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Oxygen uptake during Wingate tests for arms and legs in swimmers and water polo players

Emilson Colantonio[1,2,3], Ronaldo Vilela Barros[1] and Maria Augusta Peduti Dal Molin Kiss[1]

ABSTRACT

Objective: The aim of the present study is to compare the values of the maximal oxygen uptake ($\dot{V}O_2$ max) during two consecutive bouts in Wingate tests for arms and legs in swimmers (S) and water polo players (WP). **Methods:** Sample – seven national level athletes (4 S and 3 WP), age 17,90 ± 2,14 years, body mass 71,41 ± 6,84 kg, height 176,65 ± 7,02 cm, % body fat 13,23 ± 4,18. Two Wingate bouts with 30 sec each with 3 min interval between them, for arms and legs in alternated days. Oxygen uptake: breath-by-breath using the gas analysis system *K4 b² Cosmed*. Statistical analysis: Wilcoxon test for dependent variables and Kolmogorov-Smirnov test for independent variables. **Results:** The mean values found at the $\dot{V}O_2$ peak (P$\dot{V}O_2$), mean power (MP) and peak power (PP) for each bout of the Wingate test, for arms and legs. For Arms: P$\dot{V}O_2$ = 55.16 ± 5.72 ml.kg^{-1}.min^{-1}, MP = 5.28 ± 0.59 watts.kg^{-1} and PP = 6.71 ± 0.88 watts.kg^{-1} got in the first bout (1st Arms) and P$\dot{V}O_2$ = 60.12 ± 6.10 ml.kg^{-1}.min^{-1}, MP = 5.03 ± 0.40 watts.kg^{-1} and PP = 6.25 ± 0.51 watts.kg^{-1}, got in the second bout (2nd Arms). For legs: P$\dot{V}O_2$ = 55.66 ± 6.85 ml.kg^{-1}.min^{-1}, MP = 4.75 ± 1.79 watts.kg^{-1} and PP = 7.44 ± 1.96 watts.kg^{-1} got in the first bout (1st Legs) and P$\dot{V}O_2$ = 62.09 ± 5.99 ml.kg^{-1}.min^{-1}, MP = 4.28 ± 1.47 watts.kg^{-1} and PP = 6.68 ± 1.63 watts.kg^{-1} got in the second bout (2nd Legs). **Discussion and conclusion:** All variables studied did not present significant difference among arms and legs, as much the first as the second bout for arms for P$\dot{V}O_2$ ($p < 0.05$). There was no difference between the PM mean values of the first and the second bout. But the mean of the second bout of legs was significant smaller than the first bout ($p < 0.05$). For the PP variable there was no difference among the mean values to the first and second bout as much for arms as for legs. It looks like to exist larger magnitude to O_2 adjustment for arms than legs, that could be associated to specific demands to which S and WP athletes are daily submitted in their trainings.

Key words: Oxygen uptake. Wingate test. Swimming and water polo.

1. Centro de Excelência Esportiva – Cenesp/Laboratório de Desempenho Esportivo – Ladesp/Escola de Educação Física e Esporte da Universidade de São Paulo – EEFEUSP.
2. Laboratório de Pesquisas em Educação Física e Fisioterapia – Lapeffi/ Universidade Cidade de São Paulo – Unicid.
3. Centro Universitário Monte Serrat – Unimonte.

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Correspondance address:
Prof. Ms. Emilson Colantonio
Cenesp/Ladesp/Escola de Educação Física e Esporte da Universidade de São Paulo
Av. Mello Moraes, 65
05508-900 – São Paulo, SP
E-mail: nunoec@uol.com.br

INTRODUCTION

The number of infantile and juvenile competitions has significantly increased over the past two decades[1-4], which has favored world records to be broken by 14-year old athletes. One knows well metabolic and functional responses to exercises in adults, whether normal or with impairments[5,6], but there are many issues that are yet to be solved regarding physical training of children and adolescents[1,7]. Aerobic fitness is instrumental for children and adolescents, not only for healthfulness[8], but also for the practice of a number of sports[9].

Human capability of performing mid- and long-duration exercises chiefly depends on aerobic metabolism. Thus, one of the main indices used to assess this condition is the maximum oxygen uptake ($\dot{V}O_{2max}$), known as aerobic power[10,11].

According to the literature, in maximum exertion tests, swimmers (S) and water polo players (WP) typically present $\dot{V}O_{2max}$ values close to 69.0[12] and 55.5[13] (ml.kg-1.min^{-1}), respectively. In judo practitioners, it has been observed, from four consecutive Wingate test bouts for upper limbs, that oxygen uptake ($\dot{V}O_2$) in the first bout was lower than that in the second, but there were no differences from the later in the third and fourth bouts, showing a tendency to stabilization[14]. For swimming and water polo, when comparing two consecutive Wingate test bouts for upper (ARMS) and lower limbs (LEGS), and specific tests at the pool, there was good correlation only for ARMS ($r = 0.85$, $p < 0.05$) at the second bout, in S[15].

In spite of evidences about mean $\dot{V}O_{2max}$ values at exercises in which aerobic metabolism prevail, it is interesting to observe its behavior in exercises in which anaerobic metabolism prevail. The purpose of this study is, thus, to compare O_2 uptake during two consecutive Wingate tests bouts, for ARMS and LEGS in S and WP.

LITERATURE REVIEW

$\dot{V}O_{2max}$ may be defined as the highest oxygen (O_2) uptake accomplished by an individual breathing air at sea level[16]. This variable is one of the main items examined in endurance studies, in spite of the use of the expression oxygen peak uptake ($\dot{V}O_{2peak}$) to describe O_2 uptake values from any maximum exertion test, with no plateau level between two adjacent loads[11].

More recently, a conceptual difference between energetic system power and capability has been used. Aerobic power ($\dot{V}O_{2max}$) is, thus, defined as the maximum amount of ATP produced per unit of time by the aerobic system[17]. Therefore, $\dot{V}O_{2max}$ equals to the maximum O_2 amount a stimulated body may draw from the air, transport to tissues through the cardiovascular system, and use on a cellular level at the unit of time[18].

For many years, $\dot{V}O_{2max}$ has been used as a parameter to predict performance by many investigators, when assessing athletes performing submaximal exertion, based on the hypothesis of a strong relationship with maximum endurance performance[19]. In the literature we find a number of studies associating athletes of endurance sports, in particular, to high $\dot{V}O_{2max}$ values. Some reference values may be found in specific literature, such as athletic march = 73.2; mild distance runners = 73.3; marathon = 72.0; road cycling = 78.8[12], mild distance runners = 75.5[20]; elite rowers = 61.4[21], cross-country skiers = 85.0 $ml.kg^{-1}.min^{-1}$ for males[22]. It is also common to find swimmers with high $\dot{V}O_{2max}$, such as 69.0 on a treadmill and 55.0 to 75.0[12] in swimming flume; 68,6[23] when comparing swimmers and runners on a treadmill; 50-70 for males and 40-60 $ml.kg^{-1}.min^{-1}$ for females between 15 and 25 years of age[24].

However, for swimming, about 80% of all competitions are of 200 m or less, i.e., with less than two minutes duration. Therefore, training at maximum speed is necessary for adjustments to occur for utilization of anaerobic energy[25]. As in swimming contests anaerobic metabolism prevails, it is fascinating to think why swimmers present such high $\dot{V}O_{2max}$ values when compared to athletes who practice other, chiefly aerobic sports?

Few studies have investigated swimmers or water polo players using anaerobic lab and/or field tests, in order to observe their metabolic and functional responses under these conditions, particularly with athletes still under development[26-31].

METHODOLOGY

All athletes and their parents or guardians signed an informed consent form where study procedures were explained, agreeing to volunteer to the study and the use of data for scientific publication, in accordance with EEFEUSP Ethics Committee. Two bouts of Wingate tests were performed, with 30 sec duration each and a 3-min interval between them, for arms and legs, in alternate days. A *Monark* cycle ergometer was used for legs, and an adapted *Monark* bicycle for arms. The relative loads used in the Wingate tests were of 7% and 5% of body mass for legs and arms, respectively. Gas analyses for O_2 uptake were assessed breath by breath, with *Cosmed K4 b²* ergospirometer. For comparing the means between the first and second bouts of the Wingate test, Wilcoxon non-parametric test was used, for dependent variables, and for comparing means between arms and legs, Kolmogorov-Smirnov non parametric test for dependent variables.

RESULTS

The sample included seven national level athletes, four swimmers (S) and three water polo players (WP), mean age of 17.9 ± 2.14 years, body mass of 71.41 ± 6.84 kg, stature of 176 ± 7,02 cm.

Mean values of $\dot{V}O_2$ peak ($P\dot{V}O_2$), mean power (MP), and peak power for each Wingate test bout, for both arms and legs were assessed. Outcomes for arms were: $P\dot{V}O_2$ = 55.16 ± 5.72 $ml.kg^{-1}.min^{-1}$, MP = 5.28 ± 0.59 $watts.kg^{-1}$ and PP = 6.71 ± 0.88 watts.kg-1 from the first bout (1st arms), and $P\dot{V}O_2$ = 60.12 ± 6.10 ml.kg-1.min-1., MP = 5.03 ± 0.40 $watts.kg^{-1}$ and PP = 6.25 ± 0.51 $watts.kg^{-1}$ from the second bout (2nd arms). For legs, the outcomes were: $P\dot{V}O_2$ = 55.66 ± 6.85 $ml.kg^{-1}.min^{-1}$, MP = 4,75 ± 1,79 $watts.kg^{-1}$ and PP = 7.44 ± 1.96 $watts.kg^{-1}$ from the first bout (1st legs), and $P\dot{V}O_2$ = 62.09 ± 5.99 $ml.kg^{-1}.min^{-1}$, MP = 4.28 ± 1.47 $watts.kg^{-1}$ and PP = 6.68 ± 1.63 $watts.kg^{-1}$ from the second bout (2nd legs).

None of the examined variables presented significant differences between arms and legs, for both Wingate test bouts. There was significant difference between 1st and 2nd bouts for arms, for the variable $P\dot{V}O_2$ ($p < 0.05$) (chart 1). MP means between 1st and 2nd bouts for arms were similar,

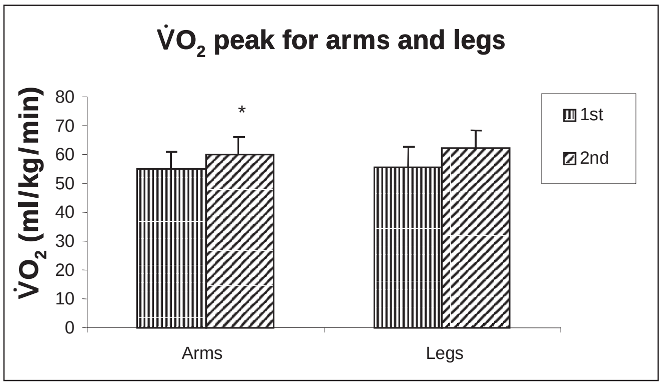

Chart 1 – *Mean values and standard deviation of peak oxygen uptake for arms and legs at Wingate test 1st and 2nd bouts (* p = 0.01 vs 1st bout)*

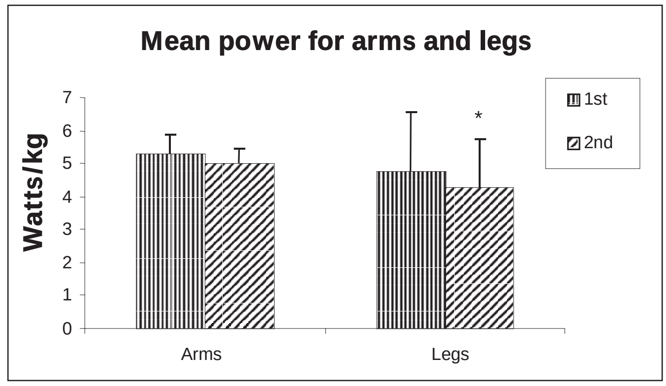

Chart 2 – *Mean values and standard deviation of mean power for arms and legs at Wingate test 1st and 2nd bouts (* p = 0.02 vs 1st bout)*

differently than for legs, in which mean for the 2nd bout was significantly lower than for the 1st bout ($p < 005$) (chart 2). For variable PP, there were no differences between mean values for 1st and 2nd bouts, for both arms and legs.

DISCUSSION AND CONCLUSION

Mean P$\dot{V}O_2$ values for the sample were considered high compared to those from swimmers or water polo players assessed when performing specific swimming movements, both at regular pool and at swimming flume. In our study, however, for both Wingate test bouts, there were no significant differences between arms and legs.

An important aspect that was noted, in spite of the short duration of the tests, was the high mean oxygen uptake values, of 60.12 $ml.kg^{-1}.min^{-1}$ for arms, and 62.09 $ml.kg^{-1}.min^{-1}$ for legs, from the second Wingate test bout. These values are higher than those mentioned in the literature[32] (54.27 ± 1.05 $ml.kg^{-1}.min^{-1}$), from maximum stepped tests for arms and legs of competition swimmers assessed at swimming flume.

In another study, investigators have determined anaerobic capability (maximum deficit of stored oxygen) and $\dot{V}O_{2max}$ during exercise of arms only, legs only and the whole body swimming at swimming flume, and compared the results from the three different modes of performing tasks[26]. The investigators found as mean values for swimming with arms only 2.53 ± 0.37 l/min; legs only, 2.93 ± 0.37 l/min, and for swimming with the whole body, 3.23 ± 0.43 l/min. In this trial, mean $\dot{V}O_{2max}$ values for exercises performed only with arms or only with legs were significantly lower than swimming with the whole body, 78.2% and 91.0% respectively. These proportions were similar to those reported in previous studies[33-35].

Outcomes of the above study suggest that the amount of $\dot{V}O_{2max}$ depends on the volume of muscular mass engaged in the activity, and this is a core idea in the physiology of exercise. However, according to authors themselves, this does not necessarily means that the muscular mass engaged in the activity determines $\dot{V}O_{2max}$ upper limit, since this variable does not increase in the same proportion of that muscular mass[26]. During swimming with the whole body, $\dot{V}O_{2max}$ includes arms and legs simultaneously, and was significantly lower than the sum $\dot{V}O_{2max}$ for activity with arms only and with legs only (corresponding to just 59.3%). Anaerobic capability and $\dot{V}O_{2max}$ for swimming with the whole body were significantly lower than from the sum of the activities for arms only and for legs only. This shows that the potential of the process of aerobic and anaerobic energy liberation in the muscular groups involved in arms and legs workout cannot be completely achieved during swimming with the whole body, and the complex neuromotor aspect from swimming is accountable for dissipating the potential of the liberated energy.

Studies investigating athletes of other sports showed that a test performed with an arm ergometer typically reaches values close to 70% of the $\dot{V}O_{2max}$ measured during leg ergometry[36,37].

In this study, in spite of the small number of subjects in the sample, and the relative specificity of the used ergometer, particularly for swimming and water polo movements, mean P$\dot{V}O_2$ values found by the Wingate tests for legs and arms were not significantly different. They were, however, higher or similar to $\dot{V}O_{2max}$ values found in the literature[24], even taking into consideration the characteristic of the test applied and its relationship with anaerobic metabolism.

On the other hand, there was significant differences between P$\dot{V}O_2$ means of the 1st and 2nd bout for arms ($p < 0.05$), but not for legs, which characterizes an important physiologic adjustment of the aerobic component, due to the specific type of training of arms, compared to training of legs.

This can be explained by observing mean MP values between 1st and 2nd bout, for arms, which were not different; *i.e.*, S and WP may generate a more constant MP for legs, in which the mean of the 2nd bout was significantly lower than of the 1st bout ($p < 0.05$).

There seems to be a higher magnitude of O_2 adjustment for arms rather than for legs that may lead to this similarity of values between them, and is associated to specific demands posed to swimmers and water polo players in their daily practice.

Due to a lack of papers on the subject and the limitations of our study, further investigations and better controlled trials are necessary for more conclusive assertions.

All the authors declared there is not any potential conflict of interests regarding this article.

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