual aim was to validate RAST in this sport modality.

The aim was to validate a running test (RAST) with reference to the Wingate test. However, it has been demonstrated that the anaerobic performance result in RAST was different from that in the Wingate test. Consequently, RAST should not be used by cyclists for the above-mentioned purpose. In other studies, RAST results, too, could not be transferred to Wingate test results (Adamczyk, 2011). However, RAST has been validated as for an evaluation protocol option for sports that use locomotion (Roseguini, 2010, Aziz & Chuan, 2004). If Wingate test is the most common test to evaluate anaerobic power (Denadai et al., 1997), it should be emphasized that post-effort physiological responses (lactate concentration and HR) were highly similar, and that they suggest a significant contribution of the glycolytic pathway in RAST. In spite of the higher anaerobic power generated in the Wingate test, which involves a greater muscular mass and body mass sustainability, RAST had the same metabolic requirement as found for the Wingate test in the analyzed cyclists .

The use of running test protocol to evaluate anaerobic power performance in Wingate test in the current study did not determine peak power, mean power and fatigue index for RAST test. The results suggested that RAST test was not a valid method to evaluate cyclists' anaerobic power performance considering Wingate test as a reference.

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Manuscript received on February 15, 2013
Manuscript accepted on August 8, 2013