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Physical Activity in Confined Conditions as an Indicator of Free-Living Physical Activity

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Abstract

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Objective: The main determinants of daily energy expenditure are body size and physical activity. Activity energy expenditure is the most variable component of total energy expenditure. It was assessed whether the physical activity level in confined conditions is an indicator of free-living physical activity.

Research Methods and Procedures: Activity energy expenditure was measured over 1 day in a confined environment of a respiration chamber (floor space, 7.0 m^2), where activities were restricted to low-intensity activities of daily living, and over 2 weeks in a free-living environment using doubly labeled water. Subjects were 16 women and 29 men (age, 31 ± 10 years; BMI, 24.2 ± 2.7 kg/m^2).

Results: The free-living activity level of the subjects, as a multiple of resting energy expenditure, was 1.76 ± 0.13. Activity energy expenditure in the chamber was 47 ± 13% of the value in daily life, and the two values were correlated ($r = 0.50$, $p < 0.001$; partial correlation corrected for age, gender, and BMI: 0.40, $p < 0.01$). The chamber value explained 25% of the total variance in free-living activity energy expenditure.

Discussion: The activity level of a subject under sedentary conditions is an indicator of activity energy expenditure in daily life, showing the importance of nonexercise activity for daily energy expenditure.

Key words: indirect calorimetry, respiration chamber, doubly labeled water, body size, exercise

Introduction

Daily energy expenditure can be divided into three components: basal metabolic rate (BMR),[1] diet-induced energy expenditure, and activity-induced energy expenditure (AEE). BMR represents the energetic costs of the processes essential for life. Diet-induced energy expenditure results from the digestion, absorption, and conversion of the monomeric forms of the absorbed macronutrients to their polymeric form. AEE is the energy expenditure associated with muscular contractions to perform body postures and movements, including exercise. Under most circumstances, individual BMR accounts for the largest proportion of daily energy expenditure or average daily metabolic rate (ADMR) and is mainly determined by body size. Diet-induced energy expenditure is ~10% of ADMR in subjects consuming an average mixed diet that meets energy requirements (1). AEE is the most variable component of ADMR. In the general population, physical activity level (PAL; ADMR/BMR) ranges between 1.2 and 2.5 (2). As a fraction of ADMR, AEE varies from 5% in a subject with a minimum PAL of 1.2 to 50% in a subject with a PAL of 2.5. At a PAL value of 1.75, the average reported for the general population (3,4), AEE is one-third of ADMR.

Recently, Snitker et al. (5) showed, for a group of healthy Pima Indians, that AEE, as measured in a respiration chamber, was correlated to habitual, free-living physical activity. They speculated from these data that there might be a genetic determinant of AEE and encouraged further studies. AEE has been shown to be important for the maintenance of body weight (6). An increase in daily PALs could decrease the rising prevalence of obesity (7). Here, to quantify the importance of nonexercise activity for daily energy expenditure, we assessed whether the activity level of a subject under sedentary conditions is an indicator for AEE in daily life.

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[1] Nonstandard abbreviations: BMR, basal metabolic rate; AEE, activity-induced energy expenditure; ADMR, average daily metabolic rate; PAL, physical activity level; 24EE, 24-hour energy expenditure; SMR, sleeping metabolic rate; AEE_{ch}, activity-induced energy expenditure in the chamber; AEE_{fl}, activity-induced energy expenditure in free-living activity.

Research Methods and Procedures

Subjects were16 women and 29 men, with an average age of 31 ± 10 years (range, 19 to 61 years) and a BMI of 24.2 ± 2.7 kg/m^2 (range, 19.4 to 30.4 kg/m^2). They were participants in studies on effects of intake pattern and diet composition on energy expenditure (8,9). Selection criteria included being white, living within 30 km from Maastricht, participating in sporting activities <7 h/wk, having an alcohol consumption of <21 drinks/wk for women and <28 drinks/wk for men, and having no dietary restrictions. All subjects were certified by a staff physician to be in good health and gave informed consent to participate in the study after procedures were explained to them. The protocol was approved by the university ethics committee.

Subjects were weight stable at least 6 months before and during the study. Observations included measurement of energy expenditure over 24 h (24EE) in a respiration chamber and under daily living conditions (ADMR) over a 2-week interval using doubly labeled water.

Measurement of energy expenditure in the respiration chamber was performed as described before (10). The chamber measured 3.10 × 2.25 m and was furnished with a bed, chair, table, TV, radio, telephone, wash bowl, and toilet facilities. During daytime hours, subjects were allowed to move freely, sit, lie down, study, use the telephone, listen to the radio, and watch television; only sleeping and purposeful exercise were not allowed. At night, subjects were supposed to sleep from 11:00 PM until 7:00 AM, when lights were switched off. Body movement was monitored by means of a radar system based on the Doppler principle. Subjects were fed according to estimated energy balance. Sleeping metabolic rate (SMR) was measured from 3:00 AM to 6:00 AM, when subjects were asleep.

ADMR was measured over a 2-week period, immediately after the measurement of 24EE. Dose, sampling protocol, sample analysis, and calculation procedure were as described before (11,12). Briefly, subjects were given a weighed dose of water with a measured enrichment of ~5 atoms % ^2H and 10 atoms % ^{18}O, so that baseline levels were increased with 150 ppm for ^2H and 300 ppm for ^{18}O. Urine samples for isotope measurement were collected before dosing at night, from the second and last voiding on the next day, and after 7 and 14 days. Isotope abundance in the urine samples was measured with an isotope-ratio mass spectrometer (Aqua Sira; VG Isogas, Cheshire, United Kingdom). CO_2 production was calculated from isotope elimination rates, as calculated from the slope of the elimination curve, correcting for changes in body water assumed to be proportional to changes in body mass from the start to the end of the observation interval. CO_2 production was converted to ADMR using an energy equivalent based on the individual macronutrient composition of the diet.

AEE in the chamber (AEE_{ch}) and under free-living conditions (AEE_{fl}) were calculated, respectively, with the equations: $AEE_{ch} = 24EE - (0.1 \times 24EE + SMR)$ and $AEE_{fl} = ADMR - (0.1 \times ADMR + SMR)$, where diet-induced energy expenditure was estimated as 10% of ADMR (1). AEE was normalized by division by body weight, an appropriate means for comparing the volume (intensity × time) of physical activity among individuals of different body sizes (13). In a subgroup of 30 subjects, body movement in free-living conditions was evaluated during a 7-day period with a tri-axial accelerometer (14). Partial correlations of chamber and free-living energy expenditure parameters were calculated with correction for age, gender, and BMI.

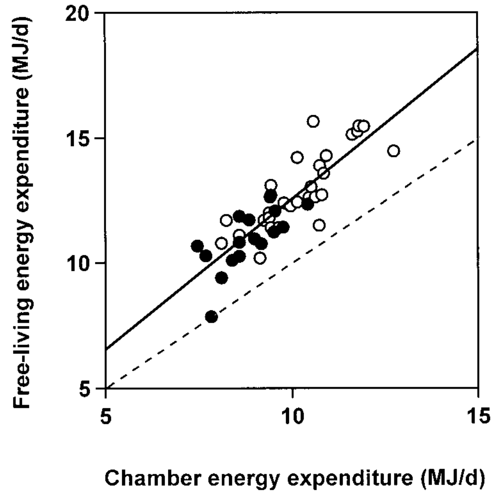

Figure 1: Free-living energy expenditure plotted as a function of energy expenditure in the confined environment of a respiration chamber (women, closed circles; men, open circles), with the line of identity (dotted) and the linear regression line (continuous, $r = 0.85$, $p < 0.0001$).

Results

Free-living energy expenditure was higher than energy expenditure in the confined environment of a respiration chamber for all subjects, and the two values were closely correlated (Figure 1, $r = 0.85$, $p < 0.0001$; partial correlation, 0.65; $p < 0.0001$). The activity level of the subjects in the respiration chamber (24EE/SMR) was 1.40 ± 0.06 (range, 1.30 to 1.58). The activity level in free-living conditions (ADMR/SMR) was 1.76 ± 0.14 (range, 1.38 to 2.04). The partial correlation of chamber and free-living ADMR/SMR was 0.38 ($p < 0.05$). AEE in the chamber was 47 ± 13% of the value in daily life, and the two values were correlated (Figure 2, $r = 0.50$, $p < 0.001$; partial correlation, 0.40; $p < 0.01$). In a subgroup of 30 subjects, there was a similar relation between body movement in daily life (accelerometer counts) and in the chamber (radar counts): $r = 0.57$, $p < 0.001$.

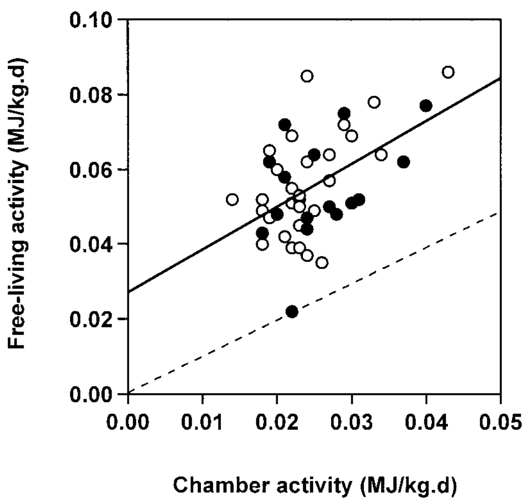

Figure 2: Free-living activity energy expenditure plotted as a function of activity energy expenditure in the confined environment of a respiration chamber (women, closed circles; men, open circles), with the line of identity (dotted) and the linear regression line (continuous, $r = 0.50$, $p < 0.001$).

There were no significant effects of BMI, gender, and age on AEE. Women had a lower 24EE and a lower ADMR (Figure 1). However, AEE adjusted for differences in body weight was similar for women and men in the chamber (0.026 ± 0.006 and 0.024 ± 0.006 MJ/kg, respectively), as well as free living (0.055 ± 0.014 and 0.056 ± 0.014 MJ/kg, respectively).

Discussion

The activity level of the subjects in free-living conditions was close to the average reported for the general population (2–4). The activity level of the subjects in the respiration chamber was very close to literature values. Snitker et al. (5) observed a value of 1.42 ± 0.10 in a slightly larger chamber (3.33 m long and 2.45 m wide, floor space 8.2 m^2) compared with the 7.0-m^2 chamber in the current study. Astrup et al. (15) reported a value of 1.27 for a slightly smaller chamber (3.66 m long and 1.77 m wide, floor space 6.5 m^2). All chamber values mentioned above are for conditions where subjects were allowed to move around without access to exercise equipment like a treadmill, ergometer, or stepping benches.

Physical activity in confined conditions was measured in a single 24-h stay in a room calorimeter. It has frequently been shown that 24EE, as measured in a respiration chamber, is reproducible (15–18). Therefore, this 24EE can be used to estimate physical activity in confined conditions.

One could speculate from these results that a major part of AEE in free-living conditions is associated with low-intensity activities such as lying, sitting, and standing, and moderate intensity activities such as walking. We recently showed that subjects with a PAL ranging from 1.51 to 2.04, a subgroup of the subjects of the current study, spent on average 9% of the active time in high-intensity activity (19). The data clearly showed that in the normal PAL range, the distribution of time spent at activities with low and moderate intensity is the major contributor to the daily activity level. High-intensity activity does not have much impact as a determinant of PAL in the normal population. An average subject with a PAL of 1.75 spends, respectively, 65%, 25%, and 9% of the active time in low-, moderate-, and high-intensity activity. When the ratio of the energy costs for low, moderate, and high intensity is 1:2:4, high-intensity activity contributes ~25% to AEE.

We adjusted AEE for differences in body weight by division by body weight as a means for comparing the volume (intensity × time) of physical activity among individuals of different body size. Ekelund et al. (20) compared AEE as well as activities in obese (BMI > 30 kg/m^2) and matched nonobese adolescents. AEE was measured with doubly labeled water, and activities were measured simultaneously with accelerometry. The obese performed fewer activities than the nonobese despite no difference in PAL. Activity counts in the obese, as monitored with an accelerometer, were 68% of the nonobese, and AEE in megajoules per kilogram was similarly lower at 65% of the values in the nonobese.

Future studies should indicate whether there is a genetic component in AE, as suggested by a >2-fold variation in AEE among individuals in the same confined environment of a respiration chamber and the significant relation with AEE in free-living conditions. Pérusse et al. (21) have shown that the level of habitual physical activity, as derived from a 3-day activity record, has a genetic component. Additionally, behavioral choices could be similar within subjects and different among subjects whether or not they are in a confined living space.

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