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Original Research Article

VO_2 Master Analyzer versus Parvo Medics TrueOne 2400 Canopy System for assessing Resting Metabolic Rate and Oxygen Consumption

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Abstract

Introduction: Resting Metabolic Rate (RMR) is the energy expended by the body at rest. The Parvo Medics TrueOne 2400 Canopy System is considered a "gold standard" system for measuring RMR, but it is limited by its high cost, lack of portability, and need for expertise. In contrast, the VO_2 Master analyzer is a portable metabolic system offering a more cost-effective RMR measurement solution. However, the accuracy of the VO_2 Master Analyzer for RMR compared to a gold standard is unknown. The purpose of this study was to compare the accuracy of the VO_2 Master in a group of college students. **Methods:** Seventy-eight 18 to 23-year-old college students (mean ± SD: height = 173.2 ± 11.18 cm and weight = 74.8 ± 15.48 kg) attending a Midwest University performed an RMR test using both the VO_2 Master and the Parvo Medics TrueOne 2400 Canopy System in a crossover study. A paired sample t-test was used to determine statistical differences between RMR and VO_2 between the two systems. A Bland-Altman Analysis was performed for RMR to visualize bias and limits of agreement. **Results:** A significant difference ($p < 0.05$) for RMR (Parvo Medics = 1978.0 ± 454.9 vs. VO_2 Master = 1875.3 ± 494.1 kcal/day) and VO_2 (Parvo Medics = 3.90 ± 0.60 vs. VO_2 Master = 3.56 ± 0.69 ml/kg/min) was found between the two systems. Bland-Altman analyses for RMR and VO_2 revealed a constant bias of 102.7 kcal/day and 0.34 ml/kg/min, respectively. **Conclusions:** This study found that the VO_2 Master underestimates RMR by almost 103 kcal/day and VO_2 by 0.34 ml/kg/min. Thus, the VO_2 Master may not be a suitable RMR or VO_2 measure for college students. Further studies in other populations are recommended.

Key Words: Caloric, Energy Expenditure, Metabolism, RMR

Introduction

Resting metabolic rate (RMR) has been a focus of studies on human physiology, especially concerning health, nutrition, and exercise science[1]. RMR is the energy expended by the body at rest[2] and represents about 60-70% of total expenditure[3]. Measuring or estimating

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one's RMR is important when determining caloric needs. Measurement of RMR is often used in research and clinical settings to create weight maintenance and exercise plans[3]. RMR in sedentary adults can range from 1,200 to 3,000 kilocalories per day (kcal/day)[4]. Many factors can affect one's RMR such as weight, height, amount of muscle mass, and age (i.e., due mainly to muscle mass loss)[5]. For instance, heavier individuals often have higher RMRs compared to lighter individuals and younger individuals tend to have higher RMRs than older individuals. However, up to 80% of RMR variability can be explained by the amount of lean versus fat tissue an individual has[4].

A person's RMR is often estimated using one of several prediction equations such as the Harris-Bendict[6] or the Mifflin St. Jeor[7] equations. Both equations estimate one's RMR from weight, height, age, and gender. Although these equations are easy to use and require simple measures, they are often inaccurate[5,8,9]. While individuals can use equations to estimate their RMR, laboratory equipment provides more accurate measurements. Indirect calorimetry, considered to be a gold standard for measuring RMR, is offered by some facilities and will provide a metabolic rate that is more reliable than using a calculation[10,11]. Indirect calorimetry often includes measures of oxygen consumption and carbon dioxide production[10]. The Parvo Medics TrueOne 2400 system (Parvo Medics, Salt Lake City, UT) is used for indirect calorimetry and considered a "gold standard" for measuring RMR[12]. However, this equipment is primarily utilized in clinical settings due to its high cost, lack of portability, and required expertise.

Newer brands of RMR systems that are cheaper and more portable have emerged. One such system is the portable VO_2 Master analyzer. The average cost is around $6,000 USD, making it a more appealing option than other well-known, more expensive brands from companies like COSMED or Oxycon, which sell their portable analyzers for more than $30,000 USD. However, limited independent validation studies on the VO_2 Master analyzer exists. One study assessed the validity and reliability of the VO_2 Master analyzer during exercise and concluded that the equipment may be a suitable and cheaper option for measuring VO_2[13]. However, the accuracy of the VO_2 Master in measuring RMR is unknown. Therefore, the purpose of this study was to determine the RMR and VO_2 accuracy of the VO_2 Master analyzer compared to the Parvo Medics TrueOne 2400 Canopy System. The Parvo Medics TrueOne 2400 Canopy System is highly accurate; however, its disadvantages include its price, size, and lack of portability. Thus, a cheaper, more accessible, simple-to-use, portable, and accurate device is desirable. We hypothesized that the VO_2 Master analyzer will yield RMR and VO_2 values similar to the Parvo Medics TrueOne 2400 Canopy System.

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Methods

Participants

Seventy-eight college students from a Midwest University volunteered to participate in this study. All participants were between the ages of 18 and 23 years old. Before reporting to the lab, participants were asked to refrain from vigorous physical activity and high-intensity weight training for at least 12 hours before testing. In addition, participants were instructed not to eat, drink (except water), consume caffeine, or engage in any exercise at least 4 hours before testing. Before testing, each participant was provided an informed consent explaining the study's purpose, method, benefits, and risks. After being given the opportunity to ask questions, each participant agreed to participate by signing the consent form. The University Institutional Review Board (IRB) approved the study before any testing occurred.

Experimental design

Testing was conducted on a small Midwestern university campus in the Human Performance Lab. The lab is climate controlled with ambient temperatures ranging from 69-71 degrees Fahrenheit and humidity ranging from 45% to 55%. Only four people were in the lab simultaneously, including two researchers and two participants. Upon arrival, participants were asked if they had adhered to the pre-testing guidelines. Those who did not comply were rescheduled for testing. Participants who met the criteria proceeded to complete the informed consent. After signing the informed consent, the participant's body weight was measured using the laboratory's scale (Detecto). They then received instructions for each RMR test. For instance, they were instructed to relax, breathe normally, not talk, and not fall asleep during the Parvo Medics TrueOne 2400 Canopy System and VO_2 Master analyzer testing.

During the testing process, two participants were tested at the same time. One participant performed the Parvo Medics TrueOne 2400 Canopy System RMR test, while the other underwent the VO_2 Master Analyzer RMR test. Thus, the order of testing equipment was alternated, with half of the participants starting with the Parvo Medics TrueOne 2400 Canopy System and the other half starting with the VO_2 Master Analyzer. Each participant completed both tests consecutively, with each instrument's testing session lasting 20 minutes. Participants were asked to lie supine on an athletic table during testing with the Parvo Medics TrueOne 2400 Canopy System and to sit relaxed in a chair for the VO_2 Master Analyzer testing. The first five minutes of data from each instrument were discarded to account for the participant settling into a relaxed state and to allow for the calibration of the gas dilution pump on the Canopy System, resulting in 15 minutes of data collection for each test.

Measurements/Instruments

Each participant's RMR and VO_2 were measured using the Parvo Medics TrueOne 2400 Canopy System (Parvo Medics, Salt

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Lake City, UT) and estimated using the VO_2 Master Analyzer. The Parvo Medics TrueOne 2400 Canopy System uses a ventilated canopy and a mixing chamber to determine VO_2 and VCO_2, which is used to calculate RMR using Weir's equation. Weir's equation[14] is expressed as follows:

Metabolic rate (kcal per day) = 1440 (3.9 VO_2 + 1.1 VCO_2)

where VO_2 is oxygen consumption in liters per minute and VCO_2 is carbon dioxide production in liters per min. The Canopy System was calibrated before testing the first participant of the day. The flowmeter and gas calibrations were performed according to Parvo Medics directions. The portable VO_2 Master Analyzer uses a pumpless system for gas sampling, a galvanic fuel cell O_2 sensor, and a differential pressure flow sensor. The device measures breath-by-breath ventilation and VO_2, although it does not measure VCO_2 due to the absence of a CO_2 sensor. RMR is calculated using the Weir equation, assuming an RQ of 0.85, where VCO_2 = 0.85 * VO_2. The device was calibrated before testing the first participant of the day. The flow and gas calibration were performed as stated in the VO_2 Master manual. Additionally, the mask and strap on the device were fitted to each participant.

Statistical analyses

Data analysis was performed in Excel. Descriptive statistics included mean, standard deviation, minimum, and maximum values. A paired sample t-test was used to determine statistical differences for RMR and VO_2 between the Parvo Medics and VO_2 Master. Statistical significance was set at $p \leq 0.05$. Bland-Altman plot with 95% limits of agreement was used to visualize the mean differences in RMR between the Parvo Medics and VO_2 Master. A Pearson correlation coefficient was calculated for VO_2 and RMR to measure the linear association between the devices.

Results

Table 1 displays the characteristics of the participants (N=78). There were 47 females and 31 males.

Table 1. Participant Characteristics.

	Mean ± SD	Min - Max
Age (yr)	20.1 ± 1.44	18 - 23
Height (cm)	173.2 ± 11.18	149.9 – 198.1
Weight (kg)	74.8 ± 15.48	44.9 – 119.6
BMI	24.8 ± 4.39	18.2 – 40.0

Note: BMI = Body Mass Index.

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Descriptive data for RMR and VO_2 are shown in Table 2. The paired t-test revealed a significant difference between the Parvo Medics and VO_2 Master for RMR and VO_2. The Bland-Altman plot for RMR (Figure 1) revealed a constant bias of 102.7 kcal/day, and 73 out of 78 participants (93.6%) fell within the 95% limits of agreement (mean difference ± 2 SD). The Bland-Altman plot for VO_2 (Figure 2) revealed a constant bias of 0.34 ml/kg/min, and 72 out of 78 participants (92.3%) fell within the 95% limits of agreement (mean difference ± 2 SD). There was a significant correlation between the devices for VO_2 ($r = 0.51$, $p < 0.001$) and RMR ($r = 0.79$, $p < 0.001$).

Table 2. Descriptive and p-values for RMR and VO_2 for each system.

	Parvo Medics	VO_2 Master	P-Value
RMR (kcal/day)	1978.0 ± 454.9 (923-3180)	1875.3 ± 494.1 (999-3312)	0.00487
VO_2 (ml/kg/min)	3.9 ± 0.60 (2-5.5)	3.6 ± 0.69 (2.3-5.1)	0.00001

Note: Date represents Mean ± SD (minimum–maximum).

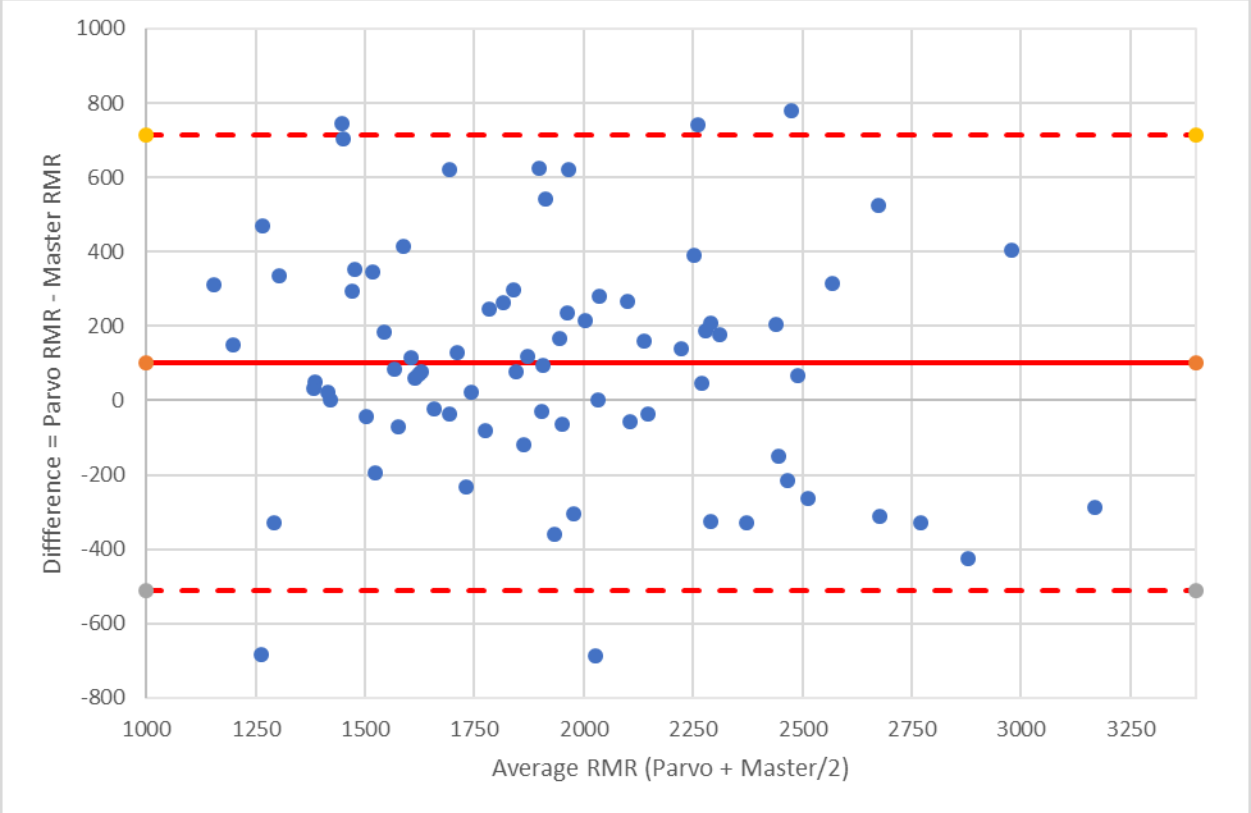

Figure 1. Bland-Altman Plot of individual RMR differences between Parvo Medics and VO_2 Master. The solid line represents the constant bias (102.7 kcal/day). The dashed lines are the 95% confidence interval (-510.3 to +715.6 kcal/day). RMR= Resting Metabolic Rate (kcal/day). Parvo = Parvo Medics TrueOne 2400 Canopy system. Master = VO_2 Master analyzer.

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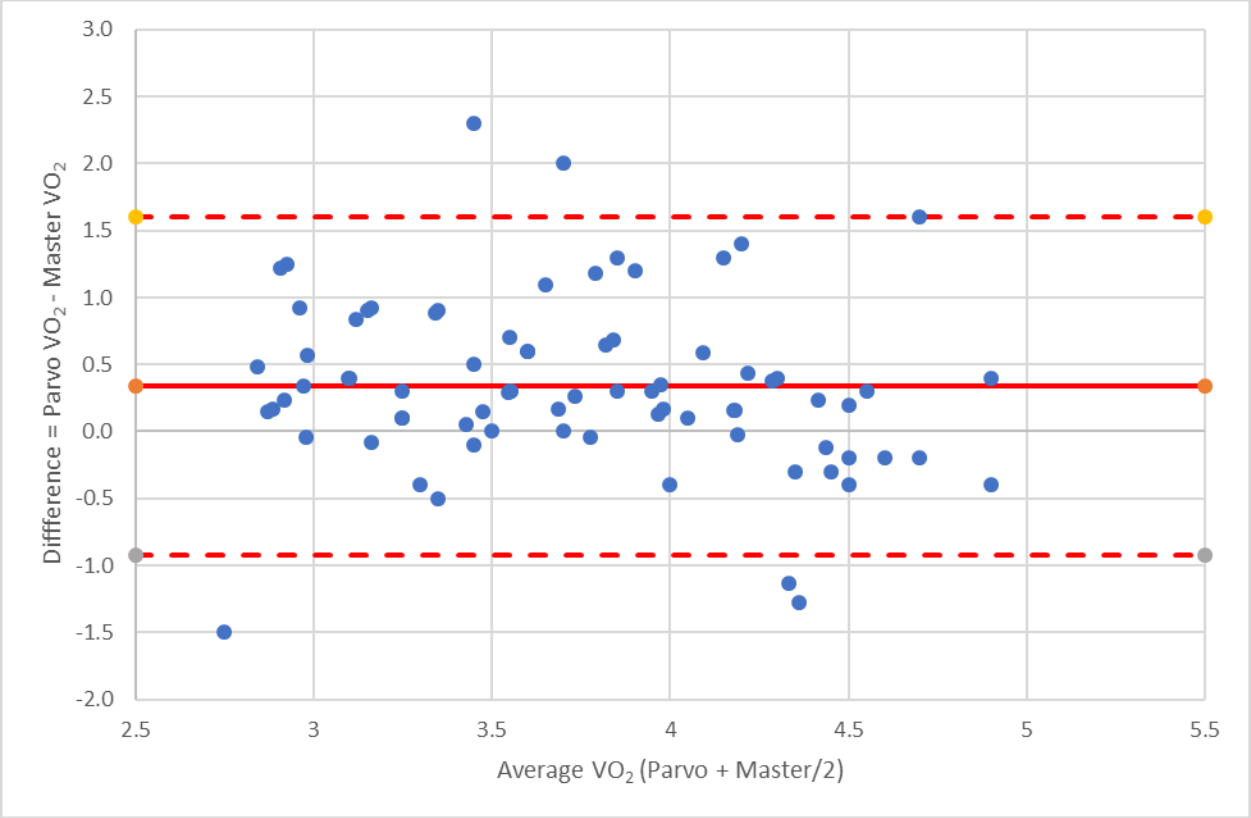

Figure 2. Bland-Altman Plot of individual VO_2 (ml/kg/min) differences between Parvo Medics and VO_2 Master. The solid line represents the constant bias (0.34 ml/kg/min). The dashed lines are the 95% confidence interval (-0.92 to +1.60 ml/kg/min). VO_2 = milliliters of O_2 per kilogram of body weight per day (ml/kg/day). Parvo = Parvo Medics TrueOne 2400 Canopy system. Master = VO_2 Master analyzer.

Discussion

This is the first study known to compare RMR and VO_2 between the portable VO_2 Master analyzer and the Parvo Medics TrueOne 2400 Canopy System. The purpose of this study was to determine the RMR and VO_2 accuracy of the VO_2 Master Analyzer by comparing it to a "gold standard" metabolic instrument, the Parvo Medics TrueOne 2400 Canopy System. It was hypothesized that the VO_2 Master Analyzer would yield similar RMR and VO_2 results as the Parvo Medics TrueOne 2400 Canopy System. Our results did not support this hypothesis, as there was a significant difference in RMR and VO_2 values between the Parvo Medics and the VO_2 Master analyzer. The VO_2 Master underestimated RMR and VO_2 by 103 kcal/day and 0.34 ml/kg/min, respectively. However, there was a moderate correlation between the devices for VO_2 (r = 0.51) and a high positive correlation for RMR (r = 0.79)[15].

In a study by Montoye et al.[13], the researchers evaluated the validity of the VO_2 Master analyzer in measuring VO_2 during moderate-to-vigorous and maximal-intensity exercise with the Parvo Medics TrueOne 2400 Canopy System. In contrast to the present study, their study focused on measuring the VO_2 of physically active

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males (average age of 41.0 years), while the present study measured the resting VO_2 of male and female participants (average age of 20.1 years) consisting of a diverse fitness level. Despite these differences, Montoye et al.[13] findings indicated a trend toward significantly lower VO_2 measurements with the VO_2 Master Analyzer at lower workloads. This is similar to the present study's findings in that compared to the Parvo Medics, the VO_2 Master analyzer measured significantly lower VO_2 during resting conditions. However, Montoye et al.[13] found adequate VO_2 validity during moderate- and vigorous-intensity exercise and concluded that the VO_2 Master is a suitable option for measuring VO_2. In contrast, this study reported that the VO_2 Master underestimated VO_2 significantly and concluded that the VO_2 Master may not be a suitable measure of VO_2. Thus, the results and distinctions between both studies suggest that the VO_2 Master analyzer's performance in measuring VO_2 may vary with factors such as population demographics and exercise intensity, warranting further research into its validity.

A study similar to the present study was done by Welch et al.[16]. The purpose of their study was to determine the validity of a portable metabolic device (Cosmed K4b2) in measuring RMR compared to the Parvo Medics TrueOne 2400 Canopy System. The participants' characteristics were similar to the present study. Both studies included young male and female adults with similar BMIs (present study: 47 females, 31 males; 20.1 ± 1.44 yrs, 24.8 ± 4.39 kg/m^2 vs Welch et al.[15] study: 13 females, 18 males; 27.3 ± 7 years, 24.8 ± 3.1 kg/m^2). Both studies implemented pre-testing instructions. Welch et al.[16] instructed participants to refrain from eating, drinking, and exercising for at least 12 hours before testing. The present study asked participants to refrain from vigorous physical activity and high-intensity weight training for at least 12 hours before testing and not to eat, drink (except water), consume caffeine, or exercise at least 4 hours before testing. Welch et al.[16] found no differences in RMR between the portable Cosmed K4b and the Parvo Medics TrueOne 2400 metabolic system. In contrast, this study found a significant difference in the RMR between the portable VO_2 Master and the Parvo Medics TrueOne 2400 metabolic system.

Limitations and Strengths of Study

This study had two known limitations and three strengths. First, heart rate monitors to confirm resting state were not utilized. While it was assumed the participants were resting during both tests, including a physiological measure (e.g., heart rate) would have helped to confirm this. Second, there is uncertainty regarding participants' adherence to the pre-testing requirements, such as refraining from vigorous physical activity and high-intensity weight training for at least 12 hours before testing, fasting from food and caffeine, and refraining from general exercise at least 4 hours before testing. Although each participant was asked to follow these requirements, there is

no guarantee, and thus, there is a possibility that some participants did not follow the pre-testing instructions.

This study has three known strengths. First, our study included a large sample (78 participants) of male and female college students. Second, this study was a crossover randomized repeated measures study. Half of the participants underwent testing with the Parvo Medics TrueOne 2400 system first, while the other half started with the VO_2 Master Analyzer. This intentional variation contributes to the reliability of the collected data and minimizes potential biases associated with the order of testing. Third, participants completed both tests during the same visit, which helped to prevent inter-day variations that may occur during normal living conditions.

Study Implications

This study's findings may impact the lives of the participants in this study. After determining one's resting metabolic rate through both methods, study participants are now aware of their RMR. This knowledge enables them to better estimate the calories needed for effective weight management. Furthermore, the study's findings indicate that the portable VO_2 Master Analyzer may offer a suitable alternative to the Parvo Medics TrueOne 2400 Canopy System. However, it should be noted that the VO_2 Master Analyzer underestimated RMR by 103 kcal/day on average, which although considered significant, only represents 5% of the average RMR's (i.e., 1875 kcal/day) and thus may not be impactful. However, on an individual level the VO_2 Master Analyzer underestimated and overestimated by as much as 779 kcal/day and 688 kcal/day, respectively, compared to the Parvo Medics. These individual differences are considered very high and thus should be kept in mind.

Conclusions

This study found a significant difference in the RMR and VO_2 values between the VO_2 Master analyzer and the "gold standard" Parvo Medics TrueOne 2400 Canopy System. Specifically, the VO_2 Master underestimated RMR by 103 kcal/day and VO_2 by 0.34 ml/kg/min. While further research is needed to confirm these findings, our results indicate that one should consider these underestimations when interpreting the VO_2 Master Analyzer RMR and VO_2 results.

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