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Research article

Familiarization Effects of an Elliptical All-out Test and the Wingate Test Based on Mechanical Power Indices

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Abstract
The Wingate all-out test (WAT) is commonly used to estimate anaerobic capabilities of athletes by using an upper or lower body cycle ergometer, however, a new test modality called elliptical all-out test (EAT) which measures activated whole-body locomotor tasks has recently been proposed. The purpose of this study was to evaluate the familiarization effects of a 30-s EAT versus WAT. Twenty male trained athletes performed pre-familiarization (Trial-I), post-familiarization (Trial-II) and retest of Trial-II (Trial-III) sessions on both cycle ergometer and elliptical trainer. Peak power (PP), average power (AP), power drop (PD) and fatigue index ratio (FI%) were analyzed using student's t-test for paired samples and correlated by intra-class correlation coefficients (ICC). Moreover, an error detection procedure was administered using data attained from illogical interrelations among 5-s segments of 30-s tests. The main results showed that there were significant familiarization effects in all mechanical power outputs obtained from Trial-I and Trial-II in both EAT (ICC = 0.49-0.55) and WAT (ICC = 0.50-0.57) performances ($p \leq 0.01$). Significant segmental disorders were detected in power production during Trial-I of EAT, however, none existed in any of test trails in the WAT ($p \leq 0.001$). After familiarization sessions, reliability coefficients between Trial-II and Trial-III showed moderate to strong-level agreements for both EAT (ICC = 0.74-0.91) and the WAT (ICC=0.76-0.93). Our results suggested that prior to the performance tests, combination of a well designed familiarization session with one full all-out test administration is necessary to estimate the least moderately reliable and accurate test indices for both WAT and EAT.

Key words: Adaptation; anaerobic; coordination; practice; reliability; Wingate.

Introduction

The traditional *Wingate all-out test* (WAT) is a commonly used assessment in exercise physiology to analyze anaerobic performance (Scott et al., 1991), to estimate the effectiveness of specific training programs in-season, as well as to document off-season changes in physical fitness (Farzad et al., 2011; Gibala and McGee, 2008; Magal et al., 2009; Michailidis et al., 2013). On the other hand, elliptical trainers have gained a popularity for fitness-purpose (Mier and Feito, 2006; Sweitzer et al., 2002). Recently, *elliptical all-out test* (EAT) has been used to reveal general anaerobic characteristics of athletes by using a modified elliptical trainer (Ozkaya et al., 2009a; 2012). Ozkaya and his colleagues claim that an elliptical trainer activates whole-body locomotor tasks by its weight-bearing configuration specificity. Indeed, it has been shown that EAT performance always reveals greater external power indices compare to WAT (Ozkaya et al., 2009b), and is also characterized by very good correlation coefficients ranging from 0.80 to 0.98 (Ozkaya et al., 2009a; 2012). EAT modality is administered on the basis of a 30-s Wingate test protocol specialities via constant-intensity and varying-velocity.

Traditionally, before testing begins, all individuals must be thoroughly instructed and indoctrinated in the proper test methods. Familiarization requires that practice tests are conducted during stable test conditions, besides the type of test methods and used ergometers are taken into account. Evidently, Barfield et al. (2002) reported a systematic change in peak power (14%) and average (mean) power (5%) indices between the first and second WAT trials. They suggested that at least one full administration should be performed on the cycle ergometer prior to a baseline measurement. However, they have only focused a single practice effect on mechanical power production in the test, and did not investigate the effects of familiarization.

While cycling is a much more common exercise modality, elliptical trainers have recently become a widely used exercise tool. Specifically, during short-duration and high-intensity activities on elliptical trainers, familiarization with the test modality may be more necessary to obtain accurate and reliable assessments. No studies exist which specifically addresses the effects of familiarization session on the use of ergometers. Therefore, the main purpose of this study was to investigate how a familiarization session affects 30-s all-out test performed on an elliptical trainer compared to a cycle ergometer.

Methods

Participants

The study protocol was approved by the university ethics committee and written informed consent was obtained after explanation of the nature and risks involved during the study. Twenty male athletes who did not use cycle or elliptical ergometers in their training and testing, specialists of basketball, football, ice-hockey and rugby volunteered to take part in the study (age: 20.1 ± 1.4 years; body mass: 73.7 ± 10.9 kg; height: 1.73 ± .08 m; body fat percentage: 12.6% ± 1.5%). 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 7.5 ± 2.6

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years. All tests were performed in a standard 20-22 °C temperature and 50% relative humidity conditions within a period of ~12 days, and after the end of the competitive season to minimize the effects of training load or periodization. In addition, the testing time of day was replicated to minimize any effect of circadian variance for each volunteer. They were requested not to take part in any exhaustive exercise 24-h prior to the testing sessions, and none of the participants suffered from any injury or were under any specific medication.

Overview

A randomized cross-over study design was used in order to establish how a familiarization session affects 30-s all-out test performed on an elliptical trainer compared to a cycle ergometer by using repeated-measures, and 30-s tests were carried out with one day intervals between elliptical trainer and cycle ergometer trials. Pre-familiarization (Trial-I) and post-familiarization (Trial-II) tests were performed over a one week period. The participants performed a familiarization session in the middle of the week between Trial-I and Trial-II. After a period of three days from Trial-II, Trial-III was carried out as a retest of Trial-II.

Procedures

Performance tests

A mechanically braked Monark cycle ergometer was used for the WAT (Monark 894, Varberg, Sweden). A resistance corresponding to 10% of athlete's body weight (0.10 $N \cdot N^{-1}$) was used as previously suggested by Bar-Or (1987). The seat height was adjusted for each participant to allow appropriate knee extension with the ankles flexed at 90° and toe clips were used. A 5-min warm-up was applied with a resistance corresponding to 20% of test load, and a pedal rate of 70-80 rpm. Three acceleration bursts were performed during the 3rd, 4th and 5th minutes of the warm-up, each lasting two to three seconds. At the end of the warm-up period, volunteers rested for a period of 5-min. The all-out test started with a 3-s unloaded period, in order to overcome the inertia of the cycle ergometer and to provide the opportunity to reach a maximal pedal rate. Immediately after the unloaded period, the test load was administered and the 30-s all-out test initiated. Participants received strong verbal encouragements throughout the test in order to produce a maximal effort, and were not allowed to stand up during the test. After termination of the test, volunteers were supervised to pedal the cycle ergometer against no resistance for a cool-down period of 5-min. A modified mechanically braked elliptical trainer was used for the EAT (Precor Experience series EFX 576i, Precor, Inc., Woodinville, USA). A resistance corresponding to 13.5% of athlete's body weight (0.135 $N \cdot N^{-1}$) was used for non-elite trained male athletes as suggested by Ozkaya et al. (2012). The EAT was standardised by the same procedure as described above for the traditional Wingate test, except that volunteers were in a standing position, instead of a sitting position. In addition, cadence of step rate was set at 100 stairs per minute (50 rpm) (Dalleck et al., 2004) during warm-up.

Mechanical power indices

The mechanical power outcomes were automatically measured during the test by the computer software interface from the mean power produced at each 5-s interval. Five basic Wingate indices were then calculated including; (a) peak power (PP) defined as the greatest mechanical power production in any 5-s interval, (b) average (mean) power (AP) defined as the mean power production sustained throughout the 30-s test period, (c) minimum power (MP) defined as the lowest power production in any 5-s interval, (d) power drop (PD) defined as the degree of power drop-off during the test duration, and (e) fatigue index ratio (FI%) defined as the relative decline in power over 30-s (Bar-Or, 1987).

Error detection protocol

An error detection procedure was administered using data attained from illogical interrelations amongst 5-s segments of 30-s all-out tests (Ozkaya et al., 2009a; Ozkaya et al., 2012). For this purpose, 5-s segments of 30-s test duration were numbered from one to six. Logical segmental order was examined by using error detection criteria as follows; Eq.1. The segment number of PP has to be lower than the 3rd segment, Eq.2. The segment number of MP has to be at 6th segment, Eq.3. The power value of the 2nd segment has to be higher than the power value of the 3rd segment, Eq.4. The power value of the 3rd segment has to be higher than the power value of the 4th segment, Eq.5. The power value of the 4th segment has to be higher than the power value of the 5th segment. If the results are compatible as expected with the above criterions, a score of zero point, otherwise a score of one point was awarded.

Familiarizing of the cycle ergometer

The participants performed a 5-min warm-up with a resistance corresponding to 20% of test load and a pedal rate of 60-80 rpm. Following the warm-up, a 10-min familiarization session was administered as follows; (a) participants were supervised to use only toe clips (pedal belts) as they pedalled for 2-min, (b) they pedalled without the toe clips for 2-min, (c) they hiked one pedal up using toe clips as they pushed the contra-lateral pedal down for 2-min, (d) and conversely, they focused to hike up the other pedal using toe clips, while they pushed the contra-lateral pedal down for 2-min, and finally (e) they were supervised to use all techniques synchronously over the last 2-min. After termination of the familiarization session, volunteers were instructed to cool-down by pedalling the cycle ergometer for 5-min.

Familiarizing of the elliptical trainer

A 5-min warm-up was performed with a resistance corresponding to 20% of test load and a cadence of 100 stairs per minute. Following this, a 10-min familiarization session was supervised as follows; (a) as participants pedalled, they were supervised to use only foot-platform, while they held the stable handle-bars for 2-min, (b) they only pulled the moveable handle-bars for 2-min, (c) they only pushed the moveable handle-bars for 2-min, (d) participants were instructed pull one handle-bar as they synchronously pushed the contra-lateral bar for 2-min,

Table 1. Results of paired samples t-test, Cohen's effect size, intra-class correlation coefficients (ICC) and 95% confidence intervals (95% CI) between Trial-I and Trial-II of 30-s elliptical all-out test (EAT) and the traditional Wingate all-out test (WAT) (n = 20). Data are means (±SD).

Tests	Variables	Trial-I	Trial-II	Cohen's *d*	t	p	ICC	95% CI	p
EAT	PP (W·kg^{-1})	13.2 (1.7)	15.3 (1.8)	-1.23	-12.34	.001	.54	-.04–.88	.001
	AP (W·kg^{-1})	9.8 (1.7)	11.1 (1.7)	-.78	-10.98		.55	-.06–.89	
	PD (W·s^{-1})	14.1 (5.0)	18.9 (5.1)	-.95	-9.24		.52	-.03–.82	
	FI (%)	42.8 (10.8)	49.5 (8.6)	-.69	-6.37		.49	-.03–.80	
WAT	PP (W·kg^{-1})	9.8 (1.0)	11.8 (1.0)	-1.31	-12.70		.61	-.32–.87	
	AP (W·kg^{-1})	8.2 (.7)	8.7 (.7)	-.71	-7.85		.57	-.05–.90	
	PD (W·s^{-1})	10.1 (3.2)	12.7 (3.3)	-.80	-9.95		.51	-.05–.84	
	FI (%)	40.5 (6.5)	45.1 (5.3)	-.78	-6.58		.50	-.03–.81	

PP: Peak power; AP: Average power; PD: Power drop; FI%: Fatigue index ratio.

and finally (e) as participants pushed the foot-platform down with one leg, they were supervised to pull the handle-bar with their contra-lateral arm, and at the same time, synchronously push the handle-bar with ipsi-lateral arm for the last 2-min. After termination of the familiarization session, volunteers were supervised to cool-down by pedalling elliptical trainer for 5-min.

Statistical analysis

Results were evaluated using SPSS 19.0 (SPSS Inc., Chicago, USA) statistical software. Descriptive results were reported as mean values and standard deviations (SD). Paired samples t-test was conducted to assess differences in the variables obtained from EAT and WAT performances between trials. Intra-class correlation coefficients (ICC) and 95% confidence intervals (95%CIs) were computed using two-factor mixed-effects single-measure reliability method with absolute agreement. Effect size was analysed based on Cohen's *d*. Results with a $p \leq 0.05$ were considered statistically significant for all the statistical analyses.

Results

The main results showed that there were significant familiarization effects in all mechanical power outputs obtained from Trial-I and Trial-II of EATand WAT ($p \leq 0.001$). ICC analyses also indicated fair and moderate agreements between Trial-I and Trial-II (Table 1).

Additionally, significant segmental disorders were detected during Trial-I of EAT by Eq. 1, Eq. 2 and Eq. 3, while any error score didn't exist in Trial-I of WAT or the other test trials ($p \leq 0.001$) (Table 2).

On the other hand, after familiarization sessions, ICCs between Trial-II and Trial-III increased to moderate and high-level correlations for both EAT and WAT (Table 3).

Discussion

Although many studies have been focused on the validity, reliability and/or reproducibility bout of the 30-s Wingate test protocol, the effect of the familiarization to the test ergometers has not been fully evaluated. Therefore, the main purpose of this study was to investigate how a familiarization session affects 30-s all-out test performed on an elliptical trainer compared to a cycle ergometer. High-level reliability correlations (0.80-0.98) have been estimated with good-level familiar athletes in previous studies (Ozkaya et al., 2009a; 2012), however, ICCs between Trial-I and Trial-II ranged between 0.49 and 0.55 for the EAT in present study. Although generally accepted

Table 2. Error scores of a 30-s elliptical all-out test (EAT) and the traditional Wingate all-out test (WAT) (n = 20). Data are means (±SD).

Tests	Variables	Trial-I	Trial-II	ES-1	ES-2	p
EAT	PP (W·kg^{-1})	13.2 (1.7)	15.3 (1.8)	7	0	.001
	AP (W·kg^{-1})	9.8 (1.7)	11.1 (1.7)			
	PD (W·s^{-1})	14.1 (5.0)	18.9 (5.1)			
	FI (%)	42.8 (10.8)	49.5 (8.6)			
WAT	PP (W·kg^{-1})	9.8 (1.0)	11.8 (1.0)	0	0	
	AP (W·kg^{-1})	8.2 (.7)	8.7 (.7)			
	PD (W·s^{-1})	10.1 (3.2)	12.7 (3.3)			
	FI (%)	40.5 (6.5)	45.1 (5.3)			

PP: Peak power; AP: Average power; PD: Power drop; FI%: Fatigue index ratio; ES-1: Error scores of Trial-I; ES-2: Error scores of Trial-II.

Table 3. Intra-class correlation coefficients (ICC) and 95% confidence intervals (95% CI) between Trial-II and Trial-III of 30-s elliptical all-out test (EAT) and the traditional Wingate all-out test (WAT) (n = 20). Data are means (±SD).

Tests	Variables	Trial-II	Trial -III	ICC	95% CI	p
EAT	PP ($W \cdot kg^{-1}$)	15.3 (1.8)	15.6 (2.0)	.89	-.78–.98	.001
	AP ($W \cdot kg^{-1}$)	11.1 (1.7)	11 (1.8)	.91	-.89–.98	
	PD ($W \cdot s^{-1}$)	18.9 (5.1)	19.6 (4.4)	.79	-.63–.97	
	FI (%)	49.5 (8.6)	47.7 (6.3)	.74	-.59–.96	
WAT	PP ($W \cdot kg^{-1}$)	11.8 (1.0)	12.2 (1.1)	.91	-.79–.98	
	AP ($W \cdot kg^{-1}$)	8.7 (.7)	8.9 (1.9)	.93	-.89–.98	
	PD ($W \cdot s^{-1}$)	12.7 (3.3)	12.9 (3.7)	.78	-.68–.91	
	FI (%)	45.1 (5.3)	45.4 (6.4)	.76	-.62–.89	

PP: Peak power; AP: Average power; PD: Power drop; FI%: Fatigue index ratio.

reliability coefficients have been indicated between 0.89 and 0.98 for the WAT (Bar-Or, 1987), estimated ICCs were not well correlated (0.50-0.61). On the contrary, after familiarization sessions, estimated ICCs from Trial-II to Trial-III ranged between 0.74 and 0.91 for the EAT, and 0.76 and 0.93 for the WAT in present study. Our results, therefore, indicate that there are significant learning effects from first to second EAT and WAT trials ($p \leq 0.001$).

There has only been one investigation to analyze the single practice effect of a 30-s Wingate test. Barfield et al. (2002) estimated that at least one full administration of an all-out cycling test is needed several days prior to baseline WAT measurements. They described that there is a substantial (14%) and moderate (5%) level changes in PP and AP respectively from first to second Wingate trials performed within a week interval. The present study showed 20% and 6% increases for PP and AP respectively in the WAT. Regional-level athletes who volunteered to take part in this study never practiced any 30-s all-out cycle ergometer or elliptical trainer test. This may explain the estimated higher learning effect between first and second Wingate test trials in present study. On the other hand, combination of a well designed familiarization session and one full test administration compared to a single 30-s test administration seems more effective to appear a greater learning effect.

Prior studies that have noted the importance of familiarization sessions in the 1-RM tests (Cronin and Henderson, 2004; Ploutz-Snyder and Diamis, 2001), Ploutz-Snyder and Diamis (2001) have reported an increase in the muscular strength in both young (12%) and elderly women (22%). They have evaluated that the number of familiarization sessions were lower in young women compared to elderly women (3-4 vs. 8-9 trials, respectively). Dias et al. (2005) indicated that two familiarization sessions of 1-RM tests for the arm curl and three sessions for the bench press and squat are needed. Furthermore, Capranica et al. (1998) stated that the familiarization of five trials on each of the two days for the isokinetic knee extension/flexion test is also essential. Our results provide increasing evidence that a familiarization session several days prior to the main test administrations is needed. These differences can be explained in part by the proximity of the types of exercise, equipments used, gender differences and different training status.

An error detection procedure was created by Ozkaya et al. (2009a) to estimate illogical interrelations in power production during an all-out test. This procedure relies on commonly accepted success criteria of Wingate Institute. Those criteria were also used to determine the lack of familiarization to the ergometers in the present study. Indeed, because of the lack of familiarization, undulations in power production occurred during Trial-I of EAT. Some of the athletes were not able to reach the desired velocities with elliptical trainer, and thus, before a familiarization session, significant segmental disorders were detected in power production during EAT ($p \leq 0.001$). Results of the error scores highlighted that before a familiarization session, logical segmental order could not be obtained from elliptical trainer tests ($p \leq 0.001$). Thus, at least one additional familiarization session is necessary for elliptical tests compared to those for the cycle ergometer to accurately estimate test indices ($p \leq 0.001$).

The main limitation of the familiarization in elliptical tests may be derived from lack of overall pedalling. During an all-out cycling test, athletes hike one pedal up with toe clips, while they push the contra-lateral pedal down. Despite limited literature present regarding the use of pedal belts, it has been well known that it is important to perform a Wingate test with toe clips. LaVoie et al. (1984) demonstrated an all-out cycling test with toe stirrups resulted in higher mechanical outputs. During all-out tests with an elliptical trainer, athletes have to push the foot-platform down with one leg, while they pull with the handle-bar with the contra-lateral arm, and at the same time push the other handle-bar with the ipsi-lateral arm. Because of more muscle recruitment and whole-body movement patterns of on an elliptical trainer, especially during high-velocity movements, it seems that lack of familiarization is a greater problem for the elliptical trainer when compared to a cycling test. Indeed, cycling is a much more common locomotion mode of exercise when compared to elliptical movement pattern. This could explain why higher error scores between first and second trials of elliptical tests were obtained when compared to cycle tests ($p \leq 0.001$).

Conclusion

In conclusion, at least one familiarization session, several days prior to main test administrations is suggested to estimate more accurate and reliable retest correlations for both cycling and specifically for elliptical all-out test modalities. Moreover, it can be more effective to combine a well designed familiarization session with one full test administration together to have more valid and reliable test outcomes.

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Key points

- A well designed familiarization session, and then, one additional all-out test administration, several days prior to main test, is suggested to estimate more accurate and reliable retest correlations for both cycling and elliptical all-out test modalities.
- Because of greater muscle recruitment and different movement pattern, familiarization seems more effective for a 30-s all-out test performed on an elliptical trainer compared to a cycle ergometer.

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