School and Residential Neighborhood Food Environment and Diet Among California Youth

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Background: Various hypotheses link neighborhood food environments and diet. Greater exposure to fast-food restaurants and convenience stores is thought to encourage overconsumption; supermarkets and large grocery stores are claimed to encourage healthier diets. For youth, empirical evidence for any particular hypothesis remains limited.

Purpose: This study examines the relationship between school and residential neighborhood food environment and diet among youth in California.

Methods: Data from 8226 children (aged 5–11 years) and 5236 adolescents (aged 12–17 years) from the 2005 and 2007 California Health Interview Survey were analyzed in 2011. The dependent variables are daily servings of fruits, vegetables, juice, milk, soda, high-sugar foods, and fast food, which were regressed on measures of food environments. Food environments were measured by counts and density of businesses, distinguishing fast-food restaurants, convenience stores, small food stores, grocery stores, and large supermarkets within a specific distance (varying from 0.1 to 1.5 miles) from a respondent's home or school.

Results: No robust relationship between food environment and consumption is found. A few significant results are sensitive to small modeling changes and more likely to reflect chance than true relationships.

Conclusions: This correlational study has measurement and design limitations. Longitudinal studies that can assess links between environmental, dependent, and intervening food purchase and consumption variables are needed. Reporting a full range of studies, methods, and results is important as a premature focus on correlations may lead policy astray.
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Introduction

Obesity remains a leading health concern for youth.[1] In sharp contrast to the goal of Healthy People 2010 that aimed to reduce obesity of children and adolescents in the U.S. to 5% by 2010,[2] obesity among those aged 2–19 years increased steadily from 14% in 2000 to 17% in 2008.[3] This triggered a burst of recent policy activities, including a $400 million healthy food initiative,[1] the founding of White House Childhood Obesity Task Force,[4] and an updated strategic plan giving obesity prevention a priority in the DHHS.[5] Many of those efforts targeted food environment as a central area for interventions. The CDC recommended counts of supermarkets as a measure[6] and the White House Childhood Obesity Task Force proposed to increase the number of supermarkets in order to reduce childhood obesity.[4]

Two commonly proposed hypotheses are that diet quality can be improved, and unhealthy weight gain can be prevented through (1) improved access to supermarkets and large grocery stores or (2) reduced exposure to fast-food restaurants, convenience stores, and small food stores. Evidence for these hypotheses is still developing and, at this point, more tentative than presented in media and policy arguments.[7–9] The Obesity Task Force's recommendation to promote supermarkets, for example, was based on a single study[10] that associated chain supermarkets in a postal ZIP code with lower body weight among adolescents. Yet earlier studies[11,12] using very similar methods that reported null findings were not cited.

The present study investigates the relationship of food environments with consumption and BMI among Californian youth. It makes two contributions: (1) One of the behavior measures (i.e., dietary intake) in the California Health Interview Survey (CHIS) is linked to the neigh-

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borhood food environment. The data have not been used in this context before. (2) Both home and school neighborhoods are analyzed. Actual locations of homes and schools are used, and neighborhoods are measured based on distance for each individual. Studies so far have considered either residential or school neighborhood food environments,[13–15] but never both.

The primary outcome variables in the current study are self-reported consumption of fruits, vegetables, 100% juice, milk, soda, high-sugar foods, and fast food, with BMI percentile as a secondary outcome. The primary explanatory variables are the counts of a particular type of food outlet (distinguishing fast-food restaurants, convenience stores, small food stores, grocery stores, and supermarkets) within a specific distance from a respondent's home and school.

Methods

Study Sample

The individual data, analyzed in 2011, come from the 2005 and 2007 waves of CHIS. Within each household, separate interviews were conducted with a randomly selected adult (aged ≥18 years); adolescents (aged 12–17 years); and parents of children (aged 0–11 years). In the two waves, a total of 11,851 children (aged 5–11 years) and 7574 adolescents (aged 12–17 years) were interviewed. Among them, 3625 (30.6%) and 2338 (30.9%), respectively, do not have valid school and residential latitude/longitude, possibly because of unsuccessful geocoding by CHIS. The main analysis as reported here uses only cases with complete data. For sensitivity analyses, missing values were imputed using the MI procedures in Stata, version 12.0, and the entire sample reanalyzed.

The primary dependent variables are a respondent's consumption of fruits; vegetables; juice; milk (only for children); soda; high-sugar foods; and fast food on the day before the interview. It is a self-report for adolescents, and a parent-report for children. The adolescent questions are, *Yesterday, how many servings of fruit, such as an apple or banana did you eat? Do not count juices*; *Yesterday, how many servings of vegetables, like corn, green beans, green salad, or other vegetables did you eat?*; *Yesterday, how many glasses of 100% fruit juice such as orange or apple juice did you drink? Include only 100% pure juices. Do not include fruit drinks*; *Yesterday, how many glasses or small cartons of milk did you drink? Include milk on cereal*; *Yesterday, how many glasses or cans of soda, such as Coke, or other sweetened drinks, such as fruit punch or Sunny Delight did you drink? Do not count diet drinks*; *Yesterday, how many servings of high-sugar foods, such as cookies, candy, doughnuts, pastries, cake or popsicles did you have? Do not include kinds that are completely sugar-free. Include low-fat kinds*; and *Yesterday, how many times did you eat fast food, such as food you get at McDonald's, Panda Express, or Taco Bell? Include fast-food meals eaten at school, at home, or at fast-food restaurants, carryout, or drive thru*. It should be noted that serving of food is self-defined in CHIS; in the child component of the survey, "a serving is the child's regular portion of this food," and in the adolescent component, "a serving is whatever it means to you."

As a secondary outcome measure, parent-reported (for children) and self-reported (for adolescents) height and weight is used to calculate age- and gender-specific BMI percentile based on the 2000 BMI-for-age growth chart issued by the CDC. It is considered as secondary because measurement error, at least for parent-reported child height/weight, is believed to be substantial and higher than in the adult self-report.[16–18]

The analysis uses separate multivariate models for children and for adolescents. The following individual variables are included as control variables in the regression: gender; age (in years and age squared); race/ethnicity (indicator variables for white, African-American, Hispanic, Asian or Pacific Islander, Native American, and other race/multirace); household size; annual household income (in national logarithm); parent's education (indicator variables for education lower than high school, high school graduate, education higher than high school but lower than college, college graduate, and education higher than college); parent's BMI; and survey wave. In CHIS, one parent was randomly selected within each surveyed household with children. Some school and home census tract characteristics (using the 2000 Census data) are included as additional control variables—population density, median household income, and proportion of non-Hispanic whites.

Measurement of the Neighborhood Food Environment

ArcMap, version 9.3.1, is used to draw circular buffers with four different radii (0.1, 0.5, 1.0, and 1.5 miles), centered at students' schools and residences. A distance of 0.1 to 1.5 miles is approximately a 2- to 30-minute walk[19] and thus captures a wide range of what might be considered a "neighborhood." Food outlet data are geocoded to latitude/longitude and overlaid over the buffers, and neighborhood food environment is constructed as the counts of a particular type of food outlet located within each buffer.

Food outlet data come from the 2006 release of InfoUSA, which compiles business data including name, type, location, and sale volume for about 14 million businesses in the U.S. Businesses in InfoUSA are classified using the North American Industry Classification System (NAICS). Although there is no NAICS code for fast-food restaurants, 63 major fast-food franchises are identified with main menus containing items such as hotdogs, burgers, pizza, fried chicken, subs, or tacos under the NAICS codes 72221105-6. Convenience stores are identified as NAICS code 44512001, and small food stores (annual sales <$1 million); midsize grocery stores (annual sales $1–$5 million); and large supermarkets (annual sales >$5 million) are identified as NAICS codes 44511001-3.

Statistical Methods

The primary dependent variables (i.e., counts of food consumption) are regressed on the explanatory variables using negative binomial regression models, a generalization of Poisson models that avoids the Poisson restriction on the mean-variance equality.[20] Separate regressions are conducted for children and adolescents, for school and residential neighborhood, and for each of the four buffer sizes (0.1-, 0.5-, 1.0-, and 1.5-mile radius). Outlet counts are created for school and home buffers separately, but also for the joint area that corrects for overlap. For instance, if the school and home buffer contain three and five fast-food outlets, respectively, and one of them is located in their overlapping area, the outlet count is 7. If a respondent's school and home are located in different census tracts, average tract characteristics are used.

Results

Table 1 shows descriptive statistics of the sample population in CHIS 2005 and 2007 waves. Adolescents aged 12–17 years consume considerably more soda, high-sugar foods, and fast food compared to children aged 5–11 years ($p<0.0001$), whereas daily consumptions of fruits, vegetables, and juice are similar.

Appendix A (available online at www.ajpmonline.org) shows the percentages of children and adolescents who have zero, one, two, and three or more food outlets of a specific type within 0.5 mile (about 10-minute walking distance) from home or school. Children and adolescents interviewed in CHIS lived and attended schools in 3534 and 3508 census tracts in California, respectively, with considerable variation in population, median household income, and minority composition. Similar variation exists in neighborhood food environment across respondents. For example, 45% of adolescents had no fast-food restaurants in 10-minute walking distance, whereas 28% had three or more in proximity from school. Seventy percent of families with children had no supermarkets within 0.5 mile from home, but 7% had two or more.

Table 2 shows the estimated associations between neighborhood food environment and dietary intake for the 0.5-mile radius buffer. The numbers show estimated incidence rate ratios (IRRs) for consumption of different types of food as a function of the food environment measure. Most of the estimated IRRs from negative binomial models are close to unity and are not significant at the 0.05 level. Moreover, the small number of significant findings do not show systematic patterns and some of them are contradictory to the hypotheses. In total, 780 effects are estimated. In the absence of any actual relationship, about 39 significant findings (5%) could well be due to chance. In fact, 38 relationships are found significant at $p<0.05$. If the Bonferroni adjustment for multiple comparisons is adopted, none of them turns out to be significant.

Appendix B (available online at www.ajpmonline.org) shows the results from ordinary least squares (OLS) regressions of BMI percentile on neighborhood food measures, controlling for other covariates. Almost none of the coefficients of food outlet types is significant.

Several sensitivity analyses were conducted to assess the robustness of findings across alternative model specifications, population subgroups, and approaches to deal with missing data. Although the statistical tool for Table 2 (i.e., negative binomial regression for counts) appears to be the most appropriate for this type of dependent variable, all models were re-estimated using OLS and Poisson regressions. Instead of BMI percentile, indicator variables of overweight and obesity status were created and analyzed with Logit models. Subgroup analyses were performed separately for boys and girls and for urban and rural areas. The analyses were repeated also by omitting parents' BMI and using imputed values (mainly for food environment, as the main source of missing data is geocoding failure). The qualitative results are not sensitive to those alternative model specifications, population subgroups, and the way missing data are handled and do not indicate any systematic evidence that local food outlets were associated with consumption or BMI.

In contrast to the null findings for the relationship between neighborhood environment on dietary intake and body weight among California children and adolescents, the estimated effect sizes of key individual covariates are significant and stable across models. Gender, age, and parents' BMI are consistent predictors for students' BMI percentile. Boys tend to consume less vegetables and fruits but more milk, fast food, and soda than girls.

Discussion

The present study found no evidence to support the hypotheses that improved access to supermarkets, or less exposure to fast-food restaurants or convenience stores within walking distance, improves diet quality or reduces BMI among Californian youth. There are isolated significant coefficients, but the number of significant coefficients is about what would be expected due to chance.

No single study resolves a major research question. Establishing reliable empirical relationships (even without establishing causality) requires the accumulation of evidence through many studies. Every study will have its own set of limitations and this analysis certainly has many. The response rate of CHIS (29.5% in 2005 and 21.1% in 2007) remains low, and the current study sample has a large proportion of missing values (30.6% for children and 30.9% for adolescents). The data are not complete dietary recalls but single-item questions without probing or guidance on serving size. Similarly, self-reported height and weight (and even more so for parent-reported height and weight) is likely to have substantial measurement errors. Relatively small sample sizes and noisy measures of dependent variables lower the statistical power to detect small but true associations.

Possibly even more of a limitation is the quality of the InfoUSA business listings, although this is a criticism that applies to all similar studies, including those reporting significant findings. An earlier study[21] advises caution when using commercial listings, reporting only fair agreement between commercial data and field observations for supermarkets, grocery stores, convenience stores and full-service restaurants, and poor agreement for fast-food restaurants. Field studies[22,23] find reason-

Table 1. Descriptive statistics of sample population, M (SD)

Variable	Attribute	Child	Adolescent
Daily food consumption (servings)			
Fruit	Count	1.79 (1.22)	1.68 (1.41)
Vegetables	Count	1.30 (1.01)	1.37 (1.30)
100% juice	Count	1.06 (1.24)	1.01 (1.14)
Milk	Count	1.79 (1.21)	—
Soda	Count	0.61 (0.91)	1.09 (1.39)
High-sugar food	Count	1.07 (1.02)	1.31 (1.60)
Fast food[a]	Count	0.34 (0.45)	0.49 (0.59)
Body weight			
BMI percentile	Continuous	0.69 (0.34)	0.68 (0.27)
Gender			
Male	Dichotomous	0.51 (0.50)	0.51 (0.50)
Age			
Years	Continuous	8.28 (1.98)	14.52 (1.67)
Years squared	Continuous	72.49 (32.47)	213.50 (48.59)
Race/ethnicity			
White (non-Hispanic)	Dichotomous	0.46 (0.50)	0.39 (0.49)
African-American (non-Hispanic)	Dichotomous	0.08 (0.28)	0.08 (0.27)
Asian or Pacific Islander (non-Hispanic)	Dichotomous	0.11 (0.31)	0.11 (0.31)
Native-American (non-Hispanic)	Dichotomous	0.01 (0.10)	0.01 (0.10)
Other race or multirace (non-Hispanic)	Dichotomous	0.06 (0.23)	0.10 (0.30)
Hispanic	Dichotomous	0.27 (0.45)	0.31 (0.46)
Household size (*n*)			
Adults, children, and adolescents	Count	4.54 (1.28)	4.49 (1.32)
Income			
Natural logarithm of annual household income ($)	Continuous	10.85 (1.26)	10.74 (1.45)
Parent's education			
< high school	Dichotomous	0.12 (0.33)	0.21 (0.41)
High school graduate	Dichotomous	0.23 (0.42)	0.21 (0.41)
> high school but < college	Dichotomous	0.19 (0.39)	0.18 (0.39)
College graduate	Dichotomous	0.32 (0.46)	0.28 (0.45)
> college	Dichotomous	0.14 (0.35)	0.12 (0.32)
Parent's body weight			
BMI	Continuous	27.13 (6.03)	27.52 (6.14)
Survey wave			
Proportion of sample in 2005 wave	Dichotomous	0.48 (0.50)	0.51 (0.50)

Note: Sample size is 8827 for children aged 5–11 years and 5236 for adolescents aged 12–17 years. Statistics are adjusted using California Health Interview Survey sampling weights. Individual covariates are controlled.
[a]Number of times fast food was consumed

Table 2. Estimated associations (incidence rate ratios) between neighborhood food environment and dietary intake

		Child			Adolescent		
Food outlet type	Daily food consumption	School	Home	School and home	School	Home	School and home
Fast-food restaurant	Fruits	1.003 (0.005)	0.999 (0.006)	1.002 (0.004)	1.007 (0.006)	0.991 (0.007)	1.000 (0.005)
	Vegetables	0.997 (0.006)	0.992 (0.007)	0.994 (0.005)	1.017 (0.008)*	1.004 (0.008)	1.012 (0.006)*
	100% juice	0.986 (0.009)	0.995 (0.009)	0.990 (0.007)	0.994 (0.010)	1.000 (0.009)	0.997 (0.007)
	Milk	0.992 (0.004)	1.001 (0.005)	0.996 (0.003)	—	—	—
	Soda	1.006 (0.011)	1.021 (0.016)	1.010 (0.010)	0.989 (0.011)	1.005 (0.009)	0.997 (0.008)
	High-sugar food	0.998 (0.008)	1.005 (0.009)	0.999 (0.006)	1.029 (0.016)	0.983 (0.011)	1.007 (0.010)
	Fast food	0.991 (0.010)	1.000 (0.012)	0.998 (0.008)	0.993 (0.012)	1.006 (0.012)	0.995 (0.008)
Convenience store	Fruits	0.986 (0.015)	1.003 (0.015)	0.997 (0.011)	1.000 (0.021)	1.016 (0.020)	1.008 (0.015)
	Vegetables	1.003 (0.019)	0.994 (0.019)	1.002 (0.014)	0.987 (0.026)	0.988 (0.022)	0.986 (0.017)
	100% juice	0.989 (0.027)	0.984 (0.026)	0.984 (0.021)	0.930 (0.032)*	0.979 (0.027)	0.961 (0.021)
	Milk	0.993 (0.015)	1.016 (0.012)	1.008 (0.010)	—	—	—
	Soda	0.984 (0.036)	1.051 (0.030)	1.018 (0.024)	0.984 (0.039)	0.936 (0.031)*	0.952 (0.024)*
	High-sugar food	0.986 (0.027)	1.015 (0.024)	0.995 (0.018)	1.051 (0.055)	0.986 (0.043)	1.025 (0.041)
	Fast food	0.987 (0.033)	0.984 (0.031)	0.987 (0.023)	1.005 (0.032)	0.935 (0.031)*	0.965 (0.023)
Small food store	Fruits	1.002 (0.005)	1.003 (0.004)	1.002 (0.003)	0.996 (0.007)	0.992 (0.006)	0.995 (0.004)
	Vegetables	1.004 (0.005)	1.004 (0.005)	1.003 (0.003)	1.002 (0.010)	0.998 (0.005)	1.001 (0.004)
	100% juice	1.007 (0.007)	1.006 (0.008)	1.005 (0.006)	0.988 (0.010)	1.004 (0.006)	0.999 (0.005)
	Milk	0.998 (0.004)	0.996 (0.004)	0.998 (0.002)	—	—	—
	Soda	1.002 (0.011)	1.001 (0.008)	1.003 (0.006)	1.002 (0.009)	1.009 (0.006)	1.004 (0.005)
	High-sugar food	0.999 (0.007)	1.010 (0.005)	1.003 (0.004)	1.013 (0.015)	1.008 (0.008)	1.008 (0.007)
	Fast food	1.006 (0.009)	0.996 (0.009)	1.003 (0.007)	1.010 (0.009)	1.017 (0.005)**	1.009 (0.005)
Grocery store	Fruits	1.015 (0.015)	1.002 (0.017)	1.004 (0.012)	0.962 (0.028)	0.982 (0.028)	0.980 (0.019)
	Vegetables	1.015 (0.018)	0.980 (0.022)	0.998 (0.015)	0.995 (0.029)	0.971 (0.028)	0.988 (0.020)
	100% juice	1.030 (0.030)	1.035 (0.028)	1.038 (0.021)	0.947 (0.036)	0.966 (0.038)	0.968 (0.028)
	Milk	1.001 (0.015)	1.001 (0.015)	1.000 (0.011)	—	—	—
	Soda	1.013 (0.039)	0.960 (0.042)	0.987 (0.033)	1.023 (0.036)	1.088 (0.031)**	1.050 (0.025)
	High-sugar food	1.022 (0.025)	1.041 (0.025)	1.019 (0.018)	0.960 (0.047)	1.019 (0.048)	0.988 (0.037)
	Fast food	1.029 (0.035)	1.010 (0.032)	1.028 (0.025)	1.042 (0.043)	1.083 (0.034)*	1.050 (0.029)
Large supermarket	Fruits	1.009 (0.016)	1.022 (0.016)	1.018 (0.012)	1.020 (0.021)	1.016 (0.025)	0.016 (0.017)
	Vegetables	0.996 (0.019)	0.988 (0.020)	0.986 (0.015)	1.001 (0.026)	1.026 (0.024)	1.008 (0.018)
	100% juice	0.965 (0.030)	1.009 (0.028)	0.991 (0.022)	1.006 (0.029)	1.011 (0.030)	1.000 (0.022)
	Milk	0.993 (0.021)	1.010 (0.021)	1.007 (0.017)	—	—	—
	Soda	0.995 (0.035)	1.078 (0.035)*	1.036 (0.026)	1.038 (0.039)	0.988 (0.032)	1.011 (0.026)
	High-sugar food	0.955 (0.024)	1.043 (0.029)	0.996 (0.019)	1.033 (0.040)	0.928 (0.045)	0.967 (0.032)
	Fast food	1.008 (0.031)	1.045 (0.031)	1.022 (0.025)	1.060 (0.036)	0.930 (0.036)*	0.993 (0.026)

Note: Sample size is 8226 for children aged 5–11 years and 5236 for adolescents aged 12–17 years. Incidence rate ratio and its SE (in parentheses) using negative binomial models are reported. Responses are daily servings of fruits, vegetables, 100% juice, milk, soda, high-sugar food, and fast food. Census tract characteristics are controlled. Neighborhood food environment is measured as the counts of a particular type of food outlet (e.g., supermarket) within a circular buffer with a 0.5-mile radius centered at a student's school or home. "School and home" denotes school AND residential food environment measured by the food outlet counts within the total area identified by the school and the home buffer. Statistics are adjusted using California Health Interview Survey sampling weights. Eicker-Huber-White sandwich estimator is used to calculate SEs.

*$p<0.05$; **$p<0.01$

ably good predictive values, although there are substantial discrepancies. The precision of coding on a very small scale (i.e., less than 100 m) is unreliable. That is not surprising, however, as 100 m is a distance smaller than a shopping center (or even a strip mall), and street-address geocoding will not match to the exact location within a shopping center. More generally, categorizing food outlets by type tends to be insufficient to reflect the heterogeneity of outlets, and it is possible that more detailed measures, such as store inventories, ratings of food quality, and measuring shelf space, would be more predictive for health outcomes.[24–26] Unfortunately, such data are very costly and time consuming to collect and may never exist on a national scale.

Simple measures will remain important for surveillance and tracking on a large scale where feasibility is paramount. This is reflected in the recommendations by the CDC to use the number of full-service grocery stores and supermarkets as one community measures in efforts to prevent obesity.[6] But unless such measures have predictive value for what are the ultimate desired outcomes (e.g., to improve diet or lower obesity rates), they are not useful to inform policy.

The findings here seem to be in conflict with a recent study that reports a positive association between proximity of fast-food restaurants surrounding schools, and soda consumption and obesity among adolescents using the California Healthy Kids Survey.[27] That study focuses on BMI and the BMI results clearly differ from the current study. The inconsistency could result from statistical power as that study has much larger sample size (more than half a million survey respondents).

Even so, a few issues remain unexplained. For instance, the regression coefficient for counts of soda consumption in that study is nonsignificant just as in this analysis (in both cases, the point estimate is positive). Nor did that study find an effect on fried potato consumption, the diet measure with a direct plausible causal relationship to nearby fast-food outlets. No relationships between other type of food outlets and consumption patterns are reported. The study by Powell et al. (2007)[10] is cited as support for the hypothesis that supermarkets have a protective effect, but that study reports no results on fast-food outlets, although that variable was analyzed as well.

While the null findings may be due to technical limitations (e.g., data quality, sample size), there are substantive reasons why the association between local food outlets and consumption or BMI may be much weaker than commonly believed. Today's society is very mobile and the role of transportation has altered the definition of the shopping environment—both across areas and individuals.[28] Access to transportation could be a more essential determinant of dietary behaviors than immediate availability, an issue highlighted in the USDA report on "food deserts."[28] In a Los Angeles study, Inagami et al. (2006) found that less than 20% of respondents shop in their census tract.[29] Only 3% of households in the 2007 CHIS data report not having access to a car.

Research on how environmental factors affect obesity and related health behaviors is rapidly growing. One particular problem in new fields of investigation is that early results often do not hold up, or require some qualification that is detectable only through replication, a central principle of scientific method. The rate of false-positive results is particularly high for new and competitive research topics, which has led some methodologists to claim that "most published research results are false."[30,31] Research on environmental impacts on obesity is probably not dissimilar to other emerging research areas where there is an initial explosion of findings, but successful replication rates are low.[32]

The current study can provide only one data point, but reporting a full range of results is important as a selective focus on significant results (and especially those that appear to confirm—rather than contradict—a hypothesis) may lead policy astray. In contrast to basic research, publications on associations between obesity and the environment have an immediate and sizeable impact on policy. Accelerating this "shake down" period through systematic replication is thus potentially beneficial. At least equally important is the research design. Existing studies examining the environmental impact on body weight are mostly correlational. To infer causality from the mechanisms through which community retail food outlets might (or might not) influence youth's diet and obesity, new studies should focus on improvement in research design by examining the critical intervening variables (such as shopping and purchasing practices), through experimentation, or through the rigorously founded and carefully implemented quasi-experimental methods.[33]

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Appendix

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amepre.2011.10.012.