Validation of the Garmin Forerunner 920XT VO2max Estimation and the Polar RS300X Fitness Test

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Abstract

Several fitness watches have developed tests to estimate VO2max to provide important data and save money by reducing the need for a metabolic cart. Some watches provide results based on heart rate (HR) while others combine HR data with global positioning satellite (GPS) data. The purpose of this study was to validate VO2max from the fitness test on a Garmin Forerunner 920XT (HR and GPS-based) and a Polar RS300X (HR-based) fitness watch against a maximal graded exercise test (GXT) using a metabolic cart.

10 male and 7 female college students (age = 21.5 ± 2.9 years) participated in this study. Session 1 consisted of completing the Informed Consent, PAR-Q, and Garmin fitness test. Session 2 comprised the Polar fitness test and a maximal Bruce treadmill test using the metabolic cart. Maximal performance during the Bruce test was validated by obtaining age-predicted HRmax. Data were analyzed using one-way ANOVA with a significance level of $p < 0.05$. Secondary analysis was conducted using Pearson correlations.

VO2max from the Garmin, Polar, and metabolic cart tests were 47.82 (± 9.60), 45.53 (± 5.42), and 45.63 (± 8.84) ml/kg/min, respectively. ANOVA tests revealed no significant differences between any of the tests ($p = 0.6$ between the Garmin and the metabolic cart; $p = 0.3$ between the Polar and the metabolic cart). Pearson correlations revealed that the Garmin test was highly correlated with $r = 0.83$ ($p < 0.001$) while the Polar test was strongly correlated ($r = 0.65$, $p < 0.001$).

The findings indicate that Garmin and Polar fitness tests may serve as an adequate substitute for testing using a metabolic cart. The Garmin test may be a more appropriate choice as the correlation was stronger and the Polar test tended to overestimate VO2max.

Keywords: aerobic capacity; fitness watch; metabolic cart;

1. Introduction

Maximal aerobic capacity is "the maximum rate at which oxygen can be taken up and used by the body during exercise" (Brooks, Fahey, & Baldwin, 2005). A low aerobic capacity is a strong predictor for health issues such as cardiovascular disease, pulmonary function, respiratory function, and overall mortality (De Alkmim Moreira Nunes et al., 2017; Keteyain et al., 2008; Mandsager et al., 2018; Myers et al., 2002; Romero-Fallas, Soto-Arias, Moncada-Jimenez, 2012). In addition, elite endurance athletes generally have a high aerobic capacity (Brooks et al., 2005). Coaches often build training plans based on knowing an athlete's maximal aerobic capacity.

Aerobic capacity testing indicates the person's ability to supply oxygen to working muscles for a certain length of time. (Hill, Long, & Lupton, 1924). Historically, researchers measured aerobic capacity through direct calorimetry; however, the methods shifted toward an open-circuit version of indirect calorimetry as technology and the understanding of physiology improved (McArdle, Katch, & Katch, 2015). This type of testing often requires the use of a treadmill and a metabolic cart (Cooper et al., 2005). Unfortunately, such devices are expensive with price tags ranging from $20k to $40k for portable devices (P. Yeh, personal communication, April, 8, 2016; J. Tetuan, personal communication, February 22, 2017).

Recent advancements in the technology of aerobic capacity testing could make it more readily available to the general public (Cooper et al., 2005; Nelson, Kaminsky, Dickin, & Montoye, 2016; Roos, Taube, Beeler, & Wyss, 2017). Wearable devices have been developed to combat the high cost of the metabolic cart and increase the accessibility of aerobic capacity assessment. Such devices only cost a few hundred dollars and are available through commercial retailers. They generally rely on heart rate data and may incorporate the use of global positioning satellites (GPS). These include several models of Polar heart rate monitors and Garmin fitness trackers. Other fitness watches are available on the market; however, these 2 manufacturers specifically claim to estimate maximal aerobic capacity. Polar devices use a 5 to 10 minute resting heart rate test to approximate aerobic capacity while Garmin devices rely on a 10-minute run test while wearing a heart rate strap and maintaining a GPS signal. An additional benefit to these assessments is that neither requires maximal effort. Such testing could make a person more aware of their level of physical conditioning and help them or their coaches build an aerobic training program based on the results of the test (Bassett & Howley, 2000; Ibrahim & Nuhu, 2015).

Unfortunately, almost no studies to date validate the accuracy of these tests. Polar and Garmin may have conducted extensive testing themselves; however, this is not readily available to the public. Few research articles are available to compare the findings from either test to a test conducted using a metabolic cart. In fact, only one study has been published validating the Polar fitness test. A moderate correlation was found, leading the authors to encourage caution when using the results of the Polar fitness test (Esco, Mugu, Williford, McHugh, & Bloomquist, 2011). The only other validation study discovered was for the SenseWear armband, which is no longer commercially available and which failed to evaluate aerobic capacity (Drenowatz & Eisenmann, 2011). No studies validating the Garmin test were discovered. In fact, only a couple of self-reported case studies were located on various fitness forums (ISEEKA, 2013 & salesguy, 2016). None of these forum reports provides enough detail to validate the Garmin fitness test.

The purpose of this study was to validate the Garmin fitness tests against a metabolic cart. The cost of a metabolic cart makes it inaccessible for many coaches and athletes. The Garmin and Polar devices can be purchased for a few hundred dollars each. If these tests prove to be valid, they would provide valuable information to coaches and athletes for a significant cost savings.

2. Methods

2.1 Experimental Approach to the Problem

The study employed a repeated measures design where all participants completed all test conditions. This included the fitness tests from the Garmin Forerunner 920XT and the Polar RS300X fitness watches as well as the Bruce treadmill protocol while connected to a Parvomedics TrueOne 2100 metabolic cart.

2.2 Subjects

The Institutional Review Board approved this study. All participants gave consent prior to beginning the study. At this time, they were notified about the risks and benefits associated with the study, provided an opportunity to ask questions, and informed that they could drop out at any time. Eighteen participants were recruited from the Health and Physical Education majors at the university, but only 17 (age: 21.5 ± 2.9 years, height: 160.0 ± 7.0 cm, weight: 60.5 ± 26.5 kg) completed the study. Of these 17, 10 were males and 7 were females. Participants had to be apparently healthy as determined by use of the Physical Activity Readiness questionnaire (PAR-Q) to be included in the study.

2.3 Procedures

The study was conducted in two sessions. Session 1 began with completing the informed consent and a PAR-Q. If participants had answered yes to any items on the PAR-Q, they would have been asked to receive medical clearance for physical activity before continuing. All participants answered no to all items, so medical clearance was not necessary.

After successful completion of the PAR-Q, participants underwent the VO2max test with the Garmin Forerunner 920XT watch. The test consisted of placing a heart rate strap around the participant's chest and pairing it to the Garmin watch. The participant's profile (gender, birth year, body weight, and height) was loaded into the Garmin device. At this point, the participant went outside to acquire a GPS signal with the watch. The watch was placed in the run activity mode and the start/stop button was pressed. The participant ran at a comfortable pace on a preset 0.55-mile course for 10 minutes. After 10 minutes, the participant ceased running and pressed the start/stop button again. The Garmin device displayed the participant's VO2max, which was recorded. The participant returned to the lab for monitoring during recovery, where they remained until heart rate dropped below 120 bpm.

Session 2 was conducted 48-72 hours later to ensure adequate recovery. This session began by completing the Polar fitness test with the Polar RS300X watch. For the test, researchers entered the participant's profile into the Polar device, placed a heart rate strap around the participant's chest, and paired the heart rate strap with the watch. The profile included the following: birthday, height, weight, sex, activity level, maximum heart rate (optional) and resting heart rate (optional). The participant then reclined comfortably, the researcher placed the watch in test mode, and the test began. The watch notified the subject when the test was complete, generally after 5-10 minutes. VO2max was displayed on the watch and recorded at this time.

Session 2 continued with the metabolic cart testing. The heart rate strap remained on the participant in order to monitor heart rate during the maximal GXT. Resting blood pressure was evaluated to provide a baseline for testing and recovery. The researcher then entered the participant's profile (age, height, weight, and sex) into the software for the Parvomedics TrueOne 2100 metabolic cart. After being fitted with the facemask for the device, the participant stepped onto the treadmill to begin a Bruce protocol maximal GXT. Heart rate was monitored continually throughout the test while blood pressure was measured in the third minute of every stage. The participant was determined to have reached VO2max if they obtained a heart rate that was within +/- 10 bpm of their age-predicted maximum heart rate (Neiman, 2011). Participants ran on the treadmill until volitional fatigue, and all reached maximal exertion based on heart rate. The test was terminated at this point, and VO2max was recorded. Participants remained on the treadmill and cooled down until heart rate dropped to 120 bpm or less. They remained in the lab until blood pressure returned to near pre-testing levels.

2.4 Statistical Analyses

A one-way ANOVA was used to evaluate differences in VO2max from the Garmin, Polar, and metabolic cart tests. A bivariate correlation was then completed to determine the relationships between the 3 assessments. IBM SPSS Statistics 23 was used for all analyses. A significance level of $\alpha = 0.05$ was selected. Effect sizes were calculated with the formula of

$ES = (M1 – M2) / s$

Statistical power was calculated using G*Power version 3.1.9.2. Based on a sample size of 17, power was determined to be 0.99, indicating that the risk of committing a Type II error is 1%.

3. Results

VO2max from the Garmin, Polar, and the metabolic cart tests were 45.53 (± 5.42), 47.82 (± 9.60), and 45.63 (± 8.84) ml/kg/min, respectively. The one-way ANOVA analysis revealed no significance for the Garmin ($p = 0.6$) or Polar ($p = 0.3$) tests when compared to the metabolic cart data.

The Garmin test was highly correlated to the metabolic cart with a Pearson correlation coefficient of 0.832 ($p < 0.001$). In contrast, the Polar test had a moderately strong correlation to the metabolic cart ($r = 0.554$, $p < 0.001$). The Garmin and Polar tests were significantly correlated to each other ($r = 0.548$, $p = 0.02$); however, this is not very meaningful as each is an estimate of the metabolic cart data.

Effect size for the Garmin to metabolic cart comparison was 0.01, while effect size for the Polar to metabolic cart comparison was 0.2. These weak effect sizes are further verification that there are no meaningful differences between the data obtained from the fitness watches, particularly the Garmin device, when compared to the metabolic cart.

4. Discussion

The findings from this study indicate that the Garmin and Polar fitness tests may serve as adequate substitutes for aerobic capacity testing using a metabolic cart. The scale for correlations provided by Miller indicates that a high correlation in the field of exercise science is between 0.3 and 0.7 (2012). Cronk (2018) states that a correlation above 0.7 is considered to be strong. The Pearson correlation coefficient for the Garmin test was 0.832, classifying it as a strong or very strong correlation. The Garmin test is a meaningful alternative as the variance accounted for between it and the metabolic cart test is 69% (r2 = 0.692). Thus, this test serves as an appropriate alternative to testing with a metabolic cart.

While the Polar test was highly correlated to the metabolic cart (r = 0.554) according to Miller's scale (National Strength and Conditioning Association, 2012), others would consider this to be a moderate correlation (Cronk, 2018). This only accounts for 31% of the variance between the Polar test and the metabolic cart test (r2 = 0.307), which is less meaningful than the finding from the Garmin test. A validation study by Esco et al. (2011) found a similar correlation for the Polar test (r = 0.54) to the current study. Esco and colleagues encouraged caution when utilizing the Polar fitness test citing the "moderate validation correlation" as a primary reason (Esco et al, 2011) . The correlation discovered in the current study is minimally stronger than that of Esco et al. In addition, the Polar test tended to overestimate VO2max, which should be taken into consideration when using the device. The moderate correlation, along with the tendency of the Polar test to overestimate VO2max, indicates that caution should be applied to use of the Polar fitness test in predicting maximal aerobic capacity.

5. Conclusion

Metabolic carts can be quite expensive and many practitioners do not have access to them. Those who desire to assess athlete's aerobic capacity have had limited opportunities to measure or assess VO2max for this reason. The Garmin and Polar fitness tests provide a much cheaper alternative while providing moderate to highly correlated results. Given a choice between the 2 devices, the Garmin device seems to be a superior choice. The correlation was much stronger and the actual value obtained for VO2mas was nearly identical to the value obtained from the metabolic cart. The downside to the Garmin device is that it requires access to GPS signals. Weather conditions may make testing difficult as GPS signals are generally acquired outdoors.

While caution should be used when relying on the Polar fitness test, it may still have some value in approximating VO2max as the device is inexpensive and, thus, more accessible. Practitioners should be aware of the weaker correlation and the tendency to overestimate VO2max. The Polar test only requires 5 to 10 minutes to complete, which could make it useful for larger teams where precision in VO2max is not critical.

In conclusion, both the Garmin and Polar fitness tests correlate to the metabolic cart test highly enough to serve as a substitute for evaluation of aerobic capacity in non-research environments; however, the Garmin test is a much better choice than the Polar test. For those coaches, personal trainers, physical educators, and other practitioners who do not need research quality data, the Garmin and Polar fitness tests may serve as alternatives for aerobic capacity testing. The data provided by these two tests, particularly the Garmin test, is accurate enough for use in developing training programs.

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7. References

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