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Original Article

Differences of energy expenditure and physical activity patterns in subjects with various degrees of obesity☆

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SUMMARY

Background & Aims: An imbalance of energy intake and energy expenditure leads to obesity. However, little detailed information of energy expenditure and physical activity patterns in obese subjects is available. Therefore, we assessed total energy expenditure (TEE) with its components resting energy expenditure (REE) and activity thermogenesis (AT) and the patterns of physical activity in non-obese and in subjects with different degrees of obesity.

Methods: TEE and activity pattern were assessed with the SenseWear™ armband in 78 subjects (46 ± 12 years; 28 with normal weight/overweight, 13 each with obesity I° and II°, and 24 with obesity III°). In addition, REE was measured by indirect calorimetry and AT was calculated.

Results: Although TEE (and REE) increased with increasing weight category from 2567 (1437) kcal/d in non-obese subjects to 3033 (1931) kcal/d in subjects with obesity III° ($p = 0.016$, $p < 0.001$, respectively) body weight adjusted TEE decreased from 33.1 to 22.1 kcal/kg/d ($p < 0.001$). This was mainly due to decreased body weight adjusted AT (11.3–5.8 kcal/kg/d, $p < 0.001$). AT consisted almost completely of non-exercise AT. In particular, for obese subjects exercise-related AT was negligible.

Conclusions: Higher degrees of obesity are associated with decreased body weight adjusted AT. These differences have to be considered for therapeutic strategies.

1. Introduction

An imbalance of energy intake and energy expenditure leads to obesity which is associated with increased morbidity and mortality.[1,2] In contrast, persistent weight loss significantly reduces the increased overall mortality.[3] Physical activity improves weight loss and is also a good predictor of long-term weight loss maintenance.[4]

While energy intake, the effect of different diets and the composition of macronutrients for the prevention and treatment of obesity have extensively been studied and reported,[5] there is little detailed information of energy expenditure and patterns of physical activity in obese subjects available.

Total energy expenditure (TEE) consists of resting energy expenditure (REE), the thermic effect of food (TEF) and activity thermogenesis (AT). AT can be further separated into the two components, exercise-related AT and non-exercise AT (NEAT). According to Levine et al.[6] NEAT is reported to be the most variable component of TEE and is hypothesised to play an important role in the pathogenesis of obesity.

TEE (and also REE) can be measured with indirect calorimetry (IC). However, this technique requires specialized laboratory equipment and can not be used to assess TEE in subjects performing normal daily activities. The doubly labelled water method is the "gold standard" for measuring TEE in daily life.[7] Disadvantages of this complex method are the low suitability for clinical purposes and the inability to provide information on the different patterns of physical activity and components of TEE.

So far, mainly physical activity recall questionnaires have been used to quantify physical activity in daily life in both research and clinical settings.[8] Energy equivalents of the logged activities are determined from the physical activity recall questionnaires, multiplied with the duration of activity and then summed to derive an estimate of AT. The accuracy of the activity logs and the determination of energy equivalents are the major limitations of this approach.

Non-standard abbreviations: AT, activity thermogenesis; IC, indirect calorimetry; MET, metabolic equivalent; NEAT, non-exercise activity thermogenesis; REE, resting energy expenditure; SWA, SenseWear™ armband; TEE, total energy expenditure; TEF, thermic effect of food.

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Mahabir et al.[9] demonstrated a deviation of up to 60% when evaluating physical activity by using four different questionnaires in comparison with the doubly labelled water method. In particular, obese participants tended to overestimate their activity to a higher degree than normal weight subjects. These findings agree with a recent review by Prince et al.[10] that addressed the poor correlations between self-report and direct measures of physical activity.

Motion sensors, used to monitor body movements, provide another approach to assess physical activity more objectively. These devices basically include simple and inexpensive pedometers (measurement of steps) and technologically more advanced accelerometers (detection of body acceleration). The SenseWear™ armband (SWA, SMT medical technology, Wuerzburg, Germany) is a device that, in addition to movement data, also collects physiologic data from multiple sensors and estimates TEE and physical activity by using specific algorithms. Therefore, SWA appears to provide a suitable approach for measuring the different components of TEE.

Our major aim was to test the hypothesis that the degree of NEAT is associated with the severity of obesity. Therefore, we analysed the components of TEE and compared them in non-obese and in subjects with different degrees of obesity. Furthermore, we compared REE estimated by SWA to that measured by IC in subjects of different weight categories.

2. Subjects, material and methods

2.1. Subject recruitment

Thirty outpatients seen between March and November 2008 in the Division of Clinical Endocrinology, Charité Universitätsmedizin Berlin, who came for evaluation prior to bariatric surgery were included. In addition, 28 outpatients with non-alcoholic steatohepatitis seen at the Department of Medicine, Gastroenterology, Hepatology and Endocrinology, Charité Universitätsmedizin Berlin and 20 healthy subjects were included in the analysis.

The cross-sectional study was approved by the institutional ethical committee and all subjects gave informed consent.

A medical history was taken and all subjects underwent a complete physical examination. Subjects suffering from diseases preventing them to perform normal daily physical activities such as clinical relevant heart failure, limiting pulmonary diseases, severe arthropathies or amputations were excluded. Weight was measured to the nearest 0.1 kg and height to the nearest 1 cm. Body mass index (BMI) was calculated as kg/m^2. The severity of obesity was classified according to the WHO criteria as normal weight/overweight (BMI 18.5 to 29.9 kg/m^2), obesity I° (BMI 30.0 to 34.9 kg/m^2), obesity II° (BMI 35.0 to 39.9 kg/m^2) and obesity III° (BMI $\geq$ 40.0 kg/m^2).[11]

2.2. The SenseWear™ armband (SWA)

The SWA utilizes a multi-sensor array including a 2-axis accelerometer, heat flux sensor, galvanic skin response sensor, skin temperature sensor, and a near-body ambient temperature sensor. Data were analysed by using a generalised proprietary algorithm developed by the manufacturer (InnerView™ Professional, Version 6.1, SMT medical technology, Wuerzburg, Germany).

2.3. Resting energy expenditure (REE)

REE data were simultaneously obtained by both IC and SWA. Respiratory gas exchange was measured by IC (Deltatrac II™, Datex-Ohmeda, Freiburg, Germany) under standardised conditions after an overnight fast and after a resting period of at least 30 min with the subjects lying under a ventilated hood. The gas analyzers were calibrated before each measurement with a mixture of 95% oxygen and 5% carbon dioxide and gas flow was adapted to body weight according to the manufacturer's manual (80 l/min for >120 kg body weight; 40 l/min for 20–120 kg body weight). REE was calculated according to Consolazio et al.[12] At the same time the subjects wore the SWA on the right upper arm over the triceps muscle. The SWA was attached securely with an adjustable elastic strap for a period of 5–10 min before data collection to allow for acclimatisation of the SWA to skin temperature.

2.4. Total energy expenditure (TEE)

TEE was continuously measured for three days (preferably two weekdays and one weekend day) with the SWA. Patients were asked to wear the SWA as described above at least 23 h per day.

The number of steps, metabolic equivalents (MET), the duration of energy expenditure to distinct levels of physical activity graded in METs, and the time spent in supine position as well as the duration of sleep were calculated. METs define the energy expenditure related to body weight. One MET is equivalent to 1 kcal/kg body weight/hour. Moderate physical activity is usually classified between 3 and 5 METs.

2.5. Activity thermogenesis (AT)

AT was calculated according to the equation: $AT = TEE - TEF - REE$.

We chose REE obtained by IC for our calculations due to recent concerns that the SWA may not be designed to estimate REE appropriately.[13,14] TEF was estimated as 10% of TEE and was calculated as $TEE \times 0.10$.[15]

Energy expenditure of more than 5 METs was classified as exercise-related activity thermogenesis. Energy expenditure up to 5 METs was classified as NEAT.

2.6. Fat-free mass (FFM)

Bioelectrical impedance analysis was performed using a BIA 2000-M analyzer (Nutrigard-M™, Data Input, Darmstadt, Germany) at 50 kHz to measure resistance (R) and reactance (Xc).[16] Total body water (TBW) was calculated as $0.69 \times \text{height}^2/R + 0.8$ and than FFM was calculated as TBW/0.732.[16]

2.7. Laboratory measurements

Glucose tolerance was assessed with a 75 g oral glucose tolerance test after an overnight fast. Plasma glucose (mg/dl) was measured at 0, 60 and 120 min. TSH (normal range 0.3–4.0 mU/l) and fT_4 (normal range 0.78–1.83 ng/dl) were measured with fluorescent immunoassay (AutoDELFIA™, PerkinElmer, Waltham, MA, USA). For the assessment of cortisol excretion, subjects collected their urine for 24 h. Free cortisol (normal range 11.8–485.6 nmol/d) was measured with immunoassay (ARCHITECT™, Abbott Diagnostics, Abbott Park, IL, USA).

2.8. Statistical analysis

Distribution of the data was determined by using the Kolmogorov-Smirnov test. Results are expressed as means and standard deviations (SD) for parametric data. Median and interquartile ranges are given for non-parametric data. Chi-squaretest (for categorical variables), two-tailed paired *t*-test (for normally distributed paired data), one-way ANOVA (for normally distributed data), and Kruskal-Wallis-test (for not normally distributed data) were used. Pearson's coefficient of correlation was used to determine the degree of strength for the linear association between