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Original article

Reduction in energy expenditure during weight loss is higher than predicted based on fat free mass and fat mass in older adults

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S U M M A R Y

Background & aim: The aim of this study was to describe a decrease in resting energy expenditure during weight loss that is larger than expected based on changes in body composition, called adaptive thermogenesis (AT), in overweight and obese older adults.
Methods: Multiple studies were combined to assess AT in younger and older subjects. Body composition and resting energy expenditure (REE) were measured before and after weight loss. Baseline values were used to predict fat free mass and fat mass adjusted REE after weight loss. AT was defined as the difference between predicted and measured REE after weight loss. The median age of 55 y was used as a cutoff to compare between older with younger subjects. The relation between AT and age was investigated using linear regression analysis.
Results: In this study 254 (M = 88, F = 166) overweight and obese subjects were included (BMI: 31.7 ± 4.4 kg/m^2, age: 51 ± 14 y). The AT was only significant for older subjects (64 ± 185 kcal/d, 95% CI [32, −96]), but not for younger subjects (19 ± 152 kcal/d, 95% CI [−9, 46]). The size of the AT was significantly higher for older compared to younger adults (β = 47, p = 048), independent of gender and type and duration of the weight loss program.
Conclusions: We conclude that adaptive thermogenesis is present only in older subjects, which might have implications for weight management in older adults. A reduced energy intake is advised to counteract the adaptive thermogenesis.

1. Introduction

Adaptive thermogenesis is defined as the decrease in resting energy expenditure (REE) greater than expected based on changes in fat free mass and fat mass [1]. Because the REE contributes for approximately 70% of the total daily energy expenditure [2], adaptive thermogenesis can have substantial impact on daily energy expenditure. As a result it might be more difficult to preserve energy balance to maintain weight, or to create an energy deficit to lose weight.

Adaptive thermogenesis has been described in different weight loss studies [3–5]. It has been stated that the discussion is no longer about the existence of the phenomenon of adaptive thermogenesis, but about its magnitude and practical implication [6].

In addition to the ongoing discussion on the magnitude and practical implication of adaptive thermogenesis, it has been pointed out that the relation between age and adaptive thermogenesis is unclear [7,8]. Since the prevalence of overweight and obesity is increasing as well as aging, the number of older adults with overweight and obesity increases [9]. We have been interested in providing adequate interventions for obese older adults that result in healthy weight loss, i.e. loss of fat mass with muscle mass preservation [10]. Because adaptive thermogenesis might have an unfavorable effect on the energy balance, it potentially reduces the success of weight loss interventions and weight maintenance in older adults. Therefore, the aim of this study was to describe adaptive thermogenesis in overweight and obese older adults during weight loss. For this purpose, we accumulated data over a larger age range, which made it possible to compare older with younger overweight individuals.

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2. Methods

2.1. Subjects

The data from 9 different weight loss studies were combined for this investigation, e.g. [10]. The studies were conducted at the Amsterdam Nutritional Assessment Center (ANAC) of the Amsterdam University of Applied Sciences between 2006 and 2014. Subjects were overweight or obese (body mass index (BMI) > 25 kg/m^2) but otherwise healthy. Written informed consent was obtained from all subjects.

2.2. Design

All subjects followed a hypocaloric diet. In addition, in some studies a subgroup of participants completed an exercise program. The weight loss programs lasted between 8 and 13 weeks. Baseline and Post measurements of body composition (air displacement plethysmography) and resting energy expenditure (indirect calorimetry) were performed, see below.

Q2 2.3. Measurements

REE was measured by indirect calorimetry using a ventilated hood system (Vmax Encore n29, Viasys Healthcare, Houten, the Netherlands). Each day before the first use the system was calibrated with 2 different standard gases and 1 standard volume according to the manufacturer's description. All measurements were performed in a quiet, well-ventilated, thermo-neutral environment. The subjects remained lying down and regular checks prevented subjects from falling asleep. Oxygen consumption and carbon dioxide production were measured for 30 min. The first 5 min of the measurement was discarded. A steady state period was selected (CV < 10%) based on visual interpretation of the time series graph. The Weir formula [11] was used to calculate the REE. Measurements were excluded when the respiratory exchange ratio was below 0.7 or above 1.0 [12].

Body composition was measured in duplo using air displacement plethysmography (Bodpod, Life Measurement Inc., Concord (CA), USA). The Bodpod was calibrated for weight and volume before each measurement. Body weight was measured to the nearest 0.001 kg on the electronic scale which was part of the Bodpod system. Subjects were measured wearing tight swim clothes or underwear and a Lycra swim cap. The Siri equation [13] was used to estimate the percentage body fat from the measured density. Fat mass and fat free mass were calculated using percentage body fat and body weight. Height was measured using a stadiometer (Seca 222, Seca, Hamburg, Germany).

Subjects did not drink alcohol within 24 h, eat within 5 h, exercise within 3 h and drink water within 1 h prior to each visit [12]. Subjects who were assigned to a diet and exercise program did not train on the day of the measurements. Baseline and Post weight loss measurements were performed by trained research assistants at the same time of the day for both measurements.

2.4. Calculation of adaptive thermogenesis

A backward linear regression analysis with baseline data including fat free mass, fat mass, age, gender and the fat free mass*age interaction as independent variables and REE as dependent variable was performed to derive a prediction equation for REE. Assumptions of linearity and multicollinearity of the predictors were confirmed. Analysis of the residuals showed that the regression equation was not affected by outliers and influential cases. The prediction equation was used to calculate the predicted REE at Post. In accordance with previous research [14,15], adaptive thermogenesis was quantified as the difference between measured and predicted REE at Post:

$$\textit{Adaptive Thermogenesis}(AT) = \textit{Post weight loss predicted REE} - \textit{measured REE}$$

Additionally, AT was corrected for Pre weight loss measured versus predicted REE differences between young and old subjects:

$$\begin{aligned}&\textit{Corrected Adaptive Thermogenesis}(ATcorr)\\&= (\textit{Post weight loss predicted REE}\\&\quad - \textit{Post weight loss measured REE})\\&\quad - (\textit{Pre weight loss predicted REE}\\&\quad - \textit{Pre weight loss measured REE})\end{aligned}$$

2.5. Statistical analysis

The median age of 55 years was used as cutoff for age groups, i.e. participants aged 55 and over were defined as older subjects. Differences within age groups were analyzed with paired t-test. Differences between the age groups were checked using an independent samples t-test. The relation between adaptive thermogenesis and age was investigated using a linear regression analysis that included gender and the type (diet or diet + exercise) and duration of the weight loss program. All values reported in text and tables are means ± SD. Two-sided probability values below 0.05 were considered statistically significant. Statistical analyses were performed using SPSS 22 for Windows (IBM Corp., IBM SPSS Statistics for Windows, Version 22.0. Amonk, NY).

3. Results

3.1. Subjects

In total, 254 subjects were included in this study (M = 88, F = 166). Baseline characteristics of the younger and older subjects are displayed in Table 1. On average, older subjects had a significant higher fat mass than younger subjects (39.7 ± 10.0 vs. 36.3 ± 10.0 kg, $p < 0.01$) and a lower REE (1755 ± 295 kcal/d vs. 1840 ± 340 kcal/d, $p = 0.04$).

On average body weight declined by −3.2 ± 3.0 kg (−3.4 ± 3.3 kg fat mass; +0.1 ± 1.8 kg fat free mass) in older and by −2.8 ± 3.3 kg (−3.0 ± 3.6 kg fat mass; +0.2 ± 2.4 kg fat free mass) in younger subjects. After the weight loss program the REE was on average reduced by −84 ± 202 kcal/d in older and −49 ± 168 kcal/d in younger adults (Table 1).

3.2. Adaptive thermogenesis

The backward linear regression analysis revealed small and insignificant beta values for gender and the fat free mass*age interaction term. Therefore, these variables were excluded from the prediction equation. The resulting prediction equation including fat free mass, fat mass and age explained 70% of the variation in REE at baseline (SEE = 176 kcal/d, $p < 0.001$):

$$\begin{aligned}REEpred(kcal/d) = {}& 21.630*[\textit{fat free mass}(kg)]\\&+ 8.945*[\textit{fat mass}(kg)] - 2.599*[age(y)]\\&+ 288.024\end{aligned}$$

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