Labor Saved, Calories Lost: The Energetic Impact of Domestic Labor-saving Devices

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Abstract
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Objective: As the prevalence of obesity has increased, so has sedentariness. Progressive sedentariness has been attributed to greater use of labor saving devices, such as washing machines, and less nonexercise walking (e.g., walking to work). However, there is a paucity of data to support this conclusion. In this study, we address the hypothesis that domestic mechanization of daily tasks has resulted in less energy expenditure compared with performing the same tasks manually.

Research Methods and Procedures: Energy expenditure was measured in four groups of subjects (122 healthy adult men and women total) from Rochester, Minnesota. Energy expenditure was measured using indirect calorimetry while subjects performed structured tasks such as cleaning dishes and clothes, stair climbing, and work-associated transportation, and these values were compared with the respective mechanized activity.

Results: Energy expenditure was significantly greater and numerically substantial when daily domestic tasks were performed without the aid of machines or equipment (clothes washing: 45 ± 14 vs. 27 ± 9 kcal/d; dish washing: 80 ± 28 vs. 54 ± 19 kcal/d; transportation to work: 83 ± 17 vs. 25 ± 3 kcal/d; stair climbing: 11 ± 7 vs. 3 ± 1 kcal/d; $p < 0.05$). The combined impact of domestic mechanization was substantial and equaled 111 kcal/d.

Discussion: The magnitude of the energetic impact of the mechanized tasks we studied was sufficiently great to contribute to the positive energy balance associated with weight gain. Efforts focused on reversing sedentariness have the potential to impact obesity.

Key words: sedentariness, mechanization, indirect calorimetry

Introduction

Obesity is epidemic in high-income countries, and it is emerging in middle- and low-income countries (1–3). Even the lean human body reserves 2 to 3 months of energy stores; therefore, it is the cumulative impact of energy imbalance over months and years that results in the development of obesity (4,5). This has been attributed to dietary excess and progressive sedentariness.

As industrialization and financial growth have occurred, there has been a shift in the types of activities that people perform in their daily routines, with television-watching and computer use being at the forefront (1). A variety of domestic functions have been automated. For example, transportation to and from the home has been automated through the use of motorized vehicles and elevators. Home cleaning has been automated through the use of dishwashers, clothes-washing machines, and vacuum cleaners. Each of these tasks has resulted in "labor saving" and increased sedentariness. Little data exist to quantify the impact of domestic mechanization on energy imbalance and obesity.

Indirect evidence supports our thesis that domestic automation has substantially impacted energy expenditure and thereby contributed to obesity. First, sales of domestic labor-saving devices (6) and vehicles (7) track obesity prevalence rates (2,3), whereas trends in energy and fat intake (8–10) do not seem to. Second, when actors emulated the way of life that preceded mechanization in the 19th century in "Old Sydney Town," Australia, they had 60% higher physical activity levels than control "modern-livers" (11). Third, as domestic mechanization has occurred, there has been a concurrent shift in the work practices of women (12). Many of the labor-saving devices that we now use in our homes are primarily used to replace or simplify many of the tasks that were completed predominantly by women. It is inter-

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esting that there have been greater increases in obesity rates among women compared with men (2,3). The dual working roles of women (working both at home and out of the home) may play a potentially important role in both over- and undernutrition in women (13).

In this study, we systematically studied the amount of energy expended while performing specific tasks with and without the aid of equipment or machines. We hypothesized that mechanization of daily tasks, including dishwashing, clothes washing, and occupation-related transportation has resulted in a deficit in energy expenditure. This deficit may be sufficient to account for the progressive increases in obesity observed in the last century.

Research Methods and Procedures

Subjects

Four groups of healthy subjects (122 total) who varied widely in weight were recruited. Subjects provided informed consent, and the Mayo Institutional Review Board approved the studies.

Experiment 1: Clothes and Dish Washing

Healthy subjects (12 women and 11 men), with a mean age of 30 ± 7 years (range, 20 to 47 years) and a mean BMI of 27 ± 4 kg/m^2 (range, 20–33 kg/m^2), were evaluated in the fasted state to determine the energy cost of dishwashing and clothes washing. Resting metabolic rate was measured while subjects sat quietly for 30 minutes using a portable indirect calorimeter (Vmax ST; Sensor Medics, Yorba Linda, CA). Subjects then performed four tasks in random order: clothes washing, by machine (Kenmore; Sears, Roebuck and Co., Hoffman Estates, IL) and hand, and dishwashing, by machine (Whirlpool; Benton Harbor, MI) and hand. Subjects were given directions on performing the tasks so that they were completed in a similar manner. Clothes and dishes were "dirtied" in the same manner for each subject, using a weighed amount of flour (50 g) and water (50 mL), and each subject washed the same number of items (clothes washing: seven towels; dishwashing: four plates, four glasses, four utensil sets, one pan) for each task. When subjects washed dishes using the dishwasher, they rinsed the dishes, loaded the dishwasher, watched television while seated for 20 minutes during the "cycle," and finally unloaded the dishwasher. When subjects washed clothes using the washing machine, they loaded the clothes into the machine, watched television while seated for 20 minutes during the "cycle," and finally unloaded the clothes from the machine. Each subject was observed for completeness of task. The amount of time required to complete the task (wash clothes or dishes) was recorded, including cycle time for the respective machines. As subjects performed the tasks, energy expenditure was measured using indirect calorimetry as above.

Experiment 2: Occupation-Related Transportation

To establish the energy cost of driving (primarily sitting energy expenditure), 49 healthy volunteers (28 women and 21 men, with a mean age of 40 ± 1 years and a mean BMI of 31 ± 6 kg/m^2) were evaluated in the fasted state. Resting metabolic rate was measured for 30 minutes, followed by sitting energy expenditure for 20 minutes.

To establish self-selected, "walk-to-work" velocity, 32 healthy Mayo Clinic employees (16 women and 16 men), 19 to 51 years of age (mean BMI, 28.5 ± 6.3 kg/m^2), were evaluated in the fasting state. After resting and standing energy expenditure had been measured, subjects walked on a treadmill at a pace they considered comfortable for "walking to work" or "walking purposefully." Once the velocity was established according to the subject's preference, the subject then walked at this velocity for 2.5 hours. During this time, energy expenditure was measured using indirect calorimetry (Vmax 29; Sensor Medics). Subjects were allowed to take breaks for the bathroom and water during the protocol.

Experiment 3: Elevator and Stair Usage

Elevator use is pervasive for domestic transit (apartments) and in sedentary work places. We had 18 volunteers (13 women and 5 men), with a mean age of 38 ± 10 years and a mean BMI of 27 ± 4 kg/m^2, record in 7-day diaries the number of floor transitions they made each day. We visited their work and home stairwells to count the number of steps and ensure that step-height was standard. The impact of elevators on energy expenditure was thereby determined. Stair climbing energy expenditure was measured in 18 healthy subjects. First, resting and standing energy expenditures were measured (fasted state), and then subjects ascended and descended stairs in actual stairwells for 20 minutes. Energy expenditure throughout was measured using calibrated and validated indirect calorimeters (Vmax 29; Sensor Medics) (14,15).

Statistical Analysis

Data are presented as means ± SD. Statistical analyses were performed using Systat, version 9 (Richmond, CA). Paired analysis was completed using Student's *t* tests with all variables. Statistical significance was defined as $p < 0.05$.

Results

Experiment 1

The subjects showed significantly greater energy expenditure ($p \leq 0.01$) while performing the domestic tasks by hand compared with using the machines. Subjects expended 1.83 ± 0.8 kcal/min when they washed dishes by hand compared with 1.31 ± 0.5 kcal/min whey they used a dishwasher. When washing clothes by hand, subjects ex-

Table 1. Mean ± SD energy expenditure per minute of selected tasks with and without labor-saving devices

Task	*N*	Energy expenditure (kcal/min)
Manual clothes washing	23	2.07 ± 0.90
Machine clothes washing	23	1.32 ± 0.50*
Manual dish washing	23	1.83 ± 0.80
Machine dish washing	23	1.31 ± 0.50*
Walking to work (0.8 miles)	32	3.62 ± 0.75
Driving to work (0.8 miles)	49	1.09 ± 0.14†
Stair climbing	18	4.20 ± 1.10
Elevator riding	18	1.30 ± 0.40‡

* Significantly less than energy expenditure of performing task manually, $p < 0.01$.
† Significantly less than energy expenditure of walking to work, $p < 0.002$.
‡ Significantly less than energy expenditure of stair climbing, $p < 0.001$.

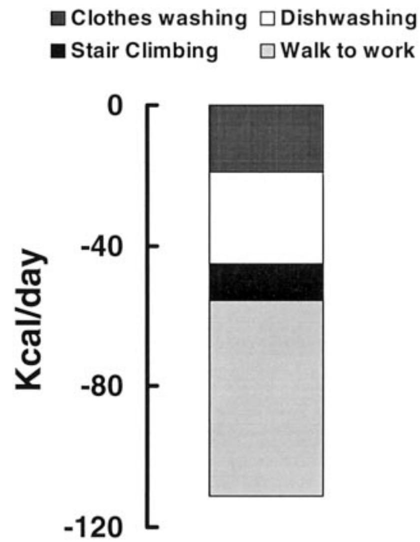

Figure 1: The energy costs of combined daily tasks in healthy subjects ($n = 122$). Subjects completed the indicated tasks with and without the aid of equipment or machines while energy expenditure was measured as described in the Materials and Methods section.

pended 2.07 ± 0.9 kcal/min compared with 1.32 ± 0.5 kcal/min when they used a washing machine. To determine daily energy expenditure related to the tasks (Table 1), the amount of time required to complete the tasks was recorded (manual and machine dish washing: 17.1 ± 4.9 and 21.4 ± 2.0 minutes, respectively; manual and machine clothes washing: 18.7 ± 5.7 and 20.0 ± 2.2 minutes, respectively). There was not a significant difference in the amount of time used to complete the tasks. On a daily basis, these subjects would expend an extra 45 kcal by washing their clothes and dishes by hand compared with washing these items with a labor-saving machine.

Experiment 2

The average "walking to work" or "walking purposefully" pace considered to be comfortable by the group of subjects was 2.1 ± 0.5 mph. By accessing local county records from 1920, when cars were not commonly in use (7), we identified the diameter of Rochester to be 1.6 miles. At that time, the primary employer in this city was Mayo Clinic, so we determined the average walking commute in 1920 to be 0.8 miles (outbound plus homebound). We then extrapolated the energy expended by Rochester residents walking to and from work to be 3.62 ± 0.75 kcal/min. The energy cost of driving was significantly less (1.09 ± 0.14 kcal/min, $p < 0.002$).

Experiment 3

By observing Rochester residents, we found that elevator and escalator use accounted for >99% of interfloor commutes at home and in the office. The amount of energy expended while making floor transitions with an elevator was significantly less than by stair climbing: 1.3 ± 0.4 kcal/min, compared with 4.2 ± 1.1 kcal/min for stair climbing ($p \leq 0.001$). The average number of stairs climbed each day was 219 ± 126. For each stair climbed, the mean energy expenditure was 0.048 ± 0.015 kcal.

The energy expended in each of the daily tasks is summarized in Table 1.

Discussion

There is no sign of reduction in the obesity epidemic that has swept developed countries. Without changes in the environmental factors that have been associated with excessive weight gain (1,4), obesity rates are projected to increase. As obesity rates grow, the amount of dollars [currently 5.5–7.8% of all U.S. health care expenditures (16)] devoted to obesity-related health problems will also likely increase. We, therefore, need to understand more clearly the impact of environmental factors on obesity and use the knowledge to develop novel approaches to weight loss. Domestic mechanization is a likely environmental force in the obesity epidemic and was the focus of our study. We systematically examined the energetic impact of mechanization on selected daily tasks. The combined energetic impact of these tasks was sufficiently great to contribute to the positive energy balance associated with weight gain.

In this study, the combined impact of domestic mechanization was substantial and equaled 111 kcal/d (Figure 1).

If a person was to decrease their energy expenditure by 111 kcal/d and not compensate for this by an equivalent decrease in food intake, annual body weight might increase by 10 lbs (4.5 kg). This degree of weight gain exceeds the progressive weight gain associated with the obesity epidemic in the United States (17).

Overall, the magnitude of the energetic impact of mechanization seems to be sufficiently great to contribute to the progressive weight gain seen in high-income countries, where obesity is epidemic (17). What would be required to reverse this decline in energy expenditure? One approach, as a host of statutory agencies have advocated, is to promote health-related exercise, particularly walking (18). When we had volunteers walk at 2 mph, which was the average self-selected walking velocity, 111 kcal was equivalent to ~45 minutes of walking. This was reminiscent to us of these agencies' exercise recommendations that range from 30 to 60 minutes of walking-equivalent exercise per day. Perhaps the function of "health-related exercise" might be to reverse the energetic impact of mechanization.

The emergence of industrialization and wealth has been associated with a variety of labor-saving machines. Because such machines are habitually used in high-income countries, the cumulative energetic impact on our energy expenditure is likely to be substantive and to have contributed to the obesity epidemic. We do not advocate elimination of such devices, however. Rather, we would point out that to reverse the energetic impact of mechanization is readily within the grasp of us all. Moreover, although obesity is epidemic in high-income countries, it is still emerging throughout the world, even in low-income countries.

Acknowledgments

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