Advanced Exercise Sciences

MetaCheck Accuracy Validation Report

May 14, 2002

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Introduction:

The MetaCheck (Korr Medical Technologies, Salt Lake City, Utah) is an instrument designed to measure Resting Metabolic Rate (RMR) using indirect calorimetry. Indirect calorimetry is a method of calculating metabolic rate from the measured the amount of oxygen consumed by the body. Using the MetaCheck mouthpiece, the individual being tested breathes in room air and the gas the person breathes out, is conveyed to the MetaCheck through the breathing hose. The MetaCheck analyzes the volumetric flow and oxygen concentration of the expired gas to determine the amount of oxygen consumed by the body due to metabolism. The accuracy of the MetaCheck device was tested using the nitrogen injection method as described in the medical and physiology literature. The references listed at the end of the report are examples of publications where this test method is described and/or applied to validate various indirect calorimetry systems.

Methods and Materials:

The accuracy of the MetaCheck was analyzed using the nitrogen injection method. In this method, a motorized piston or other device simulates patient breathing. A precisely measured flow of pure nitrogen (N2) is added to the gas that is pumped into the MetaCheck. Injecting nitrogen simulates expired air, which has a lower concentration of oxygen than fresh air. By exactly measuring and controlling the flow of nitrogen, the amount of oxygen consumed can be exactly controlled and known. In these tests, breathing was simulated using a motorized dual piston ventilator (Model 608, Harvard Apparatus, South Natick, MA). Pure nitrogen was obtained from a tank of compressed nitrogen. The flow rate of the nitrogen was verified using a precision flow standard (VT Plus, BioTek Instruments, Winooski, VT) Since the MetaCheck reports values in Standard Temperature and Pressure Dry (STPD) conditions, results were multiplied by the STPD factor as calculated by the MetaCheck. The MetaCheck barometric pressure, ambient temperature, and relative humidity measurements were verified using independent laboratory instruments to ensure that these reported values were sufficiently similar to actual ambient conditions. A wide range of breath rates were simulated by the motorized piston to ensure that the accuracy of the MetaCheck was not limited to a narrow range of breathing patterns. The simulated oxygen consumption rate relative to the ventilation was also varied over a wide range to ensure that accuracy was not limited to a narrow range of oxygen concentrations.

Results:

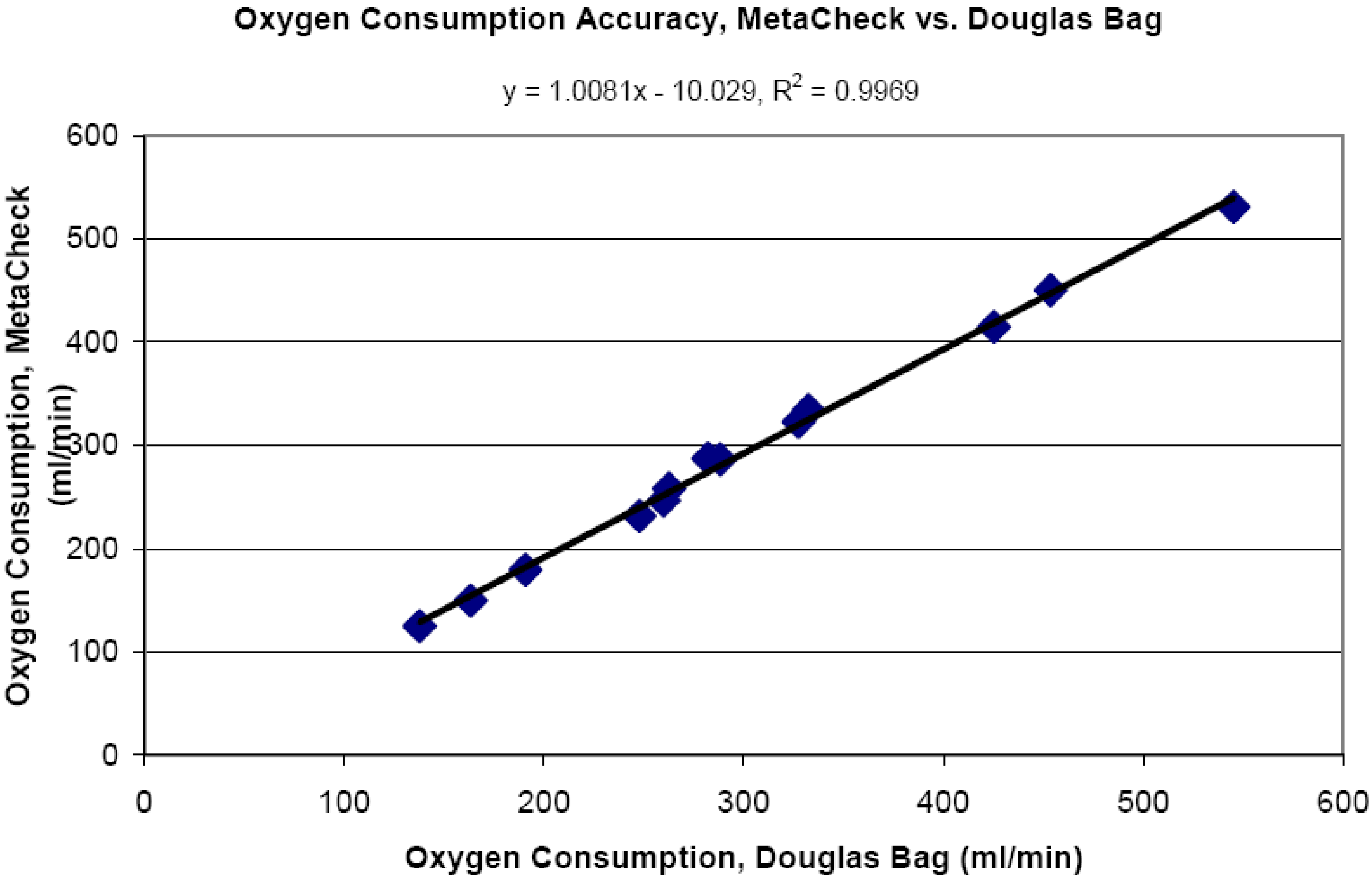
For each measurement the RMR measured by the MetaCheck and the simulated RMR was recorded. The percent difference as calculated as:

$$\%\text{Difference}=\frac{(RMR_{MetaCheck} - RMR_{Simulated}) \times 100\%}{RMR_{Simulated}}$$

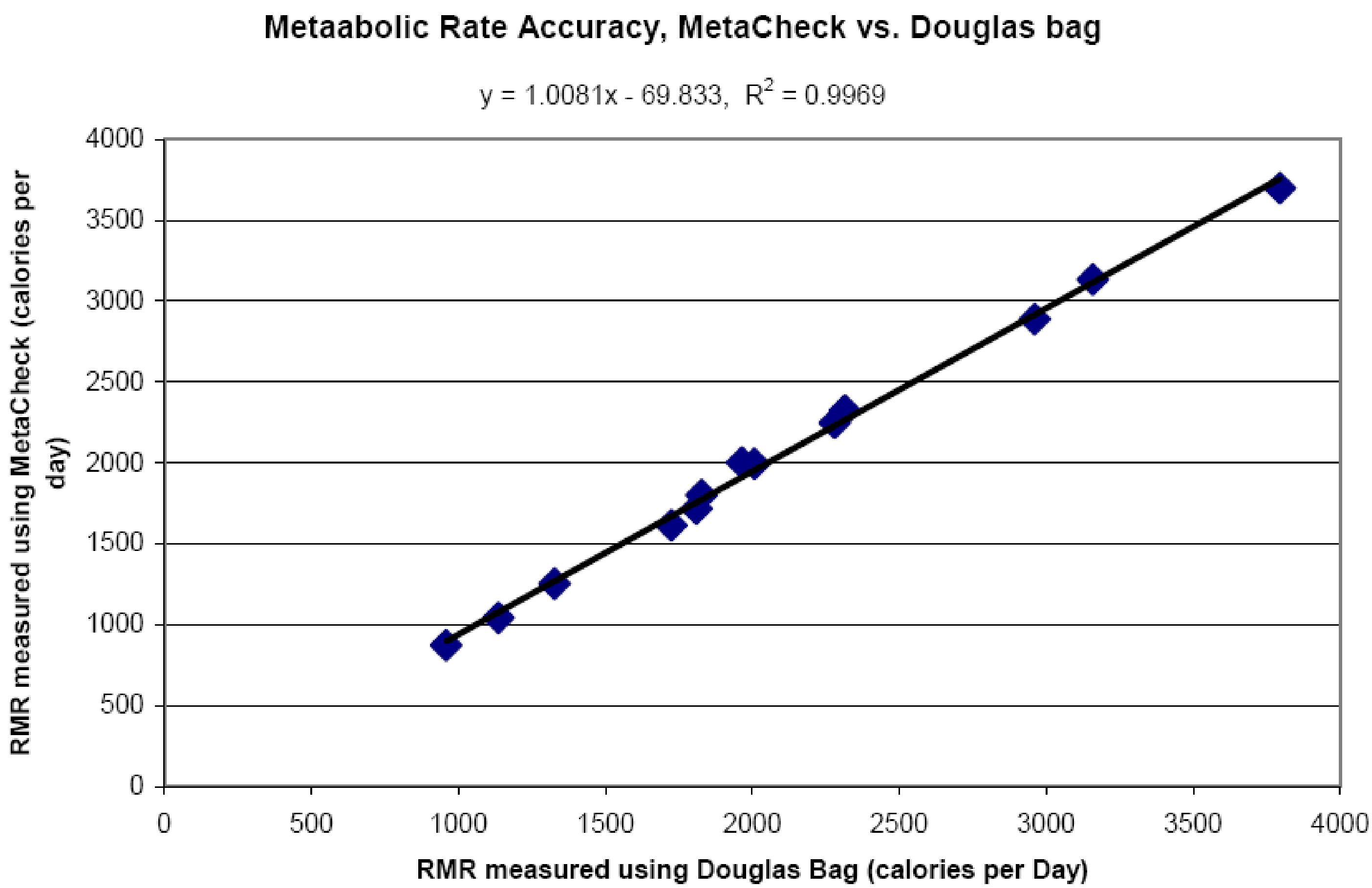
The average of the percent difference across all measurements was 0.84% (13.2 cal./day). The standard deviation of the error as 1.3% (25.8 cal./day). The Plot below shows the measured value plotted against the actual values. Regression analysis shows the correlation between the actual and measured values was r2 = 0.9992 and the factor relating the two values were near a perfect 1.0 at 1.0088.

$$\%Difference = \frac{(RMR_{MetaCheck} - RMR_{Simulated}) \times 100\%}{RMR_{Simulated}}$$

The plot below shows the percent difference of the measurements vs. the minute volume. Note that the percent difference is similarly low regardless of the simulated minute volume (minute volume is amount of air breathed in one



The next plot shows the percent difference plotted against the concentration of oxygen in the expired air. Note that the error is consistently low even at the extremes of oxygen concentration.



Inter-device Variability:
A set of five MetaCheck systems were tested to assess the variability of the results between systems. In this test, the N2 dilution technique was set up using two standard oxygen consumption and minute volume conditions. The table below shows the measured results:

Unit #	Simulated RMR	Measured RMR	error	% error
1	1392	1378	-13.9	-1.0%
2	1434	1399	-34.8	-2.4%
3	1469	1489	20.9	1.4%
4	1364	1336	-27.8	-2.0%
5	1434	1413	-20.9	-1.5%
1	2568	2561	-7.0	-0.3%
2	2624	2659	34.8	1.3%
3	2610	2610	0.0	0.0%
4	2575	2533	-41.8	-1.6%
5	2589	2589	0.0	0.0%

The average error across all units was 0.6% (9 calories per day) with a standard deviation of the error of 1.3% (24 calories per day). There is no significant difference between measurements made with different MetaCheck systems.

Long Term Stability

The MetaCheck was also tested to assess the stability of the measurements over multiple days. Simulate oxygen uptake rates were simulated at approximately the same in 10 separate tests distributed over a 22-day period. Simulations were done using the nitrogen dilution technique as discussed above. The table below lists the date of each test along with the simulated and measured oxygen consumption values.

Date	Simulated VO2 (ml/min)	Measured VO2 (ml/min)	Error (ml/min)	Percent Error
22-Apr	352	347	-5	-1.4%
24-Apr	326	326	0	0.0%
26-Apr	318	315	-3	-0.9%
30-Apr	336	337	1	0.3%
2-May	318	321	3	0.9%
6-May	323	327	4	1.2%
8-May	323	327	4	1.2%
9-May	342	344	2	0.6%
10-May	320	320	0	0.0%
14-May	339	342	3	0.9%

The average error was 0.9 ml/min (0.3%) with a standard deviation of the error of 3 ml/min (0.9%). Over the entire period of the tests, the worst case error was 1.4% of reading.

Discussion:
As can seen in the plots above, measurements reported by the MetaCheck are consistently within 2% of simulated values. This accuracy is as good as, or better than, accuracies reported in the medical literature when testing more complex indirect calorimetry devices that are used in clinical settings (see references below). The data further show that accuracy is not limited to a narrow range of breathing patterns or oxygen concentrations. The accuracy is also consistent over multiple different MetaCheck systems. Testing over multiple days showed no degradation in performance. It appears that the MetaCheck maintains excellent accuracy over time.

References:
M.C Damask., C. Weissman, J. Askanazi, A.I. Hyman, S.H. Rosenbaum, and J.M. Kinney. A systematic method of validation of gas exchange measurements. *Anesthesiology* 57:213-218, 1982

C.T. Kappagoda and R.J. Linden. A critical assessment of an open circuit technique for measuring oxygen consumption., *Cardiovascular Research*. 6:589-597, 1972

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MetaCheck Clinical Accuracy Testing Using the Douglas Bag Method

April 22, 2002

Korr Medical Technologies, Inc.

Introduction

The MetaCheck is an indirect calorimetry system that is designed to measure resting metabolic rate (RMR). The system operates by measuring the volume of oxygen consumed by the patient. Since every calorie consumed by the body requires a fixed amount of oxygen, oxygen consumed relates directly to calories burned. The MetaCheck uses an oxygen sensor and a gas flow sensor to measure oxygen consumption. The MetaCheck system auto-calibrates these sensors before each use. The microcomputer in the MetaCheck device integrates the flow and oxygen signals to calculate the rate at which oxygen is consumed. The “Douglas bag” is the “gold standard” method of validating the accuracy of oxygen consumption measuring devices, such as the MetaCheck. The Douglas Bag method uses a large, non-porous bag to collect all of the gas expired by he individual being tested. After the gas is collected, the volume, and oxygen concentration of the gas collected in the bag are analyzed. This analysis gives the total volume of oxygen in the bag. Based on the bag contents and amount of time over which the bag was filled, the rate at which oxygen was consumed can be calculated.

Methods

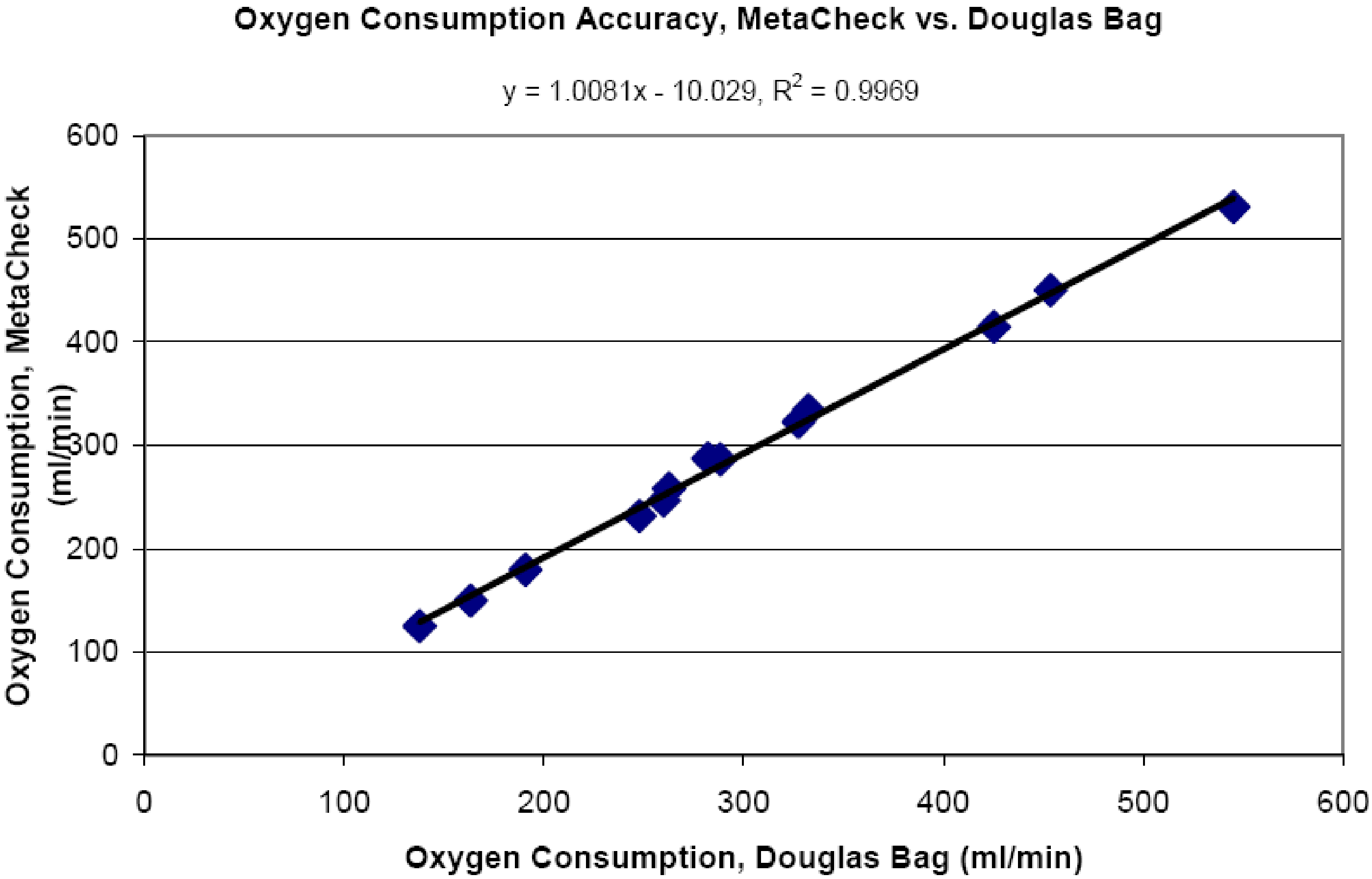
The MetaCheck system was calibrated using the standard automatic calibration before each test. Following auto-calibration, subjects breathed through a standard MetaBreather disposable airway adaptor connected to the MetaCheck system. Breathing was allowed to stabilize for at least 1 minute before data collection began. After stabilization, expired gas exiting the MetaCheck was collected in a 100 Liter Douglas Bag (Hans Rudolph P/N 112377, Hans Rudolph inc, Kansas City, MO). Oxygen consumption (VO2) for each breath along with the breath rate measured by the MetaCheck were stored digitally for each breath during the test. Expired gas was collected for at least 2 minutes and at least 20 Liters of gas was collected for each test. After the gas was collected, the bag was sealed. Average oxygen consumption for all of the breaths measured by the MetaCheck during data collection was calculated. The total time of data collection was recorded as well. The volume and ontents of the Douglas bag were analyzed following each individual's data collection. The volume was measured by drawing gas out of the bag by a vacuum pump at a fixed rate of 8 liters per minute through a precision flow measurement system (P/N RSS100-HR with Neonatal Fixed-orifice Flow Sensor P/N 101110, Hans Rudolph inc, Kansas City, MO). The gas was drawn out of the bag until a vacuum of –3 cm H2O was observed indicating that the bag had been completely emptied. The flow measurement system was set to measure expired air at room temperature and ambient barometric pressure. The average oxygen concentration of the air in the bag was measured using a gas flow analyzer (VT Plus, BioTek Instruments, Winooski, VT). The average CO2 concentration was measured using a CO2 analyzer (model 8200 Cosmo+, Novametrix Medical Systems, Wallingford, CT). The volume of oxygen inspired by the subject was calculated using the measured ambient relative humidity and temperature. Further compensation was made to account for the difference in the rate of oxygen consumption to carbon dioxide production. The oxygen consumed during the test is the difference between oxygen consumed by the subject and the volume of oxygen that was collected in the bag. The total oxygen consumed divided by the collection time gives the rate or oxygen consumption measured by the Douglas Bag method. This rate of oxygen consumption can then be compared to the average oxygen consumption rate measured simultaneously by the MetaCheck. Oxygen consumption rates were converted to metabolic rates for purposes of presenting the data.

Results

A total of 13 comparisons were made using 8 subjects. Tests were repeated in some subjects at various levels of physical activity to produce a wider range of test conditions. Measured metabolic rates ranged from 959 to 3795 calories per day. The average difference between the MetaCheck

Results

A total of 13 comparisons were made using 8 subjects. Tests were repeated in some subjects at various levels of physical activity to produce a wider range of test conditions. Measured metabolic rates ranged from 959 to 3795 calories per day. The average difference between the MetaCheck and the Douglas bag method was –3.22% (-53 calories/day). The standard deviation of the error was 3.4% (46 calories/day). The data plots below show the relationship between Oxygen consumption and metabolic rates tested using the Douglas bag and the MetaCheck. The line relating MetaCheck oxygen consumption measurements to the corresponding Douglas bag values has a slope of 1.0081 with an offset of –10 ml/min. The correlation coefficient between the two methods was R2 = 0.9969.



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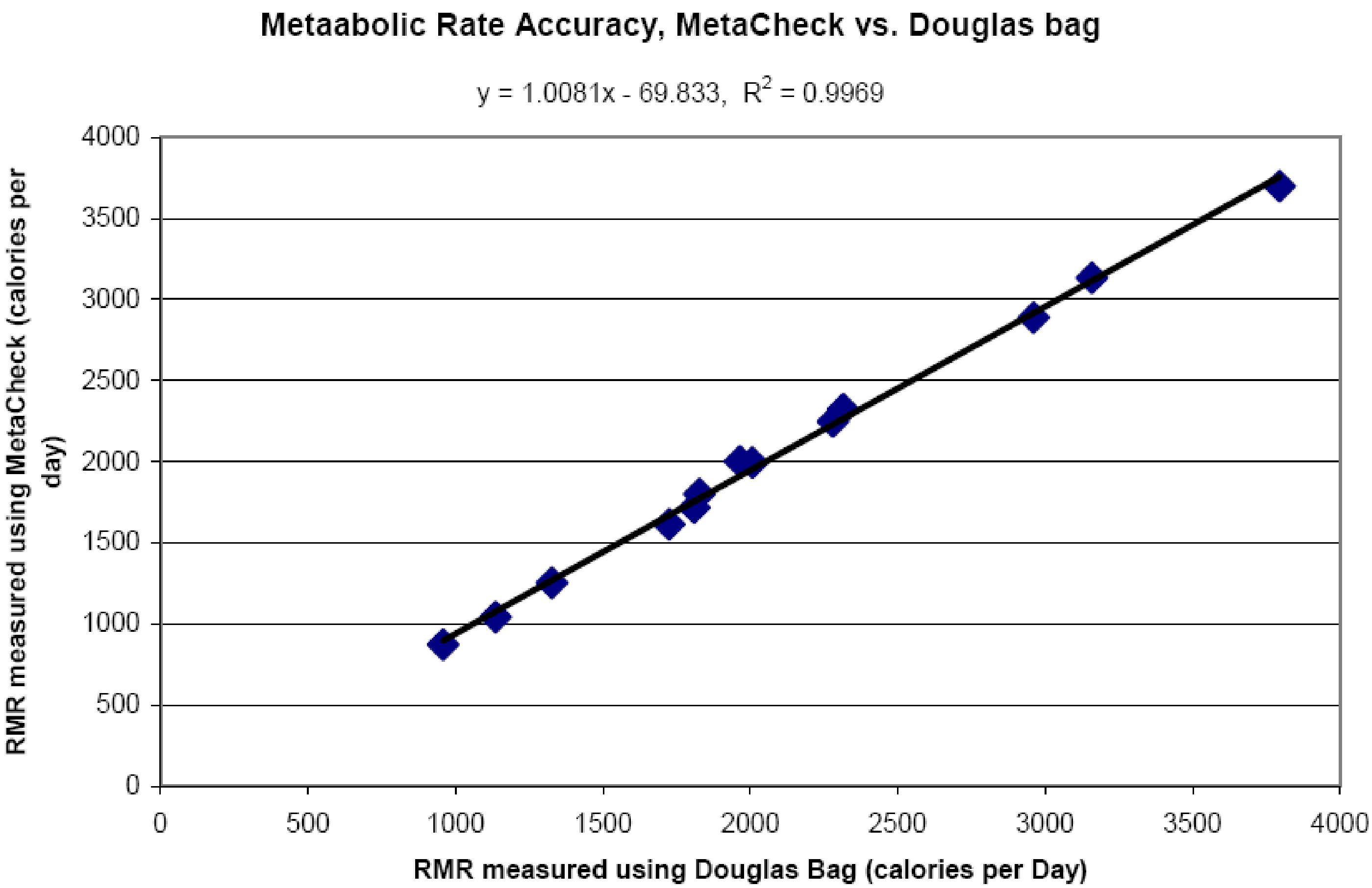

Discussion

This data shows very good agreement between the MetaCheck and the Douglas Bag method. The number of data points is small and further testing will be done in the future. However, the accuracy of this data and the range over which it was gathered, indicates that further testing should only reinforce these results. Linear regression shows a near perfect correlation between MetaCheck and Douglas bag measurements of R2 = 0.9969 and a near perfect slope factor of 1.0081. The accuracy of the MetaCheck system can be partially attributed the accuracy of the sensors. At the average expired oxygen level of 15.65% Oxygen, the “worst case” error attributable to oxygen sensor error would be 3.64% error. Since the oxygen sensor in the MetaCheck is specified to be better than 0.2%, the errors we observed may be attributable to oxygen sensor error. Competing devices claim an oxygen sensor accuracy of ±0.8%. Similar analysis of errors attributable to this level of oxygen sensor accuracy shows expected errors of 14.6% error in competing products. Another source of error is gas flow measurement. Since the MetaCheck only measures flow in one direction, errors in flow measurement do not translate into significant errors. For example, in the MetaCheck, a 2% error in flow measurement can cause an error in oxygen consumption of no greater than 2%. In some competing devices, both inspired and expired gas flow is measured. In this method, even a 1% error in flow measurement may cause errors as high as 6.7% for the competing devices.