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Abstract

The Wingate Muscular Power Test (WMPT) has existed for several decades and to this day is considered the gold standard for evaluating an individual's anaerobic capacity. The WMPT can be applied to multiple exercise fields as a means to measure fitness and changes in performance. It is also safe, only requires relatively common testing equipment, and it can be performed by a technician with minimal training required. However, the utility of this test is predicated on having accurate and relevant normative data with which to compare individual results. At present, the existing literature on this subject is either several decades old or inclusive of only specific subject groups. In this study, we seek to record the WMPT results for a large and diverse population of college-age subjects (19-35) in order to generate a new set of normative data. These data sets will include peak power (PP), mean power (MP), fatigue index (FI), and relative power (RP) based on body mass (BM). Our data can then be compared to the previous reference values to evaluate the consistency of the results in addition to comparing performance differences between sexes.

Introduction

Having a reliable method to test an individual's maximum anaerobic power is essential for assessing fitness level, changes in muscular strength, and an individual's capacity to perform in sports or exercises that require powerful bursts of activity (Brown and Weir, 2001). The Wingate Muscular Power Test (WMPT) was developed in the 1970s by the Wingate Institute in Israel (Ayalon et al., 1974). In addition to peak power (PP), the WMPT can also be utilized to measure an individual's relative power (RP) based on their body mass (BM), mean power (MP), and their rate of muscular fatigue (known as fatigue index, FI). Since its inception, it has proven to be a reliable as well as valid assessment and thus is regarded as the gold standard for measuring anaerobic power (Dotan & Inbar,1977; Harvey et al., 2017). The procedure is safe, non-invasive, requires minimal training to administer, and the equipment utilized (cycle and arm ergometer) are already commonly found in most exercise science facilities (Brown and Weir, 2001).

Due to the relative nature of anaerobic power results, it's critically important to have accurate normative data in

order to compare an individual's results to that of an analogous population (Hoffman, 2006). A large portion of this exercise research is done at universities with the subjects of those studies often being students in attendance (NSF, 2017). Therefore, it stands to reason that having normative data from a robust sample of male and female college-age participants (both athletes and non-athletes) would provide a substantial aid to future research and analysis of collegiate athletic performance. Several studies have sought to fill this gap in the literature (see Table 1), but oftentimes their sample sizes and/or population demographics prove to be highly specific and therefore limited in applicability. Past publications on WMPT norms have primarily focused on collegiate athletes (Zopan et al., 2009; Baker et al., 2011). Research by Coppin et al. (2012) found reference values from 77 male college athletes. While useful for comparing results with other male collegiate athletes, the normative data lacks applicability to non-athletes and female participants. Other studies have focused on collecting data specifically from female college athletes (Baker et al., 2011). Lack of ethnic diversity has also been observed as a limitation of some WMPT research (Ramírez-Vélez et al., 2016).

Another potential issue with the current research data has to do with the procedures by which the data was collected. Certain testing conventions have been widely adopted, but no universal procedure exists yet (Brown & Weir, 2001). Some of the testing procedures in question relate to which calculation method to use when applying weighted resistance to record PP (Hermina, 1999; Vargas et al., 2015). Another consideration in the WMPT procedure that can vary between testing protocols is the method by which the weighted resistance is applied (Robergs et al., 2015). Other considerations such as cycle ergometer revolutions per minute (rpm) and the flywheel kinetic energy must be taken into account due to their effect on PP output (Bassett, 1989; Hermina, 1999).

Based on a review of the existing literature, the two primary areas of concern for WMPT normative data relate to the sample populations and the application of standardized testing procedures. With regards to the sample population, several studies have sought to fill this gap in the literature, but oftentimes their sample sizes and/or population demographics prove to be highly specific and therefore limited in applicability. Additionally, normative data is only useful when compared to results produced from the same testing procedures. In order to generate normative data that could be utilized widely, but also maintain high standards of accuracy and reliability, this study analyzed and referenced other research procedures and followed the most efficacious testing guidelines currently available.

The purpose of this study was to collect, analyze, and share WMPT normative data that accurately reflects a broader collegiate population than has previously been published while additionally utilizing the most reliable and valid data collection methods. The subject population of this study to collect WMPT normative data includes both sexes, varying athletic abilities, diversity in age, and is non-ethnically homogenous.

Table 1. Comparison of existing WMPT normative data.

Author	*Resistance Level*	*Subjects (Male/Female)*	*Type of Participant*	*Age range of Participant*
Maud, 1989	7.5	62 / 68	Physically Active	College Age (18-32)
Zupan, 2009	7.5	1,374 / 211	College Athletes	College Age (18-25)
Coppin, 2012	8.5	77 Males	Power Athletes	College Age
Ramírez-Vélez, 2016	7.5	1,177 / 667	Healthy Adults	Adults (20-80)

Methods

Experimental Approach to the Program

The WMPT is a commonly utilized method for collecting and evaluating anaerobic power performance. However, in order for these evaluations to be interpreted and valid, the normative data with which it is compared must reflect a robust and diverse sample population and utilize proper testing methods. With these testing considerations in mind, the normative data collected for this study was obtained from a sample of 309 subjects (121 females; 188 males) while performing a standardized WMPT utilizing a resistance based on a percent of the subject's BM. This study was conducted in the Human Performance Lab at Humboldt State University. The standards of 7.5% of BM for females and 8.5% for males was determined based on the established experimental procedures (Table 1). Participants were recruited and tested from December 2015 until May 2019. Measurements of PP, MP, RP, and FI were all collected. Additionally, three RP categories were utilized. The first RP measurement was simply based on the power to mass ratio (PP / BM). The second RP measurement was based on the classic formula (PP / $BM^{2/3}$) which is less biased against heavier athletes (Haff and Triplett, 2016). The third and final RP measurement was calculated utilizing the subject's mean power (MP / $BM^{2/3}$).

Subjects

A total of 309 active healthy volunteers (188 male; 121 female) between 19 and 35 years of age were recruited for participation in this research. Many subjects participated in club or recreational sports, but not college varsity sports such as football, soccer, track and field, etc. All subjects regularly participated in moderate or strenuous exercise for a minimum of 3 days per week for a period of at least 4 weeks prior to participation. Participants were screened for cardiovascular and musculoskeletal disease using a medical history questionnaire, an activity questionnaire, and the Physical Activity Readiness Questionnaire (PAR-Q). Subjects were asked about and subsequently were excluded from the study if they were found to have two or more cardiovascular risk factors as outlined by the American College of Sports Medicine (2013). Subjects were also asked about their use of ergogenic supplements (e.g. pharmacologic aids and/or dietary supplements) that could affect their exercise performance and were excluded from the study if they regularly used them. This study was approved by the Humboldt State University Institutional Review Board, and subjects were informed of the risks and benefits of the investigation prior to signing an informed consent form to participate in the study.

Procedures

Each subject was instructed to complete a general warm-up session following self-paced running for five minutes on the treadmill and dynamic stretching focused on large muscle groups in the lower limbs. Additionally, subjects performed a familiarized submaximal cycling session with 1kg resistance at 50 rpm, including a pair of five second maximal sprints on the Monark cycling ergometer (Model 894Ea, Monark, Sweden). After completing the warm-up session, subjects rested for five minutes before the actual data collection commenced. The resistance was set at 7.5% of body mass (kg) for female and 8.5% of body mass for male subjects. Before performing the WMPT, bike fit (i.e., handlebar, saddle height) was checked and the appropriate resistance was set up on the equipped basket of the cycle ergometer based on subjects' sex and body mass in kilograms. All subjects were instructed to pedal as fast as they could for 30 seconds and remain seated on the saddle throughout the test. At the beginning of the WMPT, the weighted basket automatically dropped when subjects' cadence reached 110rpm. Then data collection began and ran for 30 seconds. Verbal encouragement was provided by the research team throughout the duration of the test. Data were recorded using the Monark Wingate Software (Monark Anaerobic Test Software Version 3.2.1.0) following four main variables: PP, MP, RP, and FI. After data collection concluded, subjects were instructed to remain seated and pedal at a lower resistance for five minutes as a cooldown phase.

Statistical Analyses

The normal distribution of the data will be verified using a Kolmogorov-Smirnov test. Anthropometric data, absolute peak and mean power (Watts), relative and peak and mean total work (watts/BM, Watt/BM2/3), and fatigue index (% decrement of power) will be reported as mean ± standard deviation (SD). All data will be analyzed separately to provide percentile values for males and females. The descriptive statistics will be calculated in mean, standard deviation, and their ranges. A t-test for independent means will be used to verify the differences between males and females. Significance will be set to $p < 0.01$ for all tests.

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