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VALIDATION OF COSMED'S FITMATE™ IN MEASURING OXYGEN CONSUMPTION AND ESTIMATING RESTING METABOLIC RATE

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*The purpose of this study was to assess the validity and reliability of the FitMate™ metabolic system (Cosmed, Rome, Italy) in measuring oxygen consumption and estimating resting metabolic rate (RMR). The FitMate™ is a new, small (20 × 24 cm) metabolic analyzer designed for measurement of oxygen consumption and energy expenditure during rest and exercise. Subjects included 60 healthy adults (*N *= 30 males,* N *= 30 females) ranging in age from 19 to 65 years (mean ± SD age, 36.9 ± 13.4 years) and body mass index (BMI) from 19.2 to 44.8 kg/m*^{2} *(27.7 ± 6.2 kg/m*^{2}*). Subjects were given two 10 min RMR tests in one test session during which RMR was measured simultaneously with the Douglas bag and FitMate™ systems. No significant differences were found between Douglas bag and FitMate™ systems for oxygen consumption (242 ± 49 and 240 ± 49 ml/min, respectively,* P *= 0.066,* r *= 0.97, mean ± SD absolute difference 2.83 ± 11.68 ml/min) or RMR (1,662 ± 340 and 1,668 ± 344 kcal/day,* P *= 0.579,* r *= 0.97, mean ± SD absolute difference 5.81 ± 80.70 kcal/day). These data indicate that the FitMate™ is a reliable and valid system for measuring oxygen consumption and RMR in adults.*

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INTRODUCTION

Energy expenditure is commonly divided into three components: resting metabolic rate (RMR), physical activity or activity thermogenesis, and diet-induced thermogenesis (Donahoo, Levine, and Melanson 2004; Ravussin and Bogardus 1992). Resting metabolic rate is the largest single component of total daily energy expenditure for most people, and assessment has improved understanding of the pathophysiology of obesity (Frankenfield, Roth-Yousey, and Compher 2005).

The accurate measurement of RMR typically requires skilled technicians and sophisticated methodologies that are costly and cumbersome to conduct. For these reasons, RMR measurement is impractical in most clinical and community settings. Resting metabolic rate prediction equations use easily obtained variables such as age, stature, and body mass, but unfortunately only 50% to 75% of the variability in RMR is explained by these equations (Institute of Medicine 2002; Wang et al. 2001). Additionally, RMR prediction equations systematically misclassify obese children and adults, critically ill patients, and individuals with eating disorders (Ahmad et al. 1999; da Rocha et al. 2005; Luhrmann and Neuhaeuser 2004; Scalfi et al. 2001).

Advancements in technology have led to the development of new portable devices for RMR measurement that are less costly and easier to use than metabolic carts and other traditional equipment. For example, HealtheTech Inc. (Golden, CO) developed a handheld metabolic device called the BodyGem™ that has been shown to be accurate when compared with the Douglas bag system and other standards (Melanson et al. 2004; Nieman et al. 2005; Nieman, Trone, and Austin 2003; St-Onge et al. 2004).

Cosmed recently developed the FitMate™, a small (20 × 24 cm) metabolic analyzer designed for measurement of oxygen consumption and energy expenditure during rest and exercise. The FitMate™ uses a turbine flowmeter for measuring ventilation and a galvanic fuel cell oxygen sensor for analyzing the fraction of oxygen in expired gases, and incorporates an innovative sampling technology. We devised a validation study comparing the FitMate™ with the Douglas bag system, and assessed the validity and reliability of the FitMate™ metabolic system in measuring RMR.

METHODS

Subjects

Male ($N = 30$) and female ($N = 30$) subjects between the ages of 19 to 65 years were recruited from the surrounding community through advertisement.

Testing procedures were approved by the university's Institutional Review Board prior to the beginning of the study, and subjects voluntarily gave consent.

Design

Subjects were tested in one session during which two 10-minute RMR measurements were made simultaneously using the FitMate™ and Douglas bag systems. Test sessions for all subjects were at the same time of the day (late afternoon) to reduce the effect of diurnal variation. Subjects fasted and avoided caffeinated beverages for at least 4 hours and abstained from strenuous exercise for 24 hours prior to each appointment.

Stature and body mass were measured, and then the subjects sat quietly for 10 minutes prior to RMR measurement. Subjects remained seated for the duration of the testing period and were asked to remain awake and relaxed.

Douglas Bag Testing Procedures

Douglas bag collections of expired gases were made for 10 minutes using a mouthpiece connected to a Hans-Rudolph small 2-way valve (Hans-Rudolph Inc., Kansas City, MO) and noseclip. Subjects were connected to the collection apparatus for 2 minutes prior to starting gas collection to ensure that all dead space in the valves and tubing was flushed with expired gas. Expired gas fractions were analyzed using an Applied Electrochemistry S-3A oxygen analyzer and an Applied Electrochemistry CD-3A carbon dioxide analyzer (AEI Technologies, Applied Electrochemistry, Pittsburgh, PA). The analyzers were calibrated using a two-point method with outside air and medical grade primary standard gases containing 16.0% O_2 and 4.0% CO_2 (Matheson Tri-Gas, Parsippany, NJ). Expired gas volumes were measured using a Rayfield RAM 9200 air flowmeter (Waitsfield, VT) calibrated against a Tissot spirometer. Resting metabolic rate in $\text{kcals} \cdot \text{day}^{-1}$ was estimated using theWeir equation (1949): 1

$$\text{RMR } (\text{kcals} \cdot \text{day}^{-1}) = 5.675 \times \text{VO}_2 + 1.593 \times \text{VCO}_2 - 21.7$$
$$(\text{VO}_2 \text{ and VCO}_2 \text{ are ml} \cdot \text{min}^{-1}).$$

FitMate™ Testing

The FitMate™ is a new, small (20 × 24 cm) metabolic analyzer designed for measurement of oxygen consumption and energy expenditure during rest and exercise (Cosmed, Rome, Italy). It uses a turbine flowmeter for measuring ventilation and a galvanic fuel cell oxygen sensor for analyzing the fraction of oxygen in expired gases, and it incorporates a patent pending innovative sampling technology that allows the FitMate™ to retain the performance of a metabolic cart with a standard mixing chamber. Sensors measured humidity, temperature, and barometric pressure for use in internal calculations. The FitMate™ uses standard metabolic formulas to calculate oxygen uptake, and energy expenditure is calculated using a fixed respiratory quotient (RQ) of 0.85. A sample line from the FitMate™ was connected to a 3-way valve in the Douglas bag system to allow simultaneous sampling of expired air from the subjects.

Statistical Analysis

FitMate ™ and Douglas bag oxygen consumption and RMR measurements were compared using paired *t* tests with Bland-Altman plots used to show the difference scores between methods (Douglas bag—BodyGem™) over the complete range of measured oxygen uptakes and RMR. Test-to-test reliability was calculated using Pearson product-moment coefficients. Standard estimates of error (SEE) were calculated with this equation: $SEE = SD_{DB}\sqrt{1-r^2}$ (SD_{DB} = the standard deviation from the Douglas bag test data). Statistical significance was set at the $p \leq 0.05$ level, and values were expressed as mean ± SD.

RESULTS

Sixty subjects (30 males and 30 females) completed all phases of the study. Subject characteristics are reported in Table 1, with data summarized for age, stature, body mass, and BMI (kg/m^2). Age ranged from 19 to 65 years. Body mass index did not differ between genders, and ranged from 19.2 to 44.8 kg/m^2, with 42% of subjects having a BMI <25 kg/m^2, 21% 25–29.9 kg/m^2 (overweight), and 37% ≥ 30 kg/m^2 (obese).

No difference was found between males and females for the primary outcome measures, and the data are presented for all subjects combined

Table 1. Subject Characteristics for Male (*n* = 30) and Female (*n* = 30) Subjects (mean ± SD)

Variable	Males	Females	*P* value
Age (yrs)	33.9 ± 13.4	39.8 ± 12.9	0.089
Stature (m)	1.77 ± 0.07	1.65 ± 0.04	<0.001
Body mass (kg)	86.5 ± 17.8	75.6 ± 17.1	0.018
Body mass index (kg/m^2)	27.6 ± 5.4	27.8 ± 7.0	0.887

(Table 2 and Figure 1). No significant differences were found between Douglas bag and FitMate™ systems for oxygen consumption (mean of both tests, 242 ± 49 and 240 ± 49 ml/min, respectively, $P = 0.066$, $r = 0.97$, mean ± SD absolute difference 2.83 ± 11.68 ml/min) or RMR (1,662 ± 340 and 1,668 ± 344 kcal/day, $P = 0.579$, $r = 0.97$, mean ± SD absolute difference 5.81 ± 80.70 kcal/day). Standard error of estimates for oxygen consumption and RMR were 11.5 ml/min and 79.9 kcal/day, respectively. No significant differences were found between Douglas bag and FitMate™ systems for FeO_2 or ventilation (Table 2). $FeCO_2$, respiratory exchange ratio (RER), and respiratory rate (RR) data are summarized in Table 2 for descriptive purposes but could not be compared between systems.

Test-to-test reliability correlation coefficients for oxygen consumption for the FitMate™ and Douglas bag systems were $r = 0.94$ and $r = 0.95$, respectively. The RMR difference between the Douglas bag and FitMate™ systems was not significantly correlated with BMI ($r = 0.12$, $P =$

Table 2. Comparison of Oxygen Consumption (VO_2), Resting Metabolic Rate (RMR), and Other Metabolic Values Between the FitMate™ and Douglas Bag Methods During 2 Comparison Tests (*n* = 60 All Subjects Combined)

	Test 1	Test 2	*P* value*
VO_2 ($ml \cdot min^{-1}$)			
FitMate	240 ± 51	239 ± 50	0.066
Douglas bag	242 ± 48	243 ± 51	
RMR ($kcal \cdot day^{-1}$)			
FitMate	1672 ± 352	1665 ± 345	0.579
Douglas bag	1654 ± 333	1671 ± 357	
FeO_2 (%)			
FitMate	16.8 ± 0.6	16.9 ± 0.6	0.178
Douglas bag	16.7 ± 0.6	16.8 ± 0.6	
Ventilation ($l \cdot min^{-1}$)			
FitMate	7.60 ± 1.64	7.80 ± 1.78	0.270
Douglas bag	7.51 ± 1.58	7.78 ± 1.78	
			Mean ± SD (of two tests)
$FeCO_2$ (%)			
Douglas bag	3.53 ± 0.49	3.52 ± 0.53	3.53 ± 0.50
RER			
Douglas bag	0.78 ± 0.05	0.81 ± 0.05	0.80 ± 0.05
RR ($breaths \cdot min^{-1}$)			
FitMate	12.7 ± 3.6	12.4 ± 3.8	12.5 ± 3.6

VO_2 = volume of oxygen consumed; RMR = resting metabolic rate; FeO_2 = fraction of expired oxygen; $FeCO_2$ = fraction of expired carbon dioxide; RER = respiratory exchange ratio; RR = respiratory rate.

* *P* value is for both tests combined when comparing FitMate™ and Douglas bag systems.

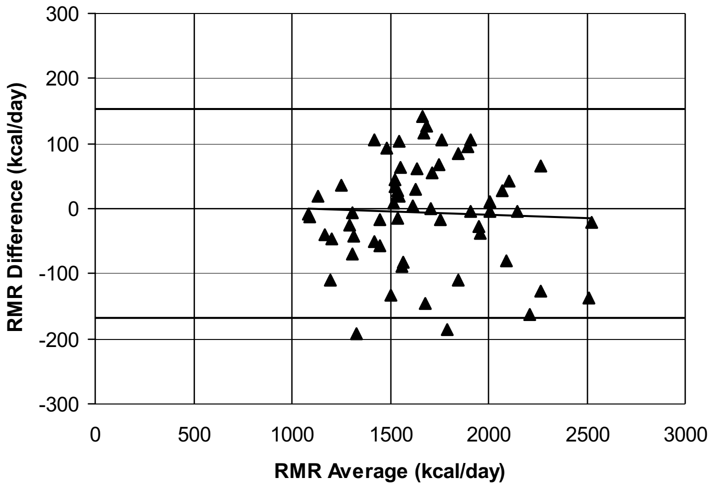

Figure 1. Bland-Altman plot depicting absolute differences in resting metabolic rate values between the Douglas bag and FitMate™ methods versus mean values (*n* = 60). The solid lines depict plus and minus 2 standard deviations from the mean difference (–5.81 ± 80.7 kcal/day). The sloped line within the data represents the linear trend of the data.

0.180), indicating no difference in RMR estimation at the lower and higher BMI levels. A Bland-Altman plot was used to show the difference scores between methods (Douglas bag—FitMate™) over the complete range of measured RMR (Figure 1). The RMR difference between the Douglas bag and FitMate™ systems was not significantly correlated with the RMR average ($r = -0.04$, $P = 0.375$), indicating no difference in RMR estimation between systems at the lower and higher RMR levels.

DISCUSSION

The purpose of this study was to compare the Douglas bag method with the FitMate™, a small, portable device used to measure oxygen consumption and RMR. The data from a heterogeneous group of 60 male and female adults indicated that the FitMate™ gave reproducible and accurate oxygen consumption and RMR measurements when compared with the Douglas bag method. When the two measurements for each method were averaged and compared, mean differences for oxygen consumption and RMR were small, and no systematic difference was found across the range of values or BMI levels. This indicates that testing with the FitMate™ will give acceptable RMR measurements for a wide range of adults.

When the Douglas bag and FitMate™ tests were combined, the SEE 2 for oxygen consumption and RMR were 11.5 ml/min and 79.9 kcal/day, respectively, relatively low values when compared with results from other 3 devices (Melanson et al. 2004; Nieman et al. 2003; St-Onge et al. 2004). The RMR measurements were made simultaneously using the FitMate™ and Douglas bag systems, and this design minimized variation due to extraneous factors.

Other portable metabolic devices have been developed for measurement of oxygen consumption, but have not been validated for use in RMR testing (King et al. 1999; McLaughlin et al. 2001; McNaughton et al. 4 2005). These portable metabolic devices were developed primarily for exercise testing and research, and thus are expensive and require skilled technicians. The FitMate™, in comparison, was developed for RMR and exercise testing, is inexpensive and easy to operate, and can be used by a wide variety of health and fitness professionals. The portable metabolic systems contain both oxygen and carbon dioxide analyzers, while the FitMate™ includes an oxygen analyzer but no carbon dioxide analyzer, estimating RMR by assuming a respiratory quotient of 0.85. This assumption, however, introduces little error in estimating RMR, as verified in previous studies in our laboratory (Nieman et al. 2005; Nieman et al. 2003).

We did not design this study to compare FitMate™ RMR measurements with RMR estimates from prediction equations. Nonetheless, our data indicate that RMR can vary substantially between individuals of the same age and BMI, highlighting the importance of direct RMR measurement. The RMR prediction equations using stature, body mass, and age introduce considerable error even when adjusted for FFM, and this may, in part, be genetically determined (Frankenfield et al. 2005; Heymsfield, Gallagher, and Wang 2000; Tataranmi and Ravussin 1995). Thus estimating RMR from equations has limited predictive value for the individual (da Rocha et al. 2005; Luhrmann and Neuhaeuser 2004). Additionally, estimation of RMR from FFM introduces the need for body composition measurements using DEXA, skinfolds, or hydrodensitometry, negating the time advantage of using prediction equations.

These findings indicate that the FitMate™ gives accurate and reproducible oxygen consumption and RMR measurements for nonobese and obese male and female adults. These results support the use of the FitMate™ by health and fitness professionals for measuring RMR.

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