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Covariation of Adolescent Physical Activity and Dietary Behaviors over 12-Months

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Abstract

Purpose—This study examined covariation among changes in dietary, physical activity, and sedentary behaviors over 12 months among adolescents participating in a health behavior intervention. Evidence of covariation among behaviors would suggest multi-behavior interventions could have synergistic effects.

Methods—Prospective analyses were conducted with baseline and 12 month assessments from a randomized controlled trial to promote improved diet, physical activity and sedentary behaviors (experimental condition) or SUN protection behaviors (comparison condition). Participants were adolescent girls and boys (N = 878) aged 11 to 15 years on entry. The main outcomes were: diet, based on multiple 24-hour recalls (total fat, grams of fiber, servings of fruit and vegetables, total calories); average daily energy expenditure (kcals/kg) based on 7-Day physical activity recall interviews; daily minutes of moderate-vigorous physical activity minutes from accelerometery; and self-reported daily hours of sedentary behavior.

Results—Covariation was found between fat and calories ($r = .16$), fiber and calories ($r = .53$), fiber and fruit/vegetables ($r = .53$), calories and fruit/vegetables ($r = .34$), and fruit and vegetables and sedentary behavior ($r = -.12$) for the total sample (all $p < .01$). The pattern of findings was similar for most subgroups defined by sex and study condition.

Conclusions—The strongest covariation was observed for diet variables that are inherently related (calories and fat, fiber, and fruit/vegetables). Little covariation was detected within or between other diet, physical activity and sedentary behavior domains suggesting that interventions to improve these behaviors in adolescents need to include specific program components for each target behavior of interest.

Introduction

The increasing prevalence of obesity in children and youth is largely attributed to unfavorable changes in diet, physical activity, and sedentary behaviors.[1-4] The Institute of Medicine calls for multiple strategies to change these behaviors in young people[5] and other groups such as the US Department of Health and Human Services[6] call for changes in the same behaviors to

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prevent several chronic diseases. Because most adolescents fail to meet recommendations for multiple health behaviors[7] interventions targeting multiple behaviors are attractive. However changing multiple behaviors simultaneously is difficult[8] and if diet, physical activity, and sedentary behavior covary over time, this could impact both the intended and unintended consequences of interventions meant to improve these behaviors.

Covariation has also been termed "clustering of health behaviors" and defined as assocations between two or more health behaviors."[9] Defining covariation in this manner does not make a distinction between measuring the behaviors cross-sectionally versus prospectively. In the present study, we examine prospective covariation, which is conceptually more relevant for informing the design of interventions. Though numerous, cross-sectional studies on the clustering of behaviors have limited implications for interventions because they provide no information about temporal change. Prospective studies can determine whether, over time, two or more behaviors are independent or tend to change in tandem. Interventions to prevent and treat obesity and chronic diseases in youth often target multiple behaviors, specifically, diet, physical activity, and sedentary behaviors. There is the possibility that these behaviors are related to one another such that improvements in one or two result in worsening of the other. If this is the case, trying to improve some behaviors can have deleterious effects on attempts to improve the others, leading to unintended consequences. Conversely, if the behaviors tend to covary in a positive way, improving together, this might suggest more efficient ways to target improvements in multiple behaviors.

If covariation occurs over time among behaviors, it could occur for several reasons. One is that the behaviors could be inherently related. For example, decreasing TV viewing reduces exposure to commercials for unhealthy foods and allows more time for other activities. Another mechanism might be that some behaviors help explain part or all of the relationships between other behaviors. An example of this might be parent modeling or use of behavior change skills such as goal-setting. Perhaps adolescents readily generalize behavior change strategies across multiple behaviors resulting in change for more than one behavior.

Physical activity and dietary behaviors are thought to be related for several reasons. Studies suggest that exercise reduces hunger and delays eating.[10] However, there are mixed results. Exercise may also change the tastes of foods. Studies have shown increases or no change in the palatability of food during or after bouts of exercise and none have shown decreases in palatability.[10] Another suggestion is that more active individuals are motivated to eat healthier diets.[10] Conversely, active individuals may justify eating unhealthy foods due to their higher activity levels.

Relationships between diet and physical activity have been demonstrated in cross-sectional studies in adults[11-16] and youth[9, 17-21] but there is less known about the covariation of these behaviors over time.[22] One study examined cross-sectional relationships between healthy eating behaviors and physical activity over 7 years, from 6th to 12th grades some of whom were part of a health behavior intervention.[9] Results showed that those who had the healthiest food habits were more active than those in the lowest quintile of healthy food habits. The largest differences were after 9th grade and for those in the intervention condition. A systematic review concluded cross-sectional evidence existed for the association between physical activity and healthy diet for children but not adolescents.[23] A recent cross-sectional study of 8-10 year old African-American girls found physical activity was negatively associated with fat intake and positively associated with carbohydrate intake.[24] However, the same study did not find covariation between diet and nutrition behaviors over 12 weeks.[25]

Additional cross-sectional studies have examined the associations between sedentary behavior and nutrition and/or physical activity in youth. In a large sample of U.S. high school students,

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TV viewing was associated with less consumption of fruits and vegetables.[26] A meta-analysis showed small effect sizes for the relationship between TV viewing and physical activity in children and adolescents.[2] Epstein has shown experimentally that reducing sedentary behaviors can increase physical activity, but effects were inconsistent across studies and, in some cases, depended on weight status of the participants. When sedentary time was reduced, obese youth decreased in PA while non-obese youth increased.[27-29]

The purpose of the present study was to examine whether and how diet, sedentary, and physical activity behaviors covary over time in a sample of adolescents enrolled in a behavior change intervention study over a one-year period. Because of the paucity of literature examining covariation over time, we did not have specific hypotheses about how covariation might occur or in what direction.

Methods

Intervention and Participants

The Patient-centered Assessment and Counseling for Exercise and Nutrition (PACE+) Project for adolescents was conducted from 2001 to 2004. The PACE+ intervention aimed to increase physical activity and fruit and vegetable intake and decrease dietary fat and sedentary behaviors. Participants were randomly assigned to receive the PACE+ intervention or participate in a sun protection behavior change intervention (SUN). Both interventions were based on constructs from Social Cognitive Theory and the Transtheoretical Model.[30, 31] Computer-assisted assessment and tailored feedback, physician advice for the targeted health behaviors, and materials tailored to stage of change were utilized for both intervention groups. PACE+ participants received monthly health counseling phone calls and mail-based educational information delivered over a 12-month period. SUN participants received up to 3 tailored SUN protection feedback reports during the intervention year.

Though the adolescents were all involved in a behavior change intervention, one group was randomized to a behavior change intervention targeting sedentary, physical activity, and dietary behaviors and the other group participated in a sun protection behavior change program. For purposes of the present study, this enabled examination of covariation in two groups: one (the SUN group) representative of the general population of adolescents not undergoing a behavior change intervention targeting PA, diet or sedentary behaviors; the other (the PACE+ group) representing a group of adolescents enrolled in an intervention specifically designed to change the behaviors under study. Thus, analyses were stratified by intervention condition. Measurements were taken at baseline and 6 and 12 months. Research on human subjects approval was obtained from the sponsoring institutions.

Participants (N = 878) were recruited from two healthcare systems in San Diego, CA. At baseline, the age of participants ranged from 10 to 15 years old and the mean age was 12.74 years (SD = 1.35). Females constituted 53.6% of the sample. The ethnic composition was 57.9% White, 14.7% multi-ethnic, 13.1% Hispanic, 6.6% African American, 3.6% other, and 3.4% Asian Pacific Islander. Eligibility criteria for the PACE+ Project included planning on living in the San Diego area for the next 2 years, ability to engage in moderate physical activity, no parent reported history of an eating disorder, ability to speak and read English (parents could be Spanish speaking), and informed consent/assent of guardian and adolescent. After recruitment, eating disorders were further assessed only for PACE+ participants with a 13-item computer-tailored screening questionnaire. The items related to potentially problematic behaviors such as purging, bingeing, poor body image, and harmful weight loss desires. If a participant answered “yes” to any items, their physician was notified and recommended to follow-up with the patient. No participants were excluded from the study based on physician opinion. If during the course of the intervention any participant made mention of a problematic eating behavior, they were assessed by a licensed project psychologist who made appropriate referrals to both the adolescent and parent, if necessary. While several participants were contacted during the course of the study, none was found in need of treatment.

Measures

The University of Minnesota Nutrition Data System was utilized to estimate dietary nutrient intake obtained from three 24-hour dietary recalls (2 weekdays and 1 weekend day).[32] Nutrient estimates from the three dietary recalls were averaged and for the present study included: total daily kilocalories, total calories from fat, total grams of fiber, and servings per day of fruit and vegetables.

The 7-Day Physical Activity Recall (PAR) measured self-reported physical activity. The PAR is a 20-minute structured interview and has been found to be reliable and valid for adolescents.[33, 34] During the interview participants recalled the hours spent sleeping and engaging in moderate, hard, and very hard physical activity over the past week. Time in each category was weighted by the intensity level, based on METs or multiple of resting metabolic rate. The scores from the PAR were summarized as kcal/kg/day.

The Actigraph accelerometer (MTI; formerly distributed by Computer Science and Applications) was used as an objective measure of physical activity. Accelerometers were given to participants to wear for one week at the baseline and 12-month assessments. Participants were instructed to wear accelerometers from the time they woke up until going to bed at night except when swimming or bathing. Accelerometer data were considered valid if the average daily counts were between 5000 and 3 million and the monitor was worn for at least 10 h/d and at least 3 days. Total moderate and vigorous physical activity was calculated using cutpoints determined by Freedson et al.[35] Complete accelerometry data was obtained for 445 participants at both time points.

Missing accelerometer data was treated as case-wise missing data. That is, only cases with accelerometer data at both baseline and 12-months were used to test relationships between objectively measured physical activity and other behaviors. The high proportion of missing accelerometer data was due to participants not completing the 12-month assessment point, refusing to wear the monitor, lost monitors, malfunctioning monitors, or less than 3 valid days of data on the monitor. No differences were found between participants who did and did not wear the monitor by treatment group, gender, age, or minutes of moderate and vigorous physical activity at BL or 12 months as measured by the accelerometer or PAR. This suggests no systematic pattern of missingness for the accelerometer data that might bias the results.

Participants reported time spent in sedentary activities using a self-reported questionnaire modified from a previously validated survey.[36] The adolescents reported time spent watching TV, playing computer/video games, sitting while talking on the phone, and sitting while listening to music. An 8-point scale was utilized with responses ranging from “none” to “6 hours or more.” The scale was completed for days not in school and days in school separately. A composite score was calculated from the responses. Test-retest reliability was determined from a separate sample to be sufficient (ICC = .76). Validity for the sedentary behavior index was demonstrated with significant coefficients for percent body fat ($r = .15$, $p < .001$), aerobic fitness ($r = -.11$, $p < .001$), and average daily energy expenditure measured with accelerometers ($r = -.13$, $p < .001$).

Demographic information was collected from self-reported surveys obtained from parents at baseline. Parents reported the highest level of education in the household and their child's age and ethnicity. Demographic variables were coded for all analyses as follows: age in years, ethnicity as white or non-white, and highest level of education in household as less than a bachelor's degree or a bachelor's degree or higher.

Statistical analyses

All behavior variables were converted into relative change scores. Relative change scores for each behavior were calculated as [(score on post-test measure − baseline measure)/baseline measure] * 100 to account for initial status on each behavior and create a common metric across behaviors.[25] Partial correlations were conducted to analyze the relationships between the relative change on the 4 nutrition behaviors (total fat, fiber, servings of fruit and vegetables, and total calories), total sedentary time, total self-reported physical activity (METs per day), and objectively measured total moderate-vigorous physical activity.

Several outliers were observed in the dataset. Values greater than 1500% change were removed for fruit and vegetables (N = 3), values greater than 10000% change were removed for fiber (N = 1), and for sedentary greater than 1500% change were removed (N = 2) for a total of 6 excluded cases. The resulting sample size was 684. After removal of outliers distributions for some of the variable were still not normally distributed. Thus, all percent change variables were truncated such that cases changing more than 200% were recoded as having values of 200. After these adjustments, the data were within acceptable ranges for skew and kurtosis.

Analyses were performed for the entire sample and also separately by gender and treatment condition (PACE+ or SUN). Covariates included age, highest level of parent education, and ethnicity. Due to the large number of analyses performed, the significance level was set to .01.

Results

Of the 878 enrolled in the study, 690 completed 12 month measures and were included in the current analysis. There were no differences at baseline on the behaviors included in this study between completers and noncompleters (all *p*s > .10). There were no sex, age, body weight, or highest level of parent education differences between those randomized to the PACE+ and SUN groups. More non-white adolescents were enrolled in the PACE+ (45%) than SUN treatment group (38%).[37]

Means and standard deviations for all behavior change variables are presented in Table 1. In analysis of the entire sample, see Table 2, significant positive correlations were observed for fat and kilocalories, fiber and kilocalories, fiber and fruit and vegetables, kilocalories and fruit and vegetables. A significant negative association was observed for fruit and vegetables and sedentary time.

For boys (see Table 2), regardless of study condition, there were positive associations for fiber and kilocalories, fiber and fruit and vegetables, kilocalories and fruit and vegetables. However, boys in the SUN group also had a positive association between fat and kilocalories.

For girls (see Table 2), there were positive correlations between fiber and kilocalories, fiber and fruit and vegetables, and kilocalories and fruit and vegetables for both PACE+ and SUN conditions. However, girls in the SUN group also had significant negative associations between fiber and sedentary time, and fruit and vegetables and sedentary time.

Discussion

In this large sample of adolescents, diet, physical activity, and sedentary behaviors did not covary over a one-year period. Similarly, no covariation was found between physical activity and sedentary behaviors, physical activity and diet, or diet and sedentary behaviors. An implication of these results is that intervening to improve physical activity, diet, or sedentary behaviors among adolescents would be unlikely to affect any of the other behaviors positively or negatively.

Exploratory analyses by gender did show that female participants in the SUN condition demonstrated weak covariation between sedentary and dietary behaviors with improvements in fiber and fruits and vegetables associated with a reduction in sedentary behavior. This result is consistent with previous research that eating unhealthful foods and fewer fruit and vegetables is related to more time spent watching television.[26, 38] However, the association in present study was small and would not support a recommendation about intervening to reduce television time as a means to improve diet behaviors.

Covariation was found within the domain of diet behaviors for the entire sample. For all subsamples, there were medium to large relationships between changes in fiber and kilocalories, fiber and fruit and vegetables, and kilocalories and fruit and vegetables. These most likely reflect the high degree of autocorrelation among these diet behaviors. The only dietary behavior not consistently associated with other dietary behaviors was dietary fat. This result is most likely due to the manner dietary fat was calculated (as percent of total calories from fat), which adjusts for total energy intake.[39]

No covariation was found between changes in time spent in sedentary behaviors and engaging in physical activity, confirming previous cross-sectional findings that these two behaviors are independent.[40] Given that both of these behavior domains may have important but independent effects on health, sedentary behavior should continue to be assessed separately from physical activity, and intervention approaches specific to each should be developed.

Study limitations and strengths

A limitation of this study was that the number of physical activity behaviors assessed was limited to broader categories. It may be the case that more specific types of physical activity such as stretching, vigorous physical activity alone, or moderate physical activity alone may be correlated with other health behaviors. Johnson et al.[12] found relationships between different components of activity and eating habits (for example, in men there was an association between moderate activity and higher fat intake). Perhaps other specific dietary components not included in present analyses are more related to physical activity change. For example, most dietary variables were nutrient-based, and behavioral variables such as eating breakfast, controlling portion size, soft drink consumption, and eating at fast food restaurants may have different relationships to physical activity and sedentary behavior. It was expected that change in total physical activity would covary with energy intake. The lack of such a finding may be due to measurement error in both diet and physical activity measures. Another limitation was the variation in sample size across analyses, due to different completion rates for the various measures. A major strength of this study was the large and diverse sample of adolescents studied prospectively for 12 months. Also, the use of an objective measure of physical activity and a well validated measure of dietary behaviors were strengths.

Conclusion

The present study found little evidence of covariation in changes over one-year among diet, physical activity, and sedentary behaviors in adolescents, a finding in concordance with the few other prospective studies that have examined this issue.[22, 24] The implication is that multiple behavior change interventions need to address each behavior separately and that there are no shortcuts to helping adolescents improve health behaviors. While this study did not demonstrate negative impacts on some behaviors related to improvements in other behaviors, caution is still appropriate. One study of adolescents that specifically compared single versus multiple behavior interventions found less overall behavior change when two behaviors were targeted, compared to one target behavior.[8] As with other studies, present findings raise as many questions as answers and indicate the need for further studies to inform better approaches for helping adolescents make improvements on multiple health behaviors.

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Table 1

Means and standard deviations for relative percent change in behavior variables.

	Total			**PACE boys**			**SUN boys**			**PACE girls**			**SUN girls**		
Behavior	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
Fat	684	-1.80	25.55	173	-2.73	20.95	152	-.25	25.13	178	-1.43	28.77	181	-2.58	26.64
Fiber	684	11.27	53.96	173	9.08	54.13	152	12.92	57.37	178	15.71	56.07	181	7.62	48.57
Kcals	684	.18	33.43	173	-1.40	31.18	152	5.50	33.79	178	-1.55	35.65	181	-1.05	32.75
FV	684	49.21	88.69	172	45.80	85.21	152	55.65	87.43	178	56.04	92.51	182	40.39	88.92
Sed	677	12.05	75.60	171	-2.67	65.82	152	22.60	83.29	175	-2.40	63.58	179	31.28	82.79
Mets/day	682	.51	3.36	172	.36	3.50	151	.52	3.90	178	.50	3.32	181	.66	2.76
MVPA	445	-26.81	37.87	106	-29.32	31.99	98	-26.58	36.07	119	-24.35	45.66	122	-27.21	35.86

Abbreviations: Kcals = kilocalories; FV = fruit and vegetables; Sed = sedentary behavior; MVPA = moderate to vigorous physical activity

Table 2

Partial correlations (r)* among dietary, sedentary, and physical activity behaviors.

Behaviors	Total Sample		Boys PACE+		Boys SUN		Girls PACE+		Girls SUN	
	r	DF	r	DF	r	DF	r	DF	r	DF
Fat & Fiber	-.057	667	-.08	166	.036	145	-.084	169	-.123	172
Fat & Kcals	**.163**†	667	.169	166	**.301**†	145	.079	169	.148	172
Fat & FV	-.003	667	.02	165	-.031	145	.01	169	-.028	172
Fat & Sed	.02	660	.012	164	.023	145	.023	166	.017	170
Fat & Mets/day	-.016	665	.051	165	.035	144	-.041	169	-.112	172
Fat & MVPA	-.027	430	.074	99	.014	91	-.057	111	-.12	114
Fiber & Kcals	**.531**†	667	**.573**†	166	**.496**†	145	**.502**†	169	**.575**†	172
Fiber & FV	**.528**†	667	**.408**†	165	**.609**†	145	**.590**†	169	**.52**†	172
Fiber & Sed	-.098	660	-.034	164	-.097	145	.008	166	**-.215**‡	170
Fiber & Mets/day	-.036	665	.013	165	-.12	144	-.074	169	.057	172
Fiber & MVPA	.05	430	.181	99	-.031	91	.05	111	-.017	114
Kcals & FV	**.339**†	667	**.337**†	165	**.267**†	145	**.404**†	169	**.351**†	172
Kcals & Sed	-.068	660	.054	164	-.116	145	-.045	166	-.143	170
Kcals & Mets/day	.029	665	.07	165	.09	144	-.011	169	-.081	172
Kcals & MVPA	.007	430	.01	99	.083	91	-.023	111	-.055	114
FV & Sed	**-.124**†	660	-.10	164	-.083	145	-.051	166	**-.241**†	170
FV & Mets/day	-.016	665	.081	165	-.124	144	-.018	169	.00	172
FV & MVPA	.079	430	-.001	99	.06	91	.168	111	.033	114
Sed & Mets/day	.019	660	-.083	164	.108	144	.096	166	-.026	170
Sed & MVPA	-.063	430	.023	99	-.018	91	-.036	111	-.169	114
Mets/day & MVPA	.123	430	.077	99	.182	91	.237	111	-.089	114

Abbreviations: Kcals = kilocalories; FV = fruit and vegetables; Sed = sedentary behavior; MVPA = moderate to vigorous physical activity

*Adjusted for parent education, ethnicity, and age

†p <= .001

‡p <.001