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Comparison between two metabolic monitors in the measurement of resting energy expenditure and oxygen consumption in diabetic and non-diabetic ambulatory and hospitalized patients

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ABSTRACT

Objective: The aim of this study was to assess the validity and reliability of the Fitmate metabolic system in measuring the oxygen consumption and resting metabolic rate (RMR) in ambulatory and hospitalized patients.
Methods: We conducted a prospective simultaneous clinical comparison. We enrolled 37 patients (19 women and 18 men) for the four groups of the study. Group 1 ($n = 12$) included patients receiving home parenteral nutrition. Group 2 ($n = 5$) included diabetic overweight outpatients with body mass index >30 kg/m^2 and hemoglobin $A_{1c} > 8$ g/dL. Group 3 ($n = 10$) included hospitalized patients receiving artificial nutrition. Group 4 ($n = 10$) included patients with congenital heart disease, pulmonary hypertension of any etiology, and other heart disease who have had hemodynamic evaluation during catheterization by the adult congenital team. The patients were tested successively during the same session using the Fitmate metabolic system for 15 min and the Deltatrac II metabolic monitor for 20 min, measuring resting energy expenditure and oxygen consumption. The test was conducted in random order.
Results: No significant differences were found between Fit Mate and Deltatrac II for oxygen consumption (238 ± 18 and 240 ± 18 mL/min, respectively, $P = 0.72$, $r = 0.86$, mean ± SD absolute difference 22.32 ± 16.99 mL/min) or RMR (1659 ± 122.34 and 1625 ± 118.4 kcal/d, $P = 0.28$, $r = 0.87$, mean ± SD absolute difference 152.9 ± 111.95 kcal/d). A degree of limit of agreement (403 kcal) was observed using the Bland-Altman test. When compared with Harris-Benedict predictive equations, Fitmate was found to be superior in accuracy.
Conclusions: These data indicate that the Fitmate using a mask provided a fair evaluation of REE despite a large limit of agreement. It remains a reliable and valid system for measuring oxygen consumption and RMR in nonventilated patients.

Introduction

Total energy expenditure (EE) comprises the basal metabolic rate, thermic effect of food, and thermogenesis from activity and exercise [1]. The basal metabolic rate is usually derived from formulas that have been in use for nearly 100 y [2,3]. However, although these formulas may be accurate for normal healthy volunteers, they are not accurate in older individuals and in disease states [4,5]. Therefore, measurement of resting energy expenditure (REE) remains the gold standard to increase accuracy in the determination of energy requirements. Additionally, if the measurements are used to target nutritional support, outcome can be improved [6]. Today, the devices available to measure REE accurately require specialized professionals and sophisticated methodologies that are costly and cumbersome to conduct. For this reason, most clinicians use the formulas and do not actively measure REE in their patients.

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Advances in technology have led to the development of new portable devices that allow for easier measurement of REE and with lower cost. The Fitmate (Cosmed, Roma, Italy) is a metabolic analyzer designed to measure oxygen consumption and REE. It uses a turbine flow meter for measuring minute ventilation and a galvanic fuel cell oxygen sensor for analyzing the fraction of oxygen in expired gases, incorporating an innovative technology. Taking a value of 0.85 for the respiratory quotient (RQ), the Weir equation uses only the oxygen consumption (VO_2; kcal/min) measurement. Using this approach and assuming the greatest error to be 2.3%, this approach is reaching high precision.

We conducted a validation study comparing the Fitmate with the Deltatrac II metabolic monitor, which is considered the reference tool, and assessed the validity and reliability of the Fitmate metabolic system in measuring REE.

Material and methods

A prospective, compared single-center study was performed at the Rabin Medical Center in Petah-Tikva, Israel. The study protocol was approved by the local ethics (Helsinki) committee and informed consent was obtained from all participants. Patients were recruited according to inclusion (>18 y of age and signed an informed consent) and exclusion criteria (pregnancy, mechanical ventilation, or receiving oxygen supplementation).

Four groups of patients were tested:

Group 1: Patients receiving home parenteral nutrition.
Group 2: Diabetic overweight outpatients with body mass index (BMI) > 30 kg/m^2 and hemoglobin (Hb)A_{1c} > 8 g/dL.
Group 3: Hospitalized patients receiving artificial nutrition.
Group 4: Patients with congenital heart disease, pulmonary hypertension of any etiology, or any other heart disease who were undergoing hemodynamic evaluation during catheterization (measurement of oxygen consumption required for the Fick Formula of flow calculation).

Design

Patients were tested during the same session using the Fitmate and Deltatrac II, in randomized order. Measurements were conducted while patients remained seated and at the same time of day to reduce the effects of diurnal variation. No sustained exercise was performed for the 24 h before the study. Age, sex, height, weight, BMI, and predicted EE using the Harris-Benedict formulas were noted.

Fitmate testing procedure

The Fitmate uses a turbine flow meter for measuring minute volume and a galvanic fuel cell oxygen sensor for analyzing the FeO2 fraction of oxygen in expired gases (FeO_2). Sensors in the device measure temperature and barometric pressure for use in internal calculations. Calculation of REE is obtained by using a fixed RQ of 0.85 [7–10]. The Fitmate, a portable battery-operated device, weighs 1.5 kg and has a built-in color display and graphic printer. It also can be connected to a PC for data download. No warm-up time is required. If the mask applied to the face of the patient is not well adapted, a warning is displayed. The device performs self-calibration. The VO_2, REE, and minute ventilation are recorded after 15 min of steady state, as shown in Table 1.

Deltatrac II testing procedure

The Deltatrac II metabolic monitor includes an infrared carbon dioxide analyzer while a fast differential paramagnetic oxygen analyzer and constant flow generator are integrated into this open system and connected to the canopy hood. The Deltatrac II is calibrated by a quantitative alcohol burning process as described in the technical manual. Before each measurement, the Deltatrac II is allowed to warm up for 60 min, following which gas and pressure calibrations are performed according to the manufacturer's instructions. The FiO_2, REE, VCO_2, and RQ are recorded after 20 min of steady state [10,11], as shown in Table 1.

Table 1
VO_2, VCO_2, RQ, REE and minute volume calculated using the two devices

	VO_2	VCO_2	RQ	REE	Minute volume
Fitmate	+	−	0.85 as a given value	+	+
Deltatrac II	+	+	+	+	−

REE, resting energy expenditure; RQ, respiratory quotient; VCO_2, carbon dioxide production; VO_2, oxygen consumption

Table 2
Study participants' characteristics

Variable	Mean ± SE	Range
Age (y)	48 ± 16	18–78
Body mass (kg)	68 ± 20	35–114
Stature (cm)	167 ± 9.5	150–183
Body mass index (kg/m^2)	24.1 ± 5.8	15.1–43.2

Statistical analysis

Statistical analysis was performed using Statistics for Windows, v 7.5. The agreement between the gold standard Deltatrac II measurement and the Fitmate metabolic module was assessed according to a previously described method [12]. The mean difference between the two methods (bias) and the SD of the differences were calculated, as well as the error (double SD divided by the mean of the measurements of SD). A priori we defined as 30% or less as acceptable between the methods, according to a previously described process [13]. Statistical significance was set at $P \leq 0.05$ level and values are presented as mean ± SD. The frequency (%) of EE estimates, using the different methods of Harris-Benedict or Fitmate, to assess EE to within 80% and 110% of REE was calculated. The number of estimates that were <80% and >110% of REE measured by Deltatrac II also were calculated. The ratio of Fitmate to Deltatrac II and Harris-Benedict to Deltatrac II, as well as the differences, were calculated for each patient. Comparisons between the two methods were made (means procedure).

Results

In all, 37 participants (18 men and 19 women) were recruited and completed the study. Participant characteristics are presented in Table 2. The patients reflected the population profile of individuals requiring EE assessment or VO_2 assessment.

REE

The readings for REE are presented in Table 3, Table 4, and Figure 1. Deltatrac II was used as the reference measurement. There were no differences in mean REE measurements between Fitmate and Deltatrac II ($P = 0.3$). The Bland-Altman test showed a mean EE difference (2 SD) of −33.8 (335 to −403) kcal between Deltatrac II with canopy and FitMate with mask. There was no systematic over- or underestimation using Fitmate. The EE differences were symmetrically distributed along the line of equality, demonstrating that the errors were not influenced by low or high EE and showed good limits of agreement. The range of values was high, giving a relative precision to the Fitmate mask method. These limits of agreement are shown in Figure 1, using the Bland Altman diagram.

The Harris-Benedict predictive equation result was compared with the measurement obtained by Fitmate in relation to the Deltatrac II measurement. Using the means procedure, there were more Harris-Benedict predictions in the 5% and the 95% percentile than Fitmate measurements (Table 5). When the results were assessed in terms of values within the 80% to 110% optimal values, more values ($P < 0.004$) were within this range

Table 3
Results of REE calculations and VO_2 measurements using the two devices

	Deltatrac II	Fitmate	Harris-Benedict	
REE kcal/d	1625 ± 360	1659 ± 372	1490 ± 275	$P = 0.3$
VO_2 mL/min	240 ± 55	238 ± 53	Not applicable	NS

REE, resting energy expenditure; NS, not significant; VO_2, oxygen consumption