Validation of the Bodygem™ Hand-held Indirect Calorimeter

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Abstract

Background: Indirect calorimetry using a metabolic cart is the standard by which resting metabolic rate (RMR) is measured in research settings, but this method is not practical in clinical settings.

Objective: To assess the validity and reliability of a hand-held indirect calorimeter, using measurements obtained from a standard metabolic cart as the criterion measure.

Design: RMR was measured on two mornings in 47 healthy adults. On each morning, RMR was measured using both a metabolic cart (SM-2900) and the BodyGem™ (BG) hand-held indirect calorimeter. Body composition was determined using dual-energy X-ray absorptiometry.

Results: There were no trial-to-trial differences in RMR measured by the BG (1614 ± 39 vs. 1600 ± 39 kcal·d^{-1}) or the SM-2900 (1529 ± 39 vs. 1528 ± 40 kcal·d^{-1}). Trial-to-trial intraclass reliability coefficients were acceptably high for both the BG (R=0.92, 95% CI=0.85 to 0.96) and SM-2900 (R=0.97, 95% CI= 0.94 to 0.98). RMR measured by the BG was significantly higher than that measured by the SM-2900 during both trial 1 (mean difference, 85 ± 18 kcal·d^{-1}, p=0.0001) and trial 2 (72 ± 19 kcal·d^{-1}, p=0.0001). FFM was strongly correlated with RMR measured by the BG (r=0.86, p<0.0001) and the SM-2900 (r=0.90, p<0.0001).

Conclusion: Measurements of RMR obtained with the BG hand-held indirect calorimeter compare favorably with measurements obtained with a metabolic cart, although the BG tended to produce significantly higher values. This may be in part due to the increased energy demands required to hold the BG in position.

Background

Technical specifications and operation of the BodyGem™. The BodyGem™ (Figure 1) is a low-cost, easy to use, hand-held indirect calorimeter. The principle of operation of the BodyGem™ is based on the deactivation of ruthenium in the presence of oxygen. The active and reference ruthenium cells are excited by an internal light source and fluoresce. This reaction is quenched by the presence of oxygen, and the amount of quenching is proportional to the concentration of oxygen. The oxygen sensor has a rapid, 50 msec response time, and the oxygen concentration in the flow path is sampled at 10 Hz.

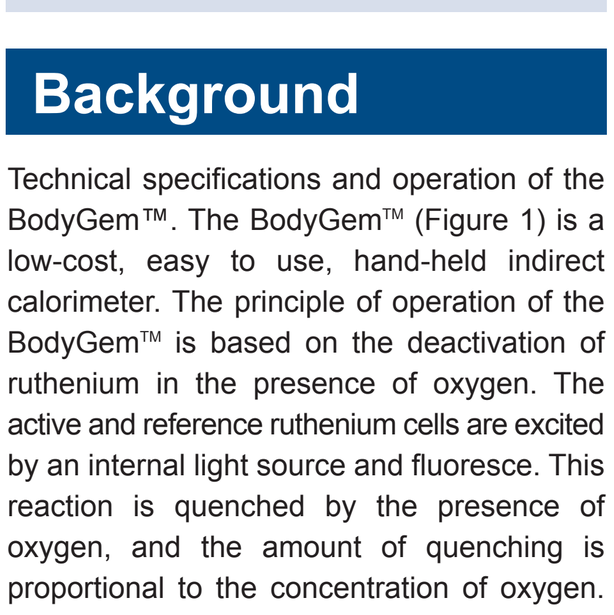

Figure 1. The BodyGem™ hand-held indirect calorimeter.

The volume of inspired and expired air is measured using ultrasonic sensing technology. A transducer at each end of the flow tube emits sound pulses, and the transmission time from the sending to the receiving transducer is increased or decreased in proportion to the rate and direction of gas flow. Inspired and expired volumes are sampled at 100 Hz.

Sensors measure relative humidity, temperature and barometric pressure for use in internal calculations. RMR is calculated from oxygen consumption and a fixed respiratory quotient (RQ) of 0.85.

The specifications for the sensors (sensitivity, resolution) are as follows: Pressure (±4 mmHg, 0.05 mmHg); Temperature (±1°C, 0.01°C); relative humidity (±4.2%, 0.01%); oxygen concentration (±0.4-0.8%, 0.03%); volume (±0.5%, 0.001 L·sec^{-1}).

Methods

Subjects Subject characteristics are listed in Table 1.

Table 1. Subject characteristics. Mean (SD).

	N	Age (yrs)	Wt (kg)	BMI (kg·m^{-2})	Body Fatness (%)
Male	14	38 (12)	84.8 (12.9)	25.9 (3.9)	24.8 (7.7)
Range		21-61	64.6 – 111.8	20.7 – 35.0	16.1 – 44.6
Female	27	42 (11)	71.5 (14.4)	26.2 (4.6)	39.1 (8.1)
Range		27-59	53.1 – 109.9	20.6 – 35.4	23.0 – 51.5

Resting metabolic rate (RMR)

- Measured on two separate mornings (between 7 and 10 AM), after a 12 h fast and at least 24 h abstention from exercise
- On each morning, RMR was measured using both the BodyGem™ and a metabolic cart (SM-2900, model 2900, Sensormedics Metabolic Cart, Yorba Linda, CA) with a ventilated canopy.
- Tests were performed in a counterbalanced order.
- SM-2900 measurements were obtained for 15-20 min. Criteria for a valid RMR was 15 minutes of steady-state (<5% variation in respiratory quotient and <10% fluctuation in oxygen consumption).
- The BodyGem™ units are programmed to begin collecting data when the first breath is detected and continue until either a steady state or 12 minutes is reached. Steady state is determined using a proprietary algorithm. In this process the data collected during the first 2 minutes of collection is not used for calculation of steady state.

Body composition: Body composition, including fat free mass (FFM), was determined using dual-energy X-ray absorptiometry (Lunar DPX-IQ bone densitometer, Lunar Corp, Madison, WI).

Results

- Measurements of RMR obtained with the BodyGem™ hand-held indirect calorimeter compare favorably with measurements obtained with indirect calorimetry coupled with the ventilated canopy technique (Figure 2). The difference between instruments was 85 ± 18 kcal·d^{-1} during trial #1 and 72 ± 19 kcal·d^{-1} during trial #2.

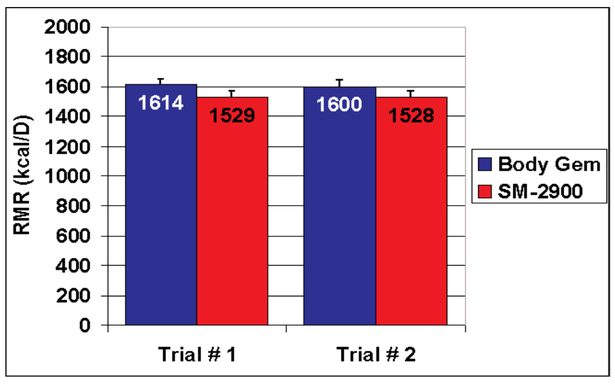

Figure 2. Comparison between the BodyGem™ and Sensormedics 2900. Mean ± SE.

- Trial-to-trial intraclass reliability coefficients were acceptably high for both the BodyGem™ (R=0.92, 95% CI=0.85 to 0.96) and SM-2900 (R=0.97, 95% CI= 0.94 to 0.98).
- Measurements obtained with the BodyGem™ were highly correlated with those obtained by the SM-2900 (Figure 3), and both systems were similarly correlated with FFM, a strong predictor of RMR (Figure 4).

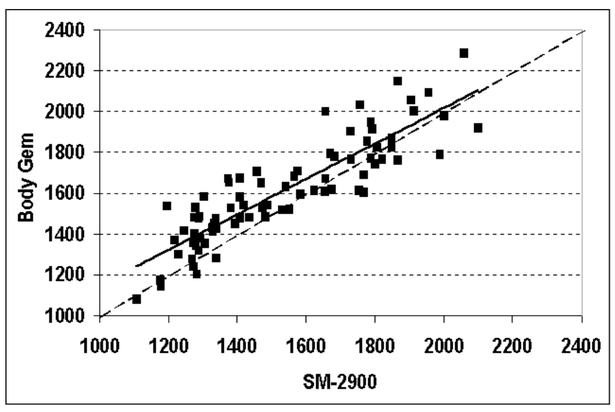

Figure 3. Relation between RMR measured by the SM-2900 and BodyGem™, all observations (n=82, r2=.79, p=<0.01). Dashed line is line of identity.

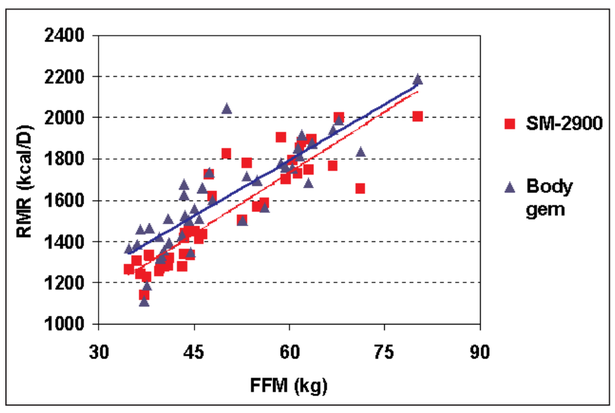

Figure 4. Relation between fat free mass (FFM) and average RMR (n=41) measured by the SM-2900 (r2=0.80, p=<0.001) and BodyGem™ (dashed line r2=0.74, p<0.0001)

- The magnitude of difference between trials with each system was positively and significantly correlated (Figure 5), suggesting that both systems detected day-to-day variations in RMR within a subject.

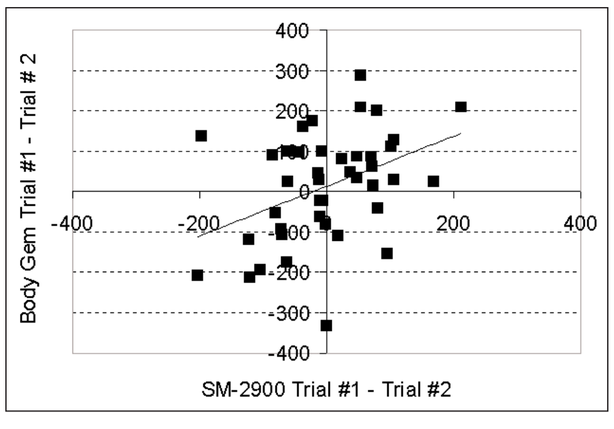

Figure 5. Relation between trial-to-trial variation measured by the BodyGemTM and SM-2900, all subjects (n=41, r2=0.16, p<0.001).

- *Post-hoc*, we hypothesized that a portion of the elevated RMR measured by the BodyGem™ may have been due to the increased energy demands required to hold the BodyGem™ in position. To test this hypothesis, 10 subjects (Table 2) performed a simulated test with the SM-2900. In 8 of the 10 subjects, RMR was higher during the simulated BodyGem™ test (average difference = 61 ± 20 kcal·d^{-1}, which was similar to the pooled difference between the BG and the SM-2900 (70 ± 15 kcal·d^{-1}). Thus, at least a portion (0.04 kcal·min^{-1}) of the difference appears to be due to the effect on RMR of holding the BodyGem™ at the mouth.

Table 2. Difference in RMR (kcal·d^{-1}) measured while holding Body Gem compared to supine resting.

Subject #	Standard RMR	Simulated Body Gem	Difference
1	1232	1344	162
2	1647	1684	37
3	1212	1180	-32
4	1274	1315	41
5	1366	1456	90
6	1533	1606	73
7	1707	1843	136
8	1243	1270	27
9	1340	1326	-14
10	1644	1734	90
Mean (SE)	1420 (61)	1481 (71)	61 (20)

- The distribution of differences between the two systems is displayed in Figure 6. Of the 82 observations, 43 (52.5%) of the measurements obtained with the BG were within ±100 kcal·d^{-1} of the SM-2900. The BG overestimated RMR measured by the SM-2900 by more than 100 kcal·d^{-1} in 34 (41.4%) of the trials. In 31 of the 47 subjects tested, BG RMR was within –99 to +200 kcal·d^{-1} on both observations (~66% of observations). Given the estimated effect on RMR due to the energy cost of holding BodyGem™ (increase ~60 kcal·d^{-1}), this suggests that in 2/3 of the subjects tested, both measurements with the BG were within ±150 kcal·d^{-1} of RMR measured with the SM-2900.

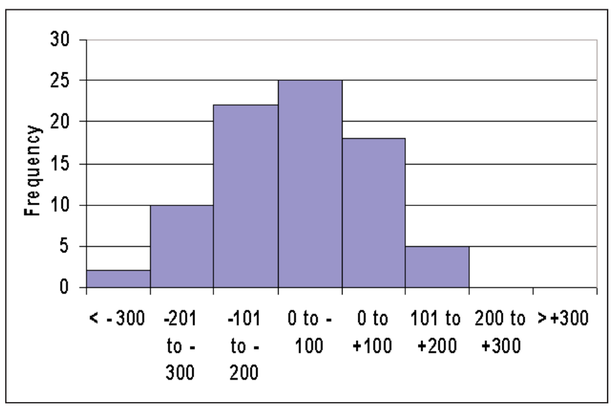

Figure 6. Distribution of differences between the BodyGem™ and SM-2900.

Conclusion

- The BodyGem provides valid and reliable measurement of RMR. The ease of use and low-cost make the BodyGem™ a viable option for measuring RMR in a clinical setting.