Validation of the Garmin Forerunner 920XT Fitness Watch VO_{2peak} Test

Gina Leigh Kraft
Assistant Professor, the Program Director for Strength and Conditioning Studies
Arkansas Tech University, USA

Rachel A. Roberts
Graduate assistant, the Strength and Conditioning Studies program
Arkansas Tech University, USA

Abstract

Aerobic capacity (VO_{2peak}) testing equipment can be expensive. Garmin fitness watches are significantly cheaper, and Garmin has developed a fitness test that estimates VO_{2peak}. The purpose of this study was to validate the Garmin fitness test, using a Garmin Forerunner 920XT fitness watch, against VO_{2peak} measurement, using a Parvomedics TrueOne 2400 open circuit spirometry device. Sixteen college students (10 male and 6 female) volunteered to complete the Garmin fitness test followed several days later by a Bruce treadmill test while oxygen consumption was measured via open circuit spirometry. The average VO_{2peak} from the Garmin test was 45.4 (± 5.6) ml/kg/min, compared to 45.0 (± 8.9) ml/kg/min from open circuit spirometry. There were no significant differences between the measurements ($t = 0.221$ with $p = 0.828$). The two measurements were highly correlated with a correlation coefficient of 0.84 ($p = 0.000$). The Garmin fitness test seems to be a highly accurate estimation of VO_{2peak}.

Keywords: maximal aerobic capacity, indirect spirometry, Bruce treadmill protocol, heart rate sensor

Introduction

Aerobic capacity is defined as "the maximum rate at which an athlete can produce energy through oxidation of energy sources" (Haff & Triplett, 2016, p. 261). Aerobic capacity has also been called maximal oxygen consumption, maximal oxygen uptake, maximal aerobic power, and $\dot{V}O_{2max}$ (McArdle, Katch, & Katch, 2016, p.165-166). In the late 1800s, Wilber Olin Atwater and Edward Bennett Rosa created the first calorimeter designed for a human (McArdle, Katch, & Katch, 2016, p. 178). These early pioneering experiments measured the body's heat production as a means of determining energy expenditure. These early studies led to the discovery of a direct relationship between energy expenditure and oxygen consumption, paving the way for indirect calorimetry to be used as a means of estimating energy expenditure (McArdle, Katch, & Katch, 2016, p. 179; Powers & Howley, 2015, p. 21).

The development of indirect calorimetry to evaluate aerobic capacity led to the decline of direct calorimetry. Brooks, Fahey, and Baldwin cite 4 reasons for this decline: "First, such devices are very expensive. Second, the heat generated by an ergometer…may far exceed that of the subject. Third, body temperature increases during exercise because not all the heat produced is liberated from the

body…Finally, the body sweats during exercise, which also affects the calorimeter and changes body mass" (Brooks, Fahey, & Baldwin, 2005, p. 51). Thus, direct calorimetry was not a great tool for evaluating exercise energy expenditure. Indirect calorimetry increased in use over direct calorimetry as these issues did not apply to the new technique.

According to Powers and Howley, open-circuit spirometry is now the most popular method used for indirect calorimetry (2015, p.21). Open-circuit spirometry allows the subject to breathe ambient air. The exhaled air is collected and compared to ambient air for its oxygen and carbon dioxide content. Inhaled and exhaled air are measured to evaluate the amount of air consumed. By knowing the volume of air consumed and the difference in content of exhaled air versus ambient air, energy expenditure can be determined (McArdle, Katch, & Katch, 2016, p. 180).

Open-circuit spirometry devices may be significantly cheaper than direct calorimeters; however, they are still quite expensive (e-mail from info@parvomedics.com dated April 18, 2016). This cost is prohibitive for many educational and fitness facilities. For this reason, other, cheaper means of estimating aerobic capacity have been sought out. Some of these include the use of pedometers, acceleromters, heart rate monitors, and even personal fitness devices (such as FitBit, Jawbone Up, Nike FuelBand, VivoFit) (Porcari, Bryant, & Comana, 2015, p. 104).

One of the new types of devices is designed by Garmin. The Garmin devices use a combination of heart rate monitoring and GPS data. While Garmin has several models that will estimate aerobic capacity, the Forerunner 920XT fitness watch is designed for runners, cyclists, and tri-athletes. It currently costs $450 and up, according to Garmin's website (www.garmin.com). The cost of a fitness watch is significantly more affordable than an open-circuit spirometry system which would make such a device much more accessible for schools, universities, and training programs desiring to evaluate aerobic capacity. This is especially true as the Garmin Forerunner 230 starts at $250.

Very little research can be found that evaluates the accuracy of the Garmin fitness watch. Garmin does not make this information readily available on the company website. Several online forums discuss the accuracy; however, none of them provide any real answers. Some individuals posting indicate high levels of accuracy (salesguy) while others are extremely skeptical (ISEEKA; KSB123 Racehourse). Few of these users have completed a laboratory test to evaluate their maximal aerobic capacity. Recently, an article was published where a single individual performed a comparison between a Garmin fitness watch and open-circuit spirometry (Stables, 2016). While the VO_{2peak} data from the two assessments were similar, the data is from only one subject and cannot, on its own, validate the accuracy of the Garmin fitness watch.

The purpose of this study was to evaluate the accuracy of the Garmin Forerunner 920XT fitness watch by comparing the data obtained from the watch to data from a maximal treadmill test completed while using

open-circuit spirometry. Determining the strength of the correlation between the two measurements could allow those needing to know aerobic capacity to invest in a watch rather than in an expensive open-circuit spirometry device. Accurate estimation of aerobic capacity by the Garmin fitness watches could save institutions and fitness facilities thousands of dollars.

2. Methods

This study was approved by the Arkansas Tech University Institutional Review Board.

2.1 Subjects

Subjects were recruited from the Health and Physical Education Department at Arkansas Tech University. There were 16 total subjects (10 male and 6 female). The average age of all subjects was 22.4 (± 5.0) years. All subjects completed an informed consent and a PAR-Q form prior to participation in the study. Subjects had to be fit enough for physical activity in order to participate in the study; therefore, any subjects who answered "yes" to any PAR-Q items were excluded from the study.

2.2 Procedures

The study was conducted in 2 sessions which were held between 2 and 5 days apart. This delay was to allow adequate recovery between testing sessions. During session 1, VO_{2peak} data from the Garmin Forerunner 920XT fitness watch was obtained while Session 2 consisted of performing the maximal aerobic capacity test with the open-circuit spirometry system. For this study, the Parvomedics TrueOne 2400 Metabolic measurement system was used.

Session 1 began by measuring subjects' height and weight. This data was entered in to the Garmin watch interface. A heart rate strap was connected to the subject and paired with the watch. Subjects were then taken outside for the watch to acquire satellites in order to ensure GPS accuracy. Once satellites were obtained, the watch was placed on the subject's wrist. The watch was placed in running mode, and subjects were instructed to press Enter on the watch to begin recording data. They jogged or ran for 10 minutes around the campus football field. At the completion of the 10 minute run, they pressed enter again to save the data and returned to the lab. The session ended after data was recorded, the watch and heart rate strap were removed, and the subject had recovered adequately to leave the supervision of the lab.

The second session was scheduled 2 to 5 days after session 1. Session 2 began by measuring height and weight and entering the data into the TrueOne Exercise software for the Parvomedics TrueOne 2400 Metabolic Measurement system, the indirect spirometry system.

Subjects were fitted with the HR strap to allow constant monitoring of exercise heart rate. Resting blood pressure measurement was also taken. After connecting the facemask for the indirect spirometry system to the subject, they began the maximal aerobic exercise test on the treadmill following the Bruce

Treadmill Protocol (see Table 1). Blood pressure measurements were taken at the end of each stage and during recovery to monitor health and safety of subjects.

Table 1 Bruce Treadmill Protocol

Stage	Speed (mph)	Grade (%)	Duration (min)
1	1.7	10	3
2	2.5	12	3
3	3.4	14	3
4	4.2	16	3
5	5	18	3
6	5.5	20	3
7	6	22	3

According to the ACSM, the criteria for obtaining maximal aerobic capacity is a leveling off of the subject's oxygen consumption (ACSM's Guidelines for Exercise Testing, 2014, p. 73). While this was the desired test termination point, not all subjects reached such a leveling off of oxygen consumption; therefore, the test was terminated when the subject reached one of the alternate criteria for maximal oxygen consumption. These include obtaining the age predicted heart rate max (HR_{max} = 220 – age) or having a respiratory exchange ratio greater than 1.15 (McArdle, Katch, Katch, 2015, p. 237). The age predicted HR_{max} equation has been found to have a standard deviation of ±10 beats per minute (McKardle, Katch, Katch, 2015, p. 244). Therefore, HR_{max} was determined to be obtained once heart rate was within ±10 beats per minute of age predicted heart rate max or subject requested to stop. Additionally, researchers followed the indications for test termination as set forth by the American College of Sports Medicine.

The absolute indications are as follows:

- Drop in systolic BP of ≥10 mm Hg with an increase in work rate, or if systolic BP decreases below the value obtained in the same position prior to testing when accompanied by other evidence of ischemia
- Moderately severe angina (defined as 3 on standard scale)
- Increasing nervous system symptoms (*e.g.*, ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties monitoring the ECG or SBP
- Subject's desire to stop (other than V_1 or aVR) (taken directly from ACMS's Guidelines for Exercise Testing, 2014, p. 131).

The relative indications are as follows:

- Drop in systolic BP of ≥10 mm Hg with an increase in work rate, or if systolic BP below the same value obtained in the same position prior to testing
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Increasing chest pain

- Hypertensive response (SBP of >250 mm Hg and/or a DBP of >115 mm Hg (taken directly from ACMS's Guidelines for Exercise Testing, 2014, p. 131).

ECG was not monitored during the test, so guidelines relating to ECG were omitted from this list.

Once the test was completed, subjects cooled down by walking at a slow, comfortable speed on the treadmill for three minutes followed by three minutes of sitting. Heart rate and blood pressure continued to be monitored during the cool down. Subjects were not permitted to leave the laboratory until their heart rate dropped below 120 bpm and their blood pressure returned to near normal.

2.2 Statistical Analysis

All statistical analyses were performed with IBM SPSS Statistics 22. A paired samples T-test was used to evaluate the similarity of the VO_{2peak} obtained from the Garmin Forerunner 920XT fitness watch and the VO_{2peak} from open-circuit spirometry. The p-value for statistical significance was set at $p = 0.05$ for a 2-tailed test. Descriptive statistics were evaluated to determine that the data met the assumptions for a paired samples T-test.

3. Results

The data is presented in Table 1. Using the Garmin fitness watch, VO_{2peak} averaged 45.4 (± 5.6) ml/kg/min. The aerobic capacity results from open-circuit spirometry averaged 45.0 (± 8.9) ml/kg/min.

Table 2 Aerobic Capacity Data

Subject	Garmin (ml/kg/min)	Open-Circuit Spirometry (ml/kg/min)
1	52.0	52.6
2	38.0	42.5
3	42.0	34.9
4	48.0	53.5
5	41.0	33.0
6	46.0	42.6
7	48.0	51.8
8	52.0	54.1
9	49.0	59.3
10	39.0	39.4
11	56.0	58.3
12	42.0	36.4
13	50.0	47.3
14	39.0	37.3
15	46.0	39.4
16	39.0	38.0
Mean	45.4	45.15

No significant differences were determined between the two means ($t = 0.221$ with $p = 0.828$). The data from the Garmin fitness watch was not significantly different from the data obtained via open-circuit spirometry. In addition, the paired samples T-test revealed a Pearson correlation coefficient of $r = 0.840$ ($p < 0.000$) between the two sets of data. This was adequate to meet the requirements for statistical significance, which was set at $p = 0.05$. The data sets were not significantly different from each other; however, they were significantly correlated.

4. Discussion

No significant differences were discovered between the Garmin Forerunner 920XT aerobic capacity test and the data obtained from open-circuit spirometry. This can be interpreted to mean that the Garmin fitness watch is an appropriate means of evaluating aerobic capacity. In addition, the two data sets were 84% correlated. According to the National Strength and Conditioning Association, a high correlation in the field of exercise and fitness would be between 0.3 and 0.7 (Miller, 2012, p. 8). The correlation coefficient between the Garmin fitness watch and open-circuit spirometry measurement of aerobic capacity was found to be 0.84. This is well above what is considered a strong correlation in the field of exercise and fitness.

This would seem to indicate that a Garmin fitness watch (particularly the Garmin Forerunner 920XT) is a cheaper means of assessing aerobic capacity for individuals or organizations who cannot afford an open-circuit spirometry system. This could be particularly beneficial for smaller academic institutions that do not have a research quality exercise physiology laboratory. Coaches and personal trainers may also find this information very helpful. Smart aerobic training programs are built on aerobic capacity (Haff & Triplett, 2016, p. 563). Being able to assess aerobic capacity more cheaply, ought to be a huge asset to individuals, coaches, and to educational programs.

5. Conclusion

The Garmin Forerunner 920XT fitness watch assessment of aerobic capacity is highly correlated to aerobic capacity measurements obtained via open-circuit spirometry. This may provide a significantly less expensive means of assessing aerobic capacity. Many people could potentially benefit from using a Garmin fitness watch; however, this may be of particular interest to small academic programs, sport coaches, personal trainers, and athletes.

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