Energy Balance in Adolescent Girls: The Trial of Activity for Adolescent Girls Cohort

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Objectives: To study correlates of change in BMI percentile and body fat among adolescent girls.

Methods: A longitudinal prospective study following 265 girls from the Trial of Activity for Adolescent Girls (TAAG) cohort measured in 8th grade and during 10 and 11th grade or 11th and 12th grade. Twice during 2009-2011 girls wore an accelerometer and completed a food frequency questionnaire and 7-day diary documenting trips and food eaten away from home and school. Physical activity, BMI, and percent body fat were objectively measured at each time point.

Results: Moderate to vigorous physical activity (MVPA) declined, but the change was not independently associated with changes in BMI percentile. Increased vigorous physical activity was associated with reductions in body fat. Diet was associated with both changes in BMI percentile and body fat. Girls who increased the percentage of caloric intake from snacks and desserts reduced their BMI percentile and body fat.

Conclusions: Some relationships between energy balance behaviors and BMI and body composition were counter-intuitive. While it is plausible that vigorous physical activity would result in reductions of body fat, until more accurate methods are devised to measure diet, the precise contribution of dietary composition to health will be difficult to assess.

Introduction

As overweight and obesity have become major problems among children and adolescents with dramatic increase in prevalence since 1980, the importance of increasing physical activity and controlling one’s food intake has never been more clear (1). Yet sedentary behaviors and easy access to all kinds of foods have been fully integrated into the modern lifestyle, making a positive energy balance difficult to counter or compensate for, since without specialized tools, people generally lack a means of accurately estimating both energy intake and output (2). Furthermore, people are naturally inclined to conserve and build energy stores (3).

For youth, the challenge of adhering to dietary and physical activity guidelines is particularly difficult. Physical activity is often constrained by educational structures, which require long periods of sedentary behaviors and limit the time in physical education (PE) (4). The visual excitement of electronic media keep youth sedentary (5) and the ubiquitous availability of cheap foods and snacks leads to the frequent incorporation of eating into multiple social activities and events (6).

Moreover, adolescence is a particularly important developmental period, as the body composition attained during this period usually tracks into adulthood, as do a wide variety of habits and preferences (7). Studies have indicated that as girls mature their level of physical activity declines (8,9). The quality of dietary intake may also change as girls increase the frequency with which they may eat away from home and the quantity consumed may change as girls mature and reach their maximum height. Although a consensus has developed on the ideal level of physical activity for youth (10) and on the components of a nutritious diet (11), there is still a paucity of evidence to support the recommendations, especially since very few youth meet these guidelines and most nevertheless remain healthy in the short term (12). Understanding the role that physical activity and dietary behaviors play in changing BMI and body composition would be useful.

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to inform future public health guidelines to avoid long-term negative health outcomes.

To more finely understand the factors that play a role in energy balance, we followed a cohort of adolescent girls from middle to high school and repeatedly measured dietary intake and physical activity. Furthermore, during high school, these measures were complemented by detailed travel diaries, to illuminate the contextual factors that may be associated with diet and physical activity (PA) over time.

**Methods**

We investigated physical activity and nutrition behaviors of an adolescent female subsample the trial of activity for adolescent girls (TAAG) from two sites, San Diego, CA and suburban Minneapolis/St. Paul, MN (13). Control participants enrolled in the 8th grade TAAG study cohort were invited to participate in a longitudinal follow-up. Of 532 eligible girls in these two areas, we randomly selected and recruited 303 respondents attending 7 different high schools. The participants were ages 13 to 18 years during the study period. Each girl completed an 8th grade assessment as part of the TAAG protocol, and was followed up twice, 1 year apart, during 2009-2011 in 10th/11th grade or 11th/12th grade (grades staggered to represent the full high school range). Of the 303 participants, 265 girls (87%) completed all three assessments. All methods were approved by the four affiliated Institutional Review Boards.

At each study assessment, participants completed a student questionnaire that asked about their participation in PE classes, sports teams inside and outside of school, driving status, mode of transportation to and from different activities, employment, screen time, along with background questions about parental education and household living arrangement.

During the two follow-up periods girls completed the Youth/Adolescent Questionnaire (YAQ), a validated food frequency questionnaire (14,15). They also completed a Neighborhood Places Log (NPL) using a personal digital assistant, detailing the trips they took over six consecutive days, how they got to their destinations (car, walking, other), the type of destinations (friend’s house, mall, restaurant, community activity facility, etc.), with whom they went, and what food they ate anywhere other than school or at home.

Simultaneously, in each of the follow-up periods participants wore the Foretrex 201 portable GPS unit (Garmin, Olathe, KS) and the ActiGraph model 7164 (Pensacola, FL) (16). Participants were asked to wear the GPS monitor and accelerometer during all waking hours for six consecutive days, except when showering, bathing, swimming, or engaging in activities that would result in submerging the units in water. They were instructed to wear the ActiGraph unit on the right hip and to wear the GPS units on either their wrists or on a belt around their waists, and to charge the GPS unit overnight every night. At the end of the week, study staff retrieved the devices and downloaded the data.

**Measures**

*Body composition measures.* Height was measured in centimeters using a SECA stadiometer, and weight was measured in kilograms using a SECA 880 or 876 scale. BMI was computed as weight in kilograms/height in meters$^2$. BMI percentile was calculated using sex and age specific norms (17). In 8th grade, body fat was estimated using skinfolds, but in the high school years was measured with a Tanita Scale (Tanita TBF-300A Body Composition Analyzer, Arlington Heights, IL) using bioelectrical impedance analysis.

**Moderate to vigorous physical activity (MVPA) and sedentary behavior**

The physical activity measures were derived from accelerometer data. A day was considered valid if the accelerometer was worn for more than 8.3 h on a weekend day or 10.6 h on a week day (18). The physical activity for each participant was classified using counts as sedentary (<50 counts/30 sec), light (≥100 and < 1,500 counts/30 sec), moderate (≥1,500 and <2,600 counts/30 sec), and vigorous (≥2,600 counts/30 sec), thresholds developed from TAAG participants (19). MVPA was defined as ≥1,500 counts/30 sec.

Because participants may have forgotten to wear the accelerometer or could have engaged in sporting activities in which wearing the device may be prohibited, the number of hours in which the accelerometer data was worn varied across participants. This created missing physical activity data for some participants. A common approach to deal with missing physical activity data is to exclude participant days with insufficient accelerometer data but this has been shown to result in higher bias than if imputation is used (18). Thus, the expectation maximization (EM) imputation method was used to predict missing physical activity data, resulting in 16.8% of the time points being imputed.

**Measurement of eating occasions away from home**

Foods reported on the NPL were classified into 12 food categories, to aid in discerning whether foods were high in solid oils, fats and added sugars (SOFAS) or not. We identified eating occasions in which items classified as sugar sweetened beverages (SSB), candy, sweetened baked goods, salty snacks, frozen dairy treats, and fried side dishes were consumed. Because it was not possible to determine the SOFAS content for entrees without knowing specific ingredients, these were not counted among SOFAS eating occasions.

**Participation in sports, teams, and PE class**

Participation in physical exercise, classes, and sports teams in and out of school was self-reported at each assessment.

**Dietary behaviors**

From the YAQ questionnaire, we estimated total daily calories, daily servings of fruits and vegetables, and calories from SSBs and snacks, and calories consumed from carbohydrates, protein, and fat. To estimate the proportion of calories consumed in SSBs and snacks considered high in SOFAS, we summed the calories of items listed as snacks/desserts, assigning the calories per serving based upon the USDA Nutrient Database (20). Because the average total calories reported among overweight girls was significantly lower than among normal and underweight girls, and based upon evidence that overweight individuals are more likely they are to underreport calories, we also modeled the data in two ways: as reported and after multiplying total calories by 134% for girls with BMI ≥ 85% for age (21).

**Covariates**

Girl-level data on age, race/ethnicity, mother’s education, and neighborhood percent households in poverty from the US Census, demographics,
and population density were also examined. Age and race/ethnicity (classified as White/non-Hispanic or not) were reported by the student in 8th grade. Individual-level income data were not available.

Analysis methods
We generated descriptive statistics overall and compared the dietary intake and physical activity of individuals who maintained their BMI percentile to those who increased or reduced their BMI percentile by more than 10 percentile points over the study period. We estimated the total decline in energy expenditure for physical activity, assigning 8 calories/min for changes in vigorous physical activity, 5 calories/min for moderate, and 2 calories/min for light (22).

The primary analysis involved linear models, with participant-level random effects, conducted using the Statistical Analysis System (version 9.2, SAS Institute, Cary, NC) with the sample of participants that completed all three assessments. The random coefficient models estimated a separate intercept and linear slope for each individual, and also a random intercept for school. This modeling approach also allows us to account for correlations in repeated measurements for each participant. Standard errors for the predictors were constructed to reflect the appropriate sources of variation. The random-coefficients model was designed to examine whether habitual physical activity, diet, and environmental exposure are predictive of future weight gain and changes in percent body fat. All variables, including all the neighborhood variables that were never significant in the models were dropped from further analysis. All others were combined into one single multivariate model, which is the final model presented in the article.

The regression effects for each predictor measured over time were decomposed into between- and within-subject domains. Specifically, two orthogonal scores were computed: (i) an average value of the predictor across the three assessments, and (ii) a deviation from the average at each assessment point. The regression coefficient for the average score estimates the difference, for example, in mean BMI percentile between persons who differ by one unit on that score. Similarly, the regression coefficient for the deviation score estimates the mean change in BMI percentile points within persons associated with a one unit increase in that score. These main effects examine (a) whether measures of diet and/or physical activity are associated cross-sectionally with body weight and percent body fat (b) whether changes in diet and physical activity over time are associated prospectively with changes in body weight and percent body fat (23).

Results
A total of 265 participants had complete data for all three assessment periods. The 38 girls without complete data did not differ from the others in terms of race/ethnicity, mother’s education, and age.

Descriptive characteristics of the 265 participants are shown in Table 1. At baseline the mean age was 13.9 years. The racial-ethnic composition was: 54.3% non-Hispanic white, 27.1% Hispanic, 4.2% non-Hispanic black, 7.9% non-Hispanic Asian and 6.4% non-Hispanic other; 30.9% qualified for free/reduced lunch. Among participants, 37.4% of their mothers had a high school education or less and 59.6% had some college or a college degree. Study participants from MN were predominantly non-Hispanic white (82.8%) while in San Diego the majority was Hispanic (51.2%). Population density and the percent households in poverty were higher in San Diego than in Minneapolis neighborhoods.

Baseline and follow-up data regarding physical activity and diet are shown in Tables 1 and 2. At baseline, girls engaged in a mean of 22.2 min of MVPA/day, about 1/3 of the recommended amount (10). At first follow-up measurement of diet, reported consumption of desserts or snacks high in SOFAS and SSB was 459 calories/day, 28% higher than recommended for a 2,400 calorie diet, the average amount of intake recommended for growing adolescents. Fruit and vegetable servings were 27% lower than the 4.5 cups recommended. Participants also engaged in an average of 3.5 h per day of screen time, considerably more than the 1-2 h recommended as a maximum (24).

On average, there was a small increase in BMI between baseline and first follow-up, with almost no change during high school (first and second follow-ups). We noted a small, but significant decrease in percent body fat during high school. Average minutes of sedentary behavior increased and MVPA decreased by the first and second follow-ups, with an overall decline in estimated energy expenditure of 88 calories/day and 111 calories/day, respectively, from light, moderate, and vigorous physical activity compared to 8th grade. Participation in school teams and physical activity classes declined as did the percentage that took PE, from 86% in middle school to <30% in high school. Girls who took PE at first follow up had a higher BMI percentile than girls who didn’t (65.4% vs. 59.0%; P < 0.01), but there were no differences in BMI percentile at second follow-up.

In high school between the first and second follow-up, the percentage of girls with a driver’s license increased from 27.8 to 52.8%. Based upon the travel diary, we found that the total number of trips taken increased, with driving increasing from 81 to 88% of all trips. The biggest increases included those in which the girl or a friend drove. Walking trips declined from 10 to 7% of all trips. The total number of trips to food outlets did not change, but the number of trips where foods high in SOFAS were eaten declined by 18%. Findings from the food frequency questionnaire confirmed that there was a slight decrease in reports of snack/dessert calories between the first and second high school measures, but no change in fruit and vegetable consumption.

Table 3 reports the characteristics, physical activities, and eating behaviors of girls associated with a loss of ≥10 BMI percentile points, a maintenance of BMI percentile within 10 points, or an increase of ≥10 BMI percentile points at the 2nd follow-up compared to baseline. Overall 61.1% did not change, 20.0% increased, and 18.9% decreased. An increase in BMI percentile was associated with consuming more than 300 snack calories per day, but not with any individual level or physical activity-related variables.

Table 4 shows the final combined model predicting changes in girls BMI percentile for age and % body fat. Among the control variables, increasing age and being non-Hispanic white were associated with declines in body fat, and being white was associated with a decline in BMI percentile. Cross-sectionally, in the unadjusted model, there was no relationship between total calories, fruit and vegetable consumption with BMI percentile and body fat. Controlling for average total calories, however, a higher proportion of calories from snacks was associated with a lower BMI percentile and a trend for lower body fat. Sedentary physical activity was not associated, but each minute/day of
moderate physical activity was associated with 0.7% higher BMI percentile and 0.26% higher percentage of body fat.

**Longitudinal changes in BMI and body fat**

The bottom third of Table 4 shows the impact of changes in the independent variables over time, and it suggests that longitudinally, for every increase of 100 calories over baseline consumed per day, girls will gain 0.4 BMI percentile points, with a trend to increase body fat by 0.1% \( (P = .07) \). Given the same total calories consumed, increasing the proportion of calories consumed in snacks high in SOFAS, girls reduced their BMI percentile and percent body fat. Increasing fruit and vegetable consumption had no impact on BMI or percent body fat. Girls who increased the number of trips to food outlets, had greater decreases in their BMI percentile. With respect to physical activity, every additional minute of increase in vigorous PA per day was associated with a decline of body fat by nearly 0.1%. However, increasing participation in school PE was associated with 0.7% increase in percentage body fat, opposite of what might be expected.

When we inflated the calories reported by girls whose BMI was above the 85th percentile, the cross-sectional associations between many dietary measures and BMI percentile and body fat became statistically significant, but the longitudinal associations remained unchanged. In the adjusted model higher total calorie consumption was strongly associated with higher BMI percentile and body fat and higher levels of intakes of fruits and vegetables were now associated with lower BMI percentile by 2.6% per serving and lower body fat by nearly 1% per serving.
Table 5 models the relationship of specific dietary components and physical activity with BMI and body fat. Moderate physical activity was again associated with higher BMI percentile and higher body fat. Over time, however, increasing protein consumption was associated with increases in body fat, but increased consumption of total fats was associated with lower body fat, such that for every 100 fat calories consumed, body fat was reduced by 0.5%. Increases in vigorous physical activity showed a trend in decreasing in body fat ($P = 0.07$). When we stratified total fat by saturated, polyunsaturated fat and monosaturated fat, however, none of the relationships between fat consumption and body fat were significant (data not shown).

**Discussion**

In this study, we observed a significant decline in light, moderate, and vigorous physical activity, as girls move from middle to high school, roughly equivalent to expending 88-111 fewer calories per day. Concurrently, there was a highly heterogeneous picture of

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**TABLE 2** Measures of BMI, diet and physical activity at baseline and follow-up ($n = 265$)

| Variables                                           | Baseline; 8th Grade | 1st Follow-up 10/11th grade | 2nd Follow-up 11/12th grade | $P$-value |
|-----------------------------------------------------|---------------------|-----------------------------|-----------------------------|-----------|
| BMI                                                 | Mean (SD)           | Mean (SD)                   | Mean (SD)                   |           |
| Percentage body fat                                 | 22.1 (5.2)          | 23.5 (5.2)                  | 23.9 (5.3)                  | 0.0001    |
| BMI $\geq$ 85th Percentile                          | 29.3$^a$            | 29.3 (9.6)                  | 28.4 (9.0)                  | 0.0001    |
| BMI $\geq$ 95th Percentile                          | 30.9%               | 30.9%                       | 29.8%                       | 0.80      |
| Physical activity (PA)                              |                     |                             |                             |           |
| Avg sedentary min day$^{-1}$                        | 533.3 (61.5)        | 571.2 (59.0)                | 570.6 (58.9)                | 0.0001    |
| Avg min day$^{-1}$ of light physical activity       | 303.8 (51.4)        | 264.9 (50.8)                | 257.4 (49.7)                | 0.0001    |
| Avg min day$^{-1}$ of moderate physical activity    | 17.2 (6.7)          | 17.4 (8.5)                  | 16.3 (8.2)                  | 0.14      |
| Avg min day$^{-1}$ of vigorous physical activity    | 5.0 (4.5)           | 3.6 (4.2)                   | 3.3 (4.6)                   | 0.0001    |
| Reduction in daily caloric expenditure due to declines in light, moderate, and vigorous PA since 8th grade | Ref.                | 88                          | 111                         |           |
| Number of sports/PA teams/classes in past year     | 3.4 (3.3)           | 2.1 (2.0)                   | 1.7 (1.7)                   | 0.0001    |
| Currently taking physical education (PE) in school  | 85.7%               | 29.8%                       | 23.0%                       | 0.0001    |
| Average minutes per day of MVPA among girls taking PE | 23.0 (10.3)         | 22.0 (11.4)                 | 22.7 (10.9)                 | 0.52      |
| Average minutes per day of MVPA among girls in sports | 22.8 (10.5)         | 21.4 (10.8)                 | 20.0 (11.0)                 | 0.0001    |
| Has a driver’s license                              | 0.0%                | 27.8%                       | 52.8%                       | 0.0001    |
| Average minutes per day of MVPA among girls with a driver’s license | 20.5 (9.7)          | 19.5 (9.6)                  | 0.04                        |
| Dietary measures                                    |                     |                             |                             |           |
| Total calories                                      | -                   | 1703 (712.4)                | 1620 (656.9)                | 0.01      |
| Snack calories                                       | -                   | 370 (263.2)                 | 328 (239.6)                 | 0.0012    |
| SSB calories                                         | -                   | 89 (94.6)                   | 80 (98.6)                   | 0.0001    |
| Daily servings of F&V                                | -                   | 3.3 (2.02)                  | 3.2 (2.13)                  | 0.7450    |
| Travel diary measures                                |                     |                             |                             |           |
| Mean trips per girl                                  | -                   | 25.0 (9.0)                  | 27.1 (9.1)                  | 0.0001    |
| # Walking trips                                      | -                   | 2.6 (3.6)                   | 1.9 (3.5)                   | 0.004     |
| # Driving trips                                      | -                   | 20.2 (9.3)                  | 23.8 (9.4)                  | 0.0001    |
| # times that girl drove                              | -                   | 4.8 (8.7)                   | 9.5 (11.6)                  | 0.0001    |
| # times that friend drove                            | -                   | 3.0 (4.9)                   | 4.2 (5.5)                   | 0.002     |
| # times that parent drove                            | -                   | 9.3 (7.2)                   | 7.5 (7.2)                   | 0.0001    |
| Mean trips to someone else’s house                   | -                   | 2.7 (2.9)                   | 3.0 (3.1)                   | rs        |
| Mean trips to food outlets                           | -                   | 2.9 (2.5)                   | 3.0 (2.6)                   | rs        |
| Mean trips to other destinations                     | -                   | 2.6 (2.6)                   | 3.0 (2.8)                   | 0.05      |
| Mean trips where foods high in SOFAS eaten           | -                   | 4.4 (3.2)                   | 3.6 (2.7)                   | 0.001     |

$P$ value comes from repeated measures ANOVA $F$ test.

$^a$Not measured with bioimpedance at baseline.
weight change. Nearly 40% of girls moved their BMI percentile up or down 10 percentile points or more over this 4- to 5-year period. Dietary behaviors, rather than physical activity, explained a small portion of these changes.

Although no measures of physical activity were associated with prospectively measured BMI changes, one index of physical activity, an increase in vigorous physical activity, was associated with decreases in percent body fat. Cross-sectional correlations between moderate physical activity, weight, and BMI percentile were observed in the opposite direction one usually expects, with more physical activity associated with a higher BMI percentile and higher body fat. The finding that enrollment in PE classes was correlated with a substantially higher BMI percentile, potentially explains why heavier girls engaged in more physical activity, possibly representing either individual efforts to control weight gain or a difference in socioeconomic status, with college bound youth more likely to choose academic subjects over PE.

The diary data partly illuminate mechanisms for the observed MVPA declines in adolescence. Active transport was highly limited. Walking trips comprised <10% of all trips taken, limiting the influence of the local neighborhood environment. School-based PE added only an average of one extra minute per day of MVPA and girls reporting sports participation were no more active than nonsports participants, indicating that both the quality of school PE and sports coaching likely needs improvement.

Although reports of dietary intake may have underestimated consumption, we observed a relationship between an increase in calories consumed over time and an increase in BMI percentile, a relationship which was strengthened when we adjusted for presumed underreporting. Yet, we observed a pattern of eating that predicted a significant decrease in BMI percentile and body fat, in which girls who increase in the proportion of calories consumed of foods high in SOFAS (controlling for total calories consumed). This eating pattern

| Sample characteristics | N | Percentage of girls with BMI percentile increase of ≥10 points (n = 53) | Percentage of girls with no or small change in BMI percentile (<10 point variation) (n = 162) | Percentage of girls with BMI percentile decrease of ≥10 points (n = 50) | χ² |
|------------------------|---|---------------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------------|-----|
| Overall                | 265 | 20.0%                                                        | 61.1%                                                        | 18.9%                                                             | -   |
| White                  | 144 | 24.3                                                        | 57.6                                                        | 18.1                                                              | ns  |
| Black or Hispanic      | 83  | 19.3                                                        | 61.5                                                        | 19.3                                                              |     |
| Other                  | 38  | 5.3                                                        | 73.7                                                        | 21.5                                                              |     |
| Mother’s education ≤ high school | 99 | 14.1                                                        | 65.7                                                        | 20.2                                                              | ns  |
| Mother’s education > high school | 166 | 23.5                                                        | 58.4                                                        | 18.1                                                              |     |
| Receive free/reduced lunch | 70 | 12.9a                                                       | 64.3                                                        | 22.9                                                              |     |
| Doesn’t receive free/reduced lunch | 195 | 22.6                                                        | 60.0                                                        | 17.4                                                              | ns  |
| Ave % poverty in res. neighborhood | 265 | 5.52                                                        | 5.70                                                        | 5.82                                                              | -   |
| Engaged in sports at follow-up | 176 | 21.4                                                        | 62.3                                                        | 16.2                                                              | ns  |
| Not engaged in sports at follow-up | 89 | 18.0                                                        | 59.5                                                        | 22.5                                                              |     |
| Enrolled in PE every year | 70  | 24.3                                                        | 52.9                                                        | 22.9                                                              | ns  |
| Not enrolled in PE every year | 195 | 18.5                                                        | 64.1                                                        | 17.4                                                              |     |
| MVPA ≥ 20 min each yr | 40  | 20.0a                                                       | 65.0                                                        | 15.0a                                                              | ns  |
| MVPA < 20 min each yr | 225 | 20.0                                                        | 60.4                                                        | 19.6                                                              |     |
| Report eating ≥ 300 calories of snacks daily | 88 | 27.3                                                        | 58.0                                                        | 14.8                                                              | b   |
| Report eating < 300 calories of snacks daily | 177 | 16.4                                                        | 62.7                                                        | 20.9                                                              |     |
| Report drinking ≥ 1 SSB daily | 60  | 26.2                                                        | 61.9                                                        | 11.9a                                                              | ns  |
| Report drinking < 1 SSB daily | 205 | 18.8                                                        | 61.0                                                        | 20.2                                                              |     |
| Report eating ≥ 5 F & V servings | 49  | 26.9a                                                       | 53.9                                                        | 19.2a                                                              | ns  |
| Report eating < 5 F & V servings | 216 | 19.3                                                        | 61.9                                                        | 18.8                                                              |     |
| ≥212 min of screen time | 177 | 22.2                                                        | 56.6                                                        | 21.2                                                              | ns  |
| <212 min of screen time | 88  | 25.3                                                        | 54.8                                                        | 19.9                                                              |     |
| Works for money | 99  | 21.2                                                        | 58.6                                                        | 20.2                                                              | ns  |
| Doesn’t work for money | 166 | 19.3                                                        | 62.7                                                        | 18.1                                                              |     |

Each row adds to 100%.

aSample size of cell < 10.

bP < 0.05;

ns- not significant; F & V = fruits and vegetables; SSB = Sugar sweetened beverages.
TABLE 4 Models predicting BMI percentile and body fat

| Calories as reported on the YAQ | Calories inflated by 34% for girls with BMI% ≥ 85% |
|--------------------------------|--------------------------------------------------|
| **BMI percentile** | **Percent body fat** | **BMI percentile** | **Percent body fat** |
| Beta | SE | Beta | SE | Beta | SE | Beta | SE |
| **Intercept** | 116.83 | 38.45 | 51.20 | 11.38 | 73.87 | 38.78 | 38.58 | 11.22 |
| **Age** | −0.054 | 0.05 | −0.07 | 0.018 | −0.07 | 0.05 | −0.08 | 0.02 |
| **NH White** | −7.20 | 3.74 | −2.63 | 1.14 | −8.96 | 3.62 | −3.15 | 1.09 |
| **Min/day of accel. wear-time** | −0.071 | 0.05 | −0.04 | 0.016 | −0.03 | 0.05 | −0.02 | 0.02 |
| **Total calories** | −0.01 | 0.01 | −0.00 | 0.00 | 0.02 | 0.00 | 0.01 | 0.00 |
| **Snack (junk) calories** | −0.02 | 0.01 | −0.01 | 0.00 | −0.03 | 0.01 | −0.01 | 0.00 |
| **Fruit and vegetable servings** | 1.56 | 1.17 | 0.23 | 0.35 | −2.64 | 1.14 | −0.96 | 0.33 |
| **# trips to food outlets** | 0.83 | 0.85 | 0.38 | 0.25 | 0.54 | 0.85 | 0.29 | 0.24 |
| **# trips where SOFAS consumed** | −1.12 | 0.72 | −0.22 | 0.21 | −1.69 | 0.72 | −0.38 | 0.21 |
| **Sedentary PA (min day⁻¹)** | 0.02 | 0.04 | 0.02 | 0.01 | 0.00 | 0.04 | 0.01 | 0.01 |
| **Moderate PA (min day⁻¹)** | 0.74 | 0.27 | 0.26 | 0.08 | 0.84 | 0.26 | −0.28 | 0.08 |
| **Vigorous PA (min day⁻¹)** | 0.01 | 0.51 | −0.13 | 0.15 | 0.18 | 0.51 | −0.17 | 0.15 |
| **Takes physical education** | 8.98 | 5.26 | 2.81 | 1.55 | 9.39 | 5.24 | 0.87 | 0.51 |
| **Prospective (change over time)** | 0.004 | 0.002 | 0.001 | 0.00 | 0.002 | 0.00 | 0.00 | 0.00 |
| **Total calories** | −0.007 | 0.003 | −0.003 | 0.00 | −0.01 | 0.00 | −0.00 | 0.00 |
| **Snack (junk) calories** | 0.03 | 0.40 | −0.16 | 0.16 | 0.42 | 0.40 | 0.06 | 0.15 |
| **Fruit and vegetable servings** | −0.38 | 0.18 | −0.01 | 0.07 | −0.37 | 0.19 | 0.00 | 0.07 |
| **# trips to food outlets** | −0.13 | 0.16 | −0.12 | 0.06 | −0.12 | 0.16 | −0.12 | 0.06 |
| **Sedentary PA (min day⁻¹)** | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 |
| **Moderate PA (min day⁻¹)** | 0.02 | 0.06 | 0.01 | 0.02 | 0.02 | 0.06 | 0.01 | 0.02 |
| **Vigorous PA (min day⁻¹)** | −0.06 | 0.11 | −0.09 | 0.04 | −0.04 | 0.11 | −0.08 | 0.04 |
| **Enrolled in physical education** | 1.11 | 0.88 | 0.70 | 0.35 | 1.08 | 0.88 | 0.7 | 0.35 |

*P < 0.10; *P < 0.05; **P < 0.01; ***P < 0.001.

has been reported elsewhere (25) and may reflect a methodological limitation or the deliberate attempts of girls to control weight by consuming foods high in SOFAS, instead of foods known to comprise a healthy diet (26,27). On the other hand, given that decreases in BMI percentile were also associated with increasing trips to food outlets, it may be that the increase in high calorie snacks and desserts is a consequence of a busy schedule that precludes routinely sitting down to full meals at home (28,29). The consumption of high calorie snack foods/desserts are a primary source of calories among adolescent girls (30) as they are among most Americans (30,31). Nevertheless, during the high school years, the amount of calories from snacks and desserts high in SOFAS girls consume shows evidence of decline, both absolutely and as a percentage of all calories consumed. The adjusted model also suggests a protective association of fruit and vegetable consumption on BMI percentile and body fat, not apparent in the unadjusted model.

The declines in snack food consumption during the high school years may partly explain why weight gain among this group is not higher at a time when energy expenditure has dropped significantly. Accompanying a reduction in snack/dessert foods as measured on the FFQ, are fewer trips to places where SOFAS were eaten as measured on the NPL log at the second follow-up. This suggests that snacking on foods high in SOFAS may be malleable, and targeting them may be a successful intervention strategy to improve the diets of adolescent girls. Fruits and vegetables consumption remained stable during high school, but if the adjusted model is correct, and fruit and vegetables are associated with a lower BMI, emphasizing their consumption may be worthwhile.

In adjusting for simultaneous changes in diet and physical activity in our regression models, we cannot easily determine whether behavioral choices and outcomes reflect the desire for weight control or whether changes in BMI percentile are a consequence of those choices. On the surface, it appears that the girls who decide to take PE nevertheless gain weight, while girls who consume more of their calories in snacks are able to reduce their weight. Ultimately, the latter may lead to negative health consequences associated with excess consumption of added sugars (32). The associations between increased consumption of calories from protein and increased body

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**Note:** The table includes beta coefficients (Beta), standard errors (SE), and significance levels (*P* values) for various factors affecting BMI percentile and percent body fat. The data suggests that certain factors, such as energy balance, physical activity, and dietary choices, significantly influence BMI percentile and body fat. The table also highlights the importance of controlling for simultaneous changes in diet and physical activity to accurately assess the impact of behavioral changes on BMI. The authors also note the protective association of fruit and vegetable consumption on BMI, which is not apparent in the unadjusted model.
Changes in dietary composition predicting BMI percentile and body fat

| Variables               | Beta  | (SE)  | P value | Beta  | (SE)  | P value |
|-------------------------|-------|-------|---------|-------|-------|---------|
| Intercept               | 117.12| 38.71 |         | 51.92 | 11.42 |         |
| Age                     | −0.06 | 0.05  | 0.18    | −0.07 | 0.02  | <0.0001 |
| NH White                | −8.34 | 3.78  | 0.03    | −3.02 | 1.15  | 0.009   |
| Minutes/day of accelerometer wear-time | −0.06 | 0.05  | 0.23    | −0.03 | 0.02  | 0.04    |
| Cross-sectional         |       |       |         |       |       |         |
| Protein calories        | 0.04  | 0.03  | 0.29    | 0.009 | 0.01  | 0.40    |
| Carbohydrate calories  | −0.02 | 0.01  | 0.09    | −0.006| 0.00  | 0.05    |
| Fat calories            | −0.02 | 0.02  | 0.31    | −0.002| 0.00  | 0.65    |
| Sedentary PA (min day⁻¹) | 0.01  | 0.04  | 0.81    | 0.01  | 0.01  | 0.29    |
| Moderate PA (min day⁻¹) | 0.79  | 0.28  | 0.005   | 0.26  | 0.08  | 0.001   |
| Vigorous PA (min day⁻¹) | −0.05 | 0.52  | 0.93    | −0.14 | 0.15  | 0.37    |
| Prospective (change over time) |       |       |         |       |       |         |
| Protein calories        | 0.018 | 0.01  | 0.13    | 0.008 | 0.00  | 0.07    |
| Carbohydrate calories  | 0.00  | 0.00  | 0.29    | 0.001 | 0.00  | 0.51    |
| Fat calories            | −0.01 | 0.01  | 0.16    | −0.005| 0.00  | 0.03    |
| Sedentary PA (min day⁻¹) | 0.00  | 0.01  | 0.70    | 0.00  | 0.00  | 0.62    |
| Moderate PA (min day⁻¹) | 0.00  | 0.06  | 0.96    | −0.00 | 0.02  | 0.95    |
| Vigorous PA (min day⁻¹) | −0.03 | 0.11  | 0.80    | −0.08 | 0.04  | 0.07    |

Limitations
The study’s greatest limitation is one faced by most research in this area, namely, the limitations of self-report instruments to accurately measure diet, and those of individuals to accurately recall what they eat, including the greater underestimation by those who are overweight or obese (21,33). Although we attempted to adjust the dietary measures by inflating the calories recalled by as much as 34% among girls who were overweight or obese (34), the overall relationships between our predictors and outcomes did not change. The imperfection of dietary reporting complicates the ability to pinpoint exactly which dietary factors are most important in determining health outcomes.

Our study has limitations including a relatively small sample, making some of the trends seen potentially of interest, but precluding stratified analysis by race-ethnicity or socioeconomic status. Our geographic locations of San Diego and Minneapolis may not be generalizable. Other potential limitations include the inability of the accelerometer to measure isometric physical activity and water sports (35). However, fewer than 5% of girls reported any swimming.

Conclusion
Both diet and physical activity, particularly MVPA, contribute to overall energy balance and theoretically, to the development of overweight and obesity among adolescent girls. However, we documented minimal walking and PA in local neighborhoods and extensive exposure to low nutrient foods away from home. The declining rates of physical activity did not directly correlate with weight gain.

Our study followed girls over a limited time period and the long-term consequences of their dietary choices cannot be surmised. The greatest strength of our study was the objective measures of physical activity and our ability to distinguish between moderate and vigorous physical activity. We found a positive relationship between moderate physical activity and BMI as well as a temporal relationship between increases in vigorous physical activity and reductions in body fat (36). This supports theories advanced by Blundell et al. (37) who suggest that body composition influences appetite and energy intake, and in particular, Gutin (38,39) who suggests that vigorous activity may stimulate the conversion of energy consumed to muscle rather than fat, regardless of whether BMI increases or not. However, few girls engaged in vigorous physical activity routinely. Yet many reported consuming a diet high in SOFAS which yielded a counter-intuitive association with weight loss. Until more accurate methods are devised to measure dietary intake, the precise contribution of dietary composition to health will be difficult to assess.

References
1. Ogden CL, Carroll MD, Kit BK, et al. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. JAMA 2012;307:483-490.
2. Levitsky DA. The non-regulation of food intake in humans: hope for reversing the epidemic of obesity. Physiol Behav 2005;86:623-632.
3. Cohen DA, Farley TA. Eating as an automatic behavior. Prevent Chronic Dis 2008;5(1):A23. Available at: http://www.cdc.gov/pcd/issues/2008/jan/07_0046.htm.
4. Stanley RM, Ridley K, Dollman J. Correlates of children’s time-specific physical activity: a review of the literature. Int J Behav Nutr Phys Act 2012;9:50.
5. Dollman J, Ridley K, Magarey A, et al. Dietary intake, physical activity and TV viewing as mediators of the association of socioeconomic status with body composition: a cross-sectional analysis of Australian youth. Int J Obes 2007;31:45-52.

6. Cohen DA, Ghosh-Dastidar B, Beckman R, et al. Adolescent girls’ most common source of junk food away from home. Health Place 2012;18:963-970.

7. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. Pediatrics 1998;101(3, Part 2):518-525.

8. Kimm SY, Glynn NW, Kriska AM, et al. Longitudinal changes in physical activity in a biracial cohort during adolescence. Med Sci Sports Exerc 2000;32:1445-1454.

9. Webber LS, Catellier DJ, Lyrle LA, et al. Promoting physical activity in middle school girls trial of activity for adolescent girls. Am J Prevent Med 2008;34:173-184.

10. USDHHS. Physical Activity Guidelines for Americans. Washington DC: USDHHS; 2008.

11. USDA. Report of the Dietary Guidelines Advisory Committee on the Dietary Guidelines for Americans, 2010. Available at: http://www.cnpp.usda.gov/DGAs2010-DGACReport.htm. In; 2010.

12. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;40:181-188.

13. Stevens J, Murray D, Catellier D, et al. Design of the trial of activity in adolescent girls (TAAG). Contemporary Clin Trials 2005;26:223-233.

14. Rockett HR, Berkey CS, Colditz GA. Evaluation of dietary assessment instruments in adolescents. Curr Open Clin Nutr Metab Care 2003;6:557-562.

15. Rockett HR, Breitenbuch M, Frazier AL, et al. Validation of a youth/adolescent food frequency questionnaire. Prev Med 1997;26:808-816.

16. Swartz AM, Strath SJ, Bassett DR, Jr., et al. Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. Med Sci Sports Exerc 2000;32(9 Suppl):S450-S456.

17. CDC. About BMI for Children and Teens. Available at: http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. In; 2012.

18. Catellier DJ, Hannan PJ, Murray DM, et al. Imputation of missing data when measuring physical activity by accelerometry. Med Sci Sports Exerc 2005;37(11 Suppl):S353-S362.

19. Trouth MS, Schmitz K, Catellier DJ, et al. Defining accelerometer thresholds for activity intensities in adolescent girls. Med Sci Sports Exerc 2004;36:1259-1266.

20. USDA. USDA National Nutrient Database for Standard Reference. Available at: http://www.nal.usda.gov/fnic/foodcomp/search/. In; 2010.

21. Singh R, Martin BR, Hickey Y, et al. Comparison of self-reported, measured, metabolizable energy intake with total energy expenditure in overweight teens. Am J Clin Nutr 2009;89:1744-1750.

22. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32 (Suppl):S498-S504.

23. Sherwood NE, Jeffery RW, French SA, et al. Predictors of weight gain in the Pound of Prevention study. Int J Obes Relat Metab Disord 2000;24:395-403.

24. Bar-on ME, Broughton DB, Buttross S, Corrigan S, Gedissman A, de Rivas MRG, Rich M, Shifrin DL. American academy of child and adolescent psychiatry brian wilton American psychological association consultants Hogan M, Holroyd HJ, Reid L, Sherry SN, Strasburger V, Stone JS, 2001;107:423-426.

25. Larson N, Story M. A review of snacking patterns among children and adolescents: what are the implications of snacking for weight status? Child Obes 2013;9(2):104-115.

26. Schmidt M, Affenito SG, Stiegel-Moore R, et al. Fast-food intake and diet quality in black and white girls: the national heart, lung, and blood institute growth and health study. Arch Pediatr Adolesc Med 2005;159:626-631.

27. Neumark-Sztainer D, Wall M, Larson NL, et al. Dieting and disordered eating behaviors from adolescence to young adulthood: findings from a 10-year longitudinal study. J Am Diet Assoc 2011;111:1004-1011.

28. Goldfield GS, Murray MA, Buchholz A, et al. Family meals and body mass index among adolescents: effects of gender. Appl Physiol Nutr Metab 2011;36:539-546.

29. Vander Wal JS. The relationship between body mass index and unhealthy weight control behaviors among adolescents: the role of family and peer social support. Econ Hum Biol 2012;10:395-404.

30. Reedy J, Krebs-Smith SM. Dietary sources of energy, solid fats, and added sugars among children and adolescents in the United States. J Am Diet Assoc 2010;110:1477-1484.

31. Bachman JL, Reedy J, Subar AF, et al. Sources of food group intakes among the US population, 2001-2002. J Am Diet Assoc 2008;108:804-814.

32. Johnson RK, Appel LJ, Brands M, et al. Dietary sugars intake and cardiovascular health: a scientific statement from the American Heart Association. Circulation 2009;120:1011-1020.

33. Cutler GI, Flood A, Hannan PJ, et al. Association between major patterns of dietary intake and weight status in adolescents. Br J Nutr 2011;108(2):349-356.

34. Bothwell EKG, Ayala GX, Conway TL, et al. Underreporting of food intake among Mexican/Mexican-American Women: rates and correlates. J Am Dietetic Assoc 2009;109:624-632.

35. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. Sports Med 2001;31:439-454.

36. Stallmann-Jorgensen IS, Gutin B, Hatfield-Laube JL, et al. General and visceral adiposity in black and white adolescents and their relation with reported physical activity and diet. Int J Obes 2007;31:622-629.

37. Blundell JE, Caudwell P, Gibbons C, et al. Role of resting metabolic rate and energy expenditure in hunger and appetite control: a new formulation. Dis Models Mech 2012;5:608-613.

38. Gutin B. The role of nutrient partitioning and stem cell differentiation in pediatric obesity: a new theory. Int J Pediatr Obes 2011;6 (Suppl 1):7-12.

39. Gutin B. How can we help people to develop lean and healthy bodies? A new perspective. Res Q Exerc Sport 2013;84:1-5.