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Analysis of the performance of the portable Cortex Metamax 3B gas analysis system in simulated and real workouts with Vietnamese teenagers

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ABSTRACT

The aim of this study was to investigate the performance of the mobile Cortex Metamax 3B (MM3B) automated gas meter in simulated and real workouts involving teenagers. A total of 28 healthy volunteers (13 men, 15 female) were selected with the following characteristics (mean ± SD): age 17.2 ± 3.1; height 167.1 ± 13.5 cm; weight 54.6 ± 10.4 kg. The following equipment were used: Hypermax 3B (breath-by-breath breathing system), Validator for Gas Exchange Systems (VGES), and Douglas-bag technique (DBT). The results have shown that MM3B is stable at the permitted range during 3 hours while monitoring the gas fractions, as well as the VE, VO2, and VCO2 created by GESV, especially at moderate and high metabolic rates (2% deviation and modest physiological significance). MM3B rated both VO2 and VCO2 significantly higher by about 10-17% at moderate and strenuous activity than DBM and at all exercise levels than Oxycon Pro, although without a significant margin of error in VE. Between the two criteria systems, none of the metabolic variables showed any discernible change (DBM and Oxycon Pro). The MM3B provided acceptable data on stability and reliability, but it was decided that without further adjustment for VO2 and VCO2, the data were not valid during moderate and strenuous activity.

KEYWORDS

Cortex Metamax 3B; Dependability; Stability

1. INTRODUCTION

To assess the cardiovascular, respiratory, and metabolic needs of diverse activities, many laboratories around the world now practice the practice of monitoring oxygen uptake (VO2) and its related variables, carbon dioxide generation (VCO2) and ventilation expiration (VE). These measurements have traditionally been made using open-circuit calorimetry, a modification of the original Douglas bag method (DBM), under controlled laboratory conditions (Douglas, 1911). Most laboratories now use automated computerized metabolic gas analyzers instead of the time-consuming and skill-intensive DBM (Macfarlane, 2001). Although the DBM has the potential to be used in field trials (Daniels, 1971), its capabilities are severely limited by its weight, additional air resistance, and the difficulty of consecutive measurements (Durnin & Passmore, 1967). Therefore, some portable methods have been developed to collect indices of metabolic gases while carrying out fieldwork.

The all-mechanical Max-Planck respirometer, created during World War II and sometimes called the Kofranyi-Michaelis respirometer after the authors of a first publication, was one of the devices, earliest handheld (Johnson et al. 1967) (Kofranyi & Michaelis 1949). Early automatic handheld devices could only measure VO and VO2 (not VCO2), e.g. "Oxycon", "Oxylog" and "K2" (Macfarlane, 2001). Today's technology makes it possible for mobile devices to collect nearly as much data as their laboratory equivalents while still weighing less than 2 kg (typically recording or telemetry data of cadence). breathing and breathing rate). One such system is the Metamax System 3B (MM3B) (Cortex, Leipzig, Germany), which replaces the older Metamax I and II versions that have proven to be valid and reliable and are also sold as VmaxST in many countries (Medbo et al., 2002).

Another technique that has been criticized as not being a true gold standard is the fact that previous validation studies on MM3B simply used an automated system that has been validated as a ruler. measure its criteria (Laurent et al., 2008; Perkins et al., 2004; Meyer et al., 2005). Any metabolic gas analyzer, such as the MM3B, should ideally be declared valid against at least the DBM, and its reliability is documented using the model. gas exchange simulation. Only one comprehensive study (Vogler et al., 2010) focused on elite athletes at relatively high-performance levels and excluded rest or light exercise as the only study that published such data. on MM3B. needed to assess whether MM3B could be used for typical non-elite groups such as toddlers.

Any metabolic gas analysis system should demonstrate that it stabilizes (i.e., does not significantly drift) within the normal data collecting time following calibration. This may only need stability analyses over 20 minutes for observations taken in or near a laboratory (Prieur et al., 2003).

For some research, however, it might be challenging to calibrate a portable system on the spot due to the weight of hauling heavy calibrators, such as high-pressure alpha standard calibration gas cylinders. Because of this, some portable systems may require initial calibration in the lab before being transported and used for field research for a sizable amount of time later. Rarely does the literature explain how these conditions affect the results of each gas analyzer, including VO2 and VCO2 levels? (Atkinson et al., 2005).

Only one research, which could only go for 20 minutes, examined the stability of the Cortex Metamax 3B/VmaxST system, but numerous field investigations could go on for longer. Although numerous auto-metabolic systems are utilized in children and adolescents, only a few numbers have been validated in these populations (Unnithan et al., 1994). The validation type must also be compatible with the intended application of the test system (Unnithan et al., 1994).

Therefore, the purpose of this study was to report on the usefulness of MM3B for monitoring physiological variables outside of the elite range, especially those frequently seen in children, adolescents, or the elderly, as well as its applicability in prolonged situations. We investigated the MM3B system's performance in terms of (1) reliability, (2) stability/drift for 3 hours, and (3) validity against both the Criterion DBM and the previously validated gas analysis system (Jaeger Oxycon Pro) using a juvenile sample using a commercially available gas exchange simulator.

The aim of this study is to investigate the performance of the mobile Cortex Metamax 3B (MM3B) automated gas meter in simulated and real workouts involving teenagers.

2. METHODS

2.1. Participants

A total of 28 healthy volunteers (13 men, 15 female) were selected with the following characteristics (mean ± SD): age 17.2 ± 3.1; height 167.1 ± 13.5 cm; weight 54.6 ± 10.4 kg. All subjects, as well as their legal guardians, provided written consent after the project was approved by the Research Ethics Committee of Phu Yen University.

2.2. Equipment

Hypermax 3B (breath-by-breath breathing system)

A moving metabolic system called the MM3B is made up of a measurement module and a battery module. These two components, which have identical dimensions of 120 x 110 x 45 mm and weigh a total of 1.40 kg, are intended to be worn on the chest with a harness. The MM3B uses a two-way digital turbine for volume measurement. To enable measurement of O2 and CO2 concentrations

using the electrochemical cell and infrared analyzer respectively, a 60 cm Nafion/Permapure sample tube is linked to the turbine.

Standard metabolic methods (Wasserman et al. 1999) using the Haldane transformation were used to calculate VO2 and VCO2, but to account for changes in the environment, FIO2 and FICO2 were continuously monitored. instead of being treated as unchanged. Respiratory volume and gas concentration data can be provided directly via telemetry to a PC or can be saved in the built-in memory for later download. Version 3.7.0 SR2 of Metasoft 3 software was used to test the system.

The system was turned on for at least 20 minutes prior to use, and it was calibrated prior to each test according to the manufacturer's instructions. To do this, the gas analyzer must first be calibrated with a reference gas (14.97% O2, 4.96% CO2, N2 balance: 0.02% absolute, Vietnam Special Gas), and then the calibration must be checked against outside air. Second, volume calibration using a standard 3-L syringe was performed (series 5530, Hans Rudolph, Inc., MO, USA). All participants wore nose clips and had mouthpieces connected to the MM3B turbine to prevent possible gas leaks, which are known to cause trouble when wearing a mask.

Validator for Gas Exchange Systems (VGES)

The VGES, a mechanical gas exchange device that replicated human breathing and had a stated accuracy of 2% in creating VO2 and VCO2, was manufactured by MedGraphics in Massachusetts and is currently offered by Vacumed in California (Huszczuk et al. 1990). The VGES expired gas of constant expired fractions at ambient temperature and pressure may be used to mimic a range of VO2 and VCO2 when a gas of known CO2 concentration (recommended 21.00%) was introduced to the inspirate. The VGES may be modified to mimic breathing at different respiratory rates (low = 10 breaths per minute; medium = 20 breaths per minute; and high = 40 breaths per minute) and throughout a wide range of tidal volumes (0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 L). These led to minute ventilations of between 5 and 104 L min1, VO2 of between 0.30 and 2.81 L min1, and VCO2 of between 0.29 and 2.69 L min1.

Douglas-bag technique (DBT)

Each participant wore a nose clip and mouthpiece linked to a Radiax valve (dead space 28 ml) using a 1 m length of Collins spiral tubing (38 mm ID) and a Collins 3-way stopcock, and the expired gases were collected into 250 L Douglas bags (WE Collins, Braintree, USA) for analysis. The mixed expires were analyzed in less than 15 minutes using Applied Electrochemistry's S-3A oxygen and CD-3A carbon dioxide analyzer, which had previously been checked against ambient air and

calibrated using two alpha/primary-reference gases (26.13% O2 and 0.00% CO2; 13.94% O2 and 5.96% CO2; all gases 0.02% absolute, Vietnam Specialty Gases). A dry gas meter (Harvard, USA) was used to determine the volume of the Douglas bag using a vacuum pump on the exit port. When the temperature is afterward corrected to "body temperature pressure saturated" and "standard temperature pressure dry" (BTPS). Using a telethermometer, the temperature of the exhaled gas was determined. (YSI, Ohio, USA). To reduce the dilution effect of dead-space gas remaining in the bag and any stiff tubing, each bag was flushed with expired gases before use. Additionally, each bag was verified for the lack of leaks and diffusion. (no change in volume or composition of mixed expired detected during 30 minutes).

Participants used the Oxycon Pro (Jaeger, now CareFusion, Germany) while wearing a nasal clip, breathing through a mouthpiece, and utilizing a Radiax valve in its "mixing-chamber mode." The system was fully calibrated for volumes and gases (14.00% O2, 6.00% CO2, 0.02% absolute, Vietnam Specialty Gases) before each test, as per the manufacturer's recommendations. After that, the system was turned on for at least 30 minutes before use.

2.3. Reliability

To check the accuracy of the V E, VO2, and VCO2 readings taken by the MM3B, a known CO2 gas supply (20.62%) was supplied to the inspired port of the GESV as instructed by the manufacturer. Each trial featured the GESV running at 1.0 L at the low respiratory rate, 1.5 L at a medium respiratory rate, and 1.5 L at a high respiratory rate with the GESV inspiratory/expiratory ports directly attached in series to the MM3B turbine. On the same day, each trial was carried out twice at each level of VE, VO2, and VCO2 to assess the repeatability of this measurement. The MM3B was calibrated in between each trial.

2.4. Stability

To determine the stability/drift of two MM3B components, a known gas (15.83% O2 and 4.05% CO2) was injected into the MM3B's sample line at 0, 20, 40, 60, 120, and 180 minutes. According to the manufacturer's instructions, a 20.62% CO2 gas was connected to the GESV's inspired port in order to deliver simulated VO2 and VCO2 throughout the whole system. Research featured the GESV running at 1.0 L at a low respiratory rate, 1.5 L at a medium respiratory rate, and 1.5 L at a high respiratory rate for 30 complete "breaths" at 20-min intervals until 180 min had elapsed. The inspiratory/expiratory port of the GESV was directly connected to the MM3B turbine. Once calibrated prior to data collection, the MM3B was predicted to run for a maximum of 180 minutes during field measurements.

2.5. Validity

The eight participants finished a test that involved increasing amounts of cycling exercise interspersed with rest intervals. (Corival 400, Lode, The Netherlands). Measurements were obtained concurrently (sequentially) using an Oxycon Pro system, the MM3B, and the DBM throughout each 13-minute training stage. The Oxycon Pro system was utilized as a "secondary criterion" since it has been shown to be a trustworthy metabolic system when employed in its mixing-chamber mode. (Foss and Hallen 2005). The DBM collections of expired gas served as the main criterion for the order of measurement technique, which used a counterbalanced Latin-Square approach to avoid any order influence. (Bradley 1958). The expired gas collected by the DBM was immediately measured by the calibrated S-3A oxygen and CD-3A carbon dioxide analyzers before being sent through the dry gas meter, whose accuracy (0.8% error) had previously been verified using numerous pumps of a 3-L calibration syringe. (Hans Rudolph).

2.6. Statistical analysis

The percentage differences, repeated-measures ANOVA, and Bland-Altman analysis were used to examine differences between the dependent variables for V E, VO2, VCO2, FEO2, and FECO2 (Bland & Altman 1986). Univariate intraclass correlation coefficients (ICC) and t-tests were also used in the reliability testing between repeated data. (for change in the mean scores). Similar techniques to those outlined by Gore et al. (2000) were used to generate Technical Errors of Measurement (TEM) for both intra-TEM and inter-TEM evaluations of the dependability of various devices. The majority of analyses were performed using SPSS (8.0), with the TEM=√(∑▒D^2 /2N), where D is the difference between the measurement pairs and N is the total number of measurement pairs.

3. RESULTS

In the reliability tests of the MM3B, measuring V E, VO2, and VCO2 with a re-calibration in between, significant but minor deviations were found for VO2 and VCO2 at all levels of frequencies. (Study 1). Table 1 shows that the percentage differences between the two trials were typically less than 2.5%, and that the average intra-device TEM for V E, VO2, and VCO2 across all pumping frequencies was 0.2, 1.4, and 1.1%, respectively. In the repeated measurements of V E, VO2, and VCO2, the MM3B likewise attained excellent ICC values (r = 1.00).

Table 1 presents the gas exchange system validator's dependability findings for the MetaMax 3B. The results are shown for a variety of low, moderate, and high metabolic rates. Additionally, it

shows the median values, standard deviations, and intra-device TEM (%) for V E, VO2, and VCO2 (L min^-1).

Table 1. Gas exchange system validator's dependability findings for the MetaMax 3B

Metabolic rate	Trial 1	Trial 2	% difference#	Intra-device TEM (%)	Intra-device TEM (%)
V E (BTPS, L min−1)	Low	9.92 ± 0.05	9.92 ± 0.07	0.1	−0.1
	High	57.06 ± 0.55	58.10 ± 0.65	0	0.1
	Medium	29.53 ± 0.28	29.69 ± 0.23	0.4	0.5
*V*O2 (STPD, L min−1)	Medium	1.62 ± 0.01	1.65 ± 0.01	1.2	1.7*
	Low	0.31 ± 0.01	0.30 ± 0.00	1.2	1.8*
	High	2.72 ± 0.03	2.80 ± 0.03	1.5	2.3**
*V*CO2 (STPD, L min−1)	Low	0.29 ± 0.01	0.29 ± 0.00	1.6	2.5*
	Medium	1.55 ± 0.02	1.59 ± 0.02	0.7	1.2*
	High	2.66 ± 0.04	2.69 ± 0.04	0.7	1.1*

Technical measurement error is given as a percentage of the mean
#The statistics are only provided here to two decimal places, while percentage differences were derived from mean values using four decimal places.
** Significant difference from the t-test (p< 0.05)*
*** Significant difference (p< 0.01)*

Table 2 provides stability/drift data, including mean and standard deviation (SD) values for FEO2, FECO2, VO2, and VCO2 at various metabolic rates (low, medium, and high) as simulated by the Gas Exchange System Validator during a 180-minute period, as measured by MetaMax 3B from the calibration gas bottle. When compared to the baseline, significant but subtle variations were found for FEO2 and FECO2 over each subsequent measurement period, according to the results of the stability/drift tests of the MM3B gas analyzers (Table 2). (0 min). (20, 40, 60, 120, and 180 min). The differences were 0.01 to 0.09% for FEO2 and 0.05 to 0.16% for FECO2. Table 2 includes the descriptive data for the gas concentration in percentages as well as comparisons between each time point and the baseline by the MM3B. At the first 20-min interval, FECO2 immediately fell by more than 4%. Up until 120 minutes, when there was only a 1% variation from the baseline, this under-measurement steadily improved. As FEO2 steadily dragged upwards, very slight but statistically significant increases were also seen.

Table 2. Stability/Drift Data for FEO2, FECO2, VO2, and VCO2 at Various Metabolic Rates as Simulated by the Gas Exchange System Validator Using MetaMax 3B

Time (min)	FEO2 (%)	FECO2 (%)	*VO*2 (L min−1)			*VCO*2 (L min−1)		
			Low	Med	High	Low	Med	High
180	15.92 ± 0.00 (0.6***)	4.03 ± 0.03 (−1.2***)	0.30 ± 0.00 (2.1***)	1.67 ± 0.01 (1.3***)	2.67 ± 0.03 (1.8***)	0.27 ± 0.00 (2.1***)	1.57 ± 0.01 (0.7)	2.66 ± 0.04 (1.1)
160	–	–	0.31 ± 0.00 (2.6***)	1.66 ± 0.02 (1.3**)	2.85 ± 0.03 (1.0*)	0.29 ± 0.00 (2.8***)	1.58 ± 0.02 (0.8)	2.68 ± 0.04 (0.8*)
140	–	–	0.31 ± 0.00 (2.7***)	1.69 ± 0.01 (1.0**)	2.86 ± 0.03 (1.5***)	0.29 ± 0.00 (3.2***)	1.58 ± 0.02 (0.8)	2.69 ± 0.03 (1.3)
120	15.91 ± 0.00 (0.4***)	4.05 ± 0.03 (−1.2***)	0.31 ± 0.00 (2.6***)	1.69 ± 0.02 (1.1*)	2.84 ± 0.03 (0.8)	0.29 ± 0.00 (3.2***)	1.58 ± 0.02 (1.0)	2.67 ± 0.05 (0.4**)
100	–	–	0.31 ± 0.00 (2.7***)	1.68 ± 0.01 (0.6)	2.85 ± 0.03 (1.0*)	0.29 ± 0.00 (3.5***)	1.58 ± 0.01 (0.6)	2.68 ± 0.04 (1.0)
80	–	–	0.31 ± 0.00 (2.8***)	1.68 ± 0.02 (0.6)	2.84 ± 0.03 (0.9)	0.29 ± 0.00 (3.8***)	1.59 ± 0.02 (1.3*)	2.68 ± 0.04 (1.1)
60	15.88 ± 0.00 (0.3***)	3.97 ± 0.03 (−3.2***)	0.31 ± 0.00 (2.0***)	1.67 ± 0.02 (−0.2)	2.83 ± 0.03 (0.3)	0.29 ± 0.00 (3.4***)	1.58 ± 0.02 (0.8)	2.67 ± 0.03 (0.4)
40	15.87 ± 0.00 (0.2***)	3.99 ± 0.03 (−2.7***)	0.30 ± 0.00 (−0.7)	1.67 ± 0.01 (0.1)	2.82 ± 0.03 (−0.2)	0.28 ± 0.01 (0.7)	1.58 ± 0.01 (1.1*)	2.68 ± 0.03 (0.8)
20	15.85 ± 0.00 (0.1***)	3.94 ± 0.04 (−3.9***)	0.30 ± 0.00 (−0.1)	1.66 ± 0.01 (−0.4)	2.81 ± 0.04 (−0.5)	0.29 ± 0.00 (1.5***)	1.58 ± 0.02 (0.7)	2.68 ± 0.04 (1.1*)
0	15.84 ± 0.00	4.10 ± 0.02	0.30 ± 0.00	1.67 ± 0.02	2.82 ± 0.03	0.28 ± 0.00	1.57 ± 0.02	2.66 ± 0.04

At time = 0, the relative percentage error as a consequence of comparison with the baseline is displayed in brackets. Clearly difference from time at 0 minutes (ANOVA).
*The error (%) between the values of FEO2, FECO2, VO2, or VCO2 was computed using mean data with four decimal places as [each time (min)baseline (0 min)]/value of baseline 100%. * p < 0.05; ** p < 0.01;*** p < 0.001*

The findings from Table 2 regarding the time-dependent variability of VO2 and VCO2 indicate that at low metabolic rates, VO2 starts to increase from baseline around the 60th minute, resulting in a mean difference of approximately 2%. The VCO2 starts to significantly diverge from the baseline at the 20th minute and continues to do so until the 60th minute, resulting in an average deviation of 3%. Between 100 and 120 minutes, values that were marginally to considerably above baseline for VO2 were observed for both moderate and high metabolic rates. There are not many discernible or consistent variations in VCO2 at moderate and high metabolic rates.

4. DISCUSSION

This is the first study to properly evaluate the Cortex Metamax 3B's dependability and stability across a variety of simulated training scenarios. It conducted value comparisons for non-elite individuals on a metabolically relevant range for both primary (DBM) and secondary (Oxycon Pro) objectives. (such as adolescents and young adults). As 180 minutes is the longest time the MM3B may be used in the field after being calibrated in a lab, the major goal of this study was to assess the stability (or drift resistance) of the significant variables captured by the MM3B (gas fractions, VO2, and VCO2). (e.g., 60 minutes of travel time to the destination, 30 minutes of on-site preparation, and then up to 90 minutes of data collection in batches). It is frequently not practical to transfer calibrators to the site when some field measurements are conducted in distant areas without private automobile parking in nations like Hong Kong. As a result, prior lab calibration is required, and it is assumed that the equipment will be sufficiently stable over time. The research by Eriksson et al. (2011) and our investigation, although restricted to static laboratory circumstances, both partially answer the criticism made by Atkinson et al. (2005) that there is a lack of information on the stability of certain gas analysis techniques.

Few research has examined the topic of determining the dependability of portable gas analysis equipment, Meyer et al. (2005) noted; nevertheless, it appears that three studies have published data on the Metamax 3B's dependability. Perkins et al. (2004) performed repeated measurements on human participants in their investigation to assess the dependability of MM3B, which increased variability by accounting for the patients' relatively high biological error. individuals whose contributions to the overall variability were estimated to be 90% and 10%, respectively (Macfarlane, 2001). According to Perkins et al. (2004), MM3B has very tiny confidence intervals and highly excellent single- and multiple-test reliability. Even though data are supplied for just one rate, Prieur et al. (2003) reported data from a stability study utilizing a thorough gas exchange simulator that demonstrates MM3B's exceptional reliability. the only metabolic process (VO2 = 2.6 l/min). The findings from Vogler's analysis (Vogler et al., 2010) further support the superior performance of MM3B in comparison to the system's conventional Douglas bag system, with mean errors ranging from 2.0% (VO2) to 3.6%. Reliable results from our investigation, where GESV was utilized to recreate numerous common field trial conditions (such as low, moderate, and high metabolic rates), demonstrate that the technical variability of the MM3B values is very low. For VE, VO2, and VCO2 the relative percentage error between tests is often less than 2%, and for TEM% it is typically less than 1.5%. The 1% relative error obtained by the sophisticated automatic calibration method, which

is significantly below the TEM confidence level of 3% specified by the Australian Sports Commission's (Gore, 2000).

5. CONCLUSIONS

The findings of this investigation showed that MM3B remained stable at acceptable levels (significant alterations of small physiological consequence) when delivered in distant settings for up to 180 minutes. In-depth field studies will usually employ this gadget. When monitoring VO2 and VCO2 at moderate and high levels, MM3B does not seem to be sufficiently valid, even if these mistakes may be minimized by applying a straightforward linear regression equation (proof of systematic and random errors, respectively).

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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