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Intermachine Reliability of the Velotron During Wingate Anaerobic Testing

Original Investigation

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Intermachine Reliability of the Velotron During Wingate Anaerobic Testing

Prologue

This plan B master's project aimed to test 40 participants. The goal was to test track and field and football athletes on Utah State University's rosters to add to existing data of normative Wingate values and to establish intermachine reliability of the Velotron ergometer. Unfortunately, the data set does not have enough data to be reviewed and did not meet the advised number of participants for a powerful study. On March 15th, 2020, the IRB halted all human data collection due to the COVID-19 pandemic. As a result of this halt and with an indefinite pause, the research was ended due to the student researcher graduating but will be continued at a future point. At the time of the pause, only 5 out of 14 participants who started the study had completed all three trials, which was required for data to be included in the results. Nine participants who did not complete all three trials were not included in the results. Complications with IRB approval delayed data collection and therefore did not allow enough time for complete data collection given implications of the pandemic.

Intermachine Reliability of the Velotron During Wingate Anaerobic Testing

Abstract

Purpose: The purpose of this study was to evaluate inter-machine reliability of the Velotron electromagnetically-braked cycle ergometer for the Wingate anaerobic test (WAnT) with power-trained athletes. **Methods:** Anaerobic athletes participating in football or track and field at a National Collegiate Athletics Association Division I program were recruited for participation in the study. Each participant visited the laboratory 3 times (1 familiarization trial, 2 experimental trials) within 2 weeks and at least 24 hours between visits. Participants completed a "practice trial" on the first visit to familiarize themselves with the 30-second WAnT. The WAnT procedure included a 5-minute warmup at a resistance of 75 W and a cadence of 60-100 rpms followed by a 3-minute rest before the test start. WAnTs were performed with a traditional flying start in which participants had 6 seconds of acceleration before a load of 8.5% of body mass was applied. Data of interest included mean power (MP), anaerobic capacity (AC), peak power (PP), anaerobic power (AP), and maximum revolutions per minute (RPMmax). **Results:** Results from a limited number of subjects suggested high reliability between Velotron ergometers. Peak power (1256.8±332.2W [Ergo A], 1234.6±344.0W [Ergo B]) and MP (770.2±154.9W [Ergo A], 807±120.0W [Ergo B]) did not differ substantially between trials. However, power outputs from testing trials were generally greater than from a familiarization trial. **Conclusion:** A familiarization trial is necessary for reliability testing. These preliminary findings also suggest that normative values can be established on different Velotron ergometers, and that tests completed on different Velotron ergometers are reliable.

Word Count: 251

Keywords: athlete, ergometer, football, track and field, power-trained

Introduction

The Wingate Anerobic Test (WAnT) was developed and established in the 1970s as a test to measure power in an anaerobic setting.[1] The 30-second WAnT is a maximal effort test performed on a cycle ergometer to measure anaerobic power. It involves the participant pedaling at maximum effort for 30 seconds against a predetermined percentage of their body weight and is widely considered the "gold standard" for measuring anaerobic power. A 30-second test elicits maximal glycolytic power and anaerobic endurance and is short enough for participants to maintain maximal effort throughout the test.[2] A major difference between the WAnT and other lower extremity power measurement tools (i.e., vertical jump, standing long jump) is that the WAnT stresses the glycolytic system while other explosive anaerobic tests involve the phosphagen system only.

In athletics, the WAnT has been used to assess anaerobic fitness in American football, and track and field athletes.[23] Power can be useful in determining status and setting training goals, and data established from WAnT can be used as a reference across athletics to establish and compare to normative values. Reference values for power for the WAnT performed by National Collegiate Athletics Association (NCAA) Division 1A male athletes have been established, giving athletes categorical data for peak and mean power.[23-24]

The WAnT was originally developed using a mechanically-braked ergometer (ME). With ME, resistance is achieved with friction from a belt wrapped around the flywheel, and manually adding weights to a basket attached to the belt increases the resistance.[21] Many contemporary ergometers use an electromagnetic flywheel interfaced with a computer to apply a specific resistance.[21] These are known as electromagnetically-braked ergometers (EE). Most contemporary ergometers measure data at instantaneous points, whereas traditional ergometers captured data in 5-second increments, which may produce greater variability between tests. Several studies investigated the differences between WAnT on a ME and EE with the purpose of comparing performance and metabolic outcome measures between the two types of ergometers.[3,21] Micklewright et al.[21] found no difference in peak power or mean power between ergometers, but found significant differences in minimum power, fatigue rate, and peak cadence.[21] However, they concluded that WAnT results produced using EE are valid indicators of anaerobic exercise performance and metabolic responses.[21] Astorino and Cottrell[3] investigated WAnT trials between an EE and a ME, finding significant moderate correlations for all variables between ergometers and concluding that the EE provides relatively consistent Wingate-derived data.[3] However, the EE revealed higher PP yet lower MP and peak cadence than the ME.[3] These differences may be explained by instantaneous measures, load application or differences in protocols between ergometers.

Ensuring reliability of measurements between tests was key in establishing validity of the WAnT. Previous work on WAnT test-retest reliability, including tests on ME (n=8) and EE (n=7), showed high test-retest reliability, with intraclass correlation coefficients (ICC) > 0.7, most being > 0.85.[3-17] When conducting and comparing variables across multiple trials, Bringhurst et al.[7] demonstrated that repeated measures of the WAnT test performed on an EE were reliable for measuring anaerobic power in a power trained athletic population. Though reliability in latter studies were high, early studies[3,18,19,22,23,28,30] after the introduction of the WAnT could have shown a testing effect as participants were completing the test without a familiarization trial. To improve reliability, recent research has investigated whether a familiarization trial was necessary to achieve high test-retest reliability. Multiple studies have found that practice trials increased the test-retest reliability of concurrent trials.[6-7,15,17-20] While many athletes may use ergometers as part of their training regime, not many are completing sessions of maximal sprinting. Familiarizing participants with policies and procedures surrounding the WAnT may play an important role in producing the highest possible output.

Plenty of test-retest and inter-ergometer reliability studies exist; however, intermachine reliability is another key component to establishing valid and reliable testing methods and data. Intermachine reliability is assumed to be high due to the consistency of automated mass production; however, this type of reliability is rarely evaluated. To our knowledge, only one clinician has investigated intermachine reliability between two EE ergometers, which was completed using the Wattbike.[22] Interbike reliability and test-retest reliability were examined using the Wattbike, an air and magnetically braked cycle ergometer, at nineteen different intensities using a LODE motorized calibration rig.[22] Significant relationships were found between each of the Wattbikes and the LODE, also finding each Wattbike valid and reliable with good interbike agreement and no significant difference in the test-retest condition.[22]

Reliability between two of the same EE is necessary to ensure results can be replicated and validated between ergometers. Intermachine reliability studies are lacking. Therefore, the purpose of this study was to evaluate the intermachine reliability of the WAnT performed on two Velotron (RacerMate, Seattle, WA) EE for power-trained athletes. Secondary purposes of this study were to further investigate the effect of a familiarization trial on experimental trials and to add to existing data of Division 1 male athletes. We hypothesized that high intermachine reliability would be achieved on the Velotron EE for all participants.

Methods

Experimental approach to the problem

A repeated measurements design was used for this study. Each participant visited the exercise physiology laboratory 3 times (1 familiarization trial, 2 experimental trials) within 2 weeks and with at least 24 hours between visits. This design allowed for determining reliability between EEs through the use of dependent t-tests.

Subjects

Twenty-five track and field athletes from the Utah State University Track and Field team and 110 athletes from the Utah State University Football team were recruited for participation in the study. With a small pool of power-trained female athletes at Utah State University and the intention of adding to a small data pool of male athletes, females were not invited to participate in the study. All participants were required to be at least 18 years of age. Athletes who had sustained an injury within 3-months of the study or those who had surgical intervention on the lower extremity within 9-months of the study and had not returned to full activity were excluded. All athletes were between the ages of 18-30 years old. Demographic characteristics of the sample are represented in *Table 1*. Only anaerobic-based and power-trained athletes were invited to participate in this study, which included football players and sprinters, jumpers, and throwers from the track and field team. An athlete that is "power-trained" includes lifting and practice methods that are anaerobic and powerful in nature, where there is a force applied quickly. Football and some events of track and field are anaerobic based, and require strong, quick, and decisive movements. Track and field events including jumps, throws, and sprints are all based on how fast an athlete can move a load (sometimes being their body weight). Basketball, for example, includes long periods of gameplay without stoppages. While much of the sport is power based through jumping, their aerobic component excludes them from this study. Athletes participating in events further than 400m were excluded due to a higher aerobic contribution compared to anaerobic contribution.[25-27]

Each participant was required to sign an institutionally approved informed consent document after being informed of the benefits and risks of participating, and an attempt was made to have each participant complete three trials. This study was approved by the University's Institutional Review Board.

Experimental design

All participants performed a 30-second WAnT each visit on a Velotron Dynafit Pro cycle ergometer (RacerMate, Seattle, WA, USA) with a 62-tooth chainring. During the initial visit, height was measured using a wall-mounted stadiometer (Seca 216; Seca Corp., Ontario, CA, USA), and weight was measured using a digital scale (Seca 869; Seca Corp., Ontario, CA, USA). Each participant had the opportunity to self-select seat height, seat setback, handlebar height, and reach on the Velotron, and these measurements were recorded for subsequent trials. On the first visit, participants completed a "practice trial" to become familiar with the testing protocol of the 30-second WAnT. Participants were not informed of the purpose of the first trial to ensure testing to exhaustion, but data were collected for this trial in order to evaluate any practice effects with a familiarization trial.

In an effort to minimize external influences, each participant was instructed not to participate in lower body training beyond their season-specific training that they were completing as part of the team for two days prior to testing. Testing was delayed if participants were experiencing lower extremity soreness that may affect their ability to complete the trial. If this delayed their participation beyond the testing period (3 trials completed within a 2-week period), this was justification for eliminating the participant from the study. Previous research suggested an existence of circadian rhythm in peak and mean power;[28] therefore, each participant completed each of three trials at the same time of day (+/- 2 hours). Participants were instructed to maintain their daily nutrition practices but to avoid eating anything 1-hour prior to the start of testing. Each trial was randomized regarding which ergometer was used for the first trial; participants used the other Velotron on the subsequent trial. Randomization was also used to determine which ergometer was used for each participants' practice trial.

Data of interest included traditional WAnT measures: mean power (MP), peak power (PP), anaerobic capacity (AC), anaerobic power (AP), and maximum revolutions per minute (RPMmax). Mean power was defined as average power output in Watts (W) over the 30-second test, and anaerobic capacity as MP per kilogram of body mass ($W \cdot kg^{-1}$). Peak power was defined as the highest instantaneous power output achieved in Watts, and anaerobic power as PP per kilogram of body mass ($W \cdot kg^{-1}$). Maximum revolutions per minute was calculated as the highest instantaneous pedaling cadence.

Test procedures

Methods used in previous studies were used during the testing procedures.[7] Each visit consisted of a review of testing procedures prior to testing. Testing was performed with a resistance of 8.5% body weight due to previous investigations determining this to be the optimal load when testing power-trained participants.[7,23,29-32]

A 5-minute warmup at a resistance of 75 W and a cadence of 60-100 rpms was used followed by a 3-minute rest before test start. After the 3-minute rest, the participants performed the 30-second WAnT and a cool down until the participant felt sufficiently recovered with no side effects. WAnT in resistance-trained males have shown higher PP and MP using a flying start compared to a stationary start.[29-30] Therefore, the tests were performed with a traditional flying start where the participant had 6 seconds of acceleration before the load was applied and the 30-second WAnT was initiated. Strong verbal encouragement was given throughout the testing procedures for all trials.

Statistical Analyses

With a low number of completed participants, statistical measures were not run. Therefore, all data-driven responses were theoretical and had no statistical confirmation. All analyses would have been performed using SPSS version 25 (IBM, Inc., Armonk, NY, USA). Statistical significance would have been accepted at $p \leq 0.05$. Trials were labeled as preliminary trial (Prelim), Trial 1 (T1), and Trial 2 (T2). Means and standard deviations were calculated for MP, PP, AP, AC, and RPMmax. Data from Prelim was ignored, and dependent t-tests would have been performed to determine differences between T1 and T2. A previous power analysis estimated a total sample of 34 would provide 80% power to detect a moderate effect size (0.5), with alpha of less than or equal to 0.05. Test-retest reliability would have been evaluated using the statistical methods recommended by Hopkins et al. (2001) and Weir (2005).[33-34] These include evaluation of the intraclass correlation coefficient ($ICC_{1,1}$ one-way random), *SEM* [$SEM = SD\sqrt{(1 - ICC)}$], minimal difference ($MD = SEM \times 1.96 \times \sqrt{2}$) and coefficient of variation (CV).

Results

Results for the 5 subjects who completed the study are detailed in *Table 1, Figure 1,* and *Figure 2. Table 2* contains data from the Prelim trial. Participants were not different in demographic characteristics, but weights varied between event groups in Track & Field athletes. Variability between trials for all data were low and reliability between ergometer A and B seems high. High standard deviations exist in PP and MP. Track and field throwers (n=2) had greater PP and MP values compared to track and field sprinters and jumpers (n=3). Peak power (1256.8±332.2W [Ergo A], 1234.6±344.0W [Ergo B]) and MP (770.2±154.9W [Ergo A], 807±120.0W [Ergo B]) did not differ substantially between trials. All other data of interest did not differ greatly between trials: AP (12.5±0.5 [Ergo A], 12.2±0.6 [Ergo B]), AC (7.8±0.7 [Ergo A], 8.3±0.9 [Ergo B]), RPM (149.4±6.0 [Ergo A], 146.4±6.9 [Ergo B]). In relation to between-bike differences, four out of five participants had higher PP on ergometer A. However, the small sample size precludes the use of traditional statistics in determining significance and conclusions drawn are not statistically confirmed.

Discussion

The intent of this study was to establish inter-machine reliability of the Velotron EE and add to normative values for male power athletes. Given the data set, practical applications cannot be drawn but are a starting point at concluding reliability between ergometers. While the data set cannot be added to normative values, minor hypotheses can be evolved from the data.

Even from the small data set, it seems that there is high test-retest reliability and intermachine reliability of the Velotron EE. Previous work on EE reliability concluded high intermachine reliability and test-retest reliability of the Wattbike.[22] Wainwright, Cooke, and O'Hara[22] demonstrated very good levels of within bike variation, but these included motorized calibration rigs instead of human participants. Although this research[22] was not conducted with human participants, this study suggests that there is high intermachine reliability between EE and may be relatable to the Velotron EE. Further research with large data sets and human participants needs to be conducted in order to verify this conclusion, however. There will always be variability in research with human subjects, but reliability can still be high.

In agreeance with previous research, this evidence further describes the need for a familiarization trial as most participants recorded higher results in PP from Prelim to T1. Extraneous factors including motivation and instruction remained the same across trials. Furthermore, three subjects improved PP from Prelim to T1, again improving in T2, suggesting a practice effect with multiple trials, although the increase from T1 to T2 was much smaller than from Prelim to T1. However, one subject showed decline across all trials. In order to improve reliability and record values that are closer to the highest possible subject output, a familiarization trial should be used.

In reference to peak power classifications for male athletes by Zupan et al.,[24] two subjects from the current study recorded a PP value considered "elite," and the remaining three subjects recorded a PP value considered "average". Anaerobic capacity classifications[24] were above average (n=2), average (n=2), and poor (n=1) for the current study. The mean PP value was 300W higher in the current study compared to values from Zupan et al.,[24] but the mean AC value was lower. Compared to reference values for PP and MP in Division 1A male power athletes,[23] subjects were similarly divided into two classifications for PP; two subjects recorded a PP value of high (>1152W), whereas the other three subjects recorded a PP value considered low (<1010W). For MP, we saw similar classifications: high (>813W, n=2) and low (<745W, n=3). Mean PP and MP values were higher in the current study compared to those in Coppin et al.,[23] as were maximum PP and MP values.

An interesting piece of results suggests power difference between events, showing higher overall values in throwers versus sprinters. Subjects with larger body mass, often seen in throwers, recorded higher PP and MP values, but lower AC values, suggesting that sprinters were able to maintain their power longer than throwers. Based on sport requirements, we may note similarities in throwing sports that require less than 5-seconds of activity whereas sprinters require a minimum of 6-seconds. Obviously, with such few subjects of each event and with no football athletes completed, there cannot be absolute conclusions drawn from this. Future research could evaluate between-event differences and between sport differences in the evaluation of power and normative values.

Limitations exist for the current investigation. Data collection started shortly before COVID-19 had its impact on NCAA sports. Shortly after the start of data collection, Utah State University shut down all sporting events, including practices and lifting, whereas the Mountain West Conference (MWC) shut down all spring sports. The university's IRB did not allow data collection to resume, effectively limiting the number of participants. Also, resistance of 75W during the acceleration phase was not well liked by the participants. Participants often complained that they felt they could have experienced more acceleration if the resistance was higher, as they felt they met the maximum RPM that 75W of resistance allowed. There are also some concerns regarding the data and between-ergometer differences. With only five participants completing 3 trials, it is impossible to determine coincidence versus statistical trends, but four out of five subjects had higher PP, AP, and RPMmax on ergometer A versus B, and conversely lower MP and AC on ergometer A versus B. These differences may be due to continued familiarization with testing procedures or due to unknown differences between ergometers. Future research needs to develop normative testing values including resistance during the WAnT and resistance during the acceleration phase and should run ergometer diagnostics prior to testing.

Practical Applications

Although limited, the data can provide insight into practical applications. The WAnT is a popular test of anaerobic fitness, and power values have high significance for Division I athletes. Future research may add to reference values that coaches and athletes may draw from in evaluations. The Velotron ergometer seems to be highly reliable between ergometers and would be a viable ergometer to use for establishing WAnT normative values. Evidence from this study suggests that values obtained from Velotron ergometers used across the world are comparable to each other, further increasing the confidence that coaches or researchers can have when evaluating normative data or conducting research.

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Tables

Subject	Age	Ht (cm)	Wt (kg)	Sport/ Position	PP Ergo A	AP Ergo A	MP Ergo A	AC Ergo A	RPM Ergo A	PP Ergo B	AP Ergo B	MP Ergo B	AC Ergo B	RPM Ergo B	1st Trial Ergo
1	21	186.2	81.5	TF/ Sprints	1001	12.3	713	8.7	147	991	12.2	730	9.0	146	B
2	22	188.3	82.6	TF/ Jumps	1005	12.2	652	7.9	146	925	11.2	693	8.4	134	B
3	21	178.1	76.4	TF/ Sprints	1003	13.1	584	7.6	157	977	12.8	710	9.3	153	B
4	20	186.9	140.1	TF/ Throws	1823	13.0	914	6.5	156	1784	12.7	918	6.6	153	A
5	23	186.4	122.7	TF/ Throws	1452	11.8	988	8.1	142	1496	12.2	984	8.0	146	B
Total (mean± SD)	21.4 ± 1.0	185.2 ± 3.6	100.7 ± 25.8		1256.8 ± 332.2	12.5 ± 0.5	770.2 ± 154.9	7.8 ± 0.7	149.4 ± 6.0	1234.6 ± 344.0	12.2 ± 0.6	807 ± 120.0	8.3 ± 0.9	146.4 ± 6.9	

Table 1. TF = Track & Field, PP = peak power in watts, AP = anaerobic power (watts/kg) MP = mean power in watts, AC = anaerobic capacity (watts/kg), RPM = maximal rotations per minute

Subject	PP Prelim	AP Prelim	MP Prelim	AC Prelim	RPM Prelim	Prelim Ergo
1	823	10.0	726	8.8	120	A
2	758	9.2	690	8.3	110	A
3	811	10.6	726	9.5	127	A
4	1723	12.3	914	6.5	147	B
5	1571	12.8	929	7.6	154	A
Total (mean±SD)	1137.2±419.6	11.0±1.4	797±102.6	8.1±1.0	131.6±16.5	

Table 2. Prelim trial data. PP = peak power in watts, AP = anaerobic power (watts/kg) MP = mean power in watts, AC = anaerobic capacity (watts/kg), RPM = maximal rotations per minute

Figures

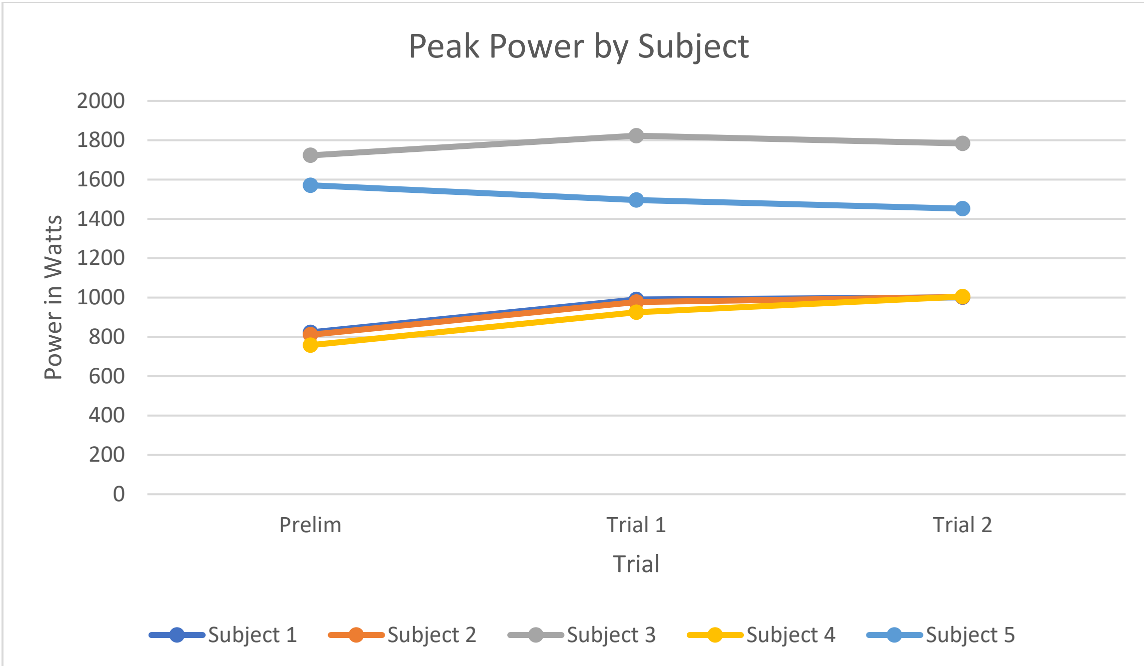

Figure 1. Peak power by subject in Watts.

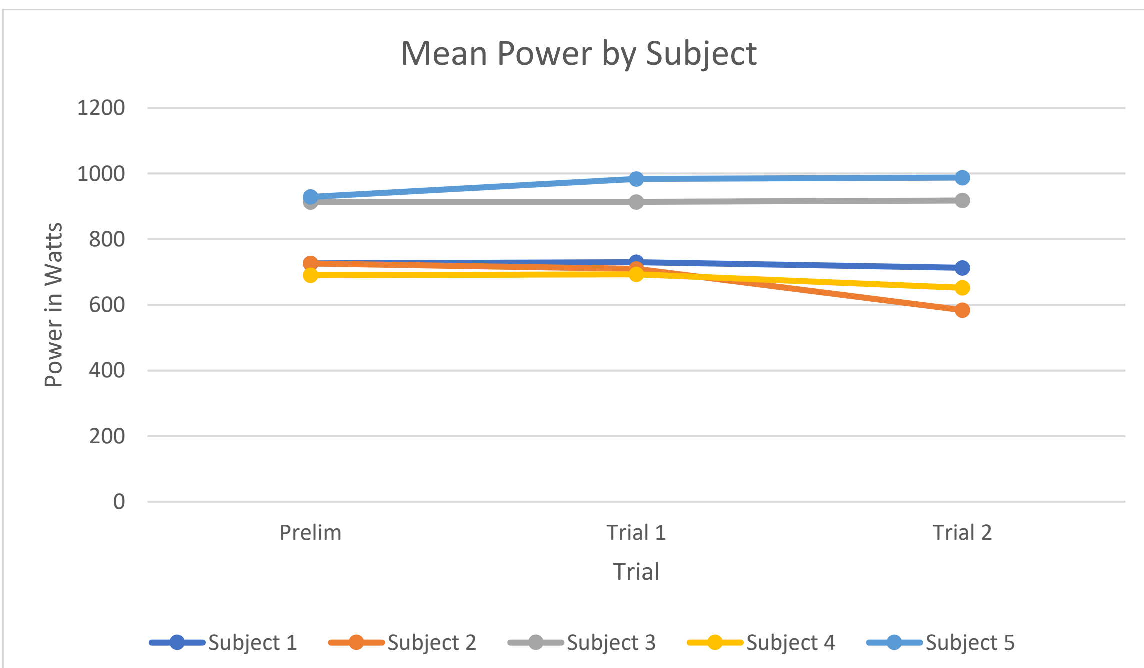

Figure 2. Mean power by subject in Watts.