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Resting energy expenditure assessment in anorexia nervosa: comparison of indirect calorimetry, a multisensor monitor and the Müller equation

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Abstract
The aim of this study was to compare the estimations provided by three different means of measuring the resting energy expenditure (REE) in anorexia nervosa (AN) patients. REE was measured, after 24 h of refeeding, using a portable multisensor body monitor [SenseWear Pro2 Armband (SWA)], FitMate™ method and the Müller equation for individuals with body mass index <18.5, the latter being based on dual-energy X-ray absorptiometry assessment of body composition. The mean differences between REE values estimated by SWA and those provided by the Müller equation and the FitMate™ method were significantly different from zero in both cases. In contrast, the mean differences between FitMate™ method and Müller equation were weakly significantly different from zero, and a significant correlation was noted between these two methods. In conclusion, the SWA does not appear to be an alternative to FitMate™ and Müller equation methods for assessing REE in AN patients.

Keywords: *eating disorders, body composition, portable armband*

Introduction

Anorexia nervosa (AN) is a common health problem afflicting mainly female adolescents and young women. It is associated with important physical health and psychosocial morbidity, and carries increased risk of death (Dalle Grave 2011).

Assessment of resting energy expenditure (REE) plays an important role in the management of severely underweight AN patients. It consents quantification of the energy necessary to optimize nutritional rehabilitation, with the aim of restoring weight while preventing serious medical complications such as refeeding syndrome (Tresley and Sheean 2008). The most widely accepted method of measuring REE (Matarese 1997) is indirect calorimetry (IC), which is generally performed with the subject in a supine position after an overnight fast. Common IC techniques used for measuring REE are room open-circuit, hood/canopy open-circuit, open-circuit expiratory collection and Douglas bag (Levine 2005). The accuracy of the measurements obtained by these techniques varies enormously with regard to complexity and cost. The most important limitation of these methods is their scarce availability in standard clinical setting since they require skilled technicians and sophisticated instrumentation, making it costly and difficult to apply (Cuerda et al. 2007).

Predictive formulae of REE, based on age, stature and body weight (Harris and Benedict 1919), are therefore widely used by clinicians as an alternative to IC, but these unfortunately tend to overestimate REE in AN patients (Krahn et al. 1993; Schebendach et al. 1995; Marra et al. 2002; Cuerda et al. 2007).

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To overcome this problem, Müller et al. (2004) developed formulae for different ranges of body mass index (BMI), one being BMI <18.5, based on fat-free mass (FFM) and fat mass (FM) values assessed by means of dual-energy X-ray absorptiometry (DXA). Compared with the Douglas bag method, the Müller et al.'s equation was found to yield an acceptable REE estimation in AN patients (El Ghoch et al. 2012).

Technological advances have recently provided relatively inexpensive means of estimating REE, such as the FitMate™ device (Nieman et al. 2006), based on measurement of oxygen consumption alone. These devices can facilitate the use of IC in clinical settings and FitMate™ in particular was found to be accurate compared with the Douglas bag system in normal, overweight and obese subjects (Nieman et al. 2006), and in 15 AN patients after 1 day of refeeding (El Ghoch et al. 2012).

Technological tools designed to monitor exercise can also be used to indirectly estimate REE through specific algorithms, for instance the SenseWear Pro2 Armband (SWA), a portable device that monitors various physiological parameters (heat flux, skin temperature, galvanic skin response and near body temperature) and movement (accelerometer; Papazoglou et al. 2006). This is potentially useful in patients with AN because, as well as providing a measure of REE, it can signal the presence of excessive exercising, behaviour commonly observed in these patients (Dalle Grave et al. 2008b). However, to date, no study has validated SWA as a means of measuring REE in AN patients.

Thus, the aim of this exploratory study was to compare the REE measurements obtained using SWA with those yielded by both the FitMate™ and the Müller et al.'s equation in assessing REE in a sample of AN patients admitted to a specialist inpatient unit for eating disorders.

Subjects

Thirty-nine female subjects with AN voluntarily and consecutively admitted to the eating disorder inpatient unit of Villa Garda Hospital during the years 2010 and 2011 were recruited for this study. The patients were referred to the unit from all over Italy by general practitioners or outpatient eating disorder specialists. Diagnosis of AN was made, according to operational DSM-IV definitions (American Psychiatric Association 2000), by means of the Eating Disorder Examination (EDE 12.0D) interview (Fairburn and Cooper 1993).

Informed written consent was obtained from all the subjects (or their legal guardians in the case of patients <18 years old, in accordance with our institutional requirements). The protocol employed was approved by the Institutional Review Board of Villa Garda Hospital (Verona, Italy).

Measurements

Data were collected on the third day of admission after 24 h of refeeding, with a diet of 1.500 kcal (carbohydrate 50%, protein 20% and fat 30%) composed of conventional foods and divided into four standard meals. Feeding was supervised by a dietician specialized in the treatment of eating disorders (Dalle Grave et al. 2008a).

Body height and weight. Before breakfast, body weight was measured with a monthly calibrated digital scale (SECA) to the nearest 0.05 kg in underwear. The subjects in light clothes, shoes off, were standing still in the middle of the scale's platform. Height was measured with a wall mounted stadiometer to the nearest 0.1 cm, calibrated on wall installation and recalibrated yearly. The subjects were standing with heels together, arms to the side, legs straight, shoulder relaxed and head in the horizontal plane (look straight ahead). Measurements were done by the same physician involved in this study. The BMI was determined according to the usual formula of body weight divided by the square of the height in metres.

Body composition. Body composition was assessed on the third day before breakfast using DXA (iDXA Luner General Electric GE Healthcare, Milan, Italy). No special preparation was involved, except for ascertaining that participants wore lightweight clothing and removed any metal jewellery or accessories. Subjects were lying on the DXA scanner bed and were positioned within the scanning area in a supine position with the arms positioned and pronated to the side of the body, fingers and toes pointed and ankles fastened together with a Velcro belt to ensure standard positioning. Once positioned, subjects were instructed to remain as still as possible for the duration of the scan.

Indirect calorimetry. IC was performed on room temperature in a single session before breakfast on the third day using the FitMate™ method. FitMate™ is a device designed to measure oxygen consumption and energy expenditure during rest and exercise (Cosmed, Rome, Italy), making use of a turbine flowmeter to measure ventilation and a galvanic fuel cell O_2 sensor to analyse the fraction of oxygen in expired gases. It is said to perform in a comparable fashion to a metabolic cart with a standard mixing chamber or canopy. Its sensors measure humidity, temperature and barometric pressure, parameters that are employed in its internal calculations; these generate the oxygen uptake and the energy expenditure using a fixed respiratory quotient (RQ) of 0.85 and the Weir equation; $REE = [3.9\ (VO_2) + 1.1\ (VCO_2)]\ 1.44$ (Weir 1949). The device has been shown to provide REE estimates comparable to those yielded by the Douglas bag method in a sample of 15 AN patients after 1 day of refeeding. The Bland and Altman plots showed no difference between the two procedures. Also, the means of differences were not significantly different from zero. (FitMate method − Douglas bag method = 1.85. Bias for the FitMate versus Douglas bag was −87 kcal/day, and precision [standard deviation (SD)] turned out to be 181. The Wilcoxon signed-ranks test showed no significant differences between the mean REE values estimated with the Douglas bag method and the mean values estimated with the FitMate method ($Z = -1.70$, $p = 0.088$, effect size = 0.65; El Ghoch et al. 2012).

In this study, participants were asked to fast overnight, to abstain from smoking and drinking caffeinated and alcoholic beverages for at least 12 h before the session and not to perform physical exertion before the tests. Patients were not in treatment with drugs medication influencing REE. Upon arrival in the laboratory, participants were placed in a comfortable position on a medical bed, with the upper part of the body partially raised (+3/4;°), while the instrument was prepared and calibrated (immediately before the measurements) and environmental data recorded. After 10 min at rest, measurements were performed over a fixed period of 11 min, during which the participants were instructed to lie quietly, to remain awake and avoid fidgeting and hyperventilating.

SenseWear Pro2 Armband. SWA (BodyMedia Inc., Pittsburgh, PA, USA) assesses both REE and physical activity. It was positioned over the triceps muscle on the upper right arm from the evening of the second day, and kept in place overnight (Papazoglou et al. 2006; Malavolti et al. 2007) until the FitMate™ measurement was performed to ensure that the patient abstained from any physical exertion before REE measurements. Then, REE was obtained before breakfast on the third morning using Chronolife® (SensorMedics Inc., Milan, Italy), compatible software that incorporates demographic characteristics (gender, age, height and weight) and SWA measurements as acceleration, heat flux, galvanic skin response, skin temperature and near body temperature.

Previous studies examining the validity of SWA in assessing REE in normal, overweight and obese patients have produced contrasting results, for this reason its validity is still a matter of debate and needs to be clarified, especially in AN patients where no study testing the performance for this scope has yet been conducted (Frankenfield et al. 1998; Fruin and Rankin 2004; Jakicic et al. 2004; Malavolti et al. 2007; Bertoli et al. 2008).

Predictive formula of REE. The following Müller et al.'s (2004) equation for individuals with a BMI <18.5 was used to give another estimation of REE: $([0.08961 \times FFM\ (kg) + 0.05662 \times FM\ (kg) + 0.667] \times 238.84$.

The formula was chosen because it was validated in a group of underweight occidental females ($n = 50$; BMI < 18.0) with an age ranging between 12 and 49 years old, which is similar to the age of our AN sample. The FFM and the FM were assessed using DXA.

Statistical analysis

The Bland–Altman method was used to study the agreement between the REE estimations provided by SWA, FitMate™ and Müller Default (Bland and Altman 1986) methods. The z-test was used to evaluate whether the mean of the differences between the values obtained by the three methods was significantly different from zero or not (Daniel 1991). Pearson product-moment correlation analyses were performed to evaluate the relationship among body weight, FFM, Müller et al.'s equation, SWA and FitMate™ methods. Partial correlation coefficients were calculated to evaluate the effect of age as a confounding variable. Statistical significance was set at $p < 0.05$. Data are presented as means and SDs. All statistical analyses were carried out using SPSS Version 15.0 (SPSS Inc., Chicago, IL, USA).

Results

Table I gives a summary of the data pertaining to the 39 participants, for age, height, weight, BMI and REE values. The age of the patients ranged from 13 to 45 years, and their BMI fell between 9.63 and 17.33, with 64.1% of the participants having a BMI <15.0. The mean REE estimated with FitMate™ method, Müller et al.'s equation and SWA

Table I. Data representative of the 39 participants with AN, reported as means (SD) and ranges.

Clinical data	Mean (SD)	Range
Height (m)	1.61 (0.07)	1.46–1.78
Weight (kg)	37.29 (5.40)	25.50–49.50
BMI (kg/m^2)	14.39 (1.75)	9.63–17.33
Age (years)	24.56 (8.62)	13–45
Body composition (DXA)		
Fat mass (kg)	3.72 (2.27)	1.17–9.92
Per cent fat mass (%)	9.97 (5.5)	4.10–23.30
FFM (kg)	33.93 (4.96)	21.25–47.13
Per cent FFM (%)	85.52 (4.99)	73.50–92.30
Resting energy expenditure		
FitMate™ method (kcal/day)	962.56 (200.74)	501.0–1382.0
SWA (kcal/day)	1073.77 (132.27)	697.0–1247.0
Müller et al. Default (kcal/day)	916.76 (111.35)	654.0–1210.0

Notes: BMI, body mass index; DXA, dual-energy X-ray absorptiometry.

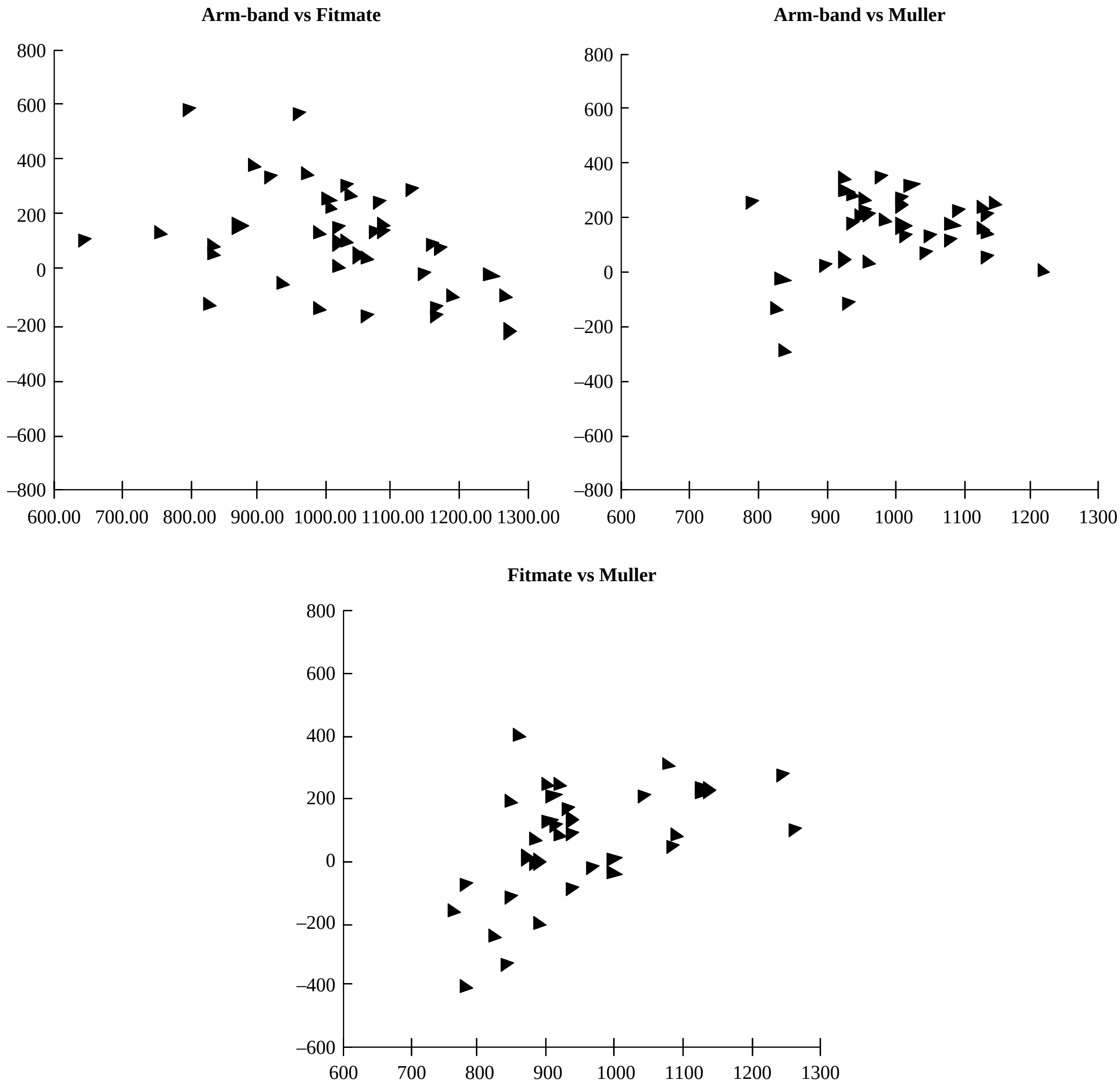

Figure 1. Bland–Altman plots comparing the three methods of measuring REE considered.

were 962.56 kcal/day (200.74), 916.76 kcal/day (111.35) and 1073.77 kcal/day (132.27), respectively.

Figure 1 shows the Bland–Altman plots reporting the differences between REE values estimated by the three methods (FitMate™, SWA and Müller). The mean of the differences between the REE values measured by SWA and those yielded by the Müller Default (bias = 158.4 Kcal/day) and the FitMate™ method (bias = 115.9 kcal/day) was significantly different from zero in both cases ($z = 6.34$, $p < 0.001$ and $z = 3.68$, $p = 0.001$, respectively). Comparison of the FitMate™ method and Müller et al.'s equation findings, on the other hand, showed a mean difference weakly significantly different from zero (bias = 65.29 kcal/day, $z = 2.06$, $p = 0.047$) and a significant correlation ($r = 0.35$, $p = 0.040$) between the two.

A significant correlation was also found between weight and REE estimated by both SWA ($r = 0.39$, $p = 0.013$) and the FitMate™ method ($r = 0.35$, $p = 0.028$), and between FFM and REE measured by the FitMate™ method alone ($r = 0.35$, $p = 0.041$). No significant association was found between FFM and the REE yielded by SWA ($r = 0.31$, $p = 0.075$). No significant differences were found when all the analyses were controlled for age.

Discussion

The principal finding of this study is that SWA is not interchangeable with either the FitMate™ method or the Müller equation in assessing REE in patients with AN. Although previous studies into SWA readings have been inconclusive, this is the first time that this device has been trialled in AN patients. Indeed, the participants in this study were severely underweight (mean BMI = 14.39) and featured markedly reduced FM (mean FM 9.97%), which confirms the clinical picture seen in AN patients treated in specialist inpatient units reported in the literature (Vandereycken 1985; Kerruish et al. 2002). Their low REE (mean REE 962.56 kcal/day, as measured by IC) was also evident in that the weight loss and alteration of body composition due to undereating were associated with a hypometabolic state arising as an adaptive mechanism (de Zwaan et al. 2002).

Although similar studies are required to confirm these results, this assessment did benefit from the use of two gold-standard techniques to measure body composition and diagnose the eating disorder, i.e. DXA and the EDE interview, respectively. Furthermore, it is worth noting that the REE was evaluated after 24 h of refeeding.

It should be noted, however, that this study has small sample size and does not feature longitudinal evaluation. Another limiting factor is the use of FitMate™ method as an IC that utilizes a fixed value of RQ, i.e. 0.85, to calculate REE. Indeed, in previous studies, poor agreement has been shown between REE calculated assuming constant and fixed values of RQ (0.85) in conjunction with a reliable criterion reference system (e.g. Deltatrac) in AN patients (Hlynsky et al. 2005). In fact, not considering VCO_2 tends to produce an underestimation of REE when the RQ is between 0.85 and 1.00 and an overestimation of REE at RQs between 0.70 and 0.85 (Holdy 2004). This might explain the systematic underestimation of REE reported with instruments not measuring VCO_2 in starved AN patients, who tend to be characterized by elevated RQ values > 0.85 (Hlynsky et al. 2005). However, it should be noted that a previous study testing, as in this case, AN participants after 24 h of refeeding found that their RQ was not significantly larger than 0.85, and that FitMate™ method furnished good REE estimates with respect to the Douglas bag method (El Ghoch et al. 2012).

As previously reported (El Ghoch et al. 2012), the Müller et al.'s equation for individuals with BMI < 18.5 is another feasible alternative of estimating REE in eating disorder units, using DXA to measure FM and FFM, two components of the Müller equation. Based on the current results, the Müller equation appears to be a more accurate method than the SWA, whose REE measurements may have been affected by the profound changes in temperature regulation, and the common occurrence of temperatures lower than 35.5° seen in AN patients (Palla and Litt 1988).

Conclusions

The most important finding of this study is that SWA does not appear to be an alternative to the FitMate™ and Müller equation methods for the assessment of REE in patients with AN. At the moment SWA should be used by clinicians treating AN patients only to assess the presence of excess exercise, behaviour commonly observed in these patients (Dalle Grave et al. 2008b), but not REE. Future studies using gold-standard methods to assess REE with samples followed longitudinally before and after weight restoration are needed to confirm this conclusion.

Declaration of interest: The authors declare that they know of no competing financial and personal conflicts of interests in relation to the work described.

References

American Psychiatric Association. 2000. Diagnostic and statistical manual of mental disorders. 4th ed. (text revision), Washington, DC: American Psychiatric Association.

Bertoli S, Posata A, Battezzati A, Spadafranca A, Testolin G, Bedogni G. 2008. Poor agreement between a portable armband and indirect calorimetry in the assessment of resting energy expenditure. Clin Nutr 27:307–310.

Bland JM, Altman DG. 1986. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1:307–310.

Cuerda C, Ruiz A, Velasco C, Breton I, Camblor M, Garcia-Peris P. 2007. How accurate are predictive formulas calculating energy expenditure in adolescent patients with anorexia nervosa? Clin Nutr 26:100–106.

Dalle Grave R. 2011. Eating disorders: progresses and challenges. Eur J Int Med 22(2):153–160.

Dalle Grave R, Bohn K, Hawker D, Fairburn CG. 2008a. Inpatient, day patient, and two forms of outpatient CBT-E. In: Fairburn CG, editor. Cognitive behavior therapy and eating disorders. New York: Guilford Press. p 231–244.

Dalle Grave R, Calugi S, Marchesini G. 2008b. Compulsive exercise to control shape or weight in eating disorders: prevalence, associated features and treatment outcome. Compr Psychiatry 49:346–352.

Daniel WW. 1991. Biostatistics: a foundation for analysis in the health sciences. New York: Wiley.

de Zwaan M, Aslam Z, Mitchell JE. 2002. Research on energy expenditure in individuals with eating disorders: a review. Int J Eat Disord 32:127–134.

El Ghoch M, Alberti M, Capelli C, Calugi S, Dalle Grave R. 2012. Resting energy expenditure in anorexia nervosa: measured vs. estimated. J Nutr Met. 2012: Article ID 652932, 6 pages. doi:10.1155/2012/652932.

Fairburn CG, Cooper Z. 1993. The eating disorder examination. In: Fairburn CG, Wilson GT, editors. Binge eating: nature, assessment, and treatment. 12th ed., New York: The Guilford Press. p 317–360.

Frankenfield DC, Muth ER, Rowe WA. 1998. The Harris-Benedict studies of human basal metabolism: history and limitations. J Am Diet Assoc 98:439–445.

Fruin ML, Rankin JW. 2004. Validity of a multi-sensor armband in estimating rest and exercise energy expenditure. Med Sci Sports Exerc 36:1063–1069.

Harris JA, Benedict FG. 1919. A biometric study of basal metabolism in man publication no. 279. Washington, DC: Carnegie Institution of Washington.

Hlynsky J, Birmingham CL, Johnston M, Gritzner S. 2005. The agreement between the MedGem indirect calorimeter and a standard indirect calorimeter in anorexia nervosa. Eat Weight Disord 10:e83–e87.

Holdy KE. 2004. Monitoring energy metabolism with indirect calorimetry: instruments, interpretation, and clinical application. Nutr Clin Pract 19:447–454.

Jakicic JM, Marcus M, Gallagher KI, Randall C, Thomas E, Goss FL, et al. 2004. Evaluation of the SenseWear Pro Armband to assess energy expenditure during exercise. Med Sci Sports Exerc 36:897–904.

Kerruish KP, O'Connor J, Humphries IR, Kohn MR, Clarke SD, Briody JN, et al. 2002. Body composition in adolescents with anorexia nervosa. Am J Clin Nutr 75:31–37.

Krahn DD, Rock C, Dechert RE, Nairn KK, Hasse SA. 1993. Changes in resting energy expenditure and body composition in anorexia nervosa patients during refeeding. J Am Diet Assoc 93:434–438.

Levine JA. 2005. Measurement of energy expenditure. Public Health Nutr 8(7A):1123–1132.

Malavolti M, Pietrobelli A, Dugoni M, Poli M, Romagnoli E, De Cristofaro P, Battistini NC. 2007. A new device for measuring resting energy expenditure (REE) in healthy subjects. Nutr Metab Cardiovasc Dis 17:338–343.

Marra M, Polito A, De Filippo E, Cuzzolaro M, Ciarapica D, Contaldo F, Scalfi L. 2002. Are the general equations to predict BMR applicable to patients with anorexia nervosa? Eat Weight Disord 7:53–59.

Matarese LE. 1997. Indirect calorimetry: technical aspects. J Am Diet Assoc 97:S154–S160.

Müller MJ, Bosy-Westphal A, Klaus S, Kreymann G, Luhrmann PM, Neuhauser-Berthold M, et al. 2004. World Health Organization equations have shortcomings for predicting resting energy expenditure in persons from a modern, affluent population: generation of a new reference standard from a retrospective analysis of a German database of resting energy expenditure. Am J Clin Nutr 80:1379–1390.

Nieman DC, Austin MD, Benezra L, Pearce S, Mcinnis T, Unick J, Gross SJ. 2006. Validation of Cosmed's FitMate in measuring oxygen consumption and estimating resting metabolic rate. Res Sports Med 14:89–96.

Palla B, Litt IF. 1988. Medical complications of eating disorders in adolescents. Pediatrics 81:613–623.

Papazoglou D, Augello G, Tagliaferri M, Savia G, Marzullo P, Maltezos E, Liuzzi A. 2006. Evaluation of a multisensor armband in estimating energy expenditure in obese individuals. Obesity 14:2217–2223.

Schebendach J, Golden NH, Jacobson MS, Arden M, Pettei M, Hardoff D, et al. 1995. Indirect calorimetry in the nutritional management of eating disorders. Int J Eat Disord 17:59–66.

Tresley J, Sheean PM. 2008. Refeeding syndrome: recognition is the key to prevention and management. J Am Diet Assoc 108: 2105–2108.

Vandereycken W. 1985. Inpatient treatment of anorexia nervosa: some research-guided changes. J Psychiatr Res 19:413–422.

Weir JB. 1949. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol (Lond) 109:1–9.