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Reliability of the Wingate Anaerobic Test with Ice Hockey Players

on the Velotron Cycle Ergometer

by

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A research project proposal submitted as part

of the requirement for the degree

of

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in

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Approved:

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Reliability of the Wingate Anaerobic Test for Ice Hockey Players
on the Velotron Cycle Ergometer

Abstract

Purpose: This study evaluated the test-retest reliability of the
Wingate Anaerobic Test (WAnT) performed on a Velotron
electromagnetically-braked cycle ergometer (EE) for power-
trained athletes and assessed whether a familiarization trial was
necessary to achieve high test-retest reliability. *Methods*: Twenty-
one male ice hockey players (age 23.5 ± 4.7 yrs, mass 86.3 ± 16.6
kg, height 180.9 ± 7.4 cm) from a collegiate club team (Club = 10)
and a recreational league (Rec = 11) performed three, 30-sec
WAnTs within 2 weeks, and with at least 24 hours between visits.
Mean power, anaerobic capacity, peak power, anaerobic power,
maximum RPM, and fatigue index were assessed. Resistance was
8.5% of the participant's body weight. *Results*: The effect of time
on power output was moderated ($p < .001$, $\eta_p^2 = .24$) such that a
significant increase was observed after a practice trial, but not
between subsequent trials for the Club players; no practice effect
was observed among Rec players. Extremely high reliability was
found between trials after excluding the practice trial ($ICC_{1,1} >$
.89). The Club players achieved higher outputs despite no
significant differences in body size or age compared to the Rec
League players. *Conclusion*: Ice hockey players performing the
30-sec WAnT on the Velotron EE had highly reliable data, and
using a familiarization trial is recommended to increase reliability
and achieve higher power outputs. Lastly, because WAnT results
from EE and mechanically-braked ergometers cannot be compared,
normative tables for EE results need to be created.

Keywords: anaerobic performance, muscular power, test-retest
reliability, electromagnetically-braked, power trained athlete

Introduction

The Wingate Anaerobic Test (WAnT) was developed over 40 years ago[1], yet it is still a popular test among coaches and exercise scientists. The 30-sec WAnT is an all-out anaerobic test, performed on a cycle ergometer, which measures lower body anaerobic power. There are other anaerobic tests that can measure peak power as well as anaerobic capacity; these tests include, the vertical jump test, standing long jump test, and Bosco repeated jumps[2]. These tests, although easier to perform, do not have the reliability and validity of the WAnT. This is because a resistance can be applied as a percentage of the subject's body weight during the WAnT[3-6], which allows for a more reliable way to compare peak power of athletes who compete in different sports[4,6-10]. Some of the benefits of the WAnT include, measuring power output, improving athletic performance, creating reference norms of athletes for coaches and trainers, and assessing changes in fatigue index[2]. Because it has been found to be so reliable and useful, the WAnT has been acknowledged by many as the primary method for measuring anaerobic power[2,5-13]. Dotan, one of the researchers who developed the WAnT in the 1970s, noted the worldwide acceptance of the test as a research and fitness-diagnostic tool yet acknowledged that technological advances such as the advent of electromagnetically-braked cycle ergometers make the WAnT "ripe for an overhaul"[10]. The WAnT was originally developed using a mechanically-braked ergometer (ME), so one area of uncertainty is the reliability of the WAnT when the test is performed on an electromagnetically-braked ergometer (EE). A high degree of reliability for a test method is crucial because small, but meaningful, changes in performance because of an experimental manipulation cannot be detected without high test-retest reliability[14].

In a review of the WAnT, Bar-Or[3] reported test-retest reliability correlation coefficients ranging from 0.89 to 0.98, and noted that mean power tended to be somewhat more reliable than peak power. The studies included in Bar-Or's review were done with MEs. Reliability studies using the Velotron EE are limited. Several researchers have concluded that time trial performance for distances ranging from 12.9 to 20 km are reproducible on the Velotron[12,13,15], but there is a lack of research for reliability of anaerobic tests. To our knowledge, only Astorino and Cottrell[7] have evaluated the test-retest reliability of the WAnT performed on the Velotron. They reported moderately high to high test-retest reliability for mean power (ICC = 0.90) and peak power (ICC = 0.70); however, their sample consisted of primarily recreationally-active men and women who were not specifically power trained.

As shown in previous research there is a difference in power output between anaerobically trained versus non-anaerobically trained athletes[4,6], as well as between males and females[2,4,7,14]. Thus, because the subjects in the Astorino and Cottrell study were not anaerobically trained, and included both males and females their data will not be useful in comparing reliability or power output results which were acquired by power trained participants. A practice effect was also not considered in their test-retest study, and a practice trial is recommended when testing anaerobic power[5,8,11-14,16,17].

As an anaerobic test, the WAnT is most useful and applicable to athletes who are anaerobically trained and compete in an anaerobic sport. Ice hockey is a sport with a high anaerobic demand, and previous investigators have demonstrated that the WAnT is highly related to on-ice skating performance in both collegiate and youth hockey athletes[18-23]. However, these investigators used MEs for the test. Peak power during a WAnT is derived from a 5-sec average on a ME, but it is recorded instantaneously on a Velotron[7]. Therefore, despite a substantial amount of previous WAnT reference values for ice hockey players, there are no published standards for this athletic population when tested on a Velotron EE. The purpose of this study was to evaluate the test-retest reliability of the WAnT performed on a Velotron EE for power-trained athletes and to determine if a familiarization trial was necessary to achieve high test-retest reliability. An additional objective was to compare the power outputs of ice hockey players from a nationally-ranked collegiate club team to those from an adult recreation league. We hypothesized that high reliability of the WAnT would be achieved on the Velotron, and that the power outputs of the ice hockey players in our sample would exceed those of previously published reports because of the instantaneous measurement of the EE compared to the 5-sec average measurement of the ME.

Methods

Subjects

Initially, 25 ice hockey players from the Utah State University club team (USU Club) and 20 ice hockey players from an adult recreation league (Rec League) were invited to participate in the study. A total of 11 from the USU Club completed a consent form, but only 10 completed all three trials. A total of 12 players from the Rec League completed a consent form, but only 11 players completed all three trials.

A total of 21 male ice hockey players completed three WAnT tests, 10 from the USU Club, and 11 from the Rec League.

Demographic characteristics of the sample are in Table 1. Each participant provided written informed consent and completed a Physical Activity Readiness Questionnaire (PAR-Q), which insures they were adequately healthy to complete the tests prior to participation. All project designs were approved by the university's Institutional Review Board.

Design

An observational approach with repeated measurements was used for this study. Each participant visited the exercise physiology lab at Utah State University three times within 2 weeks, and with at least 24 hours between visits. This design allowed for determining reliability of the EE, as well as ascertaining any practice effect using repeated-measures ANOVA. All analyses were performed using SPSS version 24 (IBM, Inc., Armonk, NY). Statistical significance was accepted at $p < 0.05$ unless otherwise stated.

Methodology

All participants performed the 30-sec WAnT each visit on the EE Velotron Dynafit Pro cycle ergometer (RacerMate®, Seattle, WA) with a 62-tooth chainring. During the initial visit, height was measured using a wall-mounted stadiometer (Seca 216, Seca Corp., Ontario, CA), and weight was measured using a digital scale (Seca 869, Seca Corp., Ontario, CA). Each participant self-selected seat height, seat setback, handlebar height and reach on the Velotron, and were recorded and used for the subsequent trials. To try to improve reliability and avoid a 'practice effect'[5,8,11-14,16,17], the first visit served as a practice trial to familiarize each subject with the Velotron and the 30-sec WAnT test. To not influence or bias their effort, participants were not informed of the purpose of the first trial. Previous investigators have recommended that a practice trial is necessary for reliable WAnT data[5,8,13,17].

Each visit lasted a maximum of 15 minutes and consisted of: a) review of testing procedures, b) 5-min warm-up at a resistance of 75 Watts and a cadence of 60-100 rpms, c) 3-min rest before test start, d) 30-sec WAnT, and e) cool down until subject's heart rate had returned to 120 bpm. Strong verbal encouragement was given throughout the 30-sec protocol and was similar for all trials and all participants. The WAnT was performed with a resistance of 8.5% body weight, as previous investigators have determined this to be the optimal load when testing power trained male athletes[4,9]. The test was performed using a traditional flying start with the participants given a 20-sec warm-up followed by 6 secs of acceleration to achieve maximal rpms before the load was applied and the 30-sec WAnT commenced[7]. The barometric

pressure and temperature within the lab were similar across all trials.

Statistical Analysis

Mean power (MP) was defined as average power output in Watts (W) over the 30-sec test, and anaerobic capacity (ANcap) as MP per kilogram of body weight (W/kg). Peak power (PP) was defined as the highest instantaneous power output achieved in Watts (W), and anaerobic power (ANpow) as PP per kilogram of body weight (W/kg). Maximum revolutions per minute (RPM_{max}) was the highest instantaneous pedaling cadence, and fatigue index (FI) was calculated as FI = [(PP – Min Power)/PP] x 100, where Min Power is minimum power. The preliminary trial (Prelim) was the practice trial, and the subsequent trials were labelled trial 1 (T1) and trial 2 (T2). Means and standard deviation (SD) were calculated for MP, ANcap, PP, ANpow, RPM_{max}, and FI. Figure 1 displays the full distribution of each measure at all trials via boxplots. Table 2 displays the summary statistics for T1; T1 and T2 were not significantly different, so T2 data are not included.

Prior to analysis with repeated-measures ANOVA, assumptions were tested: Shapiro-Wilk test for normality and Mauchly's test for sphericity. Repeated-measures ANOVA was used to investigate if a preliminary trial was needed and if its effect was consistent between USU Club and Rec League players. This was accomplished by including main effects for time and team, as well as their interaction.

Test-retest reliability was evaluated using the statistical methods recommended by Hopkins et al.[14] and Weir[16]. These include evaluation of the intraclass correlation coefficient ($ICC_{1,1}$ one-way random), standard error of measurement [$SEM = SD\sqrt{(1-ICC)}$], minimal difference ($MD = SEM$ x 1.96 x $\sqrt{2}$), and coefficient of variation (*CV*).

Results

The *ICC*s between T1 and T2 were very high and significant for all variables, and, except for PP, the *CV*s were between 11.1% and 13.8% (Table 3). Normality was determined for all variables except FI. Repeated-measures ANOVA was used to analyze PP, with time (Prelim, T1, T2) as the within subject factor and team type (USU Club vs Rec League) as the between subjects factor. Since the assumption of sphericity was violated, Mauchly's ω = .635 ☐ $\chi^2(2)$ = 8.182, p = .017, the Greenhouse-Geisser correction for degrees of freedom (ε = .732) was used. The

interaction between time and team was found to be significant, $F(1.465, 27.833) = 6.286$, $p = .010$, $\eta_p^2 = 0.249$. Visual inspection of Figure 1 (panel A) reveals the USU team members increased PP from Prelim to T1, but remained stable between T1 and T2, while the Rec League players remained constant across all 3 trials at a PP similar to the Prelim for USU Club players. Post-hoc pairwise analysis, using Bonferroni correction for multiple comparisons concluded USU Club players increased by an average of 226.1 Watts (SE = 51.11) in PP from Prelim to T1, ($p = .001$), but did not increase from T1 to T2, ($p = .760$). Rec League players did not increase across the 3 trials ($p = .763$). Similar analyses were conducted for MP, ANcap, ANpow, RPM_{max} and FI with nearly identical interactive effects. The only exception was for FI, in which none of the pairwise post-hoc comparisons reached significance (Figure 1). Marginal means for the RM ANOVA models are displayed in Figure 2.

Post-hoc comparisons using pairwise t tests showed no significant difference between T1 and T2 for any outcomes, but did; however, reveal the Prelim values to be significantly less than values obtained during T1 and T2 trials for all variables. Results further demonstrate that MP, ANcap, ANpow, RPM_{max} measurements were significantly higher for USU Club players compared to Rec League players (Table 2). The USU Club players achieved these higher power outputs despite no significant differences with the Rec League players regarding body size or age (Table 1). The only descriptive factor that was significantly different between the two groups was years of experience ($\alpha = .002$), with a higher average for USU Club players.

Discussion

The purpose of this study was to evaluate the test-retest reliability of the WAnT performed on a Velotron EE with power-trained athletes. Furthermore, we aimed to determine if a practice trial was necessary for achieving high reliability. Additionally, descriptive power output data specific to ice hockey players was obtained. This was important because previous WAnT data for this athletic group were gathered from tests performed on MEs[18-23]; this is the first study to report WAnT data for ice hockey players using an EE.

Based on current findings, the Velotron racermate EE is a reliable method for testing anaerobic power. Previous researchers have described WAnT reliability using MEs[3,10,17], but reliability studies using an EE are limited. To our knowledge, only one[7] has evaluated the test-retest reliability of the WAnT using the Velotron; however, their sample consisted of recreationally-active

men and women who were not specifically power trained. Also, a practice effect was not considered in their test-retest study. They reported ICCs of 0.70 and 0.90 for ANpow and ANcap, respectively. These are slightly less than the ICCs observed in the present study between trials T1 and T2. They reported small MDs of 0.44 W/kg for ANpow and 0.11 W/kg for ANcap. However, our sample produced substantially higher power outputs than the participants in the Astorino and Cottrell study, and that could be a contributing factor for the larger MDs in the present study. Despite similar peak cadences of 181 rpm for Astorino and Cottrell's participants and 175 rpm for our athletes, the ANpow of 14.5 W/kg of the hockey players in the present study was substantially greater than the 9.7 to 9.8 W/kg of the recreationally active participants in the Astorino and Cottrell study. Their CVs of 13.7% for ANpow and 8.9% for ANcap are comparable to ours of 11.1% and 13.8%.

Having the athletes complete a practice trial clearly improved the test-retest reliability of the entire sample. However, it is interesting that this improvement was observed primarily in the more powerful USU Club players and not in the Rec League players. Astorino and Cottrell[7] were able to achieve high reliability without a practice trial in their sample of recreationally active participants. In contrast, several research teams that have tested the reliability of WAnT using ME have reported that a practice trial is necessary[8,17]. Barfield et al.[8] described improvements of 14% and 6% for ANpow and ANcap, respectively, for two WAnTs separated by a week. Similarly, Ozkaya[17] reported improvements in ANpow of 20% and ANcap of 6% for repeat WAnTs. Our findings of improved reliability with a practice trial agree with the recommendations of many others to include a practice trial when testing anaerobic power[5,8,11,12,14,16,17].

USU Club ice hockey players had significantly higher MP, ANcap, ANpow, and RPM_{max} compared to the Rec League players. The USU Club team participated in the national championship tournament for this level of play. Thus, given their higher level of competition, higher training intensity, and more years of experience, it is not surprising that they had higher WAnT data than the Rec League players of similar age and BMI. The power output data of both the Club and Rec League players in the present study is considerably higher than the power output data reported for similar WAnT studies performed on EE[7,11]; however, these researchers reported their participants as being "physically active" rather than power trained.

Compared to data of other ice hockey players, the PP and ANpow of the athletes in the present study were comparable to the PP (1306 Watts) and ANpow (14.7 W/kg) reported for members of

an NCAA Division I national runner-up team[20], and higher than that reported for other NCAA Division I players (PP = 1112 Watts)[19] and Division III players (ANpow = 11.35 W/kg)[18]. Even the Rec League players had PP and ANpow higher than the under-20 Polish National Team of 1031 Watts and 12.97 W/kg, respectively[22]. How are these high power outputs possible for participants that clearly have less skill and realistically less anaerobic power than national team athletes? All the ice hockey comparison studies cited[18-20,22] were performed on ME. As Micklewright et al.[11] described, results obtained on an EE are not comparable to those from a ME because of mechanical differences between ergometers. Such differences include the inertia of the flywheel, load applied mechanically versus electronically, and PP identified as the highest value attained during the test on the Velotron rather than a 5-sec average on a ME[7]. WAnT reference values for male power athletes are available for tests performed on a ME[9]. However, these reference values are not applicable for tests performed on an EE. There are no reference values or normative tables for WAnT data from an EE, but the data provided in this study provide some reference point for future studies of power-trained males tested on a Velotron EE.

Practical Application

A practice trial is warranted when trying to obtain anaerobic power outputs of athletes. The Velotron EE will yield higher PP and ANpow than a ME because the Velotron software reports PP as the highest observed value rather than the highest 5-sec average, which is the original WAnT methodology developed for ME. Because normative wingate tables for EE do not exist further research is needed.

Conclusion

Ice hockey players performing the 30-sec WAnT on the Velotron EE had highly reliable data. Reliability increased with a familiarization trial. The Club players had greater power outputs than the Rec League players, and they also benefited more from the familiarization trial. Unfortunately, normative WAnT data specific to tests conducted on EE do not yet exist, and comparing WAnT data from an EE to normative data created from tests conducted on ME is not appropriate.

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Figure 1. Distributions of Measures at Each Trial
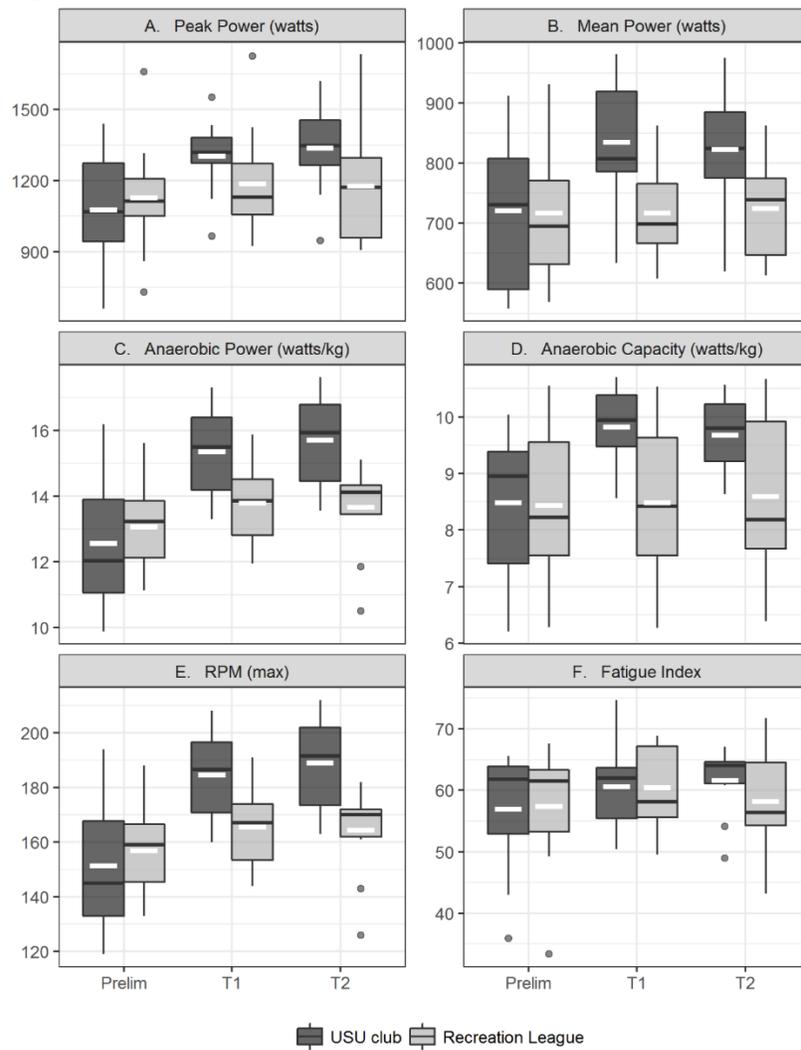
Boxes span from the 25th to the 75th percentile. The center black line indicates the median and the white line indicates the mean (these overlap in symmetrical distributions and differ in the presence of skewness or outliers).

Table 1. Descriptive/Demographics

Groups	Total	USU Club	Rec League	
n	21	10	11	sig
Age (yrs)	23.5 ± 4.7	22.0 ± 1.1	24.8 ± 6.3	0.180
Weight (kg)	86.3 ± 16.6	85.4 ± 11.6	87.1 ± 20.7	0.821
Height (cm)	180.9 ± 7.4	181.7 ± 8.0	180.1 ± 7.2	0.629
Yrs exp*	13.4 ± 5.9	17.2 ± 3.5	10.0 ± 5.5	0.002*
BMI (kg/m^2)	26.3 ± 4.0	25.7 ± 1.9	26.7 ± 5.4	0.573

Values in cells represent M±SD, significance based on independent groups t-test, Leven's test utilized to determine whether to assume equality of variance. Kg = kilogram, cm = centimeters, n = sample size, Yrs exp = years' experience, * = significant difference ($\alpha < .05$), BMI = body mass index [kilograms (kg)/meters squared (m^2)].

Table 2. Descriptives from Trial 1

	Total	**USU Club**	**Rec League**	
n	21	10	11	sig
MP (Watts)	773 ± 107	834 ± 103	718 ± 79	.008*
ANcap (Watts/kg)	9.12 ± 1.26	9.82 ± 0.73	8.49 ± 1.34	.012*
PP (Watts)	1242 ± 206	1303 ± 163	1186 ± 231	.197
ANpow (Watts/kg)	14.50 ± 1.54	15.35 ± 1.37	13.79 ± 1.33	.016*
RPM$_{max}$	175 ± 18.6	184 ± 16.5	166 ± 16.0	.015*
FI	60.5 ± 7.4	60.6 ± 7.3	60.4 ± 6.8	.960

Value in cells represent M ± SD, significance based on independent groups t-test without controlling for multiple comparisons, Leven's test utilized to determine whether to assume equality of variance. n = sample size, * = significant difference (α < .05).

Table 3. Reliability with and without Prelim Trial for all variables.

	All 3 Trials		Without Prelim Trial			
	η_p^2	ICC$_{1,1}$ (sig)	ICC$_{1,1}$ (sig)	SEM	MD	CV (%)
MP	0.234	.829 (<.0001)	.973 (<.0001)	16.98	47.00	13.3%
ANcap	0.235	.836 (<.0001)	.975 (<.0001)	0.19	0.55	13.8%
PP	0.249	.847 (<.0001)	.957 (<.0001)	45.15	125.15	17.4%
ANpow	0.246	.344 (.124)	.890 (<.0001)	0.54	1.49	11.1%
RPM$_{max}$	0.242	.350 (.118)	.890 (<.0001)	6.50	18.02	11.2%
FI	0.031	.701 (.0005)	.797 (.0003)	3.18	8.81	11.7%

ICC > .75 was considered good, SEM & MD (standard error of measurement, minimal difference) calculated using ICC without Prelim Trial using total SD of all participants for T1 and T2. η_p^2 = partial eta squared for the interaction between time and team in the RM ANOVA, CV = coefficient of variation.