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original article

Comparison of body composition and aerobic and anaerobic performance between competitive cyclists and triathletes

Comparação da composição corporal, desempenho aeróbio e anaeróbio entre ciclistas e triatletas competitivos

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Abstract – The aim of this study was to compare anthropometric characteristics and aerobic and anaerobic fitness between competitive cyclists and triathletes. The sample consisted of 11 cyclists and 12 triathletes with experience in competitions. The tests were performed on two different days, with an interval of 48 h between sessions. On the first day, the athletes were submitted to anthropometric assessment (body mass, height, and skinfold thickness) and a maximal incremental test to determine maximal oxygen uptake, maximum power, maximum heart rate, maximum lactate, and the first (LL_1) and second lactate threshold (LL_2). The Wingate test was conducted on the second day to determine peak power, average power, and fatigue index. There were significant difference ($p < 0.05$), with medium effect size (0.80 - 1.5), in mid-thigh skinfold thickness (15.2 ± 6.3 and 10.5 ± 4.8 mm), power at LL_1 (195.0 ± 30.9 and 162.7 ± 28.3 W), power at LL_2 (247.6 ± 25.0 and 219.7 ± 37.9 W), and fatigue index (47.2 ± 13.0 and 60.1 ± 16.4%) between cyclists and triathletes, respectively. The other variables did not differ between groups. Anthropometric characteristics are similar in triathletes and cyclists. However, cyclists present higher power outputs at the lactate thresholds (LL_1 and LL_2) and lower fatigue indexes.

Key words: Aerobic performance; Anaerobic performance; Anthropometry; Cycling; Triathlon.

Resumo – *O objetivo do presente estudo foi comparar as características antropométricas e aptidão aeróbia e anaeróbia entre ciclistas e triatletas competitivos. Participaram do estudo 11 ciclistas e 12 triatletas com experiência em competições esportivas. As avaliações foram realizadas em dois dias distintos, com intervalo de 48 h entre as sessões. No primeiro dia, foram realizados a avaliação antropométrica (massa corporal, estatura e dobras cutâneas) e um teste incremental máximo para determinação do consumo máximo de oxigênio, potência máxima, frequência cardíaca máxima, lactato máximo, primeiro limiar de lactato (LL_1) e segundo limiar de lactato (LL_2). No segundo dia, foi realizado um teste de Wingate para obter a potência pico, potência média e índice de fadiga. Houve diferença significativa ($p < 0,05$) e com tamanho de efeito moderado (0,80 - 1,5) para a dobra cutânea da coxa média (15,2 ± 6,3 e 10,5 ± 4,8 mm), potência no LL_1 (195,0 ± 30,9 e 162,7 ± 28,3 W), potência no LL_2 (247,6 ± 25 e 219,7 ± 37,9 W) e índice de fadiga (47,2 ± 13,0 e 60,1 ± 16,4 %) entre ciclistas e triatletas, respectivamente. As demais variáveis analisadas não diferiram estatisticamente entre os grupos. Os triatletas e ciclistas são semelhantes em relação às características antropométricas. No entanto, ciclistas apresentam maiores valores de potência nos limiares (LL_1 e LL_2) e menores valores do índice de fadiga.*

Palavras-chave: *Antropometria; Ciclismo; Desempenho aeróbio; Desempenho anaeróbio; Triatlo.*

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INTRODUCTION

Cycling is one of the most traditional sports in the world, especially in Europe where the Tour de France is the classic competition of this discipline. This sport has been part of the Olympic Games since the first games of the modern era that started in Athens in 1896. Road cycling (~ 250 km) and time trail (~ 45 km) are two of the Olympic disciplines. Triathlon is a more recent sport and the first official competition occurred in Honolulu, Hawaii, in 1978[1]. In addition to cycling, this discipline also involves swimming and running. Triathlon competitions are classified according to distance and the most important competitions are: 1) Olympic distance (1500 m swimming, 40 km cycling, and 10 km running), 2) Ironman (3.8 km swimming, 180 km cycling, and 42.2 km running), and 3) Ultraman (10 km swimming, 421 km cycling, and 84 km running)[2].

Regardless of the sport discipline, it is important that athletes have favorable anthropometric and physiological characteristics to improve performance. With respect to anthropometric characteristics, Knechtle et al.[3] showed that low body fat percentage, greater body segment length and higher lean body mass are associated with higher performance in cycling and triathlon competitions. Some studies have compared anthropometric characteristics between cyclists and triathletes[4,5]. Rust et al.[4] investigated anthropometric variables of cyclists and triathletes and found differences in muscle mass and arm, thigh and calf circumference. Furthermore, O'Toole et al.[5], analyzing anthropometric variables (height, body bass and fat percentage) in triathletes, swimmers, runners and cyclists, observed that the anthropometric characteristics of triathletes are more similar to those of cyclists.

With respect to physiological variables, triathletes and cyclists need to have high maximal oxygen uptake (VO_{2MAX}) and anaerobic threshold to achieve best performance in their respective competitions[6]. According to Caputo et al.[7] and Diefenthaeler et al.[8], cyclists have higher VO_{2MAX}, maximum heart rate (HR_{MAX}) and anaerobic threshold than triathletes. However, Laursen et al.[9] observed no differences in aerobic performance between these groups.

Other physiological variables that play an important role in cycling performance are anaerobic power and anaerobic capacity, which are required during sprints and particularly at the end of the competition[10]. Anaerobic performance has been evaluated in cyclists[11] and triathletes[12], but there are no studies comparing this parameter between the two groups. Comparison of cycling performance between triathletes and cyclists is a valid approach since cycling corresponds to approximately 50% of total race time in triathlon competitions[13]. In addition, it is important to determine whether differences exist in the anthropometric characteristics and physiological capacity of triathletes considering the specificity of training in the three disciplines[14].

In view of the above considerations, the objective of the present study was to compare anthropometric characteristics and aerobic and anaerobic fitness between competitive cyclists and triathletes.

METHODOLOGICAL PROCEDURES

Subjects

The sample consisted of male competitive cyclists (n=11) and triathletes (n=12). All athletes had participated for more than one year in regional and national competitions. The mean weekly volume of cycling training during the 2 months prior to the tests was 284.0 ± 123.4 km for cyclists and 170.0 ± 55.1 km for triathletes.

The athletes were classified as competitive level according to Ansley and Cangley[15] based on VO_{2MAX} of 50 to 60 $ml \cdot kg^{-1} \cdot min^{-1}$ and maximum aerobic power of 275 to 375 W during the incremental test.

The study was conducted in accordance with the Declaration of Helsinki and the guidelines of Resolution 196/96 of the National Health Council, and was approved by the Ethics Committee on Human Research (CEPSH) of Universidade Federal de Santa Catarina (Permit No. 065/06).

Experimental procedures

The tests were conducted on 2 days at an interval of 48 h between sessions. On the first day, the athletes were submitted to anthropometric assessment and a maximal incremental test to determine aerobic variables. On the second day, the Wingate test was performed to evaluate anaerobic fitness.

The maximal incremental test and Wingate test were completed on an electromagnetically braked cycle ergometer (Lode Excalibur Sport®, The Netherlands). The cycle ergometer was adjusted individually to reproduce the configuration of the cyclist's bicycle in terms of horizontal position and saddle and handlebar height[16]. The subjects were asked not to exercise exhaustively on the day prior to assessment and to have eaten and be hydrated on the day of the test. The temperature (20.3 ± 2.4°C) and relative air humidity (55.5 ± 7.1%) of the room were controlled with an air-conditioning system throughout all steps of the study.

Anthropometry

The anthropometric measurements were made by certified anthropometrists according to the protocols of the International Society for the Advancement of Kinanthropometry[17]. Body mass and height were measured with an electronic scale (Toledo, Brazil) to the nearest 100 g and with a wall stadiometer (Seca, Hamburg, Germany) to the nearest 1 mm, respectively.

Triceps, biceps, subscapular, iliac crest, supraspinal, abdominal, mid-thigh and medial calf skinfold thicknesses were measured with a scientific skinfold caliper (Cescorf, Brasil) to the nearest 0.1 mm. Body density was estimated using the equation developed by Petroski in 1995, which was validated for Brazilian men aged 18 to 66 years[18]: body density = 1.10726863 – 0.00081201 (Σ4SF) + 0.00000212 (Σ4SF)^2 – 0.0004176, where Σ4SF is the sum of subscapular, triceps, supraspinal and medial calf skinfolds. Body density was used to estimate body fat percentage using the Siri equation: [%Body fat = (495 / body density) – 450].

Fat mass was calculated by the transformation of percent body fat values [fat mass = (body mass x %body fat) / 100]. Lean body mass was determined by the fractionation of body mass into two components: lean body mass = body mass – fat mass).

Maximal incremental test

The incremental test was started at a load of 100 W, followed by increments of 30 W at intervals of 3 min until exhaustion[19]. At the first two stages (loads of 100 and 130 W), the athletes pedaled at their preferred cadence to determine the pedaling cadence that would be maintained throughout the test. The criteria for interruption of the maximal incremental test were the inability to maintain the required cadence, heart rate reaching the maximum value predicted for age, or voluntary exhaution[19]. The subjects were verbally encouraged to give maximal effort during the test.

Oxygen uptake and carbon dioxide production were monitored at each respiration throughout the test with a Quark PFT Ergo gas analyzer (Cosmed, Italy). The apparatus was calibrated according to manufacturer recommendations, including the calibration of ambient air for comparison of atmospheric oxygen uptake (VO_2) and production of atmospheric carbon dioxide (CO_2) (20.93% and 0.03%, respectively), calibration of the cylinder gas (VO_2 = 16%, CO_2 = 5%), calibration of the turbine to determine air flow, and delay calibration which consists of measuring the time the gas sample requires to pass the air line before being analyzed. The data from the gas analyzer were smoothed (mean of 15 s). In the last minute of each 3-min stage of the test, a mean value was calculated to determine VO_2 corresponding to each stage and the highest value obtained was defined as VO_{2MAX}. The following criteria were adopted to guarantee that the subjects reached VO_{2MAX} during the test: blood lactate concentration [La] > 7.5 $mmol{\cdot}l^{-1}$, respiratory exchange ratio ≥ 1.1, and VO_2 reaching a plateau (increase in VO_2 of less than 2.1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ with increasing load) or VO_2 starting to decline with increasing load[20].

When the last stage was not completed, maximum power (W_{MAX}) was determined according to the method of Kuipers as follows:

$$W_{MAX} = W_F + [(t / 180) \times 30]$$

where W_{MAX} is the maximum power produced, W_F is the power (in watts) during the last completed stage, and t is the time (in seconds) of the incomplete stage.

Heart rate was monitored continuously throughout the test with a Polar S610 heart rate monitor (Polar, Finland). The heart rate data were smoothed (average of 5 s). In the last minute of each 3-min stage of the maximal incremental test, a mean value was calculated to determine the heart rate corresponding to each stage and the highest value was defined as the maximum heart rate (HR_{MAX}).

At the end of each stage, blood samples were collected from the earlobe for the analysis of [La] and determination of the first (LL_1) and second

(LL_2) lactate threshold. The earlobe was disinfected with 70% alcohol and punctured with a disposable lancet. For the analysis of [La], 25-µl blood samples were collected into heparinized capillary tubes and analyzed in an YSI 2700 biochemical analyzer (Stat Select, USA), with a precision of 2%. The [La] values of each stage were plotted as a function of power output at the respective stage. LL_1 was determined by the second increase of 0.5 mmol·l^{-1} or higher in relation to lactatemia of the previous stage[21]. Two specialists analyzed the graphs in a double-blind fashion. LL_2 was obtained by adding the fixed value of 1.5 mmol·l^{-1} to the lowest equivalent[22].

Wingate test

The subjects were familiarized with the Wingate test by performing a 10-s trial after the incremental test on the first day of data collection. At the beginning of the test, the athletes performed a warm-up for 5 min by cycling at a load of 50 W, with a sprint of 3 to 5 s at the end of each minute, as proposed by Inbar et al.[23]. After the warm-up period, the subjects were asked to remain seated and to perform maximal effort over the 30 s of the test. The load (resistance) used in the Wingate test was 7.5% of the subject's body mass[23]. The athletes were asked to maintain a pedaling cadence of 120 rpm at the beginning of the test to reduce the initial inertia of the cycle ergometer[11].

During the test, the athletes were verbally encouraged to give the maximum effort possible. At the end of the test, the subjects underwent active recovery of 3 min at a load of 50 W. Peak power (highest mechanical power that can be generated by the muscle group involved in the test), average power (average power produced over the period of 30 s), and the fatigue index (difference between initial and final power) were calculated during the Wingate test using the Lode Ergometry Manager software (Lode Excalibur Sport®, The Netherlands).

Statistical analysis

The Shapiro-Wilk test was used to determine whether the data showed a normal distribution. Differences in the anthropometric and physiological variables between cyclists and triathletes were evaluated by the Student *t*-test for independent samples. A level of significance of $p < 0.05$ was adopted. Effect size was used to evaluate the magnitude of the differences between cyclists and triathletes and was classified as nonsignificant (< 0.35), small (0.35 – 0.80), medium (0.80 – 1.5), and large (> 1.5)[24]. The results were analyzed using the SPSS 15.0 for Windows (SPSS, Inc., USA) and G Power 3 (Heinrich-Heine-Universität, Düsseldorf, Germany) softwares.

RESULTS

Table 1 shows the anthropometric characteristics and body composition (mean, standard deviation and effect size) of the cyclists and triathletes studied.

Table 1. Age, anthropometric characteristics and body composition of cyclists and triathletes.

Variable	Cyclists (n=12)	Triathletes (n=11)	Effect size	Descriptor
Age (years)	30.6 ± 5.7	32.3 ± 6.6	0.27	Nonsignificant
Body mass (kg)	78.6 ± 5.8	74.7 ± 7.6	0.59	Small
Height (cm)	177.7 ± 4.2	176.1 ± 6.7	0.29	Nonsignificant
Skinfold thickness				
Triceps (mm)	11.3 ± 6.1	8 ± 1.9	0.70	Small
Biceps (mm)	5.3 ± 3.8	3.9 ± 1.2	0.89	Medium
Subscapular (mm)	11.6 ± 4.9	10.7 ± 2.8	0.32	Nonsignificant
Iliac crest (mm)	14.6 ± 6.2	12.7 ± 4.6	0.39	Small
Supraspinal (mm)	11.1 ± 5.6	7.9 ± 2.3	1.05	Medium
Abdominal (mm)	19.2 ± 9.2	16 ± 5.6	0.41	Small
Mid-thigh (mm)	15.2 ± 6.3	10.5 ± 4.8*	0.98	Medium
Medial calf (mm)	7.5 ± 3.2	7.5 ± 4.2	-	-
Sum 4SF (mm)	41.5 ± 15.4	34.3 ± 8.3	0.58	Small
Body composition				
Body fat (%)	9.5 ± 4.1	7.6 ± 2.3	0.57	Small
Fat mass (kg)	7.7 ± 3.8	5.7 ± 2.1	0.65	Small
Lean body mass (kg)	70.9 ± 3.3	68.1 ± 6.9	0.52	Small

Results are reported as the mean ± standard deviation. Sum 4SF: Sum of subscapular, triceps, supraspinal and medial calf skinfold thickness. *$p < 0.05$ (Student t-test for independent samples).

The results in Table 1 show similar values of triceps, biceps, subscapular, iliac crest, supraspinal, abdominal and medial calf skinfold thicknesses, Σ4SF, body fat percentage, fat mass, and lean body mass in cyclists and triathletes. Only medial calf skinfold thickness differed between the two groups.

The aerobic performance (mean, standard deviation and effect size) of the cyclists and triathletes studied is shown in Table 2.

Table 2. Aerobic performance of cyclists and triathletes.

Variable	Cyclists (n=12)	Triathletes (n=11)	Effect size	Descriptor
VO_{2MAX} (ml·kg^{-1}·min^{-1})	55.8 ± 5.1	56.8 ± 3.8	0.24	Nonsignificant
HR_{MAX} (bpm)	186.6 ± 6.8	182.6 ± 8.7	0.57	Small
LL_1 (mmol·l^{-1})	1.26 ± 0.3	1.49 ± 0.4	0.48	Small
LL_2 (mmol·l^{-1})	2.71 ± 0.3	2.93 ± 0.5	0.53	Small
Maximum [La] (mmol·l^{-1})	10.6 ± 1.7	10.5 ± 1.9	-	-
Power at LL_1 (W)	195 ± 30.9	162.7 ± 28.3*	1.09	Medium
Power at LL_2 (W)	247.6 ± 25	219.7 ± 37.9*	0.87	Medium
Maximum power (W)	333.6 ± 27.5	316.4 ± 35.6	0.54	Small
Maximum power (W·kg^{-1})	4.3 ± 0.6	4.4 ± 0.5	-	-
Cadence (rpm)	85.1 ± 6.5	86.8 ± 7.2	0.15	Nonsignificant

Results are reported as the mean ± standard deviation. VO_{2MAX}: maximal oxygen uptake; HR_{MAX}: maximum heart rate; LL_1: first lactate threshold; LL_2: second lactate threshold; [La]: lactate concentration. *$p < 0.05$ (Student t-test for independent samples).

The results of the maximal incremental test (Table 2) show that cyclists presented significantly higher power outputs at the blood lactate transition thresholds (LL_1 and LL_2) than triathletes. The other variables did not differ significantly between groups.

Table 3 shows the anaerobic performance (mean, standard deviation and effect size) of the cyclists and triathletes studied.

Table 3. Anaerobic performance of cyclists and triathletes.

Variable	Cyclists (n=12)	Triathletes (n=11)	Effect size	Descriptor
Peak power (W)	1411.7 ± 175.5	1319.2 ± 315.9	0.36	Small
Peak power ($W \cdot kg^{-1}$)	17.9 ± 2.1	17.7 ± 3.7	-	-
Average power (W)	738.8 ± 76.8	690.6 ± 72.1	0.65	Small
Average power ($W \cdot kg^{-1}$)	9.4 ± 0.7	9.3 ± 0.7	-	-
Fatigue index (%)	47.2 ± 13	60.1 ± 16.4*	0.89	Medium

Results are reported as the mean ± standard deviation. *$p < 0.05$ (Student t-test for independent samples).

The results of the Wingate test revealed no significant differences in peak or average power (absolute and relative values) between cyclists and triathletes. In contrast, the fatigue index was significant lower in cyclists.

DISCUSSION

The objective of the present study was to compare anthropometric characteristics and aerobic and anaerobic fitness between competitive cyclists and triathletes. We observed no significant differences in height, body mass, sum of skinfolds, body fat percentage, fat mass or lean body mass between the two groups. In a recent study, Rust et al.[4] also found no differences in body mass, height, fat percentage or pectoral, axillary, triceps, subscapular, abdominal, iliac crest and calf skinfold thicknesses between triathletes and cyclists. Similarly, Laursen et al.[9] observed no significant differences in body mass or sum of five skinfolds (biceps, triceps, subscapular, supraspinal, and abdominal) between cyclists and triathletes. These findings agree with the present study and indicate that anthropometric characteristics are similar in cyclists and triathletes.

Knechtle et al.[25] suggested that the anthropometry of triathletes is associated with total race time rather than training volume (hours per week). It is therefore believed that training volume does not cause changes in the body composition of cyclists or triathletes with low levels of body fat. However, mid-thigh skinfold thickness was significantly lower (medium effect size) in triathletes when compared to cyclists (Table 1). This finding can be explained by the specificity of triathlon training, with the run training causing a reduction in skinfold thicknesses of the lower limbs[26]. Arrese and Ostariz[27] demonstrated an association between reduced thigh skinfold thickness and increased running performance. However, Knechtle et al.[26] found no such association in ultra-endurance cyclists. These authors suggested that athletes of the two disciplines (running and cycling) use the same lower limb muscle group, but that the intensity and muscle demand during cycling races are lower.

With respect to aerobic performance (Table 2), the present results showed similar VO_{2MAX} and maximum power values in cyclists and triathletes. In a review, Suriano and Bishop[14] concluded that maximum power and VO_{2MAX} are similar in these groups. The authors suggested that triathletes have physiological values similar to those of athletes of specific sport disciplines, particularly running and cycling, although they divide their training time among three disciplines. However, other studies[7,8] reported higher VO_{2MAX} values for cyclists when compared to triathletes. According to the authors, training specificity may be a determinant factor for the difference in the levels of aerobic conditioning between cyclists and triathletes. On the other hand, since the training volume of triathletes is higher than that of cyclists due to the fact that the former spent time on three disciplines (swimming, cycling and running), we suggest that, even without a direct specificity, the swimming and running training performed by the triathletes studied may have influenced the VO_{2MAX} and maximum power results.

Although VO_{2MAX} is an important physiological index for endurance athletes, it is limited in predicting the aerobic performance of athletes of homogenous competitive level[28]. Therefore, lactate thresholds (LL_1 and LL_2) have been considered better predictors of aerobic performance since they are more sensitive to peripheral adaptations that continue to occur during training[28]. This fact may explain the results of the present study in which VO_{2MAX} was similar in cyclists and triathletes, but higher power outputs at LL_1 and LL_2 were observed in cyclists, with a medium size effect.

The present results regarding the blood lactate transition thresholds agree with the findings of other studies[7-9], which suggested that cyclists and triathletes differ in terms of aerobic conditioning due to the fact that the first and second thresholds are higher in cyclists, causing distinct physiological adaptations. According to Caputo et al.[7], the specificity of the discipline can influence aerobic performance, with cyclists presenting a higher performance than triathletes in cycling tests, whereas the opposite is observed in running tests.

Peak power or average power obtained in the Wingate test (Table 3) did not differ significantly between cyclists and triathletes. In contrast, the fatigue index was significantly lower in cyclists than in triathletes. Similar values of peak power and average power have been reported in the literature for cyclists[11] and triathletes[12]. However, none of these studies compared anaerobic performance between these two groups of athletes.

According to Faria et al.[29], the capacity of a cyclist to produce power through anaerobic metabolism is important in view of the sprints performed during a race. A cycling race is characterized by a power of 300 W maintained for prolonged periods of time and high peak power (> 800 W) for short periods of time[10]. In contrast, triathletes perform fewer sprints during the cycling race than cyclists, since higher demand of the anaerobic energy system during cycling may accelerate the process of muscle fatigue, reducing the performance of the triathlete during running[30]. However, it is believed that anaerobic fitness is important for the performance of triathletes, since the intervals in short-distance triathlon races permit the athletes to eventually perform sprints when they overtake, break away or follow with the group and when they pick up speed again.

One limitation of the present study is the fact that body circumferences, segment lengths and bone diameters were not measured. These parameters could provide further information about the anthropometric profile of cyclists and triathletes. Further studies including elite athletes are needed to compare and standardize these results.

Based on the results of this study, it can be concluded that body composition and anthropometric characteristics are similar in triathletes and cyclists. Cyclists present higher power outputs at the lactate thresholds (LL_1 and LL_2) and lower fatigue indexes, suggesting that the specificity of cycling training causes different physiological adaptations.

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