Journal of Exercise Physiologyonline

February 2020
Volume 23 Number 1

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

JEPonline

Validation of the MC-PeakPro™ for Metabolic Measures during Rest and Maximal Exercise

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ABSTRACT

Hutchison AT, Couper S, Mejia A. Validation of the MC-PeakPro™ for Metabolic Measures during Rest and Maximal Exercise. **JEPonline** 2020;23(1):113-124. The purpose of this study was to validate a recently developed metabolic gas analyzer, the MC-PeakPro™ against an established device of similar cost, the CardioCoachCO_2™. Seventeen collegiate runners (11 males, 5 females) participated in this study. The subjects performed two separate resting metabolic and maximal exercise tests using each device, one week apart. Resting metabolic measures included resting energy expenditure (REE), respiratory exchange ratio (RER), and heart rate (HR). Graded exercise was performed on a treadmill and maximal exercise measures included maximal measures for maximal O_2 consumed (VO_2 max), maximal CO_2 produced (VCO_2 max), RER max, maximal expired ventilation (V_E max), and maximal HR (HR max). The data were analyzed by Intraclass Correlation Coefficients (ICC) and Bland-Altman plots. All eight measures were significantly correlated between the two devices, with ICC's ranging from 0.81 to 0.98. Paired *t*-tests for all eight measures revealed no significant differences between the two devices. The findings indicate that the MC-PeakPro™ is a valid instrument for the measurement of resting and exercise metabolism in this population.

Key Words: Aerobic Fitness, Metabolic Rate, VO_2 max

INTRODUCTION

The measurements of O_2 consumption and CO_2 production during rest and exercise are fundamental measurements in the field of exercise physiology (2,6). Historically, resting and exercise metabolic testing was accomplished with the “gold standard”, the Douglas bag (DB) method (7). This required the collection of expired air into large, impermeable canvas or latex bags, followed by the measurement of expired volumes and gas fractions. However, the DB method is highly technical and time consuming, requiring complex, cumbersome equipment and dedicated lab space (8).

In response to these limitations, during the last three decades, numerous computerized systems that are more user-friendly have been developed and validated against the DB method. However, in many cases, with greater ease-of-use comes greater cost that can make automated systems unattainable for smaller teaching laboratories, athletic facilities, and small businesses.

The MC-PeakPro^{TM} is a compact, semi-portable, and economical gas analyzer that provides a robust set of metabolic measures such as basal metabolic rate, resting metabolic rate (RMR), maximal O_2 consumption (VO_2 max), maximal CO_2 production (VCO_2 max), respiratory exchange ratio (RER, VCO_2/VO_2), spirometry, and heart rate, as well electrocardiography and electromyography in a simple software interface that runs on both the PC and Mac operating systems. The software provides a step-by-step procedure for calibration that can be used by coaches and/or personal trainers. It is also ideal for teaching undergraduate and graduate students the underlying science of metabolic testing.

To date, the MC-PeakPro^{TM} has not been validated against any reference measures for research purposes. Thus, the purpose of the current study was to validate the MC-PeakPro^{TM} against the CardioCoachCO_2^{TM}, which is a widely used device of similar cost that has been shown to be a reliable and valid tool for the measurement of resting and maximal exercise metabolism (9,11,14). Similar publications have used this method of validation of a new device against an established, valid, and reliable system instead of using the DB method as the criterion measure (9,16). We hypothesized that the MC-PeakPro^{TM} would generate similar results to the CardioCoachCO_2^{TM} in a population of highly trained college runners tested at rest and during a graded maximal exercise.

METHODS

Subjects

Seventeen members (5 females, 11 males) of the Our Lady of the Lake University (OLLU) track and field team volunteered to take part in this study (Tables 1 & 2). Before participation, all subjects read and signed our informed consent form that was approved by the OLLU Institutional Review Board for the protection of human subjects. Additionally, each subject answered a brief health history questionnaire to screen for the exclusion criteria: (a) anyone with a BMI over 25 (i.e., overweight); (b) females who were pregnant; (c) those who had suffered joint or muscular trauma within three months prior to testing that would have prevented them from completing a maximal graded exercise test on a treadmill; and (d) anyone with a history of high blood pressure or cardiovascular disease. All subjects were classified as low risk as per the risk stratification developed by the American College of

Sports Medicine (1). The subjects were asked to avoid strenuous exercise, alcohol, and caffeine for 24 hrs before testing and to eat a similar diet, confirmed by a 24-hr food log.

Table 1. Subject Characteristics for Resting Metabolism Testing.

Subject	Gender	Order	Age (yrs)	Weight (kg)	Height (cm)
1	M	PP-CC	22	63.6	172
2	M	PP-CC	19	63.4	172
3	F	PP-CC	20	47.0	156
4	M	CC-PP	20	57.0	165
5	M	CC-PP	20	84.5	176
6	F	CC-PP	20	52.5	164
		Mean	20.2	61.3	168.0
		±SD	1.0	13.0	7.7

CC = CardioCoachCO_2™, **PP** = MC-PeakPro™, **SD** = Standard Deviation

Table 2. Subject Characteristics for Graded Exercise Testing.

Subject	Order	Gender	Stage @ VO_2 max	Age (yrs)	Weight (kg)	Height (cm)
1	PP-CC	M	5	22	63.6	175
2	PP-CC	M	7	19	63.4	172
3	PP-CC	F	7	20	47.0	156
7	CC-PP	F	6	20	50.1	158
8	CC-PP	M	6	20	72.2	177
9	CC-PP	M	7	18	69.7	177
10	CC-PP	F	7	22	57.7	158
11	PP-CC	M	7	23	74.8	177
12	PP-CC	M	8	19	62.2	170
13	CC-PP	M	8	20	66.5	176
			Mean	20.3	62.7	169.6
			±SD	1.6	9.0	8.8

CC = CardioCoachCO_2™, **PP** = MC-PeakPro™, **SD** = Standard Deviation

Procedures

One month before testing, the CardioCoachCO_2™ was sent to KORR to be calibrated as per the manufacturer's recommendation. One week prior to testing, the subjects were randomly assigned to either Session One or Session Two (Table 3). The original study design was to conduct resting metabolic testing followed by graded exercise testing on all subjects. However, an unexpected change in the team's competition schedule required us to shorten the testing protocol for the second session by eliminating the resting metabolic measures. Thus, the 6 subjects from Session One underwent both resting metabolic and graded exercise testing, while the remaining 11 subjects in Session Two only participated in graded exercise testing. All tests were conducted one week apart at the same time of the day, and under the same environmental conditions. Upon arrival at the Clinical Exercise Testing Laboratory, each subject was weighed (Precision GetFit, EatSmart, Oak Brook, IL) and then height (Seca Portable Stadiometer, SECA, Chino CA) was recorded. Heart rate was measured at rest and during graded exercise using either a Polar H7 (Polar, Inc., Lake Success, NY) heart rate transmitter (CardioCoachCO_2™) or a Scosche Rhythm™ (Scosche Industries, Inc., Oxnard, CA) armband heart rate monitor with USB ANT+ receiver (MC-PeakPro™). The subjects' resting metabolic rate (RMR) was assessed by two measures, the resting energy expenditure (REE, $Kcal \cdot d^{-1}$) and RER resting. Prior to the RMR testing, the subjects were fitted with either an A-GAK-201 series silicone respiratory mask with a one-way non-rebreathing valve (iWorx) for testing with the MC-PeakPro™ (also used for exercise testing), or a MetaBreather mouthpiece and nose clip for testing with the CardioCoachCO_2™. The MetaBreather required an RMR Hose Adapter (KORR).

Table 3. Timeline of Resting and Exercise Measures.

Session One (n = 6)		Session Two (n = 11)	
Week 1	**Week 2**	**Week 3**	**Week 4**
Resting Measures 1	Resting Measures 2	No Resting Measures Taken	
Max Exercise Measures 1	Max Exercise Measures 2	Max Exercise Measures 3	Max Exercise Measures 4

The subjects' VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$), VCO_2 max, ($mL \cdot kg^{-1} \cdot min^{-1}$), RER max ($VCO_2$ max/VO_2 max), $V_E$max ($L \cdot min^{-1}$), and HR max were assessed during graded exercise testing with both the MC-PeakPro™ and the CardioCoachCO_2™. Prior to testing with the CardioCoachCO_2™, the subjects were fitted with a complete Y-valve assembly and silicone facemask (KORR). The testing protocol (Table 4) required the subjects to run at increasing speeds (every 3 min) and grades (every 6 min) until volitional exhaustion. Peak VO_2 readings for each submaximal workload were taken in the last minute of the stage in order to allow the subjects to attain steady state exercise. With 30 sec remaining in each stage, the subjects were asked to report their rating of perceived exertion (RPE) by pointing to a number between 0 (resting) and 10 (extremely hard work) on a modified Borg scale (5). The final RPE was reported once the treadmill was stopped after volitional exhaustion.

Both systems use a 5 L mixing chamber technique that samples expired air every 15 sec. A 6-foot breathing hose connects the one-way breathing valve to a mixing chamber inlet. The volume of expired air is measured by a spirometer attached to the outlet of the mixing chamber (MC-PeakPro™) and a fixed-orifice differential pressure pneumotach inside the CardioCoachCO_2™. Oxygen consumption is directly measured using a paramagnetic O_2 sensor in the MC-PeakPro™ and a galvanic fuel cell sensor in the CardioCoachCO_2™. Both systems directly measure Carbon Dioxide expiration using a non-dispersive infrared CO_2 sensor. Each device was calibrated before each test as per the manufacturer's instructions. The treadmill was calibrated (i.e., belt speed and grade) the day before each testing session and after the last subject tested on the last day of the study.

Table 4. Maximal Exercise Test Protocol.

Stage	Total Time (min)	Grade (%)	Speed (mi·hr)	Speed (kp·hr^{-1})	Average Watts
1	3	1	3	4.8	51
2	6	1	4	6.5	67
3	9	2	5	8.1	169
4	12	2	6	9.7	202
5	15	3	7	11.3	354
6	18	3	8	12.9	405
7	21	4	9	14.5	607
8	23	4	9.5	15.3	640

Statistical Analyses

An *a priori* power analysis was made using G-power (v.3.0.5; Bonn, Germany). Predictive validity between two tests or devices is achieved at *r* (coefficient of determination) no less than 0.50 (15). However, a search of similar validation studies revealed that the lowest correlation coefficient observed between similar metabolic measurement devices was 0.897 (9,12–14,16). Thus, assuming an *r* of at least 0.897 and 90% power, it was determined that a minimum of six sampling points were needed in order to detect a correlation of similar magnitude between measurements made with the MC-PeakPro™ and CardioCoachCO_2™ (effect size = 0.897, power = 0.90). Due to the non-invasive nature of the data collection, 11 additional subjects were recruited in order to decrease the possibility of a type II error, reduce the impact of possible attrition of subjects during the study, and provide additional data to the track and field coaching staff.

Statistical significance for all tests was set at an alpha of 0.05. Statistical analysis was completed using SPSS v25.0 (IBM, Corp., Armonk, NY). Before analysis, assumptions of normality and constant variance were confirmed using quantile-quantile and residual plots, respectively. The validity of the three resting measures (REE, RER resting, and HR resting) and the five maximal exercise measures (VO_2 max, VCO_2 max, RER max, V_E max, and HR max) were determined using Intraclass Correlation Coefficients (ICC 2,2), and the associated standard error of measurement (SE_M). Bland-Altman (3) plots were used to validate the three resting measures and the five maximal exercise measures using Excel v. 14.7.2 (Microsoft, Corp., Redmond, WA). Bland-Altman (4) plot provided a graphic representation of the 95% limit of agreement (LOA) between the new method (MC-PeakPro™) and the reference measure (CardioCoachCO_2™), and are often used to assess agreement between two methods of clinical measurements (10,11). Paired samples *t*-tests comparing the mean values for each resting and maximal exercise measurement were used to support the outcome of the Bland-Altman plots.

RESULTS

During testing, 7 subjects were removed from the study before completion of the second graded exercise test. Three subjects fell ill between the first and second tests. One subject did not maintain the same diet prior to the second test as was consumed prior to the first test, and 3 subjects reported injuries suffered during team workouts between the 2 tests that prevented them from running, but did not prevent them from completing the resting metabolic testing. Thus, we finished the study with 6 subjects (2 females, 4 males) for the resting metabolic testing and 10 subjects (3 females, 7 males) for the graded exercise testing. There were no gender differences detected between the devices, thus the data were analyzed collectively. All subjects reached a true VO_2 max since the O_2 consumptions during the last stage were not higher than during the penultimate stage. Additionally, there was no learning curve observed between the first and second sessions during the graded exercise testing.

The resting metabolic measures are presented in Table 5. Resting HR (r = 0.93, P=0.007), REE (r = 0.96, P=0.002), and RER resting (r = 0.98, P<0.001) were all strongly correlated between the two devices. Paired *t*-tests for all three measures showed no statistically significant differences between measures made by the MC-PeakPro™ and the CardioCoachCO_2™. The Bland-Altman plots (Figure 1) provided additional support for these relationships, as all 6 data points for each measure fell within the upper and lower LOA (10).

Table 5. Measures of Resting Metabolism Using the MC-PeakPro™ and CardioCoachCO_2™

Subject	REE		RER resting		HR resting	
	PP	CC	PP	CC	PP	CC
1	1430	1454	0.65	0.76	53	55
2	1622	1771	0.84	0.88	55	53
3	1716	1800	0.93	0.91	66	62
4	1237	1382	0.83	0.85	63	62
5	1334	1368	0.88	0.88	64	65
6	2204	2059	0.83	0.84	67	65
Mean	1591	1639	0.83	0.85	61.3	60.3
±SE_M	143	115	0.04	0.02	2.1	2.1

PP = MC-PeakPro™, **CC** = CardioCoachCO_2™, **REE** = Resting Energy Expenditure ($Kcal \cdot d^{-1}$), **RER resting** = Resting Respiratory Exchange Ratio (VCO_2/VO_2), **VCO_2** = CO_2 Production ($mL \cdot kg^{-1} \cdot min^{-1}$), **$VO_2$** = O_2 Consumption ($mL \cdot kg^{-1} \cdot min^{-1}$), **HR resting** = Resting Heart Rate ($beats \cdot min^{-1}$), **SE_M** = Standard Error of the Mean

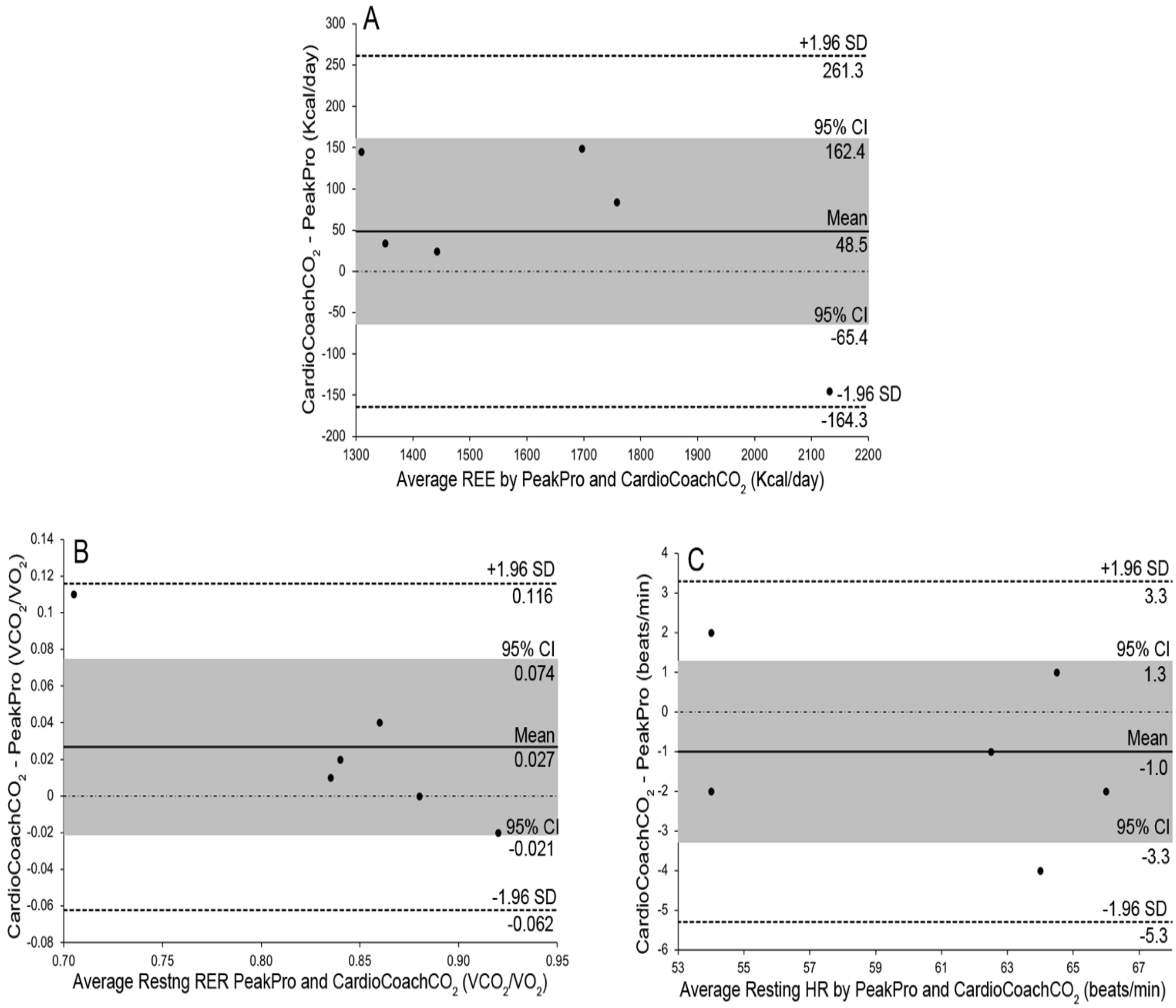

Figure 1. Bland-Altman Plots for (A) Resting Energy Expenditure, REE (Kcal·d^{-1})**, (B) Resting Respiratory Exchange Ratio, RER** (VCO_2/VO_2)**, and (C) Resting Heart Rate, HR** (beats·min^{-1}).

Maximal metabolic measures made during graded exercise are presented in Table 6. VO_2 max (r = 0.98, P<0.001), VCO_2 max (r = 0.98, P<0.001), RER max (r = 0.88, P<0.001), V_E max (r = 0.81, P<0.001), and HR max (r = 0.90, P=0.002) were all strongly correlated between the two devices. The Bland-Altman plots (Figure 2) provide additional support for these relationships, as all but one of the data points (RER max) from each measure fell within the LOA. Additionally, paired *t*-tests for all five variables showed no statistically significant differences between measures made by the MC-PeakPro™ and the CardioCoachCO_2™.

Table 6. Maximal Values Attained during Graded Exercise Testing to Volitional Exhaustion Using the MC-PeakPro™ and the CardioCoachCO_2™.

Subject	VO_2 max PP	VO_2 max CC	VCO_2 max PP	VCO_2 max CC	RER max PP	RER max CC	V_E max PP	V_E max CC	HR max PP	HR max CC
1	46.9	47.8	48.8	47.3	1.04	0.99	79.8	89.8	184	187
2	68.7	67.6	72.0	69.0	1.05	1.02	109.3	113.1	190	184
3	52.2	51.4	55.1	53.4	1.06	1.04	78.2	83.7	205	204
7	65.1	64.3	69.9	66.9	1.07	1.04	99.1	112.6	189	186
8	62.8	59.7	70.6	67.0	1.12	1.12	85.4	95.6	197	193
9	68.2	65.2	67.2	68.2	0.99	1.05	114.7	98.8	181	183
10	75.4	74.6	77.1	75.9	1.02	1.02	111.4	110.9	176	179
11	64.6	66.5	47.3	76.4	1.15	1.15	90.2	94.6	195	195
12	66.1	64.8	62.6	61.2	0.95	0.94	102.1	105.8	191	192
13	66.8	66.4	71.2	70.9	1.07	1.07	113.8	123.9	186	192
Mean	63.7	62.8	66.9	65.6	1.05	1.04	98.4	102.9	189.4	189.5
±SE_M	2.4	2.5	3.0	2.8	0.02	0.02	9.7	9.0	3.6	3.1

PP = MC-PeakPro™, **CC** = CardioCoachCO_2™, **VO_2 max** = Maximal O_2 Consumption (mL·kg^{-1}·min^{-1}), **VCO_2 max** = CO_2 Production (mL·kg^{-1}·min^{-1}), **RER max** = Maximal Respiratory Exchange Ratio (VCO_2/VO_2), **V_E max** = Maximal Minute Ventilation (L·min^{-1}), **HR max** = Maximal Heart Rate (beats·min^{-1}), and **SE_M** = Standard Error of the Mean.

DISCUSSION

The purpose of the study was to validate the MC-PeakPro™ against the CardioCoachCO_2™ for measures of resting and maximal exercise metabolism. The strong associations between the MC-PeakPro™ and CardioCoachCO_2™ measures of resting and maximal exercise metabolism indicate that predictive validity exists between the two devices in this specific population. The common variance (R^2) between the MC-PeakPro™ and the reference, CardioCoachCO_2™, for the eight measures used in this study ranged between 66% and 95%. Additionally, the lowest correlation coefficient was greater than 0.80, an acceptable value for predictive validity (15). Thus, our hypothesis was supported by the results of the study.

Although the MC-PeakPro™ and CardioCoachCO_2™ were strongly correlated, this alone does not provide enough evidence to support the use of the MC-PeakPro™ as a proxy measure for the CardioCoachCO_2™. Bland and Altman suggested that two devices designed to measure the same parameter would be expected to generate strongly correlated values (3,10). However, the new device may consistently over, or underestimate the criterion device, revealing any inherent bias between the two methods. Thus, in addition to correlation, Bland-Altman plots provide a graphic representation of the level of agreement between the two methods. The x-axis represents the mean value between the devices, and the y-axis represents the bias of the MC-PeakPro™, calculated as the difference between the values measured by the CardioCoachCO_2™ and the MC-PeakPro™. The LOA are the boundaries, i.e., ± 1.96 SD away from the mean difference between the devices, within which 95% of the data points should fall. Lastly, assuming normality, 95% confidence intervals (CI) can be established around the mean difference using the product of the standard error of the mean and the *t* distribution with *n* -1 degrees of freedom. If the line of equality, (a mean difference of zero) lies within the 95% CI, there is no significant systematic difference between the devices, that is, the measures are statistically indistinguishable between the devices. For example, the 95% CI for VO_2 max (Figure 3A) is -1.94 to 0.24, a range that includes the identity line at 0. The same is true for all seven of the other measures of resting and maximal exercise metabolism.

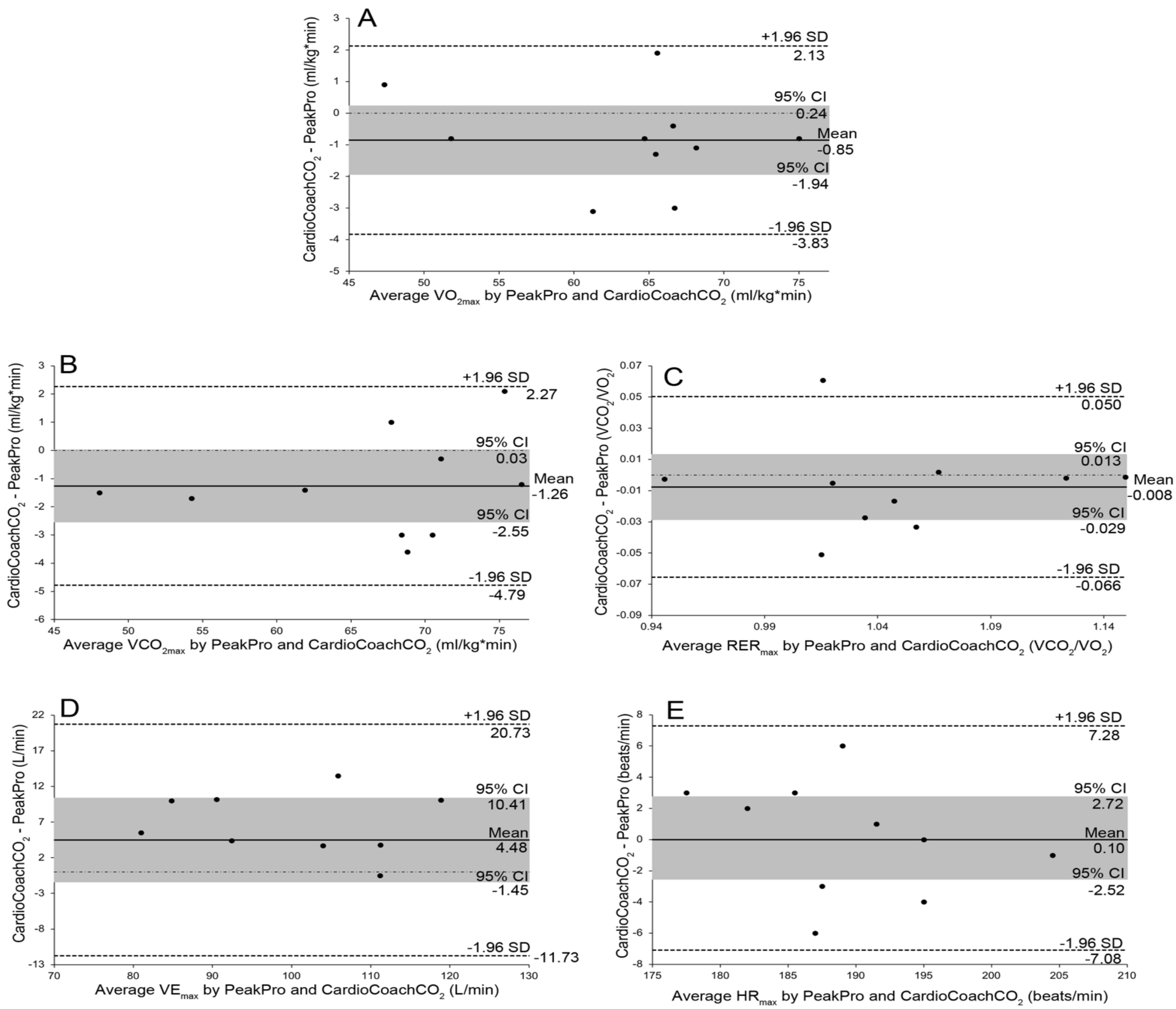

Figure 2. Bland-Altman Plots for (A) Maximal Oxygen Consumption, VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)**, (B) Maximal Carbon Dioxide Production, VCO_2 max,** ($mL \cdot kg^{-1} \cdot min^{-1}$)**, (C) Maximal Respiratory Exchange Ratio, RER max** (VCO_2/VO_2)**, (D) Maximal Minute Ventilation, V_E max** ($L \cdot min^{-1}$)**, and (E) Maximal Heart Rate, HR max** ($beats \cdot min^{-1}$).

The lone data point that fell outside the LOA was from subject 9 for the RER max (Figure 3C). This subject was assessed on the CardioCoachCO_2™ and then the MC-PeakPro™ a week later. After the second graded exercise test was completed, subject 9 reported that the second test was much easier than the first test had been. He stated that he had struggled to breathe throughout the first exercise test (unbeknownst to the researchers) because of what he described as a mild panic attack resulting from the sensation of wearing the respiratory mask. Subject 9 insisted that he could have continued past the sixth stage during the second test. Obviously, in order to maintain the same testing conditions, the second test was stopped at the same time as the first. However, each of the measures from the second test revealed a trend toward a relatively easier experience than the first test. His VO_2 max increased from 62.5 to 68.2 $mL \cdot kg^{-1} \cdot min^{-1}$, his VCO_2 max decreased from 68.2 to 67.5 $mL \cdot kg^{-1} \cdot min^{-1}$, resulting in a reduced RER max, (1.05 – 0.99). Additionally, his V_E max increased from 98.8 to 114.7 $L \cdot min^{-1}$ and his HR max decreased slightly from 183 to 181 $beats \cdot min^{-1}$. Although it is possible that these differences were simply the result of random measurement errors, the fact that subject 9 was the only person to report such an experience during graded exercise, it is plausible that his discomfort played a role in the variability between the tests. Removing subject 9 from the data set actually improved all 5 of the maximal exercise variables. Because we did not change any parameters between his two tests, we felt it appropriate to leave his data in the final analysis.

Similar concerns were expressed by all 6 subjects during RMR testing. The MC-PeakPro™ uses the same respiratory mask during RMR testing as is used during graded exercise. All 6 subjects reported that it took 5 to 10 min before they could reduce their respiratory rate. This is evidenced by the fact that the average RER resting as measured by the MC-PeakPro™ was 0.83, which was significantly higher than what would be expected for a group of highly trained athletes. The average RER resting measured with the CardioCoachCO_2™ was 0.85. The CardioCoachCO_2™ uses a MetaBreather hose for RMR testing, which has a diameter of 22 mm, less than half that of the hoses used with either system for exercise testing. All 6 subjects described a sensation akin to breathing through a straw while using the MetaBreather. It is likely that each system requires multiple tests to obtain a true resting measure.

Limitations in this Study

Although our sample was large enough to achieve our statistical objectives, care should be taken when interpreting these results beyond the population tested, that is, college-aged, competitive runners. Additionally, due to time constraints of our subjects, we were unable to determine test-retest reliability for the MC-PeakPro™. Future studies should test other suitable populations such as sedentary and recreationally active subjects of varying ages and assess the reliability of the MC-PeakPro™.

CONCLUSIONS

The findings indicate that the MC-PeakPro™ provides similar physiological results as does the CardioCoachCO_2™ during rest and graded maximal exercise testing, and is a valid device for the measurement of these parameters. The MC-PeakPro™ is an affordable and portal means of testing subjects, clients, and athletes in a clinical or classroom setting.

ACKNOWLEDGMENTS

The CardioCoachCO_2 was loaned to us by the Dr. Roger's Center in San Antonio, Texas.

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REFERENCES

1. ***ACSM's Guidelines for Exercise Testing and Prescription***. (10th Edition). Wolters Kluwer Health, 2018.

2. Astrand P-O, Saltin B. Maximal oxygen uptake and heart rate in various types of muscular activity. ***J Appl Physiol*.** 1961;16:977-981.

3. Bland JM, Altman DG. Comparing methods of measurement: Why plotting difference against standard method is misleading. ***Lancet*.** 1995;S0140-6736(95):91748-91749.

4. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. ***Lancet*.** 1986;1(8476):307-310.

5. Borg GAV. Psychophysical bases of perceived exertion. ***Med Sci Sport Exerc*.** 1982; 14:377-381.

6. Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. ***Am Heart J*.** 1973;85(4):546-562.

7. Consolazio C, Johnson R, Pecora L. ***Physiological Measurements of Metabolic Function in Man.*** New York, NY: McGraw-Hill; 1963.

8. Crouter SE, Antczak A, Hudak JR, DellaValle DM, Haas JD. Accuracy and reliability of the ParvoMedics TrueOne 2400 and MedGraphics VO2000 metabolic systems. ***Eur J Appl Physiol*.** 2006;98(2):139-151

9. Dieli-Conwright CM, Jensky NE, Battaglia GM, McCauley SA, Schroeder ET. Validation of the cardio coach CO_2 for submaximal and maximal metabolic exercise testing. ***J Strength Cond Res*.** 2009. doi:10.1519/JSC.0b013e3181a3c5e8.

10. Giavarina D. Understanding Bland Altman analysis lessons in biostatistics. ***Biochem Medica*.** 2015:1-5.

11. Jensky NE, Vallejo AF, Ong MD, Schroeder ET. Validation of the Cardiocoach™ for sub-maximal and maximal metabolic exercise testing. ***Med Sci Sport Exerc*.** 2005; 23(4):1316-20.

12. Lee JM, Bassett DR, Thompson DL, Fitzugh EC. Validation of the cosmed fitmate for prediction of maximal oxygen consumption. ***J Strength Cond Res*.** 2011;25(9):2573-2579.

13. Nieman DC, Austin MD, Benezra L, et al. Validation of cosmed's FitMate™ in measuring oxygen consumption and estimating resting metabolic rate. ***Res Sport Med*.** 2006;14(2):89-96.

14. Orr JA, Westenskow DR, Bauer A. A prototype gas exchange monitor for exercise stress testing aboard NASA Space Station. ***J Appl Physiol*.** 1989;66(1):492-497.

15. Safrit MJ. ***Introduction to Measurement in Physical Education and Exercise Science****.* Times Mirror/Mosby,1986.

16. Wahrlich V, Anjos LA, Going SB, Lohman TG. Validation of the VO2000 calorimeter for measuring resting metabolic rate. ***Clin Nutr*.** 2006;25(4):687-692.

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