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Original article

A pocket-sized metabolic analyzer for assessment of resting energy expenditure

Di Zhao [a,b], Xiaojun Xian [a], Mirna Terrera [a], Ranganath Krishnan [a,c], Dylan Miller [a,b], Devon Bridgeman [a,b], Kevin Tao [a], Lihua Zhang [a], Francis Tsow [a], Erica S. Forzani [a,b,*], Nongjian Tao [a,c,*]

[a] Center for Bioelectronics and Biosensors, The Biodesign Institute, Arizona State University, United States
[b] School for Engineering of Matter, Transport, and Energy, Arizona State University, United States
[c] School of Electrical, Computer, and Energy Engineering, Arizona State University, United States

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SUMMARY

Background & aims: The assessment of metabolic parameters related to energy expenditure has a proven value for weight management; however these measurements remain too difficult and costly for monitoring individuals at home. The objective of this study is to evaluate the accuracy of a new pocket-sized metabolic analyzer device for assessing energy expenditure at rest (REE) and during sedentary activities (EE). The new device performs indirect calorimetry by measuring an individual's oxygen consumption (VO_2) and carbon dioxide production (VCO_2) rates, which allows the determination of resting- and sedentary activity-related energy expenditure.

Methods: VO_2 and VCO_2 values of 17 volunteer adult subjects were measured during resting and sedentary activities in order to compare the metabolic analyzer with the Douglas bag method. The Douglas bag method is considered the Gold Standard method for indirect calorimetry. Metabolic parameters of VO_2, VCO_2, and energy expenditure were compared using linear regression analysis, paired *t*-tests, and Bland–Altman plots.

Results: Linear regression analysis of measured VO_2 and VCO_2 values, as well as calculated energy expenditure assessed with the new analyzer and Douglas bag method, had the following linear regression parameters (linear regression slope LRS_0, and R-squared coefficient, r^2) with $p = 0$: LRS_0 (SD) $= 1.00$ (0.01), $r^2 = 0.9933$ for VO_2; LRS_0 (SD) $= 1.00$ (0.01), $r^2 = 0.9929$ for VCO_2; and LRS_0 (SD) $= 1.00$ (0.01), $r^2 = 0.9942$ for energy expenditure. In addition, results from paired *t*-tests did not show statistical significant difference between the methods with a significance level of $\alpha = 0.05$ for VO_2, VCO_2, REE, and EE. Furthermore, the Bland–Altman plot for REE showed good agreement between methods with 100% of the results within ±2SD, which was equivalent to ≤10% error.

Conclusion: The findings demonstrate that the new pocket-sized metabolic analyzer device is accurate for determining VO_2, VCO_2, and energy expenditure.

1. Introduction

The balance between energy intake and energy expenditure is key to weight management and obesity prevention in adults. An accurate assessment and tracking of total energy expenditure (TEE) can guide individuals to achieve proper energy balance.[1] To date, most end-consumer commercial devices monitor energy expenditure related to physical activity by using physical sensors, such as accelerometers and GPS-distance tracking.[2,3] While important for long-term health outcomes, physical activities typically count for less than 15% of TEE.[1] TEE also includes a small portion of energy expenditure related to food-induced thermogenesis, which is ~10%. In contrast to physical-activity energy expenditure and thermogenesis, resting energy expenditure (REE), represents the largest percentage (>75%) of TEE.[1] REE is the energy expenditure required to maintain basic body functions in a resting state, which cannot be measured by the physical sensors mentioned above. Furthermore, the physical-activity sensors are inadequate for

* Corresponding authors. Center for Bioelectronics and Biosensors at The Biodesign Institute, Arizona State University, P.O. Box 875801, Tempe, AZ 85287-5801, United States. Te: +1 480 965 9058.
E-mail addresses: Erica.Forzani@asu.edu (E.S. Forzani), Nongjian.Tao@asu.edu (N. Tao).

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monitoring low-energy physical activities, such as office work.[4,5] For these reasons, determining REE may be critically important for weight management programs.

In fact, the American Dietetic Association has strongly recommended the use of REE measures for adult weight management.[6] Various equations have been developed to calculate REE, but the accuracy of the equations is questionable, particularly for overweight and obese populations,[7] athletes, and patients undergoing weight loss.[8–11] The most widely accepted method for measuring REE is indirect calorimetry, which determines REE based on oxygen consumption (VO_2) and carbon dioxide production (VCO_2) rates using the Weir equation.[1,6] A simplified approach is to detect VO_2 alone and estimate REE by assuming a fixed ratio of VCO_2/VO_2 (0.85). The ratio between VCO_2/VO_2 is defined as the respiratory quotient (RQ), which can vary over a wide range (e.g., 0.7–1.0). Therefore, it is desirable to perform indirect calorimetry by measuring both the VO_2 consumption and VCO_2 production rates.[1] Indirect calorimetry can be performed using several methods, which include room calorimeters, metabolic carts, and the Douglas bag method,[1,12] but these methods are unsuitable for personal use at home. A handheld device and other small analyzers have been developed,[13,14] but they determine REE based on the detection of consumed VO_2 only, which is subject to the limitation discussed above.[1]

To address these limitations, the purpose of the present study is to evaluate the accuracy of a new pocket-sized metabolic analyzer (Fig. 1), which uses an integrated sensor technology for simultaneous detection of VO_2 and VCO_2, and has the ability to determine both REE, as well as energy expenditure (EE) of low-level physical activity. The device, in combination with existing commercial physical-activity energy-expenditure trackers, creates the opportunity for a more accurate assessment of TEE in free-living conditions, and therefore, individual's caloric needs.

2. Materials and methods

2.1. Subjects

Seventeen adult subjects (10 males, 7 females) from Arizona State University (ASU) voluntarily participated in the study. The study included healthy individuals and women who were not pregnant or nursing. The number of subjects was chosen based on a power calculation[15] estimated from typical mean and standard deviation values for REE.[16] Assuming a typical mean value for REE of 1800 kCal/day, with a standard deviation of 200 kCal/day (10% error), a sample size of 16 subjects allows detection of a difference in REE values (e.g. 1800 and 1600 kCal/day) with a power of 0.80. In the present study, the 17 subjects contributed with a total of 31 online measurements of energy expenditure (described below). Physical characteristics of the subjects, including fat, lean body, and muscle mass, were assessed (Table 1). The physical characteristics represented a relatively broad range, from under weight to obese: body mass index (BMI) ranged from 15.7 to 36.9 kg/m^2.[16] The study followed a protocol approved by the Institutional Review Board of Arizona State University (IRB protocol #1012005855). All subjects provided written informed consent prior to participation. The study was carried out at ASU from January 2011 to July 2011. In addition, measurements related to off-line testing involved 17 subjects and were performed at ASU from July 2011 to July 2012.

2.2. Study overview

The subjects of the study participated in the measurements as follows. Fifteen subjects participated in the REE measurement group, which refrained from structured physical activity for 24 h prior to the REE measurement, and fasted (with no beverages or caffeine) for 12 h before the REE test to avoid the diet-induced

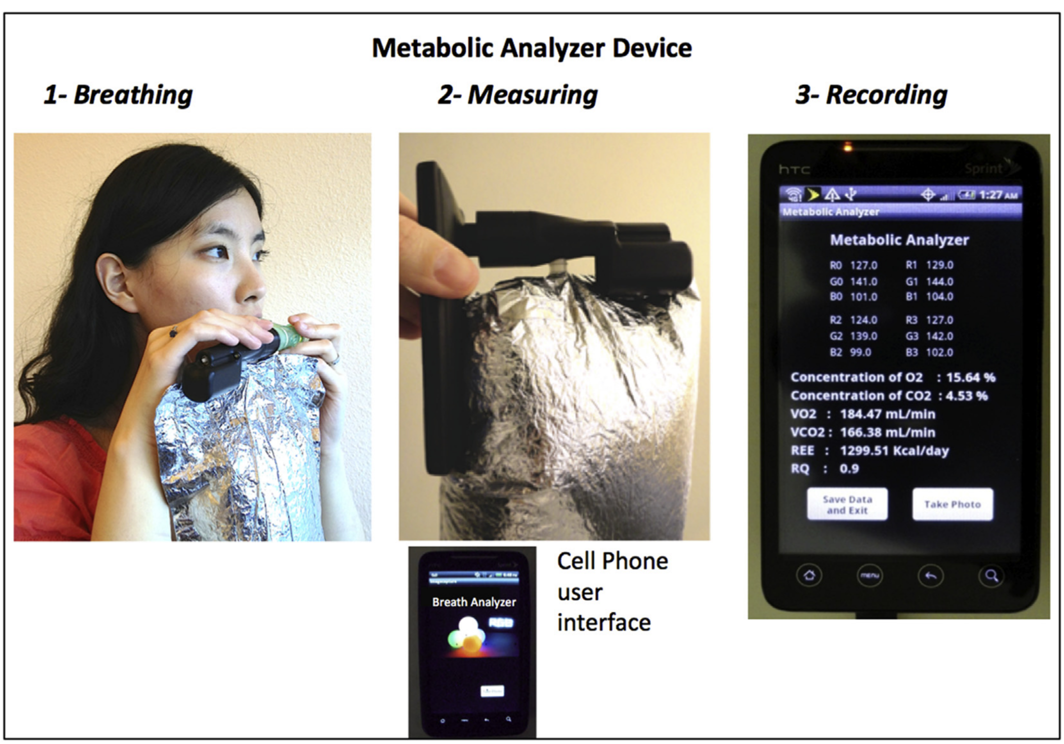

Fig. 1. Metabolic analyzer device. The device simultaneously detects the consumed oxygen and produced carbon dioxide, and the exhalation rate, from which energy expenditure is determined. It is paired to a cell-phone, which records the metabolic parameters, and track the personal metabolic history of users. Sequence of use: 1- Use of the sensor integrated mouthpiece to collect breath sample. 2- The sensor integrated mouthpiece is assembled to the cell-phone to analyze the sensor signal. 3- The user interface in the cell phone displays the results.