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Age-related changes in resting energy expenditure in normal weight, overweight and obese men and women

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ABSTRACT

Objectives: Aging is associated with changes in resting energy expenditure (REE) and body composition. We investigated the association between age and changes in REE in men and women stratified by body mass index (BMI) categories (normal weight, overweight and obesity). We also examined whether the age-related decline in REE was explained by concomitant changes in body composition and lifestyle factors.
Study design: Cross-sectional.
Main outcome measures: 3442 adult participants (age range: 18–81 y; men/women: 977/2465) were included. The BMI range was 18.5–60.2 kg/m^2. REE was measured by indirect calorimetry in fasting conditions and body composition by bioelectrical impedance. Regression models were used to evaluate age-related changes in REE in subjects stratified by sex and BMI. Models were adjusted for body composition (fat mass, fat free mass), smoking, disease count and physical activity.
Results: In unadjusted models, the rate of decline in REE was highest in obese men (slope = −8.7 ± 0.8 kcal/day/year) whereas the lowest rate of decline was observed in normal weight women (−2.9 ± 0.3 kcal/day/year). Gender differences were observed for the age of onset of REE adaptive changes (i.e., not accounted by age related changes in body composition and lifestyle factors). In women, adaptive changes appeared to occur in middle-age (∼47 y) across all BMI groups whereas changes seemed to be delayed in obese men (∼54 y) compared to overweight (∼43 y) and normal weight (∼39 y) men.
Conclusions: Sex and BMI influenced the rate and degree of the age-related decline in REE. Critical age windows have been identified for the onset of putative mechanisms of energy adaptation. These findings require confirmation in prospective studies.

1. Introduction

Aging appears to be caused by the accumulation of molecular damage [1] which results in a progressive decline of physiological and metabolic functions and changes in tissue architecture, organ size and function [2]. In particular, aging is associated with smaller mass for a number of important organs contributing to energy metabolism [3] and with reciprocal changes in lean body mass (decline) and adipose tissue (increase) [4]. These body composition changes are gender-specific since the rate of decline of lean body mass is faster and occurs at younger ages in men [5]

Abbreviations: BMI, body mass index; REE, resting energy expenditure; TEE, total energy expenditure; AEE, activity energy expenditure; TEF, thermic effect of food; IPAQ, International physical activity questionnaire; BIA, bioelectrical impedance; FM, fat mass; FFM, fat free mass; METs, metabolic equivalents time; BLSA, Baltimore Longitudinal Study of Aging; Health ABC, Health, Aging, and Body Composition Study.

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whereas changes in body shape and composition in women are almost coincidental with the onset of menopause [6,7].

These age-related changes in body size and composition co-occur with modifications of total energy expenditure (TEE) and its sub-components [(i.e., resting energy expenditure (REE), activity energy expenditure (AEE) and thermic effect of food (TEF)] [8]. REE accounts for ~60–70% of TEE and several cross-sectional and longitudinal studies have reported a progressive decline in REE of about 1–2% per decade [8–14]. This decline has been explained largely by body composition changes (85–95%), while the remainder of these adaptive changes (5–15%) has been attributed to reduced cellular metabolism driven by adjustments of sympathetic tone, thyroid function, mitochondrial efficiency, protein turnover and/or maintenance of cellular electrolyte gradients [8,9,11,15,16]. Further, it has also been suggested that the onset of these REE changes may depend on sex, degree of adiposity and lean body mass [17–20].

Here, we hypothesized that the rate and degree of the age-related decline in REE may be influenced by sex and body mass index (BMI). We tested this hypothesis in a large sample of 3442 adults with detailed assessment of body composition, REE, health status and physical activity. We specifically aimed to investigate the following questions: (1) Are age-related trajectories of REE modified by sex and body size (categorized by canonical BMI groups)? and (2) Is the age of onset of adaptive changes in REE different in men and women stratified by BMI?

2. Methods

2.1. Participants

Participants were recruited consecutively among subjects attending the International Center for the Assessment of Nutritional Status (ICANS, University of Milan) for clinical and nutritional evaluation between February 2010 and September 2013. The sample comprises adult Caucasian men and women (age ≥18 years) with a body mass index (BMI) ≥18.5 kg/m^2. Subjects were not excluded from the primary analyses based on clinical diagnosis or medication use to enhance sample representativeness. A sensitivity analysis was conducted after exclusion of subjects with medical conditions that could have influenced energy expenditure.

2.2. Study procedures

All measurements were performed in the morning after an overnight fast. 3442 subjects (male/female: 977/2465) were included in the final analysis. The higher prevalence of females is representative of the higher number of females attending our outpatient nutritional clinic. The study procedures were approved by the University of Milan Ethical Committee and all participants gave written informed consent. The STROBE statement for cross-sectional studies was adopted to provide detailed information on the study design and sample characteristics.

2.2.1. Smoking, physical activity and health status

Current smoking habits were recorded as current smokers, never smoked or former smokers. A detailed medical interview was conducted and self-reported diagnosis of medical conditions was collected. Disease count including major chronic diseases, such as cancer, thyroid and adrenal disorders, systemic inflammatory diseases (i.e., Crohn's disease, Ulcerative Colitis, Sjögren's syndrome, Systemic lupus erythematosus, Systemic sclerosis), HIV, and acute and chronic kidney failure, was calculated for each subject. Physical activity level was assessed using the short version of the International physical activity questionnaire (IPAQ) [21].

2.2.2. Anthropometry

Anthropometric measurements were collected by the same observer, according to standardized procedures. Body weight (WT, Kg) and height (HT, cm) were measured to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI) was calculated as [weight/height^2] and classified using the WHO criteria (18.5–24.9 kg m^{-2} – normal weight, 25.0–29.9 kg m^{-2} – overweight and ≥30 kg m^{-2} – obese).

2.2.3. Bioelectrical impedance (BIA)

Impedance (Z) was measured using a tetrapolar 8-point tactile electrode system (InBody 720, Biospace, Seoul, Korea) at 1, 5, 50, 250, 500 and 1000 kHz. The system measured the impedance of the participant's right arm, left arm, trunk, right leg and left leg. Total body impedance value was calculated by summing the segmental impedance values. Participants stood on the scale platform of the instrument and grasped the handles of the device, to provide contact with a total of eight electrodes (two for each foot and for each hand). Manufacturer's equations were used to estimate body composition variables. The intra-examination coefficient of variation for BIA was 0.8%.

2.2.4. Measured REE

An open-circuit ventilated-hood indirect calorimetry system was used (Sensor Medics 29, Anaheim, CA, USA). Resting VO_2 and VCO_2 measurements were measured in the early morning, after an overnight fast, under standardized conditions, with the person lying awake and emotionally undisturbed, completely at rest and comfortably supine on a bed, their head under a transparent ventilated canopy, in a thermally neutral environment (24–26 °C). When relevant, the participant was asked to abstain from smoking on the morning of the measurement. Respiratory gas samples were taken every minute for 30–40 min and data collected during the first 5–10 min were discarded, as recommended by Isbell et al. [22]. This time period allowed the subjects to acclimatize to the canopy and instrument noise. The calorimeter was calibrated daily before starting the tests, using a two-point calibration method based on two separate mixtures of known gas content. The flow rate was calibrated with a 3-L syringe, according to the calorimeter manufacturer's instructions. The average of the last 20 min of measurements was used to determine 24 h REE according to the standard abbreviated Weir equation [23].

2.2.5. Predicted REE

REE was calculated using predictive equations including FM, FFM, sex and lifestyle factors (smoking, disease count and physical activity) as independent variables. Specifically, FFM (kg), FM (kg), sex (female = 0, male = 1), smoking (0 = smoker; 1 = non-smoker; 2 = ex-smoker), disease count (range: 0–13) and physical activity (Total METs) were entered as independent variables into a stepwise multiple regression model. The following predictive equation was obtained: REE (kcal/day) = 407.2 + 70.5 * Sex + 17.2 * FFM(kg) + 7.7 * FM(kg) – 7.5 * Disease Count – 8.3 * Smoking, $R^2 = 0.82$, $p < 0.001$. This equation was then used to calculate REE and the difference between measured and predicted REE was obtained as a measure of adaptive changes in REE.

2.3. Statistical analyses

The data are reported as mean ± SD (continuous variables) and frequency and percentage (categorical variables). Groups stratified by sex and BMI groups were compared using univariate analysis of variance entering sex (S) and BMI categories (BMI-C) as between-subjects factors. A sex-BMI categories (S*BMI-C) interaction term was added to the model. Linear regression models were used to