Energy expenditure of nonexercise activity[1–4]

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ABSTRACT

Background: We found recently that changes in nonexercise activity thermogenesis (NEAT) mediate resistance to weight gain with overfeeding in sedentary adults. A potentially important, yet seldom investigated, component of NEAT is the energy expenditure of fidgeting-like activities.

Objective: Our goal was to measure changes in energy expenditure with fidgeting-like activities.

Design: Energy expenditure was measured in 24 subjects (17 women and 7 men; $\bar{x} \pm$ SD body weight: 76 ± 21 kg) while recumbent at rest, sitting motionless, standing motionless, partaking of self-selected fidgeting-like movements while seated and while standing, and walking on a treadmill at 1.6, 3.2, and 4.8 km/h (1, 2, and 3 mph). Measurements were performed by using a high-precision, indirect calorimeter connected to the subject via a transparent, lightweight facemask that enabled almost unrestricted movement.

Results: Compared with metabolic rate in the supine position (5.4 ± 1.5 kJ/min), energy expenditure increased while sitting motionless by 4 ± 6%, while fidgeting while seated by 54 ± 29% ($P < 0.0001$), while standing motionless by 13 ± 8% ($P < 0.0001$), while fidgeting while standing by 94 ± 38% ($P < 0.0001$), while walking at 1.6 km/h by 154 ± 38% ($P < 0.0001$), while walking at 3.2 km/h by 202 ± 45% ($P < 0.0001$), and while walking at 4.8 km/h by 292 ± 81% ($P < 0.0001$). There was a significant, positive correlation between changes in energy expenditure and body weight for fidgeting-like activities while standing ($r = 0.43$, $P = 0.02$) but not while seated.

Conclusions: There is marked variance between subjects in the energy expenditure associated with self-selected fidgeting-like activities. The thermogenic potential of fidgeting-like and low-grade activities is sufficiently great to substantively contribute to energy balance. *Am J Clin Nutr* 2000;72:1451–4.

KEY WORDS Obesity, fidgeting, energy expenditure, NEAT, nonexercise activity thermogenesis, indirect calorimetry

INTRODUCTION

We recently identified that nonexercise activity thermogenesis (NEAT) mediates resistance to weight gain with overfeeding (1). Nonexercise activities are the activities of daily living other than exercise (sports and fitness-related activities) and include sitting, standing, walking, and fidgeting. The increases in energy expenditure that accompany sitting (≈5–10%), standing (≈10–20%), and walking (≈100–200%) have been documented (2–5). However, there is a paucity of data regarding the thermogenic potential of fidgeting-like activities at very low workloads. This may be for several reasons. Room calorimeters, which allow unrestricted movement albeit within a confined area [eg, 8.3 m^2 (6)], are not widely available (7). Conversely, conventional configurations of indirect calorimetry equipment either prohibit movement completely (eg, hood calorimetry) or involve the application of a mouthpiece and nose clip that prevent normal body movements. In this study, the thermogenic responses to fidgeting-like activities were investigated in human subjects. Measurements of energy expenditure were performed by using indirect calorimetry equipment that allowed precise measurement of energy expenditure with unrestricted movement and rapid response time and over measurement areas greater than room calorimeters.

SUBJECTS AND METHODS

Subjects

Twenty-four healthy white volunteers (17 women and 7 men) who varied widely in weight (48–109 kg) were recruited. Subjects provided informed consent and the Mayo Institutional Review Board approved the study.

Experimental design

Subjects were in thermal comfort during the experiment and had not eaten or exercised for ≥8 h before the measurements. Throughout the study, subjects were observed to ensure compliance and their movements and activities were recorded.

Rested, fasting subjects were acclimatized to the laboratory for 60 min and then resting energy expenditure (REE) was measured for 60 min while subjects lay awake, supine and motionless, in the darkened laboratory. The initial 30 min was used to acclimatize the subjects to the equipment and the final 30 min was taken as the REE.

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TABLE 1
Energy expenditure and respiratory quotient associated with fidgeting-like activities and low levels of activity[1]

	Energy expenditure	Respiratory quotient
	kJ/min (% above resting)	
Resting	5.4 ± 1.5 (—)	0.76 ± 0.05
Sitting motionless	5.6 ± 1.6 (3.7 ± 6.3)	0.76 ± 0.04
Sitting while fidgeting	8.2 ± 2.3[2] (54 ± 29)	0.76 ± 0.04
Standing motionless	6.1 ± 1.7[2] (13 ± 8)	0.76 ± 0.04
Standing while fidgeting	10.3 ± 2.9[2] (94 ± 38)	0.75 ± 0.04
Walking at 1.6 km/h	13.7 ± 4.3[2] (154 ± 38)	0.76 ± 0.04
Walking at 3.2 km/h	16.4 ± 5.4[2] (202 ± 45)	0.77 ± 0.04
Walking at 4.8 km/h	21.3 ± 7.9[2] (292 ± 81)	0.77 ± 0.03

[1] $\bar{x}$ ± SD.
[2] Significantly different from resting value, $P < 0.001$.

Energy expenditure was then measured for 20 min each under the following conditions: *1*) While subjects were sitting motionless. Subjects were seated in an armchair with their back, arms, and legs supported. Subjects were asked to remain relaxed and to not move. *2*) While subjects were allowed to partake of self-selected fidgeting movements while remaining seated. Subjects were informed that they were allowed to move their arms and legs freely while remaining seated. *3*) While subjects were standing motionless. Subjects were instructed to stand motionless with their arms hanging by their sides and their feet spaced 15 cm (6 in) apart. Subjects were asked to remain relaxed and to not move. *4*) While subjects were allowed to partake of self-selected fidgeting movements while standing. Subjects were instructed that they were allowed to move freely and could emulate, at their discretion, activities of daily living. *5*) While subjects were walking on a treadmill (Q3000; Quinton, Seattle) at 1.6 km/h (1 mph). *6*) While subjects were walking on a treadmill at 3.2 km/h (2 mph). *7*) While subjects were walking on a treadmill at 4.8 km/h (3 mph). The order of these activities was fixed and instructions were standardized.

Methods and materials

Energy expenditure was measured in a temperature-controlled, silent laboratory environment with a SensorMedics 229 flow-over, indirect calorimeter (Yorba Linda, CA). The calorimeter was calibrated for flow daily by using a 3-L calibrated syringe and before each measurement with 2 primary standard span gases (4% CO_2, 16% O_2, and 26% O_2 and the balance N_2). Gas flow through the system was modulated to maintain oxygen and carbon dioxide concentrations within physiologic comfort. Data were integrated every 30 s and stored in a computer. The system was tested by burning measured-mass, high-purity ethanol (AAPER Alcohol and Chemical Company, Shelbyville, KN) within the system with use of a specialized apparatus (SensorMedics).

Expired air was collected by using a full-face transparent mask (Scott Aviation, Lancaster, NY). The facemask was connected to the calorimeter by 6 m of 22-mm diameter leakproof tubing (Hans Rudolph Inc, Kansas City, MO). The advantage of this system was that it permitted almost complete mobility with minimal agitation. We found that while wearing this equipment volunteers could complete tasks inside and outside the laboratory such as walking on level ground, climbing stairs in stairwells, or working in an office environment. Even in these circumstances, highly precise measures of energy expenditure could be made. The response time of the calorimeter at a flow rate of 30 L/min was ≈20 s.

Statistical analysis

Mean energy expenditure for each 20-min activity was calculated. All values are given as means ± SDs. To compare changes in energy expenditure for the 24 subjects, repeated-measures analysis of variance was used with subsequent post hoc testing by paired t test with Bonferroni adjustment. Linear regression analysis was used where appropriate. The computer program SYSTAT (version 9.0; SPSS Inc, Chicago) was used. Statistical significance was defined as $P < 0.05$.

RESULTS

The study population comprised 17 women and 7 men with a mean (±SD) age of 38 ± 11 y, weight of 76 ± 21 kg, and body mass index (BMI; in kg/m^2) of 27 ± 6. Ten subjects were of normal weight (BMI < 25.0), 9 were overweight (BMI: 25.0–29.9), and 5 were obese (BMI > 29.9). Repeated alcohol burn experiments yielded carbon dioxide and oxygen recoveries of ≈98%. The SD of the respiratory quotient for the last 15 min of measurement was <1% of the mean. The test-retest differences for duplicate measurements of REE and motionless sitting and standing energy expenditure were <3%.

The energy expenditure and respiratory quotients for each of the activities studied are shown in **Table 1**. The percentage change in energy expenditure above REE associated with fidgeting-like activities for each subject is shown in **Figure 1**.

Fidgeting-like activities increased energy expenditure in each subject compared with the relevant motionless state. The energy expenditure of fidgeting-like activities while seated was 2.6 ± 1.5 kJ/min greater ($P < 0.0001$) than the energy expenditure while sitting motionless. Activities tended to be consistent between subjects and included hand and foot tapping and arm and leg swinging. Most subjects did not move their trunks noticeably; 8 read magazines and 3 performed hair-grooming gestures and computer work.

Fidgeting-like activities while standing increased ($P < 0.0001$) energy expenditure by 4.2 ± 1.9 kJ/min compared with standing motionless. The self-selected fidgeting-like activities varied greatly between volunteers. Some ambled around the 6-m^2 laboratory; others emulated answering telephones, changing a video, or folding sheets; and one subject pretended to be interacting with a pet normally present in her home.

The correlation coefficients and regression equations between weight and energy expenditure for the activities studied are shown in **Table 2**. Total energy expenditure correlated significantly with body weight for each activity. There were also significant correlations between the changes in energy expenditure that accompanied each activity conducted while standing and body weight. There was no significant relation between the change in energy expenditure of sitting activities and body weight.

DISCUSSION

Changes in NEAT were recently found to mediate resistance to weight gain with overfeeding in sedentary, nonobese subjects (1). We are therefore starting to examine the components of nonexercise activity and their thermogenic potential. Because activities that are performed at very low workloads are conducted

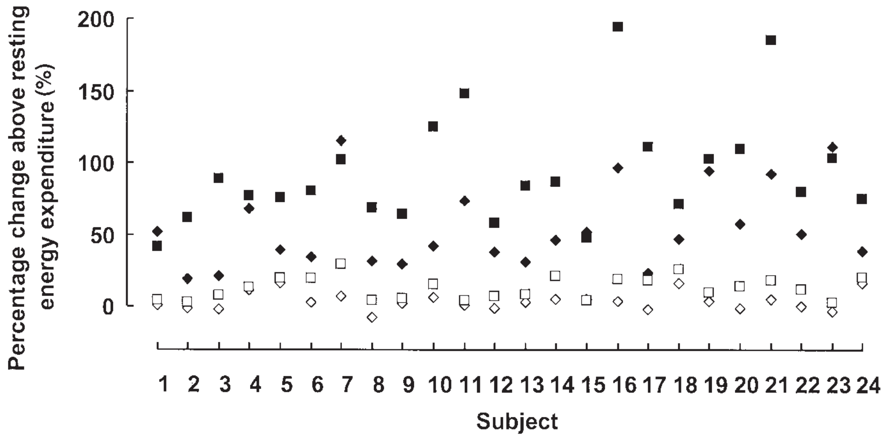

FIGURE 1. Percentage change in energy expenditure above resting values while sitting motionless (◇), partaking of fidgeting-like activities while sitting (◆), standing motionless (□), and partaking of fidgeting-like activities while standing (■) in 24 healthy subjects (subjects 1–7 were men, subjects 8–24 were women).

for several hours each day even by sedentary individuals (8), we studied the changes in energy expenditure that accompany fidgeting-like movements in a group of healthy volunteers who varied 2-fold in weight. In all the subjects studied, fidgeting-like movements at very low work intensities were associated with substantial increases in energy expenditure.

We readily acknowledge that although the measurements in this study were performed under careful laboratory conditions and that the thermogenic responses to the defined activities were highly reproducible, there were limitations to this study. For example, we did not measure or attempt to control for the amount of movement that our subjects made during the times they were instructed to fidget; rather, subjects were allowed to choose their activities. Our intent was to assess the thermic response to volitional fidgeting rather than to impose a specific activity regimen. An advantage of the calorimetry system that we used is that subjects can perform activities up to 30 m away from the device. Thus, we might better have studied subjects' self-selected, nonexercise activities in their home or office environments because the laboratory environment is somewhat restrictive (6 m^2). However, the approach we adopted enabled us to obtain careful baseline measurements at rest while allowing a wide variety of self-selected activities, albeit within the confines of a laboratory.

In all the subjects studied, fidgeting-like movements were associated with quantitatively significant changes in energy expenditure. In the past, little emphasis has been placed on the energy expenditure associated with fidgeting-like activity although the fidgeting of children involved in sedentary activities, the estimated thermic potential of fidgeting in young men, and the thermic effect of clerical work have been elegantly documented (4, 9–11). In this study we systematically measured the thermogenesis of fidgeting-like activities in nonconfined human subjects by using an indirect calorimetry system that enabled precise, rapidly responsive measures of energy expenditure in mobile subjects without the need for a room calorimeter. The changes in energy expenditure that we detected with fidgeting-like activities are comparable with observations obtained by other investigators using room calorimeters. For example, Kurzer (12), using a direct

TABLE 2
Correlation coefficients for body weight (dependent) and energy expenditure (independent)[1]

	Energy expenditure		Change in energy expenditure	
	r^2	Equation	r^2	Equation
Resting	0.34[2]	$y = 0.043x + 2.1$	—	—
Sitting motionless[3]	0.44[4]	$y = 0.049x + 1.9$	NS	—
Sitting while fidgeting[5]	0.46[4]	$y = 0.073x + 2.6$	NS	—
Standing motionless[3]	0.49[4]	$y = 0.056x + 1.8$	0.36[2]	$y = 0.013x - 0.31$
Standing while fidgeting[6]	0.48[4]	$y = 0.095x + 3.1$	0.18[7]	$y = 0.039x + 1.2$
Walking at 1.6 km/h[6]	0.49[4]	$y = 0.14x + 2.8$	0.38[4]	$y = 0.086x + 1.0$
Walking at 3.2 km/h[6]	0.56[4]	$y = 0.19x + 1.6$	0.52[4]	$y = 0.14x - 0.26$
Walking at 4.8 km/h[6]	0.64[4]	$y = 0.30x - 1.6$	0.61[4]	$y = 0.25x - 3.4$

[1] Left-hand columns represent the relations between body weight and total energy expenditure for the activity indicated. Right-hand columns represent the relations between body weight and change in energy expenditure for the activity indicated.
[2] $P < 0.005$.
[3] Change in energy expenditure above resting values.
[4] $P < 0.001$.
[5] Change in energy expenditure above values for sitting motionless.
[6] Change in energy expenditure above values for standing motionless.
[7] $P < 0.05$.

calorimeter, measured sitting energy expenditure in 17 motionless subjects and in these subjects after using reference books while remaining seated. In those subjects, energy expenditure increased by 31 ± 10% with the defined activity, which is comparable with the changes in energy expenditure of 47 ± 29% that we detected with fidgeting-like activities while seated.

Our data show marked variance in the thermic response to fidgeting-like activities. The greater variability in thermogenesis associated with fidgeting-like activities in our seated subjects than in the subjects studied by Kurzer (12) most likely reflects that our subjects freely selected their activities are were not restricted to book reading. The variance in self-selected nonexercise activity and NEAT may not be random. There is significant variability in energy expenditure that occurs independent of weight, BMI, body fat, or lean body mass and that is largely attributable to spontaneous physical activity (6, 13). Also, levels of spontaneous physical activity in humans cluster in families (14), and for mice, within strains (15). Finally, variance in exercise thermogenesis is less within twin pairs than between twin pairs (16). These observations suggest that identifiable genetic components may exist to account for variance in self-selected activity.

If resistance to fat gain with overfeeding is mediated by changes in NEAT (1, 17), it might be argued that excess fat deposition occurs in individuals who either show impaired thermogenic responses to nonexercise activity, low levels of nonexercise activity, or both. The data from this study argue against ready fat gain representing a state of impaired thermogenic responses to fidgeting-like and low-grade activities because we found a significant, positive correlation between body weight and changes in the energy expenditure associated with standing, walking, and performing fidgeting-like activities while standing. This was despite the fact that our subjects performed a variety of fidgeting-like movements. The thermic response to nonexercise activity was not diminished with increasing body weight or obesity.

This study has several potential implications. First, it may help to explain how some individuals can expend up to 3347 kJ/d (800 kcal/d) in spontaneous physical activity while confined in a small (3.3 × 2.5 m) calorimeter chamber (6). Second, these data, when combined with data showing marked interindividual variations in levels of physical activity, may provide insight into the severalfold differences in daily NEAT between individuals (18). Third, this finding may partially explain how a program directed at increasing nonexercise activity showed benefit similar to that of an exercise program when both were combined with 5021-kJ/d (1200-kcal/d) energy restriction (19). Finally, the significant thermogenesis associated with fidgeting-like activity may contribute to understanding the mechanism by which nonvolitional modulation of NEAT mediates resistance to fat gain with overfeeding (1, 17).

The World Health Organization (WHO), the National Institutes of Health, and the Surgeon General of the United States have identified that increasing physical activity is a priority for obesity prevention and treatment (20–22). The WHO specifically recommended approaches to augment nonexercise activity and thereby increase energy expenditure by ≈834 kJ/d (≈200 kcal/d). For the average obese subject in our study, 834 kJ/d was equivalent to fidgeting-like activity of ≈2.5 h/d or strolling-equivalent activity (1.6–3.2 km/h) of 1 h/d.

In conclusion, lean and obese subjects show substantial responses in energy expenditure to fidgeting-like and strolling-equivalent activities. The potential for weight loss may exist in increasing these activities,. Conversely, you might be born a fidgeter rather than become one.

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