AN ELLIPTICAL TRAINER MAY RENDER THE WINGATE ALL-OUT TEST MORE ANAEROBIC

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ABSTRACT

Ozkaya, O, Colakoglu, M, Kuzucu, EO, and Delextrat, A. An elliptical trainer may render the wingate all-out test more anaerobic. J Strength Cond Res 28(3): 643–650, 2014—The purpose of this study was to evaluate the contribution of the 3 main energy pathways during a 30-second elliptical all-out test (EAT) compared with the Wingate all-out test (WAT). Participants were 12 male team sport players (age, 20.3 ± 1.8 years; body mass, 74.8 ± 12.4 kg; height, 176.0 ± 9.10 cm; body fat, 12.1 ± 1.0%). Net energy outputs from the oxidative, phospholytic, and glycolytic energy systems were calculated from oxygen uptake data recorded during 30-second test, the fast component of postexercise oxygen uptake kinetics, and peak blood lactate concentration, respectively. In addition, mechanical power indices were calculated. The main results showed that compared with WAT, EAT was characterized by significantly lower absolute and relative contributions of the oxidative system (16.9 ± 2.5 J vs. 19.8 ± 4.9 J; p ≤ 0.05 and 11.2 ± 1.5% vs. 15.7 ± 3.28%; p ≤ 0.001). In addition, significantly greater absolute and relative contributions of the phospholytic system (66.1 ± 15.8 J vs. 50.7 ± 15.9 J; p ≤ 0.01 and 43.8 ± 6.62% vs. 39.1 ± 6.87%; p ≤ 0.05) and a significantly greater absolute contribution of the glycolytic system (66.8 ± 18.4 J vs. 57.4 ± 13.7 J; p ≤ 0.01) were observed in EAT compared with WAT. Finally, all power indices, except the fatigue index, were significantly greater in EAT than WAT (p ≤ 0.05). Because of the significantly lower aerobic contribution in EAT compared with WAT, elliptical trainers may be a good alternative to cycle ergometers to assess anaerobic performance in athletes involved in whole-body activities.

KEY WORDS energy contribution, glycolytic, oxidative, phospholytic, validity

INTRODUCTION

In many sports, the most important criteria of success rely on the ability to produce short-term maximal efforts, either in a single bout or repeatedly. Therefore, accurate, valid, and reliable testing of anaerobic performance is essential to structure and monitor training programs for these athletes. Although no single method has been yet established as a gold standard for the assessment of anaerobic characteristics, it seems that the standard Wingate all-out test (WAT) is currently the most widely used.

The validity of the standard WAT relies on the assumption that metabolic energy during the test is produced predominantly by the anaerobic metabolism (4). Although previous studies agreed that total energy turnover during this test is mainly derived from the phospholytic (alactic anaerobic) and glycolytic (lactic anaerobic) energy pathways, the magnitude of oxidative (aerobic) contribution measured in the same studies ranged from 9 to 44% (6,20,27,35–37). The large range of values reported by these various investigations is probably because of differences or limitations in the methods used to calculate energy expenditure derived from each energy pathway. This highlights the need for clarification on the extent of oxidative contribution during Wingate test, using a robust calculation method.

Although some validity studies showed a good correlation between mechanical parameters measured during the WAT and strength, speed, power, or agility (13,24,28), other investigations reported an absence of relationship between these variables and/or the incapacity of the WAT to discriminate between elite and nonelite athletes (2,10,17,26,32). Consequently, these authors criticized the ecological validity of the WAT, referring in particular to the discrepancies in the movement patterns and/or muscular mass involved in the test compared with real competition. To address these critiques, various modifications have been developed including the standing arm-crank and rowing Wingate test (15,25). However, these ergometers were designed either to target only 1 part of the body or focused on 1 specific sport discipline. Therefore, in sports involving the entire body, such as martial arts, racket sports, or team sports, there is a need to...
Elliptical All-out Test vs. Wingate All-out Test

Recent studies reported that a modified elliptical trainer may be a good alternative to traditional cycle ergometers when performing the Wingate protocol to evaluate mechanical power during whole-body activities (29,31). Ozkaya et al. (30,31) showed that the 30-second elliptical all-out test (EAT) was characterized by very good retest Pearson correlations, ranging from 0.80 to 0.98, and intraclass correlation coefficients (ICCs), ranging from 0.80 to 0.94 (p < 0.001; 95% confidence intervals = 0.62–0.90) based on the same statistical data. However, correlations between mechanical power indices (r = 0.09–0.21) and physiological parameters, such as lactate responses (r = 0.28) between EAT and WAT, were very low. Thus, despite the fact that similarities have been observed between muscular and metabolic parameters measured during exercises performed on elliptical trainers and walking or running-based whole-body activities (8,33), data on the validity of this new test modality are lacking, in particular regarding the anaerobic nature of energy production.

Therefore, the main purpose of the present study was to compare the contributions of the oxidative, phospholytic, and glycolytic pathways to total energy expenditure during two 30-second all-out tests performed on a modified elliptical trainer and a cycle ergometer. It was hypothesized that compared with WAT, EAT would result in a significantly lower contribution of the oxidative system (hypothesis 1) and significantly greater contributions of the phospholytic and glycolytic energy systems (hypothesis 2) to total energy production. A secondary aim was to investigate the relation between mechanical and physiological parameters reflecting the involvements of the phospholytic and glycolytic processes (hypothesis 3).

METHODS

Experimental Approach to the Problem

A randomized cross-sectional study design was used to investigate the anaerobic nature of an EAT compared with the standard cycling Wingate test. Both tests have been used in previous publications to assess anaerobic characteristics of athletes and their accuracy and reliability have been well established (4,30,31). The present study thus focuses on the validity of both tests. After familiarization sessions and pilot studies to allow adaptation to the various test ergometers and determine individual workloads, the two 30-second all-out tests were presented a week apart, in a random order. The main dependent variables considered were parameters classically used in previous studies as indicators of oxidative (exercise oxygen consumption), glycolytic (blood lactate concentration), and phospholytic (oxygen kinetics during recovery) energy pathways. However, because of the various criticisms regarding the calculation methods used in previous studies, the present investigation relied on the most modern method and the one currently considered as the most valid to calculate the contribution of each energy pathway to total energy expenditure (6). The hypotheses were then tested by analyzing the differences between variables measured in EAT and WAT.

Subjects

The study protocol was approved by the University Ethics Committee. Written informed consent was obtained after explanation of the nature and risks involved in participation in the experimentation. Twelve male athletes specialists of football, ice-hockey, and rugby volunteered to take part in the study (age, 20.3 ± 1.8 years; body mass, 74.8 ± 12.4 kg; height, 176.0 ± 9.10 cm; body fat, 12.1 ± 1.0%). At the time of the study, they were competing at a regional level in their respective sports and were involved in 5 ± 1 training session per week, including physical conditioning. Their average experience in their particular discipline was 7.6 ± 2.3 years. Physical conditioning practices of all the participants were quite similar, and they all had experienced repeated sprint and lactate tolerance training, classically used to enhance buffer capacity.

All the testing sessions were performed in spring (20–22 °C temperature, 50% relative humidity), after the end of the competitive season, to minimize the effects of training load or periodization. In addition, the time of day at which testing was undertaken was replicated for each participant. They were requested not to take part in any exhaustive exercise 24 hours before the testing sessions. None of the participants suffered from any injury or were under any specific medication.

Familiarization Sessions and Pilot Studies

Participants visited the laboratory a few weeks before the main testing sessions to perform 10- and 30-second all-out tests on both cycle ergometer (Monark 894, Varberg, Sweden) and elliptical trainer (Precor Experience series EFX 576i; Precor, Inc., Woodinville, WA, USA). Previously suggested workloads, from 7.5 to 10% of body weight for a cycle ergometer (4) and 13.5 to 18% of body weight for a modified elliptical trainer (30), were tested to determine the best individual test load for each athlete. This latter was defined as the load that provided the greatest PP and expected −45–50% relative decline in power production over the 30-second test period. During each participant’s familiarization session, special care was taken to supervise adaptation to high-performance level on the 2 ergometers, based on overall movement technique and pedaling/stepping rates.

Procedures

Wingate All-out Test. The WAT protocol was performed on a standard lower body cycle ergometer (Monark 894). Individual workloads were used for each athlete, as previously determined. The seat height was adjusted for each participant to allow the knee to be slightly bent when the pedal was at its lowest position. Toe clips were individually adjusted. A 5-minute warm-up was performed with
The Wingate test protocol was 0\Delta (11,23). Delta La (\(\Delta\), \(\Delta\)). www.nsca.com 0¼ consumption, "0was measured (Figure 2). Monoexponential and biexponential area integrated over time during the 2 was estimated by 2f consumption, "0¼ W$. W was considered to be 21.1 J was interpolated by using the biexponential method from the VO2 area integrated over time during the 30-second test (\(\Delta f\)) above rest (VO2). VO2 was measured during a 5-minute period before warm-up while participants were in a seated position (Figure 1). The caloric equivalent of O2 was considered to be 21.1 J L\(^{-1}\) (6).

\[
W_{\text{AER}} = \left[ \left( \frac{f(\text{VO2} f_0) + f(\text{VO2} f_b)}{2} \times 2 \right) - \text{VO2r} \right].
\]

(1)

The net energy contribution of the phospholactic energy pathway (\(W_{\text{PC}}\)) was calculated from the fast component of the postexercise oxygen kinetics. The time course of the decay in VO2 was interpolated by using exponential analysis (equation 2), where “\(a\)” is the amplitude of the fast recovery VO2 consumption, “\(t\)” is the time constant of the fast component of VO2, “\(b\)” is the amplitude of the slow component of VO2 consumption, “\(t\)” is the time constant of the slow component of VO2, “\(c\)” is the asymptotic posttest VO2 at time \(\rightarrow \infty\), “\(n\)” is the time in seconds, and VO2(\(t\)) is the time-dependent variation in VO2 (Figure 2). Monoeponential and biexponential models were applied showing that VO2 data were best fitted by the biexponential model. Therefore, the time course of the decay in VO2 was interpolated by using the biexponential analysis (equation 2). Integration of the exponential part was calculated from “\(a\)” and “\(t\)” then \(W_{\text{PC}}\) was estimated by using the caloric equivalent of O2 (equation 3) (21,34).

\[
f = a \cdot e^{-t/\tau_a} + b \cdot e^{-t/\tau_b} + c
\]

(2)

\[
W_{\text{PC}} = \int_a e^{-t/\tau_a}.
\]

(3)

Estimations of the Relative Contributions of the Energy Systems. The net energy contribution (equation 1) of the oxidative energy pathway (\(W_{\text{AER}}\)) was calculated using the trapezoidal method from the VO2 area integrated over time during the 30-second test (\(\Delta f\)) above rest (VO2). VO2 was measured during a 5-minute period before warm-up while participants were in a seated position (Figure 1). The caloric equivalent of O2 was considered to be 21.1 J L\(^{-1}\) (6).

\[
W_{\text{PC}} = \int_a e^{-t/\tau_a}.
\]

(3)

The net energy contribution of the glycolytic energy pathway (\(W_{\text{LA}}\)) was predicted from body mass, peak delta La (\(\Delta\)), O2-lactate equivalent, and the caloric equivalent of O2 (11.23). Delta La (\(\Delta\)) was calculated as the difference between rest and postexercise lactate concentrations. The mean energy equivalent of peak lactate was considered to be 3.0 ml O2 kg\(^{-1}\) mmol L\(^{-1}\), i.e., 63.3 J kg\(^{-1}\) mmol L\(^{-1}\) (11).

Total absolute metabolic work (\(W_{\text{TOT}}\)) was calculated as the sum of the energy outputs from the 3 energy systems.
Figure 1. Oxygen uptake during a 30-second all-out test. Net energy contribution of oxidative energy pathway was calculated from $V_O$ area integrated over time during the test ($t_0$–$t_{30}$) above rest ($V_O r$). Area was calculated by using trapezoidal method as follows:

$$W_{AER} = \left[ \frac{(f(V_O t_0) + f(V_O t_{30}))}{2} \times 2 \right] - V_O r.$$ 

Figure 2. Oxygen uptake during 60-minute recovery period. Time course of $V_O$ was interpolated by using biexponential analysis, where "$a$" is the amplitude of fast recovery $V_O$ consumption, "$r_a$" is the time constant of the fast component $V_O$, "$b$" is the amplitude of the slow component of $V_O$ consumption, "$r_b$" is the time constant of the slow component $V_O$, "$c$" is the asymptotic posttest $V_O$ at time $\rightarrow \infty$, "$t$" is the time in seconds. Integration of the exponential part was calculated from "$a$" and "$r_a$" to estimate anaerobic phospholytic energy pathway by using the formula of $\int a \cdot e^{-t/r_a}$.
Table 1. Paired samples t-test, Pearson r, and Cohen’s effect size analyses of mechanical indices of a 30-second elliptical all-out test (EAT) and a traditional cycling Wingate all-out test (WAT) (n = 12).*

<table>
<thead>
<tr>
<th>Variables</th>
<th>EAT</th>
<th>WAT</th>
<th>t</th>
<th>p</th>
<th>r</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP (W kg⁻¹)</td>
<td>15.3 ± 1.79</td>
<td>11.2 ± 0.98</td>
<td>10.522</td>
<td>0.001†</td>
<td>0.67</td>
<td>2.86</td>
</tr>
<tr>
<td>AP (W kg⁻¹)</td>
<td>11.1 ± 1.77</td>
<td>8.67 ± 0.67</td>
<td>5.754</td>
<td>0.001†</td>
<td>0.60</td>
<td>1.76</td>
</tr>
<tr>
<td>PD (W s⁻¹ kg⁻¹)</td>
<td>0.25 ± 0.05</td>
<td>0.17 ± 0.03</td>
<td>5.987</td>
<td>0.001†</td>
<td>0.31</td>
<td>2.48</td>
</tr>
<tr>
<td>FR0</td>
<td>49.5 ± 8.64</td>
<td>45.1 ± 5.28</td>
<td>1.889</td>
<td>0.086</td>
<td>0.41</td>
<td>0.62</td>
</tr>
</tbody>
</table>

*PP = relative peak power; AP = relative average power; PD = relative power drop; FR = fatigue index.
†Results with a p ≤ 0.05 were considered statistically significant.

Relative contributions of the oxidative (%Wₐₑᵣ), phospholytic (%Wₚₑᵣ), and glycolytic (%Wₐₑᵣ) energy systems were then estimated in relation of the Wₜₒₜ (6).

Statistical Analyses

Results were evaluated by Sigma-Plot 16.0 (Systat Software, Inc., San Jose, CA, USA) and SPSS 19.0 (SPSS, Inc., Chicago, IL, USA). Descriptive results were reported as mean values with SDs. Multiple nonlinear regression analyses were used to test whether the monoexponential single-3-parameter or biexponential double-5-parameter models sufficiently described the behavior of VO₂ over time. Parametric assumptions were accepted and thus Student t-tests for paired samples were undertaken to assess differences in the contribution of the 3 energy systems and in mechanical variables between EAT and WAT. Effect size was analyzed based on Cohen’s d. Finally, the relationship between mechanical and metabolic parameters was assessed by Pearson correlation analysis. Results with a p ≤ 0.05 were considered statistically significant for all the statistical analyses.

Table 2. Paired samples t-test, Pearson r, and Cohen’s effect size analyses of energy contributions of a 30-second elliptical all-out test (EAT) and a traditional cycling Wingate all-out test (WAT) (n = 12).†

<table>
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<th>t</th>
<th>p</th>
<th>r</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>%Wₐₑᵣ (J)</td>
<td>16.9 ± 2.49</td>
<td>19.8 ± 4.66</td>
<td>-2.298</td>
<td>0.042***</td>
<td>0.41</td>
<td>0.75</td>
</tr>
<tr>
<td>%Wₚₑᵣ (J)</td>
<td>11.2 ± 1.48</td>
<td>15.7 ± 3.28</td>
<td>-4.345</td>
<td>0.001***</td>
<td>0.17</td>
<td>1.76</td>
</tr>
<tr>
<td>%Wₐₑᵣ (J)</td>
<td>66.1 ± 15.8</td>
<td>50.7 ± 15.9</td>
<td>3.962</td>
<td>0.002***</td>
<td>0.64</td>
<td>0.97</td>
</tr>
<tr>
<td>%Wₚₑᵣ (J)</td>
<td>43.8 ± 6.62</td>
<td>39.1 ± 6.87</td>
<td>2.326</td>
<td>0.040†</td>
<td>0.46</td>
<td>0.70</td>
</tr>
<tr>
<td>%Wₐₑᵣ (J)</td>
<td>86.6 ± 18.4</td>
<td>57.4 ± 13.7</td>
<td>4.495</td>
<td>0.001***</td>
<td>0.90</td>
<td>0.69</td>
</tr>
<tr>
<td>%Wₚₑᵣ (J)</td>
<td>45.0 ± 6.79</td>
<td>45.3 ± 7.74</td>
<td>-0.146</td>
<td>0.886</td>
<td>0.76</td>
<td>0.04</td>
</tr>
<tr>
<td>%Wₐₑᵣ (J)</td>
<td>152 ± 26.9</td>
<td>128 ± 24.1</td>
<td>5.104</td>
<td>0.001***</td>
<td>0.81</td>
<td>0.93</td>
</tr>
</tbody>
</table>

*Results with a p ≤ 0.05 were considered statistically significant.
†Results with a p ≤ 0.01 were considered statistically significant.
***Results with a p ≤ 0.001 were considered statistically significant.
††Wₑᵣ = absolute contribution of aerobic energy system; %Wₑᵣ = relative contribution of aerobic energy system; %Wₚₑᵣ = absolute contribution of phospholytic energy system; %Wₚₑᵣ = relative contribution of phospholytic energy system; %Wₐₑᵣ = relative contribution of alactic anaerobic energy system; %Wₙₑᵣ = relative contribution of lactic anaerobic energy system; Wₜₒₜ = total energy output of all energy systems.

Results

Mechanical power indices recorded during both tests are presented in Table 1. The results showed that PP, AP, MP, and PD were significantly greater in EAT than WAT (p ≤ 0.001). However, no significant difference between tests was observed in FR (p > 0.05).

VO₂ above rest during the EAT was 0.80 ± 0.12 L·min⁻¹, whereas it was 0.94 ± 0.23 L·min⁻¹ for WAT. Statistical analyses showed that significantly less absolute energy was derived from the oxidative energy pathway in EAT compared with WAT (p ≤ 0.05; Table 2). When expressed as a percentage of the total energy output, the relative oxidative contribution was also significantly lower in EAT as compared with WAT (p ≤ 0.001; Table 2). Mean “a” and “w” were 2.87 ± 0.51 L and 1.09 ± 0.17 minutes for EAT vs. 2.62 ± 0.64 L and 0.91 ± 0.16 minutes for WAT. There was a significantly greater amount of energy derived from the phospholytic energy system, either expressed in absolute values, and relative to total metabolic energy (p ≤ 0.05; Table 2). There was a significantly greater ΔLₜₒₜ in EAT than WAT (14.4 ± 2.32 mmol·L⁻¹ vs. 12.1 ± 1.62 mmol·L⁻¹; p ≤ 0.001). Consequently, the absolute glycolytic energy output was significantly higher in EAT than WAT (p ≤ 0.01). However, when expressed as a percentage of the total energy output, the relative contribution of the glycolytic system was not significantly different between EAT and WAT (p > 0.05; Table 2). Finally, the total metabolic work was significantly higher in EAT than WAT (p ≤ 0.001; Table 2). During EAT,
Elliptical All-out Test vs. Wingate All-out Test

89 and 11% of the metabolic energy were derived from anaerobic and aerobic energy sources, respectively, compared with 84 and 16% in WAT (p ≤ 0.001).

Pearson r correlation coefficients between the parameters measured from EAT and WAT are presented in Tables 1 and 2. The analyses showed that there were different correlation levels ranging from little (r=0.17, p > 0.05) to high (r=0.90, p ≤ 0.001) for both metabolic and mechanical parameters obtained from EAT and WAT.

On the other hand, the correlation analysis between mechanical and metabolic parameters measured in EAT showed little- and moderate-level relationships between PP and WPC (r=0.20, p ≤ 0.05) and %WPC, (r=0.53, p ≤ 0.05), respectively. In contrast, there were high- and moderate-level correlations between PP and WLA (r=0.90, p ≤ 0.001) and %WLA (r=0.63, p ≤ 0.05). The correlation between AP and estimation of the glycolytic energy contributions were high (r=0.86, p ≤ 0.001) for WLA and moderate (r=0.66, p ≤ 0.05) for %WLA. There were moderate-level correlations (r=0.60, p ≤ 0.05) between all drop-off indices of EAT and WLA. A similar trend was observed for WAT, with little-level correlation between PP and WPC (r=0.16, p > 0.05) and %WPC (r=0.34, p > 0.05). There were high- and low-level correlations between PP and WLA (r=0.85, p ≤ 0.01) and %WLA (r=0.41, p > 0.05). In addition, AP was highly correlated with WLA (r=0.85, p ≤ 0.01), but not with %WLA (r=0.20, p > 0.05). Finally, there were moderate-level correlations between drop-off indices of WAT and WLA (p ≤ 0.05).

Discussion

The present study is the first to assess the relative energy contributions of the 3 energy systems during an EAT performed on a modified elliptical trainer compared with the standard WAT performed on a traditional cycle ergometer.

The main results showed that there was significantly less aerobic contribution in EAT compared with WAT, and thus hypothesis 1 was accepted. In addition, a significantly greater relative contribution of the phospholytic system was shown in EAT vs. WAT, whereas no significant difference between tests was observed for the relative contribution of the glycolytic system. Hence, hypothesis 2 was only partly accepted. This suggests that an elliptical trainer represents a more conceivably assessment of general anaerobic status during a 30-second all-out Wingate protocol and could be used as an alternative to the classical cycle ergometers in sports where performance relies on both upper body and lower body. These results will be interpreted in the following paragraphs with regards to methodological considerations and several potential explanation mechanisms, including mainly the muscle mass and fiber types involved in both tests.

The main issue raised in the literature regarding the use of a cycle ergometer when performing the Wingate protocol in the assessment of anaerobic performance is the extent of aerobic energy sources involvement in the production of total metabolic energy. The range reported in the literature is extremely wide, with values as low as 9% (20) and as high as 40 (27) or 44% (37). These apparent discrepancies between studies are mostly because of the various methods used to estimate relative energy contributions during anaerobic tests. Two main methods have been used in the above-mentioned studies to estimate the relative energy contributions during the WAT. The first method is based on the accumulated oxygen deficit and predicts anaerobic contribution by calculating the difference between the estimated oxygen cost of all work completed and the measured oxygen consumption during the test (27). The validity of this method during a supramaximal exercise relies on the assumption that energy demand can be estimated from the relationship between mechanical power and submaximal oxygen consumption (16). Studies based on this method assumed a constant mechanical efficiency; however, it has been shown that efficiency tends to decrease at high power outputs (22). This could result in an underestimation of anaerobic work or conversely an overestimation of aerobic contribution to total energy expenditure. The underestimation of anaerobic energy used by the accumulated oxygen deficit method has been confirmed by direct measurements from biopsied muscles (3). The second method involves directly measuring oxygen consumption to estimate aerobic contribution and then calculating anaerobic contribution based on the difference between completed total metabolic work and estimated aerobic work (20,35,36). This approach relies on other assumptions, in particular, the fact that until PP is reached, all the energy is provided by the phospholytic energy system and that there is no contribution of high energy phosphates to external work after 10-second of exercise. However, it has been shown that the 3 energy systems are not activated in a purely sequential manner, but instead start simultaneously and contribute to total energy in an overlapping way (16).

In view of these inaccuracies, a recent study proposed another method to estimate the relative contribution of the oxidative, phospholytic, and glycolytic energy systems during the standard WAT, based on the integrated VO2 area over time during the test, the fast component of the kinetics of postexercise VO2, and net lactate accumulation (6). Relying on a similar method, results of the present study were very close to those from Beneke et al., for oxidative, phospholytic, and glycolytic energy contribution rates during a traditional WAT (16, 39, and 45% vs. 19, 31, and 50%, respectively), as well as the total metabolic work (1278 vs. 1281 J, respectively).

Our results demonstrated that all mechanical power indices, except F0%, were statistically greater in the EAT than the WAT. These results are not surprising because it is known that the total work capacity produced during exercise is closely related to the active muscle mass involved during this exercise. It is well established that the muscle mass involved during a standard all-out leg cycling test represents up to 75% of whole-body muscle mass (6). Despite the limited literature on electromyographic analyses during exercise on elliptical trainers, 1 study has shown that there is
a greater muscle recruitment during an exercise bout on an elliptical trainer compared with a lower body cycle ergometer (7). In many sports, such as team sports and martial arts, performance relies on the involvement of both lower body and upper body (1,5,12,14). Within this context, assessing the power of these athletes on an elliptical trainer seems more relevant than on a cycle ergometer that restricts the participation of the upper body.

As a result of these discrepancies in muscle mass involvement between both tests, participants’ ability to naturally overcome the workload was different while exercising on EAT vs. WAT. Workloads that elicited the greatest PP and ~45–50% fatigue index were accepted optimal for both Wingate test modalities. These optimal loads yielded similar results in FI% responses during EAT and WAT (ρ > 0.05), showing that the load optimizations were accurate. Therefore, it could be assumed that the greater anaerobic involvement observed in the present study during the test on the elliptical trainer resulted from differences in test modalities rather than differences in workloads between ergometers.

Because the validity of a test assessing short-term maximal power output relies on the assumption that metabolic energy during this test is produced predominantly by the anaerobic metabolism, our results are in favor of a good validity of the EAT. An element of explanation relies on the types of fiber in the specific muscles involved during those 2 exercise modalities. It is well known that the major muscle groups of the body (shoulder, chest, back, hip, leg, etc.) have a high proportion of fast-twitch (type-II) fibers (19). Thus, a greater involvement of these type II fibers was expected during the EAT compared with the cycling test, based on high-speed movement of the major muscle groups of upper body (18). This could partly explain the greater anaerobic involvement observed in the present study between the EAT and the classical WAT.

A secondary aim of this study was to investigate the relation between metabolic and mechanical indices measured in WAT and EAT. It was hypothesized that PP and AP would not be well correlated to the contributions of the phospholytic and glycolytic processes (hypothesis 3). This hypothesis was accepted. Indeed, an interesting finding of the present study was the weak correlations observed between mechanical and metabolic variables measured. This has been a matter of debate in the literature since several decades. When the WAT was created in the 1970s, PP was originally assumed to reflect the phospholytic processes, whereas AP was supposed to represent the extent of anaerobic glycolysis in the muscle. However, after subsequent studies, it was demonstrated that PP is unlikely to reflect only the phospholytic energy (4). This latter assumption was confirmed in the present study. Indeed, only little- and moderate-level correlations ranging from 0.16 to 0.53 were observed between PP and phospholytic processes in both all-out tests. In contrast, greater levels of association were observed between PP and the glycolytic energy system, ranging from 0.41 to 0.90. Because of above-mentioned findings, we also suggest that when referring to results of such tests, the terms of “PP output” and/or “AP output” are preferable to use than the commonly used terms of “anaerobic power” and/or “anaerobic capacity.” It may also be worth considering that instead of “anaerobic test,” the terms of “all-out test” may be preferable because all energy systems are activated simultaneously and contribute to total energy in an overlapping way (16). Indeed, the present study showed that there is at least 11% oxidative energy contribution in total energy turnover during an EAT.

**Practical Applications**

Results of the present study indicate that there is less aerobic (11 vs. 16%) and more anaerobic (89 vs. 84%) energy contribution during a 30-second Wingate test when it is performed on an elliptical trainer instead of a cycle ergometer. Therefore, it is more useful to athletes and coaches because power indices obtained from elliptical testing represent whole-body locomotor tasks. All-out tests performed on elliptical trainers should thus be introduced into performance testing at different periods of the season in sports such as martial arts, team sports, or racket sports. The various indices measured could be used to assess the efficiency of various training interventions (i.e., PP as an assessment of power or speed training, AP or FI% to evaluate lactate tolerance), and determine athletes’ profiles, with some sports mainly dependent on PP (team sports played on smaller pitches), and others on AP (martial arts or team sports played on larger pitches). These tests on elliptical trainers should also be incorporated into identification programs in all sports involving whole-body movements, and norms should be obtained regarding specific sports.

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**References**


Elliptical All-out Test vs. Wingate All-out Test


