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ORIGINAL ARTICLE

Dietary-Related and Physical Activity-Related Predictors of Obesity in Children: A 2-Year Prospective Study

Jordan A. Carlson, M.A.,[1] Noe C. Crespo, Ph.D., M.P.H.,[2] James F. Sallis, Ph.D.,[3] Ruth E. Patterson, Ph.D.,[4] and John P. Elder, Ph.D., M.P.H.[5]

Abstract

Background: This observational study examined cross-sectional and 24-month longitudinal associations of physical activity and dietary behaviors with change in BMI and percent body fat among children aged 6–9 years old.

Methods: Data were from the control group (n = 271; 48% Latino) of a community-based childhood obesity prevention program. Assessments were conducted at baseline and at 24 months and included height and weight, bioelectrical impedance–derived percent body fat, and 10 physical activity and dietary behaviors measured via parent report of their child. Cross-sectional analysis of variances (ANOVA) (normal weight, overweight, obese) and longitudinal mixed-effects linear regression models were used to investigate the relation of each physical activity and dietary behavior with BMI and percent body fat.

Results: At baseline, obese children engaged in less physical activity and more sedentary behavior than normal-weight children ($p < 0.05$). Increased physical activity ($p < 0.01$) and number of breakfasts eaten with family ($p < 0.05$) were associated with decreased BMI z-score and percent body fat. Decreased sedentary behavior and sugar-sweetened beverage consumption were associated with decreased percent body fat ($p < 0.05$) but not BMI.

Conclusions: In this cohort of 271 children, increased physical activity and eating breakfast with family and reduced screen-based sedentary behaviors and sugar-sweetened beverage consumption were associated with more favorable trends in adiposity. Therefore, attention to these behaviors may be of particular importance. Results also suggest that future studies should include percent body fat as an outcome for a more precise assessment of the association of behavior with adiposity.

Introduction

Obese children are at risk of developing serious diseases such as type 2 diabetes and cardiovascular disease[1,2] and prevalence of childhood obesity in the United States has increased over the past several decades.[3] The CDC has estimated that between 1976 and 2008 obesity increased from 6.5% to 19.6% among 6- to 11-year olds.[3,4]

The obesity epidemic among children is the result of excess energy intake and inadequate energy expenditure.[5] Cross-sectional and longitudinal studies of children have generally found associations between obesity and the specific behaviors of viewing television,[6] physical inactivity,[6,7] skipping breakfast[6,8] and consumption of sugar-sweetened beverages.[6,9,10] Fast food consumption has also been associated with obesity,[6] although data are conflicting regarding the association of dietary fat with obesity in children.[6,11] Evidence regarding the relation of fruit and vegetable consumption to obesity is inconsistent.[12,13]

The majority of the research on physical activity, dietary behaviors, and obesity has used BMI as the primary obesity outcome measure. However, BMI as a measure of obesity is confounded by muscle mass,[14] whereas percent body fat is a direct measure of adiposity.[15] Thus, percent body fat may be a more sensitive outcome measure for investigating the relation of physical activity and dietary behaviors with obesity.

Identifying specific diet and activity behaviors that predict obesity is needed for development of effective

[1]Joint Doctoral Program in Public Health, San Diego State University and University of California, San Diego, CA.
[2]Exercise and Wellness Program, School of Nutrition and Health Promotion, Arizona State University, Phoenix, AZ.
[3]Department of Psychology, San Diego State University, San Diego, CA.
[4]Department of Family and Preventive Medicine, University of California, San Diego, La Jolla, CA.
[5]Institute for Behavioral and Community Health, Graduate School of Public Health, San Diego State University, San Diego, CA.

obesity prevention programs in children. The objective of the present study was to examine 24-month longitudinal associations for a wide array of physical activity and dietary behaviors with BMI and percent body fat among children aged 6–9 years old. Cross-sectional associations were also examined.

Methods

Participants

Data were from the control group (n = 271) of the MOVE Project, a 12-month recreation center—based childhood obesity prevention program that included a 24-month follow-up assessment. Participants were children aged 6–7 at baseline (aged 8–9 at 24-month assessment) and their parent or primary caregiver. Institutional Review Board approval was obtained from the sponsoring institution.

Procedures

Recruitment occurred at public recreation centers in South San Diego County, California, using targeted phone calls, flyers, presentations, and staffed information booths. Exclusion criteria for children included living in a foster or group home; having a medical and/or psychological condition that affected diet, physical activity, growth, or weight; and being unable to speak, read, and understand either English or Spanish. Parents provided informed consent and children gave verbal assent to participate. Recreation centers served as the unit of randomization: 15 recreation centers were randomized to the control group (included in the present analyses) with 16–18 child participants recruited per recreation center.

Baseline data collection took place between April, 2007, and May, 2008. Parents completed questionnaires (in English or Spanish) that asked about the child's behavior. After completing the baseline assessment, control participants received handouts regarding dental care, fire safety, environmental awareness, and video game ratings. The control group received no obesity-related intervention materials.

Measures

Body mass index. Each child's height and weight were measured by trained staff, and BMI percentiles and z-scores for age and gender were calculated using CDC growth charts.[16]

Percent body fat. Bioelectrical impedance analysis[17] was used to estimate children's percent body fat using the RJL Quantum II BIA Analyzer (RJL Systems) and the Schaefer equation for children of this age.[18] In a predictive validity study (n = 30 overweight/obese children), estimates of percent body fat using the Schaefer equation were highly correlated with dual-energy X-ray absorptiometry (DEXA)-measured percent body fat (r = 0.84) and had a low error rate as compared to three commonly used equations (mean difference in percent body fat between DEXA and bioelectrical impedance analysis was 1.18; p = N.S.).[19]

Parent reports of their child. Parents completed a survey asking about 10 of their child's physical activity and dietary behaviors. Five of the measures (physical activity, sedentary behavior, sugar-sweetened beverage consumption, juice consumption, and fruit and vegetable intake) were developed in a previous study and had 2-week test–retest intraclass correlation coefficients (ICCs) of 0.60–0.84.[20]

Physical activity was measured by taking an average of two items: (1) During the past 7 days, and (2) during a typical or usual week, how many days was your child physically active for a total of at least 60 minutes/day, excluding the time spent in school physical education.[21] Sedentary behavior was measured using a sum of three questions that asked how many hours/day, on a typical weekday, the child engaged in the following sedentary behaviors: (1) Watching television/videos/DVDs; (2) playing computer or video games; and (3) using Internet, e-mail, or other electronic media for leisure.

The number of servings of sugar-sweetened beverages consumed/day on average was reported for: (1) Soda, not diet (12 oz); (2) Hawaiian Punch, fruit drinks, lemonade, sugar-sweetened ice tea, Tampico, or other noncarbonated sugary drinks (8 oz); and (3) sports drinks like Gatorade or Powerade (12 oz).[22] Servings per day of 100% fruit or vegetable juice (8 oz) were also assessed.

The number of high-fat foods consumed/day was reported over the past 7 days using a list of 21 foods such as fried chicken, pizza, whole or 2% milk, and french fries, tater tots, or onion rings.[23] Fruit and vegetable intake (excluding juice) was assessed using a sum of two questions: On a typical day, (1) how many servings of fruit, and (2) how many servings of vegetables does your child consume?[24]

Parents reported on their child's meal habits during a typical week, including: (1) How often the child or family went out to eat or brought home ready-to-eat meals from fast food or other restaurants; and (2) how many times/week the child ate meals in front of the TV; (3) breakfasts with the family; and (4) dinners with the family.

Analysis

Analysis of variance (ANOVA) with Bonferroni *post hoc* tests was used to investigate differences at baseline for physical activity and dietary behaviors between normal-weight (5th to 84th BMI percentile), overweight (85th to 94th BMI percentile), and obese (BMI $\geq$ 95th percentile) children.[16] Paired samples t-tests were used to investigate whether BMI z-score, percent body fat, and physical activity and dietary behaviors changed from baseline to 24-month post assessment. Longitudinal mixed-effects linear regression models were used to assess the relationship of the physical activity and dietary behaviors (separate model for each behavior) with BMI z-score and percent body fat over the 24-month period. Each model included baseline and 24-month scores for the physical activity or

dietary behavior of interest and was adjusted for baseline demographic characteristics (child age, gender, race/ethnicity, and parent education) and child's height. The analyses were completed using SPSS version 17.

Results

Fourteen participants were lost to follow-up and were excluded from the analyses. Three participants were removed because they changed their percent body fat by ≥5 standard deviations (SD) from the mean change. Thus, the final sample size was 254 for all analyses. Three participants had a missing value for ≥1 independent variable of interest at baseline or 24-month follow-up. The value from the nonmissing assessment was imputed for these 3 participants. The mean child age at baseline was 6.7 years (SD = 0.7); 56% of children were girls, 39% were non-Hispanic white, and 48% were Latino. The mean age of the parent participants was 38 years (SD = 6); 93% were women, and 41% had a college degree.

At baseline, 51 children (20%) had a BMI ≥ the 85th percentile, and 39 (15%) had a BMI ≥ the 95th percentile. Average percent body fat was 29.9 (SD = 8.7). Obese children engaged in 1.39 fewer days/week of physical activity and 0.73 more hours/day of sedentary behavior as compared to normal-weight children (all $p < 0.05$; see Table 1). As compared to overweight children, obese children engaged in 0.73 more hours/day of sedentary behavior ($p < 0.05$).

From baseline to 24-month follow-up, there were increases in children's height (mean = 5.67 inches; $p < 0.001$) and percent body fat (mean = 1.34; $p < 0.001$), but no statistically significant change in BMI *z*-score (see Table 2). Children increased their sedentary behavior by 0.20 hours/day ($p < 0.01$) and decreased the number of breakfasts eaten with family by 0.45 days/week ($p < 0.001$). Children increased their fruit and vegetable intake by 0.14 servings/day ($p < 0.05$) and decreased their consumption of sugar-sweetened beverages by 0.10 servings/day ($p < 0.01$), juice by 0.45 servings/day ($p < 0.001$), fat by 0.24 foods/day ($p < 0.05$), and fast food and restaurant eating by 0.29 times/week ($p < 0.001$).

Table 3 presents the longitudinal relation of change in each behavior to change in BMI *z*-score and percent body fat over 24 months. Physical activity and eating breakfast as a family were significantly associated with BMI *z*-score and percent body fat. A 1-day/week increase in physical activity was associated with a decrease of 0.06 in BMI *z*-score and 0.77 in percent body fat ($p < 0.01$). A 1-day/week increase in eating breakfast as a family was associated with a decrease of 0.04 in BMI *z*-score and 0.35 in percent body fat ($p < 0.05$). Sedentary behavior and sugar-sweetened beverage consumption were significantly associated with percent body fat. A 1-hour/day increase in sedentary behavior was associated with an increase of 0.59 in percent body fat ($p < 0.05$). A 1-serving/day decrease in sugar-sweetened beverage consumption was associated with a decrease of 1.40 in percent body fat ($p < 0.05$).

Discussion

The 24-month longitudinal results indicated that among children aged 6–9 years, increased physical activity and

Table 1. Differences in Physical Activity and Dietary Behaviors between Normal Weight, Overweight, and Obese Children at Baseline (*N* = 254)

	Mean (SD)			
	Normal weight BMI percentile 5th–84th *n* = 164	Overweight BMI percentile 85th–94th *n* = 51	Obese BMI percentile ≥95th *n* = 39	One-way ANOVA (Bonferroni post hoc)
Physical activity (days/week)	4.66 (2.01)	4.18 (1.78)	3.27 (1.84)	[a]
Sedentary behavior (hours/day)	1.59 (1.11)	1.59 (1.25)	2.32 (1.40)	[a,b]
Juice (servings/day)	0.59 (0.57)	0.61 (0.59)	0.61 (0.65)	
Sugar-sweetened beverages (servings/day)	0.49 (0.57)	0.58 (0.59)	0.70 (0.66)	
High fat foods (foods/day)	3.49 (1.55)	3.53 (1.91)	3.41 (1.82)	
Fruit and vegetables (servings/day)	3.80 (1.61)	4.06 (1.74)	4.10 (1.87)	
Fast food/restaurants (times/week)	0.88 (0.80)	1.08 (0.96)	1.08 (0.77)	
Meals in front of TV (times/week)	1.67 (2.10)	1.49 (1.76)	2.22 (2.22)	
Breakfast as a family (days/week)	2.93 (2.05)	3.53 (2.11)	2.73 (2.12)	
Dinner as a family (days/week)	5.12 (1.57)	5.04 (1.54)	5.13 (1.39)	

[a]Normal weight different from obese
[b]Overweight different from obese
$p < 0.05$.
ANOVA, Analysis of variance.

Table 2. Change in BMI, Percent Body Fat, and Physical Activity and Dietary Behaviors in Children from Baseline to 24-Month Follow-Up (*N* = 254)

	Mean (SD)		*t*-test
	Baseline	24 months	Mean change (SD)
BMI (z-score)	0.76 (0.89)	0.71 (0.93)	–0.05 (0.49)
Body fat (percent)	29.93 (8.69)	31.27 (9.84)	1.34 (4.82)**
Height (inches)	47.54 (2.68)	53.21 (3.09)	5.67 (0.87)**
Physical activity (days/week)	4.35 (2.00)	4.25 (1.84)	–0.09 (1.90)
Sedentary behavior (hours/day)	1.70 (1.21)	1.90 (1.34)	0.20 (1.12)**
Juice (servings/day)	0.60 (0.56)	0.15 (0.25)	–0.45 (0.59)**
Sugar-sweetened beverages (servings/day)	0.54 (0.59)	0.44 (0.50)	–0.10 (0.65)**
High fat foods (foods/day)	3.49 (1.66)	3.25 (1.63)	–0.24 (1.81)*
Fruit and vegetables (servings/day)	3.90 (1.68)	4.04 (1.73)	0.14 (1.64)*
Fast food/restaurants (times/week)	1.67 (1.16)	1.39 (1.02)	–0.29 (0.97)**
Meals in front of TV (times/week)	1.72 (2.06)	1.51 (2.01)	–0.21 (1.89)
Breakfast as a family (days/week)	3.02 (2.08)	2.57 (2.07)	–0.45 (2.15)**
Dinner as a family (days/week)	5.10 (1.53)	5.10 (1.61)	0.00 (1.92)

*$p < 0.05$. **$p < 0.01$.
SD, Standard deviation.

Table 3. Longitudinal Relation of Physical Activity and Dietary Behaviors to BMI z-Score and Percent Body Fat in Children over 24 Months (*N* = 254)[a]

	BMI z-score			Percent body fat		
	Unstandardized coefficient	95% CI	*p*	Unstandardized coefficient	95% CI	*p*
Physical activity (days/week)	–0.06**	–0.09, -0.02	0.004	–0.77**	–1.13, °0.40	0.000
Sedentary behavior (hours/day)	0.04	–0.01, 0.10	0.142	0.59*	0.03, 1.15	0.040
Juice (servings/day)	–0.04	–0.21, 0.13	0.631	–1.06	–2.70, 0.57	0.202
Sugar-sweetened beverages (servings/day)	0.11	–0.03, 0.25	0.124	1.40*	0.09, 2.72	0.036
High fat foods (foods/day)	–0.02	–0.06, 0.03	0.409	–0.38	–0.81, 0.05	0.081
Fruit and vegetables (servings/day)	-0.01	–0.05, 0.03	0.644	–0.18	–0.59, 0.23	0.400
Fast food/restaurants (times/week)	0.07	0.00, 0.13	0.056	0.45	–0.19, 1.10	0.168
Meals in front of TV (times/week)	0.02	–0.02, 0.06	0.258	0.21	–0.14, 0.55	0.238
Breakfast as a family (days/week)	–0.04*	–0.07, 0.00	0.027	–0.35*	–0.69, -0.02	0.039
Dinner as a family (days/week)	–0.02	–0.07, 0.02	0.361	–0.34	–0.78, 0.11	0.139

[a]Controlling for age, gender, ethnicity (white non-Hispanic vs. other), parent education (college degree or more vs. no college degree), and height.
*$p < 0.05$. **$p < 0.01$.
CI, Confidence interval.

eating breakfast as a family and decreased sedentary behavior and consumption of sugar-sweetened beverages were related to reductions in percent body fat. Low physical activity and high sedentary behavior were also associated with higher BMI percentile in the cross-sectional analyses. These findings are generally in agreement with review studies of childhood obesity that concluded that physical inactivity, screen-based sedentary behaviors, sugar-sweetened beverages, and skipping breakfast are risk factors for obesity in children.[6,7,9–11]

Two of the 10 behaviors—physical activity and eating breakfast as a family—were related to BMI *z*-score in the longitudinal analyses, whereas 4 of the 10 behaviors—physical activity, eating breakfast as a family, sedentary behavior, and sugar-sweetened beverages—were related to change in percent body fat. Furthermore, physical activity was more strongly associated with percent body fat than BMI *z*-score. These findings suggest that increased physical activity and decreased sedentary behavior may lead to decreased body fat and increased muscle mass, which is more accurately measured by percent body fat than BMI. It is less apparent why sugar-sweetened beverage consumption was associated with percent body fat but not BMI. Sugar-sweetened bever-

age consumption had a small-to-moderate correlation with sedentary behavior (baseline $r = 0.24$; 24-month $r = 0.26$). Therefore, it is possible that children who consumed more sugar-sweetened beverages also engaged in more sedentary behavior and thus experienced increased body fat but decreased muscle mass.

Eating breakfast as a family was protective of weight gain and increased body fat, which is consistent with previous studies indicating that eating breakfast was related to healthier food choices and appetite control.[25] Consumption of fruits and vegetables, dietary fat, and juice were not associated with obesity as measured via BMI or percent body fat. Although some studies have found that consumption of fruits and vegetables, dietary fat, and juice were related to obesity in children, the results are inconsistent.[6,9–12]

It is notable that over the 24-month period of follow-up, two obesity-related behaviors changed significantly in the less-healthy direction. Children increased their sedentary screen time and reduced eating breakfast with their family. Because these behaviors were related to body fat change and were worsening, there is special justification in targeting these behaviors in interventions.

Limitations

A limitation of this study was that the physical activity and dietary behaviors were measured using one to two items per behavior for most behaviors, and these items required parents to report on the behavior of their child. Although many of these measures have evidence for validity in adolescents,[21–24] little is known about their validity when used as parent reports of their young child. Self-report measures such as food frequency questionnaires may lack validity when compared to objective measures, especially when used as parent proxy reports. However, low validity for the measures in the present study could have attenuated their relationships with outcomes. More rigorous and objective measures may provide better accuracy for detecting associations of physical activity and dietary behaviors with obesity-related outcomes. The small sample size and geographic and demographic homogeneity of the present sample may limit this study's generalizability. Finally, it is important to note that this association study could not establish a causal link between the behaviors assessed and adiposity. It is possible that greater adiposity led to decreased physical activity and sedentary time, as suggested by some studies.[26,27]

A strength of the present study was the inclusion of percent body fat as an outcome measure, which was assessed via bioelectrical impedance. The vast majority of childhood obesity studies to date have used BMI as an outcome as opposed to percent body fat. However, BMI is confounded by muscle mass and is not a direct measure of adiposity.[14] Whereas DEXA is considered the gold standard for measuring percent body fat, we used an equation for calculating percent body fat from bioelectrical impedance that correlated well with DEXA.[18,19]

Conclusion

In this cohort of 271 children, increased physical activity and eating breakfast with family and reduced screen-based sedentary behaviors and sugar-sweetened beverage consumption were associated with more favorable trends in adiposity. Therefore, attention to these behaviors may be of particular importance. Although associations with obesity-related outcomes were small, there is a growing evidence base supporting targeting these specific behaviors for childhood obesity control.[6–13] Because physical inactivity and sedentary behavior can lead to increased body fat and decreased muscle mass, BMI may be an inadequate measure of obesity in children. Thus, evaluation of childhood obesity prevention programs should include percent body fat as an outcome.

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Author Disclosure Statement

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Address correspondence to:
John P. Elder, Ph.D., M.P.H.
Distinguished Professor of Public Health
and Director, Institute for Behavioral and Community Health
Graduate School of Public Health
San Diego State University
9245 Sky Park Court, Suite 221
San Diego, CA 92123

E-mail: jelder@projects.sdsu.edu