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Anaerobic Parameters of Division I Collegiate Male and Female Tennis Players

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ABSTRACT

Simpson, AE, Helm, KD, Saez, GM, Smith, JR. Anaerobic Paramenters of Division I Collegiate Male and Female Tennis Players. **JEPonline** 2017;20(1):177-187. The purpose of the study was: (a) to determine the anaerobic capacity (AC), anaerobic power (AP), fatigue indices (FI), total work (TW), and blood lactate (BLa) concentration of Division I collegiate male and female tennis players; and (b) to establish Wingate anaerobic testing data on collegiate tennis players via an electronically braked cycle ergometer. Fifteen National Collegiate Athletic Association Division I tennis players (7 males and 8 females) performed a 30-sec WAnT on an electronically braked cycle ergometer at a torque resistance of 8.5% of their body weight (kg). Velotron RacerMate software computed AC, AP, FI, and TW. BLa was assessed with a Lactate Plus Blood Lactate Meter. Male and female AP values were 16.27 $W \cdot kg^{-1}$ (± 1.16) and 14.82 $W \cdot kg^{-1}$ (± 0.84), respectively; AC values were 11.17 $W \cdot kg^{-1}$ (± 1.02) and 9.34 $W \cdot kg^{-1}$ (± 4.2), respectively. The FI values were 44.03% (± 13.28) and 43.92% (± 12.49), respectively. The TW values were 24,351 J (± 2,615) and 17,463 J (± 1,412), respectively, and the BLa values were 12.33 $mmol \cdot L^{-1}$ (± 3.14) and 11.50 $mmol \cdot L^{-1}$ (± 2.88), respectively. Although the results of the present study are similar to the anaerobic parameters reported in other studies of athletes, it is best to use caution when attempting to objectively compare the results of the present study with other Wingate norms.

Key Words: Anaerobic Capacity, Anaerobic Power, Blood Lactate, Wingate

INTRODUCTION

Success in many sports is based on the muscles ability to produce explosive powerful movements (14,15). Sports involving long duration activity interspersed with short high intensity bouts require a continuous supply of adenosine triphosphate (ATP). Both the aerobic and anaerobic energy systems play a vital part in the success of athletes in such sports.

Tennis is a sport that is both aerobic and anaerobic in nature. Matches can last longer than 5 hrs but many short high-energy bursts are involved in the specific skills of serves, chasing tennis balls, and ground strokes (18). Tennis players need to be able to perform repeated dynamic movements of acceleration, deceleration, multi-directional agility, and explosive jumps (11,12,18,34). Such dynamic explosive movements require glycolytic ATP production.

Although tennis matches may last longer than 5 hours, which indicates aerobic metabolism of ATP production, tennis players must have enhanced anaerobic metabolic pathways (18). With the advancement of sport science and sport conditioning, assessment of physiological parameters of sport performance has become common practice. A commonly utilized anaerobic laboratory test is the 30-sec Wingate anaerobic test (WAnT) (3). Numerous investigations (8,10,19,26,27,36) have utilized the WAnT to assess sport performance and to establish physiological profiles of athletes. The WAnT assesses anaerobic capacity, anaerobic power, and fatigue index. Development of physiological profiles is important for the assessment of sport conditioning and training programs. Information regarding physiological profiles is necessary to provide a quantifiable basis for the development and maintenance of conditioning and training programs (17).

There is a dearth of information concerning tennis players' anaerobic parameters via Wingate anaerobic testing on an electronically braked cycle ergometer. The purpose of this study was twofold: (a) to determine the anaerobic capacity (AC), anaerobic power (AP), fatigue indices (FI), total work (TW), and 5-min post WAnT blood lactate concentration of Division I collegiate tennis players; and (b) to establish WAnT data on collegiate man and female tennis players via an electronically braked cycle ergometer.

METHODS

Subjects

Fifteen National Collegiate Athletic Association (NCAA) Division I tennis players (7 males and 8 females) reported to the Human Performance Laboratory (HPL) for assessments. The subjects were informed of all procedures, benefits, and risks of the investigation prior to signing the University's Institutional Review Board approved informed consent. Upon arrival to the HPL, the subjects completed a physical activity readiness questionnaire (PAR-Q). All subjects were in the age range of 18 and 22.

Procedures

Demographic and anthropometric data were collected. Gender, birth date, age, height to the nearest 0.25 in, and weight to the nearest 0.25 lb were recorded. Resting heart rate and resting blood pressure were assessed via an Omron automated blood pressure monitor. The subjects were fitted with a Polar Heart Rate Monitor. All subject information was recorded on a data collection sheet. The subject's gender, birth date, height, and weight were recorded in the RacerMate Velotron Wingate software. The RacerMate Velotron Wingate software converted weight and height measures to kilograms and centimeters, respectively. Torque resistance was set at 8.5% of the subjects' body weight (kg). The 8.5% resistance selection was based on methodology utilized by Baker et al. (2).

The Velotron cycle ergometer (RacerMate Inc., 3016 N.E. Blakeley Street, Seattle, WA 98105) seat height, seat translation, handle bar height, and handle bar translation were adjusted for optimal subject comfort. A goniometer was utilized to ascertain 25 to 30° of knee flexion in the pedal down position. Seat height was adjusted accordingly. Toe stirrups were secured on participants' shoes. Subjects warmed-up for 5 min at 25 W at 80 rev·min^{-1}. During the warm-up, the subjects performed two 4 to 6 sec sprints with a submaximal load (~225 W) at minutes 2 and 3. Following the warm-up, the subjects rested in a chair next to Velotron cycle for 3 min. During resting, the subjects were instructed to use the toe stirrups in a "pulling" action in addition to pushing down on the pedals during the test. Additionally, the subjects were instructed to give maximal effort and to remain seated throughout the test.

Wingate Test

The WAnT began with a 20-sec "ride in" at 40 rev·min^{-1} and a 7-sec count down against zero resistance in which the subjects maximally accelerated pedal revolutions. A subsequent 30-sec all-out maximal effort against the prescribed load began at the end of the 7-sec countdown. The Velotron RacerMate software computed the subjects' anaerobic capacity (W·kg^{-1}), anaerobic power (W·kg^{-1}), fatigue index (W·sec^{-1}) and total work (joules). Anaerobic capacity was calculated as the mean power divided by the subject's body weight (kg). Anaerobic power was calculated as the peak power divided by body weight (kg). Peak power is the greatest power output during a 5-sec period of the test (usually seen in the first 5 sec). Fatigue Index percentage was calculated by the following equation: [Peak P (W) – Minimum P (W)] ÷ Peak P (W) x 100. Fatigue index represents the percent decrease in power output from the beginning of the test to the end of the test. Total work was computed by multiplying average watts by test duration.

Following the WAnT, the subjects completed 5 min of active recovery, which included 1-min on the Velotron against zero resistance at a self-selected pace and 4-min on a treadmill at a self-selected pace between 2.5 and 3.0 mi·h^{-1} at 0% grade. At 5 min after the test, both heart rate (HR) and blood pressure (BP) were assessed via an Omron automated blood pressure monitor device and, then recorded on a data collection sheet.

Blood Lactate Assessment

At 5 min after completing the test, an Accu-Chek Safe T-Pro Plus lancet was used to prick the ring finger (contralateral arm of BP assessment) for a drop of blood to assess blood lactate concentration via a Lactate Plus Blood Lactate Analyzer (Nova Biomedical, 200 Prospect Street, Waltham, MA 02454). Gauze was used to wipe off the first drop of blood. The second drop of blood was collected by squeezing the middle of the finger and placing blood on the Lactate Plus lactate testing strip. Blood lactate concentration results were available within 13 sec. The results (mmol·L^{-1}) were recorded on a data collection sheet.

Statistical Analyses

Descriptive statistics were used to analyze the subjects' data by calculating means, standard deviations, and ranges of both the demographic and physiological variables. All data were analyzed using StatPlus: mac LE software.

RESULTS

The subjects were post-season male and female mid-major Division I tennis players. The demographic characteristics and body mass indices are presented in Table 1.

Table 1. Demographic Characteristics of the Participants (mean ± SD).

Characteristics	Men (n = 7)	Women (n = 8)
Age (yrs)	20.3 ± 1.3	19 ± 1.1
Weight (kg)	73.1 ± 9.8	62.4 ± 4.6
Height (cm)	179.8 ± 6.3	164.7 ± 6.7
BMI ($kg \cdot m^{-2}$)	22.65 ± 2.61	23.1 ± 1.64

BMI = Body Mass Index

Velotron RacerMate Wingate software calculated anaerobic power (AP), anaerobic capacity (AC), total work, and fatigue index (FI) measures. Descriptive statistics for male and female AP, AC, FI, and 5-min post-testing blood lactate measures are presented in Table 2.

Table 2. The Wingate Test Results.

Group	AP (W/kg)	AC (W/kg)	Total work (j)	FI (%)	BLa ($mmol \cdot L^{-1}$)
Men (n = 7)					
Mean	16.27	11.17	24,351	44.03	12.33
± SD	1.16	1.02	2,615	13.28	3.14
Range	3.7	3.1	7,870	38.23	8.70
Women (n = 8)					
Mean	14.82	9.34	17,463	43.92	11.50
± SD	0.84	4.2	1,412	12.49	2.88
Range	2.5	1.3	4,250	34.7	9.6

AP = relative anaerobic power; **AC** = relative anaerobic capacity; **FI** = fatigue index; **BLa** = blood lactate concentration

DISCUSSION

The purpose of this study was to assess the anaerobic parameters of Division I tennis players and add to the body of sport science literature on tennis players' WAnT performances. Additionally, since the majority of the WAnT has been on a manually braked cycle ergometer, the present study sought to establish WAnT data utilizing an electronically braked cycle ergometer. The results show that the WAnT performances of the present investigation are similar to other WAnT performances by athletes (23,29). Moreover, the WAnT performances of the male and female tennis players in the present study rank high according to established WAnT values in the literature (2,9,30,37).

The present study replicated procedures of the study by Baker et al. (2) in which investigators sought to develop WAnT norms for highly trained women. Investigators utilized a resistance torque value of 8.5% of body weight (kg). The subjects remained seated with their feet secured with toe stirrups. According to the norms and descriptive statistics developed by Baker et al. (2), the women in the present study were above the 95th percentile for relative anaerobic power (>12.50 $W \cdot kg^{-1}$) and anaerobic capacity (>8.90 $W \cdot kg^{-1}$). The fatigue indices of the women in the present study were between the 85th and 90th percentile (45.10 – 42.82). The women in the present study appear to be superior in anaerobic conditioning according to the norms established by Baker et al. (2).

The male tennis players in the present study also ranked high according to norms developed in the investigation by Coppin and colleagues (9). Seventy-seven college-aged highly trained males participated in Wingate testing on a manually braked cycle ergometer with toe stirrups and a resistance setting of 8.5% of body mass (kg) while remaining seated throughout the test. The results of the investigation established reference values for male power athletes. According to the reference values of Coppin et al. (9), the male tennis players in the present study ranked "high" for relative anaerobic power (>13.6 $W \cdot kg^{-1}$ BM), relative anaerobic capacity (>9.8 $W \cdot kg^{-1}$ BM), and fatigue index (<44.6). Female tennis players in the present study also ranked "high" in the relative anaerobic power and fatigue indices established by Coppin et al. (9).

Similarly, the male and female tennis players in the present study rank well according to indices established by Zupan et al. (37). The investigators developed WAnT classifications for men and women intercollegiate athletes in which an instantaneous manually braked cycle ergometer was utilized with a resistance of 7.5% of body weight (kg) for both genders. According to the categories developed by Zupan and colleagues (37), the female tennis players in the present study would be categorized as "Elite" for relative anaerobic power (>11.07 $W \cdot kg^{-1}$) and relative anaerobic capacity (>8.22 $W \cdot kg^{-1}$). The male tennis players would be categorized as "Elite" for relative anaerobic power (>13.74 $W \cdot kg^{-1}$) and relative anaerobic capacity (>9.79 $W \cdot kg^{-1}$). In the present study, toe stirrups were utilized, which permits the pulling up in addition to pushing down on pedals. Such use of toe stirrups may elicit higher anaerobic outputs, which may be why athletes in the present study were categorized as "Elite". Additionally, Zupan et al. (37) employed a 7.5% resistance setting where as the present study employed a resistance setting of 8.5% of body weight (kg).

Higher torque resistance settings have been shown to elicit higher anaerobic outputs (5,16,32). In a study by Richmond et al. (32), male and female cyclists participated in Wingate testing at two different resistance settings. Twenty-nine competitive cyclists performed the WAnT on four separate occasions on an electronically braked cycle ergometer. Two trials were performed at randomized resistances of 8% and 9.5% of body weight (kg) in which the subjects remained seated and utilized toe stirrups. Regardless of gender, all power output results were significantly greater with the heavier resistance of 9.5% of body weight (kg). Thus, attempting to objectively compare WAnT results with differing torque resistances may be arduous.

Ramirez-Velez et al. (30) studied a total of 1,873 nonathletic adults (64% men) between the ages of 20 and 80. They participated in Wingate testing to develop percentile norms in Columbian healthy adults. The investigation utilized a manually braked ergometer with a resistance setting of 7.5% of body weight (kg). The subjects remained seated throughout the test, but toe stirrups were not utilized. The male and female athletes in the present study rank in the 97th percentile (>13.4 $W \cdot kg^{-1}$ and 13.7 $W \cdot kg^{-1}$, respectively) for relative anaerobic power for the age range of 20 to 25 according to norms developed by Ramirez-Velez et al. (30). Authors of the present study anticipated the male and female tennis players would rank high on the percentile norms established by Ramirez-Velez et al. (30) because nonathletic adults were used to establish the norms. Additionally, the higher resistance setting of 8.5% and the use of toe stirrups most likely played a role in the high percentile scores of the athletes in the present study.

Comparing results of the WAnT investigations to normative data becomes laborious due to variations of testing protocols. Wingate anaerobic testing protocols differ in torque resistance, standing or seating demands, the use of toe stirrups/clips, and whether the cycle ergometer is manually or electronically braked. The aforementioned variables make it difficult to objectively compare the results with normative data established by the previous research (1,5,9,22,37).

Also, other variables have been found to modify the results, such as verbal encouragement, music, and familiarity with Wingate testing (6,7,24). These factors may have played a role in the data collected in the study by Brooks and Brooks (6). They Wingate tested 39 women and 24 men ages 18 to 38 yrs with and without motivational music. The results of the study revealed significantly higher peak power and average peak power with the motivational music. It is likely that music delays the fatigue during the test, which may increase average power and peak power because more effort is exerted when music is played. In fact, self-selected music may have played a role in the high anaerobic outputs of the present study.

While verbal encouragement was given to all the subjects in the present study, it may have affected the men and women differently. Bullinger et al. (7) concluded no increase in anaerobic performance in Wingate testing of women with verbal encouragement. They (7) suggested that females are more intrinsically motivated than males. Both males and females performed exceptionally well in the present study in comparison to the normative data.

In the present study, the subjects remained seated throughout the WAnT. Many studies disclosed that the subjects remained seated while some studies did not mention whether staying seated was required (8,10,19,26,27,37). Wilson et al. (35) sought to determine whether differences existed in power output and physiological responses between seated and standing positions of athletes during three consecutive Wingate tests. Seven elite level speed skaters completed three 30-sec WAnTs with 3.5 min of recovery between each test in both the seated position and the standing position. Torque resistance was set at 7.5% of body weight and testing sessions were separated by at least 48 hrs. The results revealed no significant differences between the seated and standing positions. Hence, investigators concluded that position during a WAnT does not produce statistically different results in power, maximal heart rate, blood lactate, and muscle oxygenation (35). However, contrary to the findings of Wilson et al. (35), Reiser and colleagues (31) found that college cyclists produced greater power output when the subjects were standing on the pedals compared to the seated trails during the Wingate tests at a torque resistance of 8.5% of body weight. Thus, at present more research is needed for clarification between the two styles of testing. It is reasonable to think that requiring the subjects in the present study to remain seated may have affected their anaerobic performance.

The anaerobic performances of athletes in the present study closely reflected results of other WAnT investigations involving athletes (23,29). McCormack et al. (23) assessed 10 Division I collegiate female soccer players with Wingate testing. An electronically braked cycle ergometer set at a torque resistance of 8.5% of body weight (kg) was utilized. Testing resulted in a peak power ($W\cdot kg^{-1}$) of 16.66 ± 3.10 and mean power ($W\cdot kg^{-1}$) of 7.70 ± 0.68 (23). Table 2 indicates that female peak power ($W\cdot kg^{-1}$), mean power ($W\cdot kg^{-1}$) and fatigue index (%) of the present study were 14.82 ± 0.84, 9.34 ± 4.2, and 43.92 ± 12.49, respectively. McCormack et al. (23) did not mention the utilization of toe stirrups or the requirement of a seated position, which may have influenced the WAnT results.

Popadic et al. (29) examined the maximal anaerobic power of elite level boxers, wrestlers, and hockey, volleyball, basketball, and soccer players. All 145 athletes were between the ages of 20.44 and 23.21 yrs. The elite athletes participated in a 30-sec WAnT to assess anaerobic power with a maximal load employed by a built-in air-resistance system on wheels. The data indicated an anaerobic peak power range of 8.58 ± 1.56 – 11.71 ± 1.56 $W\cdot kg^{-1}$ and an anaerobic capacity range of 6.02 ± 0.80 – 7.77 ± 1.10 $W\cdot kg^{-1}$ (28). In the present study, the anaerobic power outputs in the male and female tennis players were 16.27 $W\cdot kg^{-1}$ (± 1.16) and 14.82 $W\cdot kg^{-1}$ (± 0.84), respectively. The anaerobic capacities of the present study's male and female tennis players were 11.17 $W\cdot kg^{-1}$ (± 1.02) and 9.34 $W\cdot kg^{-1}$ (± 4.2), respectively. Popadic et al., (29) did not mention a definitive resistance value in their methodology. Flywheel resistance was accomplished by a built-in air-resistance system. As mentioned previously, lower resistance values may elicit lower anaerobic power outcomes. Therefore the outcomes in the present study having utilized a resistance value of 8.5% of body weight may explain the higher anaerobic performances results.

The present study further sought to establish anaerobic physiological profiles by assessing 5-min post WAnT blood lactate levels (BLa). The highest BLa values (= 15 to 25 mM) are typically observed 3 to 8 min after all out maximal effort exercise lasting 30 to 120 sec (13). Other investigations (4,21,25,28,33) have assessed BLa in conjunction with the WAnT. In a study by Price et al. (28), eight nonspecifically trained males participated in the WAnT with a resistance load of 7.5% of body weight (kg). Upon completion, the subjects cooled-down at a self-selected power output and cadence for at least 5 min. Post WAnT BLa and 5-min post WAnT BLa were assessed. The results showed a post WAnT BLa of 8.9 ± 2.0 $mmol\cdot L^{-1}$ and a

5-min post WAnT of 10.3 ± 2.1 mmol·L^{-1}. In a study by Luebbers and Fry (20), track and field power athletes completed a WAnT at a resistance load of 7% of body weight (kg) and underwent 5 min post WAnT BLa assessments. Data showed male and female 5 min post WAnT BLa values of 14.3 ± 2.0 and 14.13 ± 2.2 mmol·L^{-1}, respectively (20). Data from the present study showed similar results. Men and women had 5-min post WAnT BLa values of 12.33 ± 3.14 mmol·L^{-1} and 11.50 ± 2.88 mmol·L^{-1}, respectively.

This study utilized active recovery of 1-min on the cycle ergometer against zero resistance at a self-selected pace and 4 min on a treadmill at a self-selected pace between 2.5 and 3.0 mi·h^{-1} with 0% grade. Bielik (4) has reported that active recovery post all-out maximal exertion enhances blood lactate removal. Thus, researchers suspect that BLa values may have been higher if active recovery was not employed.

Results of this study are similar to anaerobic parameters of other investigations of athletes (23,29). Researchers conclude that caution must be exercised when attempting to objectively compare the results of the present study with other WAnT norms. Authors suggest that future research in Wingate anaerobic testing standardize testing protocols, which will permit the objective comparisons of data.

CONCLUSIONS

The findings of this study have direct implications for tennis players, coaches, and sport conditioning coaches. Anaerobic measurements can detect deficiencies and permit training programs to tailor specific programs to improve anaerobic capacities. The results of the present study could be useful to compare WAnT performances utilizing an electronically brake cycle ergometer at a torque setting of 8.5% of body weight (kg) while athletes remain seated and shoes secured in toe stirrups.

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