Influence of changes in sedentary behavior on energy and macronutrient intake in youth

Leonard H Epstein, James N Roemmich, Rocco A Paluch, and Hollie A Raynor

ABSTRACT
Background: Changes in sedentary behavior may be related to changes in energy intake.

Objective: The purpose of this study was to investigate how experimental changes in the amount of sedentary behaviors influence energy intake.

Design: Sixteen nonoverweight 12–16-y-old youth were studied in a within-subject crossover design with three 3-wk phases: baseline, increasing targeted sedentary behaviors by 25–50% (increase phase), and decreasing targeted sedentary behaviors by 25–50% (decrease phase). Repeated 24-h recalls were used to assess energy and macronutrient intakes during targeted sedentary behaviors. Accelerometers were used to assess activity levels.

Results: Targeted sedentary behaviors increased by 81.5 min/d (45.8%) and decreased by 109.8 min/d (−61.2%) from baseline (both: \( P < 0.01 \)). Girls increased sedentary behaviors significantly more than did boys (107.3 and 55.8 min/d, respectively; \( P < 0.01 \)) in the increase phase. Energy intake decreased \( (−463.0 \text{ kcal/d}; \ P < 0.01) \) when sedentary behaviors decreased: the decrease in fat intake was \( −295.2 \text{ kcal/d} \) \( (P < 0.01) \). No significant changes in energy intake were observed when sedentary behaviors were increased. Youth also increased their activity by 102.4 activity counts \( \cdot \text{min}^{-1} \cdot \text{d}^{-1} \) (estimated at 113.1 kcal) when sedentary behaviors were decreased (\( P < 0.05 \)).

Conclusions: Decreasing sedentary behaviors can decrease energy intake in nonoverweight adolescent youth and should be considered an important component of interventions to prevent obesity and to regulate body weight. 


KEY WORDS Energy intake, adolescents, television, macronutrients, behavioral economics

INTRODUCTION

Sedentary behaviors were shown to be related to eating, physical activity, and obesity through use of cross-sectional or prospective correlational designs (1–6). These designs are useful in establishing relations between variables, but experimental designs in which sedentary behaviors are manipulated are needed to establish the causal influence of sedentary behavior on energy intake (7). We used experimental within-subject designs that increase and decrease sedentary behaviors in youth by 50% to examine the influence of sedentary behavior on energy intake and energy expenditure. In nonobese 8–12-y-old youth (\( n = 13 \)), we found increasing sedentary behaviors was related to an increase in energy intake per day of 251 kcal and a decrease in energy expenditure of 100 kcal (8). Decreasing sedentary behaviors did not result in any change in energy balance. In a larger \( (n = 58) \) analysis of the influence of changes in sedentary behavior on physical activity in overweight and nonoverweight youth aged 8–16 y, we found girls increased sedentary behaviors more than boys, overweight youth showed larger decreases in physical activity when sedentary behaviors were increased, and smaller increases were seen in physical activity when sedentary behaviors were decreased (9).

One approach to understanding how youth allocate time to different types of activities is behavioral economics (10). Activities that change in the same direction as a manipulated behavior are complementary behaviors, whereas behaviors that change in the opposite direction of manipulated behaviors are substitute behaviors (10, 11). Complementary relations between sedentary behavior and energy intake can occur in 2 ways. One, youth may decrease energy intake when sedentary behavior is decreased, which may be relevant to pediatric obesity prevention (7) or treatment (12–14). Two, youth may increase energy intake when sedentary behaviors are increased (15–18), which may relate to an increase in obesity prevalence (19).

Relations between sedentary behavior and energy intake may be symmetrical or asymmetrical (9, 20). If symmetrical, then proportional changes in energy intake would accompany either increases or decreases in sedentary behavior. If asymmetrical, changes in energy intake would be observed only when sedentary behavior is either increased or decreased. We observed asymmetrical relations between sedentary behaviors and physical activity in nonobese preadolescent youth (8) and obese adolescent youth (9): increasing sedentary behavior had a greater influence on physical activity than did decreasing sedentary behavior.

The aim of this study was to examine how changes in sedentary behavior influence complementary changes in energy intake by using a within-subject design that increased and decreased sedentary behaviors. Differences in complementary relations were...
### Table 1
Demographic characteristics of participants

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Boys (n = 8)</th>
<th>Girls (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>14.7 ± 1.0</td>
<td>13.7 ± 1.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>167.4 ± 14.2</td>
<td>159.5 ± 7.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>58.5 ± 12.8</td>
<td>47.8 ± 5.8</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>20.7 ± 2.6</td>
<td>18.7 ± 1.4</td>
</tr>
<tr>
<td>BMI z score</td>
<td>0.2 ± 0.8</td>
<td>-0.2 ± 0.6</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td>47.1 ± 10.0</td>
<td>47.9 ± 10.9</td>
</tr>
<tr>
<td>Television sets</td>
<td>4.1 ± 1.6</td>
<td>3.0 ± 1.9</td>
</tr>
<tr>
<td>Computers (n)</td>
<td>2.2 ± 1.7</td>
<td>2.4 ± 0.9</td>
</tr>
<tr>
<td>Exercise equipment (n)</td>
<td>2.2 ± 2.4</td>
<td>1.8 ± 1.4</td>
</tr>
<tr>
<td>Total energy intake (kcal/d)</td>
<td>2925.2 ± 665.2</td>
<td>2483.2 ± 454.8</td>
</tr>
<tr>
<td>Fat</td>
<td>1039.4 ± 341.0</td>
<td>918.2 ± 314.0</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>1454.7 ± 324.0</td>
<td>1247.1 ± 161.3</td>
</tr>
<tr>
<td>Protein</td>
<td>431.1 ± 114.4</td>
<td>317.9 ± 87.5</td>
</tr>
<tr>
<td>Energy intake while watching TV (kcal/d)</td>
<td>354.0 ± 324.3</td>
<td>427.8 ± 410.2</td>
</tr>
<tr>
<td>Fat</td>
<td>128.2 ± 136.5</td>
<td>152.0 ± 161.8</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>184.8 ± 161.0</td>
<td>201.5 ± 174.8</td>
</tr>
<tr>
<td>Protein</td>
<td>40.9 ± 40.9</td>
<td>74.4 ± 102.8</td>
</tr>
<tr>
<td>Sedentary behaviors (min)</td>
<td>180.5 ± 72.0</td>
<td>175.1 ± 51.1</td>
</tr>
<tr>
<td>Accelerometer (counts · min⁻¹ · d⁻¹)</td>
<td>493.8 ± 210.4</td>
<td>393.2 ± 220.4</td>
</tr>
<tr>
<td>MVPA (%)</td>
<td>8.2 ± 5.3</td>
<td>7.5 ± 7.0</td>
</tr>
</tbody>
</table>

1. All values are ± SD. MVPA, moderate-to-vigorous physical activity.
2. Socioeconomic status of 46 through 48 is equivalent to owner of medium-sized business, minor professionals, and technical personnel.
3. Significantly different from boys, P < 0.05 (t tests comparing baseline values).
4. n = 7 for girls.

Studied for boys and girls, because we have shown that girls may increase sedentary behaviors more than do boys when reinforced for being more sedentary (9).

### Subjects and Methods

**Participants**

Participants were 16 nonoverweight [<95th body mass index (BMI) percentile] 12–16-y-old youth enrolled in a study of the relation between sedentary behaviors and physical activity. Entry criteria for participation were the following: 15–25 h/wk spent engaging in self-reported targeted sedentary activities (ie, television or videotape watching, video game playing, or recreational computer use); no dietary, physical activity, or medical restrictions (eg, exercise-induced asthma or orthopedic or neurologic problems); and no systematic changes in factors that could influence energy intake or energy expenditure during the 9 wk of the study, such as starting a paper route or beginning summer camp. Subjects met standard research criteria for not underreporting their dietary energy intake (21, 22). Participant characteristics, grouped by sex, are presented in Table 1. Changes in physical activity for the subjects in this study were reported (8) and are presented in this report only to provide more complete data to estimate energy balance which requires consideration of both energy intake and energy expenditure.

The 16 subjects were a subsample of 58 subjects who participated in the study (9), which included 30 nonoverweight adolescent youth and 19 overweight adolescent youth. Sixteen of the 30 nonoverweight youth (53.3%) met the criteria for not underreporting food intake (21, 22), but only 6 (31.6%) of 19 overweight youth did so. Analyses were completed only in the nonoverweight youth, because more than two-thirds of the overweight youth underreported intake, and the number of overweight youth who did not underreport was too small for analysis.

The study was approved by the Institutional Review Board of the State University of New York at Buffalo School of Medicine and Biomedical Sciences Institutional Review Board. Written informed consent was obtained from adolescent participants and parents of the children.

### Design and Procedure

Specifics of the experimental procedures were described in detail (9). Families participated in a 9-wk experiment, with a 3-wk baseline phase and two 3-wk phases in which sedentary behavior was increased (increase phase) and decreased (decrease phase), respectively, with the latter two phases counterbalanced for order. Participants were asked to maintain their usual pattern of sedentary behavior, physical activity, and energy intake during baseline. The goals were to increase and decrease targeted sedentary behaviors (ie, television or videotape watching, video game playing, and recreational computer use) by 25–50% of self-reported baseline averages. Half of the cohorts were implemented in the summer and the other half during the school year.

Families could earn up to $475 for their participation in and compliance with the experimental protocol. Families were compensated for measurements, behavior change, and completion of the study. Families attended 1 meeting during each phase of the study to determine whether the families met their goals, to determine whether all the required measurements were completed, to inform the families of their next phase of the study, and to help resolve any challenging aspects of the study. Parent and child manuals provided expectations and rationale for the study, as well as behavioral modification techniques for parents to help their child increase or decrease their sedentary behaviors. Families were provided free videotape or movie rentals if they experienced difficulty increasing their sedentary behaviors.

### Measurements

**Sedentary behavior**

Specifics of recording sedentary behavior and physical activity were previously reported in detail (9). The time and duration of the targeted sedentary behaviors were self-monitored daily during the 9-wk study. Youth provided complete records for each phase (baseline: 19.1 ± 3.0 d; increase phase: 20.5 ± 1.6 d; decrease phase: 20.6 ± 1.6 d). During baseline each family member recorded his or her television and computer use in a log, and all television and computer use was monitored by using a Brultech event logger 100 (EL-100: Brultech Research Inc, Port Colborne, Canada), a small (4.2 × 2.4 × 0.9-in) downloadable device that records minute-by-minute data of the activity (on or off) of an appliance. Correlations between the Brultech devices and family logs were significant (rₚ = 0.67, P < 0.001), with 91.8% agreement (κ = 0.67). Parents reported the number of televisions, computers, and pieces of home exercise equipment in their homes.
Energy and macronutrient intakes

Participants completed 3 computer-assisted 24-h recalls over the phone with a trained staff member on 2 weekdays and 1 weekend day during the last week of each phase of the study to focus on the final level achieved, rather than on the transitions between phases. The recalls occurred for the days the children wore the accelerometer to measure physical activity. The staff used the University of Minnesota Nutrition Data System for Research for nutrient calculations (23). This is a multiple-pass recall approach, to which were added questions about behaviors engaged in while eating to permit assessment of eating bouts and energy intake in relation to the targeted “spare-time activities.” Children were provided with food models, measuring cups, measuring spoons, and a ruler for use in estimating portion sizes.

Underreporting of energy intake is a common problem in eating research. The problem is generally greater with overweight than with nonoverweight subjects (24), but nonoverweight youth also may underreport their dietary intake (24, 25). One approach to detecting underreporting so as to exclude subjects suspected of underreporting is to establish minimal criteria for energy intake required to maintain body weight. Black et al (21) and Goldberg et al (22) provided a thorough review of using cutoffs based on the ratio of energy intake to estimated basal metabolic rate (BMR) to identify underreporting of energy intake. They suggest, based on room calorimetry and double-labeled water data, that 1.35 × the estimated BMR represents the minimum plausible levels of habitual energy intake (22), and cutoffs for dietary recording for usual levels of physical activity can be set as high as 1.55 × the estimated BMR. The cutoff may depend on the type of dietary assessment used, because diet recalls provide lower estimates of energy intake or estimated BMR than do weighed food records, and on subject characteristics, because adolescents provide lower values of energy intake or estimated BMR than do younger children. The value of 1.35 was used as a cutoff in the current study on the basis of the use of dietary recalls as the method to obtain energy intake and of research that showed energy intake or estimated BMR values in adolescents of 1.34 in 198 adolescent boys and 1.29 in 184 adolescent girls (21). Any subject who did not meet the criteria of reporting energy intake ≥1.35 times their estimated resting metabolic rate (26) during the baseline phase was not included in the data analysis.

Physical activity

Physical activity was measured on the same 2 weekdays and 1 weekend day as eating behaviors by using a well-validated unidirectional accelerometer (CSA Actigraph model 7164; Computer Science and Applications Inc, Shalimar, FL; 27–29). The participants wore the activity monitors an average of 1672.7 (baseline), 1700.4 (increase phase), and 1708.8 (decrease phase) min (1 day from baseline in the baseline, increase, and decrease phases (n = 16). ANOVA showed significant changes across phases (P < 0.001), and Tukey’s honestly significant difference tests showed significant differences between the baseline phase and the increase and decrease phases (P < 0.01). Bars with different letters are significantly different, P < 0.01.

Anthropometric measurements

At baseline, we measured height with the use of a stadiometer (Seca, Columbia, MD) and weight with use of a balance-beam scale (Healthometer, Bridgeview, IL), which was calibrated daily. We calculated BMI (in kg/m²) from height and weight. Only youth below the 95th BMI percentile were studied (30).

Socioeconomic status

We used the Hollingshead 4 factor index of social status to assess socioeconomic status (31).

Analytic plan

Differences in subject characteristics by sex were assessed by using t tests. A mixed analysis of variance (ANOVA), with sex as the between-subjects factor and baseline, increase, and decrease phase values of targeted sedentary behaviors as the within-subject factor, was used to determine whether the independent variable was manipulated as planned. Similar ANOVAs were used to determine the significance of change in total energy intake and fat, carbohydrate, and protein intakes. Separate within-subject ANOVAs across all 3 phases were used to assess changes in energy intake; fat, carbohydrate, and protein intakes; and activity level. A within-subject ANOVA was also used to assess changes in energy intake in association or not in association with the targeted sedentary behaviors; phase and targeted or nontargeted sedentary behaviors were used as within-subject variables. Tukey’s honestly significant difference (HSD) tests were used to compare the baseline with the increase and decrease targeted sedentary behavior phases. Secondary analysis included the use of the same mixed ANOVA to assess changes in accelerometer counts and estimated energy expenditure.

RESULTS

The characteristics of the participants by sex are shown in Table 1. The only significant difference was that boys had significantly (P < 0.05) higher protein intakes than did girls. The average youth engaged in 177.8 ± 60.4 min of targeted sedentary behaviors/d, consumed 2704.7 ± 595.9 kcal/d, and accumulated 443.5 ± 214.5 counts · min⁻¹ · d⁻¹.

Change in minutes per day from the baseline to the increase and decrease sedentary behaviors phases is shown in Figure 1. A
A significant effect of phase was observed on change in targeted sedentary behaviors ($P < 0.001$) measured during the 3 wk of each phase. Comparison of means by using Tukey’s HSD tests showed significant increases ($P < 0.01$) and decreases ($P < 0.01$) from baseline when targeted sedentary behaviors were increased or decreased, respectively. In addition to the overall changes in sedentary behavior by phase, there was a significant sex × phase interaction ($P < 0.05$). With the use of Tukey’s HSD test to compare means, girls showed a significantly ($P < 0.05$) larger increase in sedentary behaviors during the increase phase than did boys, but no significant differences between boys and girls were observed during the decrease sedentary behavior phase. The interaction is shown in Figure 2.

Total energy and macronutrient intakes are shown in Table 2. There was a significant effect of phase on energy intake ($P < 0.02$); Tukey’s HSD test showed a significant decrease ($-463.0 ± 644.4$ kcal/d; $P < 0.01$) during the decrease phase but no significant change when sedentary behaviors were increased and no sex × phase interaction. Energy from fat was the only macronutrient to show a significant change over the phases ($P < 0.01$). Thirteen of the 16 youth met the more stringent criteria by using a cutoff of 1.55 energy intake/estimated BMR, and analysis of the results by using the more stringent cutoff showed a similar effect of reducing television watching on energy ($-567.5 ± 668.6$ kcal/d; $P < 0.01$) and dietary fat ($-380.1 ± 369.5$ kcal/d; $P < 0.01$) intakes.

No significant differences in total energy intake or any of the macronutrients were observed as a function of whether energy intake was consumed in association or not in association with targeted sedentary behaviors (Table 2). When macronutrients were calculated as a percentage of energy that day, no significant differences ($P > 0.05$) across conditions for total energy intake were observed in fat ($35.6 ± 6.0$, $33.8 ± 5.5$, and $30.8 ± 6.3$ kcal/d), carbohydrates ($50.5 ± 6.2$, $51.6 ± 6.7$, and $54.6 ± 7.1$ kcal/d), or protein ($13.9 ± 3.3$, $14.6 ± 3.0$, and $14.6 ± 2.4$ kcal/d) during the baseline, increase, and decrease phases, respectively. Similarly, when macronutrient intake in association with television watching was considered as a percentage of energy that day, no significant differences ($P > 0.05$) were observed in fat ($13.8 ± 14.1$, $16.3 ± 21.2$, and $10.7 ± 14.8$ kcal/d), carbohydrates ($14.5 ± 12.7$, $17.8 ± 19.2$, and $10.5 ± 17.4$ kcal/d), or protein ($14.1 ± 17.8$, $12.9 ± 16.2$, and $8.7 ± 16.1$ kcal/d) during the baseline, increase, and decrease phases, respectively.

A significant effect of phase on activity levels ($P < 0.01$) was observed—activity counts · min$^{-1}$ · d$^{-1}$ increased from 426.9 ± 214.5 to 529.3 ± 264.5 during the decrease phase ($P < 0.05$) according to Tukey’s HSD test—but no significant change was observed when sedentary behaviors were increased ($442.4 ± 199.8$ activity counts · min$^{-1}$ · d$^{-1}$). When the activity counts were converted to estimated energy expenditure, decreasing sedentary behaviors was related to a significant increase in activity energy expenditure from 410.5 ± 201.8 to 523.6 ± 308.7 kcal (113.1 ± 167.7 kcal/d; $P < 0.05$).

**DISCUSSION**

This study shows the influence of sedentary behaviors on energy intake in the natural environment through the use of an

![FIGURE 2. Mean (±SEM) change in minutes of targeted sedentary behavior per day from the baseline phase to the increase and decrease phases in boys ($n = 8$) and girls ($n = 8$). ANOVA showed a significant interaction of sex with changes in sedentary behavior, and Tukey’s honestly significant difference tests showed that girls increased sedentary behavior significantly more during the increase phase than did boys ($P < 0.01$). Bars with different letters are significantly different, $P < 0.01$.](https://academic.oup.com/ajcn/article-abstract/81/2/361/4607432)

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**TABLE 2**

Total energy and macronutrient intake and energy and macronutrient intake associated and not associated with targeted sedentary behaviors

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Baseline</th>
<th>Increase</th>
<th>Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kcal/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2704.2 ± 595.9</td>
<td>2640.1 ± 570.4</td>
<td>2241.1 ± 471.5</td>
</tr>
<tr>
<td>Fat</td>
<td>978.8 ± 322.7</td>
<td>900.3 ± 269.0</td>
<td>683.6 ± 183.4</td>
</tr>
<tr>
<td>Protein</td>
<td>374.5 ± 114.5</td>
<td>384.5 ± 104.1</td>
<td>330.0 ± 99.9</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>1350.9 ± 269.5</td>
<td>1355.2 ± 327.0</td>
<td>1277.6 ± 312.6</td>
</tr>
<tr>
<td>Energy intake associated with sedentary behavior (kcal/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>390.9 ± 359.2</td>
<td>457.5 ± 507.8</td>
<td>222.2 ± 316.5</td>
</tr>
<tr>
<td>Fat</td>
<td>140.1 ± 145.1</td>
<td>164.6 ± 213.7</td>
<td>79.0 ± 111.7</td>
</tr>
<tr>
<td>Protein</td>
<td>57.6 ± 77.5</td>
<td>53.1 ± 65.4</td>
<td>27.8 ± 48.6</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>193.1 ± 162.6</td>
<td>239.8 ± 238.2</td>
<td>115.5 ± 166.1</td>
</tr>
<tr>
<td>Energy intake not associated with sedentary behavior (kcal/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2313.3 ± 632.6</td>
<td>2182.6 ± 607.2</td>
<td>2019.0 ± 550.0</td>
</tr>
<tr>
<td>Fat</td>
<td>838.7 ± 301.8</td>
<td>735.8 ± 248.1</td>
<td>604.7 ± 176.6</td>
</tr>
<tr>
<td>Protein</td>
<td>234.4 ± 149.9</td>
<td>219.9 ± 215.7</td>
<td>251.0 ± 139.4</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>1210.8 ± 305.0</td>
<td>1190.7 ± 396.8</td>
<td>1148.6 ± 348.7</td>
</tr>
</tbody>
</table>

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1. All values are $\bar{x} ± SD; n = 16$.
2. Significantly different from baseline, $P < 0.05$ (Tukey’s honestly significant difference test).
Experimental paradigm. This study also represents the first examination of detailed changes in energy and macronutrient intake when sedentary behaviors are manipulated in naturalistic settings in adolescent youth. The reductions in energy and fat intakes may be relevant to an understanding of how decreasing sedentary behavior can prevent obesity (7). Decreasing targeted sedentary behavior by ~100 min/d reduced energy intake by >450 kcal/d and fat intake by almost 300 kcal/d. The reduction in fat intake may be due to the fact that high-fat snack foods are often consumed during television watching or in association with other sedentary behaviors. Girls increased targeted sedentary behaviors more than did boys during the increase phase, but the main influence of changes in sedentary behavior occurred during the decrease phase, when the changes in energy intakes in boys and girls were similar.

Energy intakes associated with targeted sedentary behaviors shifted in the same direction as did total energy intake. Total energy intakes decreased by 17.1% when sedentary behaviors were decreased, whereas energy intakes associated with sedentary behaviors decreased by 43.2%. Likewise, total fat intakes decreased by 31.2% when sedentary behaviors were decreased, and fat intakes associated with sedentary behaviors decreased by 43.6%. These data should not be surprising, given the strong association in some youth between watching television or engaging in other sedentary behaviors and eating, and thus a decrease in opportunities to be sedentary decreased the opportunities to eat. Total energy (~8.8%) and dietary fat (~27.9%) intakes not associated with targeted sedentary behaviors also decreased when targeted sedentary behaviors were decreased. The reduction in energy and fat intakes that was not associated with targeted sedentary behaviors suggests youth did not compensate at other times of the day for the reduced energy intake when the time allocated to sedentary behaviors shifted. Reducing sedentary behaviors was associated with a reallocation of time to be more physically active, which may have reduced opportunities to eat during both targeted and nontargeted sedentary behaviors.

The combination of reductions in energy intakes and estimated increases in energy expenditure would result in a shift in negative energy balance of 576 kcal. These shifts in energy intake and estimated energy expenditure occurred as a function of changes in the environment and did not require adherence to dietary changes or to an activity program. These passive changes that occurred when the environment was shifted may be easier for parents to implement and maintain than are programs that target multiple behavior changes in eating or physical activity.

The decreases in energy intakes and increases in physical activity when sedentary behavior was decreased suggest that energy intakes may show complementary relations and physical activity may show substitute relations. The complementary changes in eating that occur in association with reductions in sedentary behaviors may be due in part to a reduction in conditioned eating responses in the presence of sedentary cues. Research suggests that environmental cues can prompt eating in satiated subjects (32, 33), and repeatedly pairing eating with watching television or other sedentary behaviors may lead to a conditioned response of eating when television watching begins. The substitution of physical activity for sedentary behavior when targeted sedentary behaviors are reduced may be due in part to the freeing up of time in which to engage in other activities, with the youth choosing to reallocate time to be more active on the basis of the reinforcing value of physical activity and access to alternatives to the targeted sedentary behaviors (10). The changes in energy intakes and physical activity that accompanied decreases in sedentary behavior were asymmetrical, because increases in sedentary behaviors had limited effects on energy intake and physical activity. It should not be surprising that increasing and decreasing sedentary behaviors may have different effects on energy intake, because variables related to the substitution of physical activity for sedentary behavior were asymmetrical (9). Further research is needed to identify mechanisms for the asymmetry in energy intake.

A different pattern of change was observed for adolescents in this study than was seen in the preadolescent youth in previous research (8). In both samples, the changes were asymmetric, and influences were observed for only one direction of change. Nonoverweight preadolescent youth in the earlier study were more responsive to increases in sedentary behavior than to decreases in sedentary behavior on energy intake, whereas the reverse was shown for the adolescent youth in this study. The differences may be due, in part, to differences in the baseline values of physical activity and energy intake. Across both samples, older (>13 y old) youth consumed more energy (2855.7 kcal) than did younger (<13 y old) youth (2422.4 kcal), and it may have been easier for older youth than for younger youth to decrease energy intake. Older youth were less active (417.4 counts \( \cdot \) min\(^{-1} \cdot d^{-1} \)) than were younger youth (642.9 counts \( \cdot \) min\(^{-1} \cdot d^{-1} \)), which provides greater opportunities for increases in physical activity.

The experimental methods used produced large changes in sedentary behavior: the goal of 50% reduction was equivalent to a reduction of almost 110 min/d in the time spent in sedentary leisure time pursuits. It would be interesting to know whether significant shifts in energy intakes would be observed when smaller reductions occur and whether there is a dose-response relation between changes in sedentary behavior and changes in energy intake. Developing a better understanding of these relations could provide insight into how reducing sedentary behaviors could be used to prevent obesity. Although this study focused on nonoverweight youth, it would be interesting if these findings could be generalized to overweight youth and if reducing sedentary behaviors resulted in concurrent shifts in energy intake during treatment programs. If overweight youth find being sedentary more reinforcing than do lean youth (34), parents may have to work harder at maintaining reduced access to sedentary alternatives to reduce the likelihood that overweight youth will increase energy intake over time, and overweight youth may be less sensitive to shifts in sedentary behavior than are nonoverweight youth (9).

One study limitation was the ability to include only slightly >50% of the nonoverweight adolescents because of underreporting of energy intake. The degree of underreporting was greater for the overweight adolescents, which is consistent with previous research (24). The degree of underreporting was so great for overweight youth that the reported energy intakes for the overweight \((n = 19)\) and nonoverweight \((n = 30)\) adolescents were approximately equal (2196 and 2187 kcal/d, respectively), despite the fact that the overweight youth were 56.8% heavier than the nonoverweight youth (84.5 and 53.9 kg, respectively), which limited analysis to the nonoverweight youth. Particularly because accelerometry in youth is strongly related to energy...
expenditure assessed by double-labeled water, an important re-
search need for future studies is to identify methods of estimating
total energy intake that are not subject to self-reporting bias,
perhaps by estimating energy intake from objectively mea-
ured physical activity. A second limitation is that the phases were relatively short, and longer phases may show a different pattern of adaptation over time. Longer phases would provide the opportunity to assess the influence of changes in sedentary behavior on body weight, which was not assessed in this study at each phase.

The method used in this study provides flexibility in assessing the changes in energy intake that are possible when sedentary behavior is changed. These findings may be important for under-
standing how changing sedentary behaviors influence energy intake and energy balance so that more effective and targeted interventions can be developed for the prevention of youth obe-
sity and the treatment of obese youth.

We thank Rekha Trivikram for assistance in conducting the study.
LHE and HAR contributed to the study design, RAP and LHE contributed to the data analysis, LHE was responsible for writing and revising the manu-
script, and the other authors contributed to the revisions. LHE is a consultant to Kraft Foods. None of the other authors had any conflicts of interest.

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