

Association Between Soda Consumption and Body Mass Index in the University of Washington
Twin Registry

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Abstract

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Background: Obesity is of major public health concern due to its association with many chronic diseases and its history of increased prevalence. Obesity development is influenced by both genetic and environmental factors. This study improves upon previous studies of body mass index and soda consumption by using an informed twin design to decipher how genetic and shared environmental affect this association.

Methods: Data was collected from a large cohort of same sex, adult twin pairs, ages 18-97 from the University of Washington Twin Registry. Associations among all twins were calculated using generalized estimating equations (GEE), accounting for twin relatedness, followed by

within-twin pair differences associations which controlled for shared genetic and environmental factors within twin pairs.

Results: All among twin analyses, including unadjusted and sequentially adjusted models, showed a positive association between BMI and soda consumption ($p < .001$). In the fully adjusted model, individuals drinking 1-2 sodas per day had a 1.0 kg/m^2 (SE: 0.11) unit greater BMI than twins reported no soda consumption per day. Additionally, all twin differences analyses showed a positive association between BMI and soda consumption ($p < .001$). The fully adjusted model suggested a 1.0 kg/m^2 unit greater BMI (SE: 0.069) for each unit increase in soda consumption, as categorized by the ordinal values of 1-2, 3-4, and 5+ sodas per day. The within-twin pair results were not statistically different when stratified by zygosity.

Conclusion: Among a large group of adult twin pairs, increased soda consumption was associated with increased BMI, and this relationship was not confounded by genetic and shared environmental factors within twins.

Key Words: nutrition; twin registry; public health; body mass index

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INTRODUCTION

The prevalence of obesity has more than doubled in the past 30 years, with 33% of adults and 17% of children currently categorized as obese based on body mass index (BMI)^{1,2}. These estimates have increased across all sociodemographic groups². The high prevalence of obesity in the U.S. population has raised public health concern because it is associated with chronic diseases such as cardiovascular disease, type 2 diabetes, and some forms of cancer, all of which are leading causes of morbidity and mortality in the U.S.³. Obesity and associated conditions have also been linked with decreased quality of life and early mortality⁴⁻⁷ as well as increased health care costs related to treatment of these diseases⁸⁻¹⁰. In order to improve population health, it is imperative to better understand factors affecting the development of obesity.

Obesity is complex and its development is influenced by both genetic and environmental factors, including several well-established sociodemographic and lifestyle factors. With respect to genetic factors, studies have shown strong genetic determinants to body weight and weight regulation systems, resulting in an estimated 50-70% of BMI differences between persons being attributable to genetic variation¹¹⁻¹⁴. Additionally, genetic factors have also been implicated in taste preferences, leading to increased preferences for sweet foods, for example¹⁵. This suggests that eating behavior, an important lifestyle factor influencing obesity, may in fact have some underlying genetic influence.

With respect to lifestyle factors, diet is strongly associated with obesity development. Among the many dietary determinants of obesity, consumption of sugar-sweetened beverages, like soda, is thought to play an important role in weight gain. Many studies have found an association between soda consumption and increased body weight¹⁶⁻²⁰, although it is important to note that other studies have not found such associations²¹.

Sugar-sweetened beverages may impact weight gain due to an incomplete compensation for calories from these drinks^{22,23}. Liquid calories from sugar-sweetened beverages do not trigger physiological satiety mechanisms in the same way solid foods do, thus leading to an increase in total calories consumed to reach satiety²⁴⁻²⁸. Data suggest that calories consumed in liquid form lead to excess total calories consumed^{26,27,29,30}. Additionally, consumption of diet soda has also been shown to play a role in weight gain and obesity through indirect mechanisms such as changes in taste preferences, although these findings are not consistent among all studies³¹⁻³³.

Importantly, diet preferences are not only affected by genetic factors as noted above, but also by shared environmental factors that arise during rearing and non-shared environmental factors that are unique to individuals, such as access to soda. Specifically, studies have shown that parental dietary pattern, parent food modeling, and parenting styles all affect child food preferences and, ultimately, the foods consumed by the child^{34,35}. Studies have shown strong correlations between child soda consumption and parent soda consumption, providing evidence that parents play an important role in child diet preferences, which may be due to both access to these drinks in the home as well as food modeling³⁶. Lastly, studies have also shown the learned diet preferences of the child persist to adulthood, proving the importance of rearing environment on dietary patterns^{37,38}.

Although ample data have shown that sugar-sweetened beverages such as soda are associated with obesity, these reported relationships may be confounded by genetic and shared environmental effects from rearing. Therefore, to fully understand the relationship between obesity and soda consumption, genetic and rearing environment factors must be adequately controlled for.

Twin study designs are a powerful tool for understanding genetic, shared environmental, and non-shared environmental factors and their effects on a range of outcomes, including body

weight^{13,39-41}. This study design provides further insight into the documented association between soda consumption and obesity by determining whether the association is confounded by genetic and shared environmental factors between exposure and outcome, or whether the association remains and is therefore indicative of a “quasi-causal” relationship.

The goal of this study is to capitalize on the genetically informed twin study design to investigate the relationship of BMI and soda consumption between and within pairs of adult twins from a community-based registry, free of confounding by genetic and environmental factors. The specific aims of this study are to determine the association between soda consumption and BMI among and between adult twins reared together. We hypothesized that increased soda consumption was associated with increased BMI both among and between adult twin pairs.

METHODS

Subjects

The cross sectional analysis included a sample of 11,840 subjects from the community-based University of Washington Twin Registry (UWTR). Twins include both monozygotic (MZ) and dizygotic (DZ) male and female twin pairs of the same sex, aged 18-97 years, reared together. Participants were recruited from Washington State driver’s license and identification card applications⁴². All twins completed an enrollment survey with questions related to childhood similarity to evaluate twin zygosity (MZ vs. DZ), a common twin registry practice with an accuracy of 95-98% compared to biological indicators^{43,44}.

All twins were mailed an invitation letter and enrollment survey including questions related to height, weight, and soda consumption. Data collected from completed questionnaires received between 2009 and 2015.

Measures

Body Mass Index

The main outcome was BMI calculated from self-reported height and weight and expressed as kg/m². These measures were collected from responses to the survey questions “What is your current height?” in feet and inches and “What is your current weight?” in pounds.

Soda Consumption

The predictor variable was soda consumption which was collected from self-reported dietary recall based on the question “During the past 4 weeks, how many servings of the following did you have on a typical day...Cans or glasses of soda?” Possible answers included “none”, “1-2”, “3-4”, or “5+.”

Covariates

Age, sex, race, annual household income, education level, smoking status, and physical activity were collected from responses to survey questions and used as covariates in the statistical analyses. Age at time of survey was calculated based on reported date of birth. Sex was categorized as male or female. Race was categorized as white, Hispanic, black/African American, American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander, or other. There was eight categories of income with the lowest being “less than \$20,000” followed by “\$20,000-29,999”, “\$30,000-39,999”, and so on, ending with the highest category of “\$80,000 or more”. Education included eight categories: grade 1-8, grade 9-11, high school graduate/GED, some college, associate’s degree, technical degree, bachelor’s degree, and graduate/professional degree. Smoking status was categorized as currently smoking or not currently smoking. Physical activity was calculated based on the reported number of days per week each subject exercised moderately for at least 30 minutes and/or vigorously for at least 20 minutes. We multiplied the frequency of

exercise by the minimum amount of time participated in to yield a continuous variable of total minutes of exercise per week.

Statistical methods

After exclusion of 234 subjects due to missing data related to soda consumption, height, or weight, 11606 subjects were eligible for inclusion in analysis and used in the unadjusted model for aim 1. After addition of all covariates identified in model D of among twins analysis, 10845 subjects were included in the fully controlled analysis treating twins as individuals. In model D of twin pair differences analysis, 5009 twin pairs were included due to necessity of data for zygosity and all covariates in both subjects of a twin pair in order to obtain a twin differences value. BMI was expressed as a continuous variable in all statistical analyses. Soda consumption was expressed as a categorical variable for the primary analysis through a series of dummy variables for each ordinal response (1-2, 3-4, 5+ sodas).

Covariates were determined prior to the study as potential confounders based on current literature and were thus controlled for in the analysis. We calculated regression coefficients in a stepwise analysis, using four different models. Each model controlled for an increasing number of covariates. Model A was unadjusted. Model B was adjusted for sex, age, race, income and education. Although, in the twin differences analysis, sex, age and race were not controlled for as these are shared characteristics among twin pairs thus naturally controlled for. Model C was additionally adjusted for smoking status. Model D was additionally adjusted for physical activity.

Descriptive statistics for subject characteristics were computed and reported for the overall subject sample and stratified by soda consumption. Following, two statistical models were used to understand the association between BMI and soda consumption in the twin subjects⁴⁵. A number of studies of similar epidemiological study design have been conducted using this registry as a

source of data⁴⁶⁻⁵⁰. First, we determined the association between BMI and soda consumption among all twins, treating each twin as an individual but accounting for the correlated nature of the data using a least squares linear regression model with generalized estimating equations (GEE)^{45,51} and robust standard errors to determine the variance in BMI with increasing soda consumption. We used an identity link and exchangeable correlation matrix to sufficiently account for the relatedness of the twins to determine the association among all twins as individuals.

Second, we determined the association between soda consumption and BMI within each twin pair using a linear regression of twin pair differences. Soda consumption was expressed as a single variable of ordinal code in which 0=no sodas, 1=1-2 sodas, 2=3-4 sodas and 3=5+ sodas. We regressed BMI on soda consumption among all twin pairs and then stratified by zygosity. The within-pair analysis inherently controls for characteristics shared between twins in a pair such as age, race/ethnicity, sex, genetics and shared environmental factors. Using the I^2 statistic we tested for inconsistency between estimates among fully adjusted overall and zygosity stratified models in the within pair analysis⁵².

Finally, to fully understand the relationship between BMI and soda consumption, we performed the two above statistical analyses using soda as a continuous and binary variable. To transform soda consumption into a continuous variable, we substituted midpoint values for each ordinal response category range (1.5 for 1-2, 3.5 for 3-4, 8 for 5+). For the final category of 5+ sodas per day, we assigned the “midpoint” value of 8. This is based on data from the National Health and Nutrition Examination Survey of 2009-2010, a year in which participants could report how many sodas they drank per day, with no ordinal categories pre-emptively provided through the survey questions. The results of this survey suggested 68% of the U.S. adults who drink 5+ sodas per day drank an average of 5.5-10.5 sodas per day, therefore we chose a midpoint of 8 sodas

per day. To examine soda consumption as a binary variable (none/any) we combined the later three ordinal groups (1-2, 3-4, 5+) into one group (any).

All statistical analyses were performed using STATA Release 13.1 (StataCorp, College Stations, TX).

RESULTS

Descriptive statistics

Sample characteristics are provided in Table 1, stratified by level of soda consumption. Among all subjects, the average age was 43 yrs., 66% were female, mean BMI was 26.0 kg/m², 35% reported an annual household income of 80K+ per year, 80% had some college education, a bachelor's degree or a graduate degree, and 92% of subjects reported their race as white. On average, subjects self-reported 116 minutes per week of physical activity with substantial variability, noted by the large standard deviations. Average BMI increased incrementally with increasing levels of soda consumption, while percentage female and percentage reporting an annual household income of 80K+ per year decreased with increasing categories of soda consumption. Figure 1 shows the distribution of BMI stratified by levels of soda consumption.

Among twin analysis

Table 2 provides results from the among twin analysis (treating twins as individuals). The unadjusted and all sequentially adjusted models showed a positive association between BMI and soda consumption ($p < 0.001$). Successive adjustment for potential confounders had essentially no effect on the strength of associations. In the fully adjusted model, individuals drinking 1-2 sodas per day had a 1.0 kg/m² (standard error, SE, 0.11) unit greater BMI than twins reported no soda consumption per day. Furthermore, twins reporting 5+ sodas per day had a 1.6 kg/m² (SE, 0.28) unit greater BMI than twins reporting no soda consumption.

Within twin pair analysis

Across all twin pairs, there was an average within-twin pair BMI difference of 3.3 kg/m² (SE, 0.047), and an average within-twin pair soda consumption difference of 0.5 sodas/day (SE, 0.0096) when soda was expressed as a “dummy variable”, suggesting that on average twin pairs had a ± 1 soda per day difference in consumption. Table 3 provides results from the within-pair twin differences approach. The unadjusted and all sequentially adjusted models showed a positive association between BMI and soda consumption ($p < 0.001$). The fully adjusted model results suggest a 1.0 kg/m² unit greater within-pair BMI (SE, 0.069) difference across all twin pairs for each unit increase in soda consumption, as categorized by the ordinal values of 1-2, 3-4, and 5+ sodas per day. The overall association remained significant when stratifying by zygosity, with a 0.94 kg/m² unit greater within-pair BMI difference among MZ twins (SE, 0.071) and a 0.84 kg/m² unit greater within-pair BMI difference among DZ twins (SE, 0.068) ($p < 0.001$). Using the I^2 test for inconsistency we concluded that the overall and zygosity stratified fully adjusted models are not statistically different from each other ($p = 0.25$).

Sensitivity analyses

Treating soda consumption as a continuous variable resulted in slightly different findings than the same analyses using soda in its ordinal form; however, the results still remained significant ($p < 0.001$ level). Among all twins, a one unit increase in soda consumption (sodas per day) was associated with a 0.27 kg/m² unit greater BMI (SE, 0.032), after controlling for all covariates. In the twin differences analysis, a one unit increase in soda consumption was associated with a 0.37 kg/m² unit greater BMI difference (SE, 0.028) between all twin pairs overall (Model D, Table 4); the associations remained significant regardless of zygosity.

When soda consumption was expressed as a binary variable, any soda consumption was associated with a 1.2 kg/m² (SE, 0.10) unit greater BMI, compared to no soda consumption. After inclusion of all covariates, the association was attenuated, although still significant, with a 1.16 kg/m² (SE, 0.10) unit greater BMI, compared to the reference of no soda consumption.

DISCUSSION

Among a large group of MZ and DZ male and female twin pairs, baseline BMI and soda consumption were positively associated. Although an association between BMI and soda consumption has been reported in a number of previous studies, the results of this study shed new light on these reports because they suggest that genetic and shared environmental factors do not confound the association between BMI and soda consumption to any important degree. Specifically, analysis among all twins showed a positive association between BMI and soda consumption, and this relationship remained significant in the within twin pair analysis overall and stratified by zygosity, which inherently controls for shared genetic and environmental factors, suggesting that these factors do not confound the associations between BMI and soda consumption commonly reported in the literature.

Although genetic and shared environmental factors do not confound the association, results suggest they do play a role. Specifically, even the test for inconsistency in the fully adjusted twin differences models was not significant, suggesting that these shared factors are not confounding the association between soda consumption and BMI, although attenuation of the strength of these associations may suggest some effect from genetic and shared environmental factors. For example, the zygosity stratified associations show some “drifting” towards the null compared to the overall association. Said another way, as we further control for the shared characteristics between twins by stratifying by zygosity, we see an attenuated BMI – soda

consumption association. Interestingly, more significant drifting toward the null occurred within the DZ twins and not the MZ twins, as might be expected because they are genetically identical, which signifies genetics are not playing a strong role in the BMI – soda consumption association. Additionally, this may signify stronger effects from shared environmental factors rather than shared genetics in the soda – BMI relationship, opening up the possibility of policy decisions designed to improve childhood environmental nutrition. Concurrently, differences among these analyses are small enough to be consistent with sampling error, although the direction would be consistent with a very small amount of residual confounding.

In support of the above notion, results of the sensitivity analysis suggest that genetic and environmental factors may be altering the effect of soda consumption on BMI. In this analysis, the association between BMI and soda consumption within twins is generally stronger compared to the associations among twins. The differences in the among and within-twin models may suggest that by not controlling for shared genetic and environmental factors (i.e., within twin pair analysis), the associations between BMI and soda consumption that are typically reported among non-related individuals may be somewhat misleading, although the extent of this effect is hard to quantify definitively due to the transformation of the predictor variable in this analysis.

Furthermore, in general, the difference between the overall and zygosity stratified twin difference associations are small (Table 3), suggesting zygosity does not play a major role in the BMI – soda consumption association. If genetics was a strong confounder, we would expect the associations to be statistically different between MZ compared to DZ pairs, however this was not the case in our study.

Previous studies have investigated potential risk factors of obesity including marital status, ethnicity, education, smoking, television watching, physical activity, diet, and soda

consumption^{17,19,20}. Many of these factors are difficult to modify, therefore do not provide good opportunity for public health intervention. Fortunately, activity and diet are at least somewhat modifiable behaviors, and in particular soda consumption is an amply modifiable risk factor because it provides no nutritive value in the normal diet, thus providing a great target for public health intervention. This study uniquely adds to the literature by using a genetically informed twin study design to demonstrate that genetic and shared environmental factors do not play a major part in the association between soda consumption and BMI.

Due to the cross sectional nature of this study, we cannot rule out that the associations reported could be because individuals with higher BMIs are driven to drink more soda, perhaps as a way to cope with depression or anxiety related to weight stigma⁵³⁻⁵⁵, or because of a predisposition to higher sugar consumption¹⁵.

This could also be because individuals who drink more soda will gain weight over time. However, previous studies have provided evidence that the BMI – soda association is causal, specifically that increased soda consumption leads to increased weight gain^{16,25,26}. From this standpoint, the present results further strengthen that argument by demonstrating that the BMI – soda consumption association is not confounded by genetic or shared environmental factors. Assuming the effects on BMI found in the present study resulted entirely from soda consumption (i.e., a direct causal association), we might expect that an American man of average height (70”) could lose 7 pounds of body weight for every 1-2 soda per day decrease he makes in his normal dietary consumption patterns, assuming no changes in overall energy expenditure. It is interesting to note that the magnitude of weight loss in the example above is similar to weight loss resulting from popular restrictive diets that are followed for one year⁵⁶.

Strengths and Limitations

The primary strength of this study is its use of twin pairs as subjects. Additionally, its large sample size of MZ and DZ from the UWTR allows for greater assumed power. The utilization of twins provides a unique opportunity to control for genetic and shared environmental effects from rearing. Twins are not only genetically similar (DZ twins) or identical (MZ twins), when reared together they also share many familial environmental exposures that may affect soda consumption and BMI. Controlling for additional factors beyond the genetic and home rearing background allows further insight into the documented association between soda consumption and obesity. In essence, it allows us to determine whether the association is confounded by genetics and shared environment, or whether a “quasi-causal” relationship exists⁵⁷.

As noted previously, the cross-sectional design of this study ultimately limits our ability to infer causality in the BMI – soda consumption relationship because we do not know the temporality of the association. Moreover, the results from the among twins analysis (Table 2) suggest a non-linear relationship, perhaps a slight threshold effect, with BMI and higher consumption of soda. The nature of the BMI – soda consumption relationship, in regards to a dose-response or threshold effect, should be better understood in order to make definitive interpretations of results in order to make recommendations for an upper limit to soda consumption to prevent excess weight gain. This non-linear relationship may also be skewed by the small percentage of subjects in the higher soda consumption categories. Additionally, the structure of data collection provides some limitations to the study. Data was self-reported, of which dietary patterns and body weight are subject to self-report bias. Furthermore, there was no differentiation between diet/non-diet soda and caffeinated/non-caffeinated soda, resulting in the inability to infer these results to just one type of soda or its additives. Based on current soda

sales, a majority of soda consumed in the United States is non-diet soda, therefore it is plausible that the effects found are weighted more heavily towards non-diet soda⁵⁸. Finally, the racial makeup of the population was largely homogenous, limiting the generalizability of the results.

Conclusion

Among a large group of adult twin pairs, increased soda consumption was associated with increased BMI, and this relationship was not confounded by genetic and shared environmental factors within twins. Further research is needed to determine whether the full association between soda consumption and BMI is causal, and twin research can aid in this quest by accounting for genetic and familial environment factors that otherwise cannot be controlled in observational studies of unrelated individuals.

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TABLE 1. Characteristics of Subject Sample Stratified by Levels of Soda Consumption.

Characteristic	Total	No Soda	1-2 sodas/day	3-4 sodas/day	5+ sodas/day
N	11,606	6,967	3,405	734	500
Age ^a	42.6 (17.8)	43.7 (18.0)	41.4 (17.6)	39.6 (16.9)	40.5 (16.9)
BMI (kg/m ²) ^a	26.0 (5.7)	25.3 (5.2)	26.9 (5.9)	27.9 (7.0)	28.2 (6.7)
Male	34.4%	31.9%	37.0%	40.9%	42.2%
Female	65.6%	68.1%	63.1%	59.1%	57.8%
White	91.8%	92.7%	91.1%	88.4%	89.2%
Non-White	8.2%	7.4%	8.9%	11.6%	10.8%
Income					
<20K	12.9%	10.5%	14.9%	20.8%	22.0%
20K-49,999K	24.5%	23.5%	25.4%	27.4%	29.2%
50K-79,999K	21.8%	22.3%	21.9%	19.4%	17.6%
80K+	35.4%	38.3%	32.8%	26.4%	26.00%
Education					
Grade 1-11	3.1%	2.0%	3.9%	6.1%	8.2%
High school/GED	15.8%	12.5%	19.4%	24.3%	25.0%
Some college/technical degree	34.6%	32.6%	36.5%	42.1%	39.2%
Bachelor's degree	26.3%	29.4%	23.6%	16.4%	16.6%
Graduate degree	19.3%	22.7%	15.7%	10.8%	9.6%
Physical activity (min per week) ^{ab}	116.5 (91.4)	123.9 (90.1)	106.4 (90.8)	101.4 (91.8)	103.9 (102.3)

^aMean and (standard deviation). ^bMean reflective of ~99.5% of N due to 0.5% subjects with missing physical activity data. Missing subjects were equally distributed among all soda consumption groups. Physical activity is sum of reported number of days per week subject exercised moderately for ≥ 30 minutes and/or vigorously for ≥ 20 minutes. Multiplied the frequency of days exercised by the minimum amount of time participated in to yield total minutes of exercise per week.

TABLE 2. Association between Body Mass Index and Soda Consumption Among All Twins as Individuals.

	<u>Model A</u> ^b Δ BMI (SE) ^a	<u>Model B</u> ^c Δ BMI (SE) ^a	<u>Model C</u> ^d Δ BMI (SE) ^a	<u>Model D</u> ^e Δ BMI (SE) ^a
Soda Consumption				
0	Reference	Reference	Reference	Reference
1-2	1.1 (0.11) kg/m ² p<0.000	1.1 (0.11) kg/m ² p<0.000	1.1 (0.11) kg/m ² p<0.000	1.0 (0.11) kg/m ² p<0.000
3-4	1.8 (0.22) kg/m ² p<0.000	1.7 (0.22) kg/m ² p<0.000	1.8 (0.22) kg/m ² p<0.000	1.7 (0.22) kg/m ² p<0.000
5+	1.7 (0.27) kg/m ² p<0.000	1.6 (0.28) kg/m ² p<0.000	1.7 (0.28) kg/m ² p<0.000	1.6 (0.28) kg/m ² p<0.000

Using GEE to treat twins as individuals to obtain population based association. Soda consumption maintained in categorical nature using dummy variables for each ordinal category (0, 1-2, 3-4, 5+). ^aChange in BMI when compared to reference value of no sodas/day; SE = Standard Error. ^bModel A unadjusted. ^cModel B adjusted for sex, age, race, income and education. ^dModel C additionally adjusted for smoking status. ^eModel D additionally adjusted for physical activity.

TABLE 3. Association between Body Mass Index and Soda Consumption Within Twin Pairs.				
	<u>Model A</u> ^b Δ BMI (SE) ^a	<u>Model B</u> ^c Δ BMI (SE) ^a	<u>Model C</u> ^d Δ BMI (SE) ^a	<u>Model D</u> ^e Δ BMI (SE) ^a
Overall	2.5 (0.063) kg/m ² p<0.000	1.4 (0.067) kg/m ² p<0.000	1.3 (0.067) kg/m ² p<0.000	1.0 (0.069) kg/m ² p<0.000
MZ	1.7 (0.068) kg/m ² p<0.000	1.2 (0.070) kg/m ² p<0.000	1.1 (0.071) kg/m ² p<0.000	.94 (0.071) kg/m ² p<0.000
DZ	1.7 (0.063) kg/m ² p<0.000	1.1 (0.067) kg/m ² p<0.000	1.1 (0.067) kg/m ² p<0.000	.84 (0.068) kg/m ² p<0.000
<p>Soda consumption maintained in categorical nature using dummy variables for each ordinal category (0, 1-2, 3-4, 5+). ^aChange in BMI with each ordinal category increase in soda consumption compared to reference value of no sodas/day; SE = Standard Error. ^bModel A unadjusted. ^cModel B adjusted for income and education. ^dModel C additionally adjusted for smoking status. ^eModel D additionally adjusted for physical activity.</p>				

TABLE 4. Association between Body Mass Index and Soda Consumption Within Twin Pairs using Soda Consumption as Continuous Variable.				
	<u>Model A^b</u> Δ BMI (SE) ^a	<u>Model B^c</u> Δ BMI (SE) ^a	<u>Model C^d</u> Δ BMI (SE) ^a	<u>Model D^e</u> Δ BMI (SE) ^a
Overall	.97 (0.028) kg/m ² p<0.000	.53 (0.028) kg/m ² p<0.000	.49 (0.028) kg/m ² p<0.000	.37 (0.028) kg/m ² p<0.000
MZ	.63 (0.029) kg/m ² p<0.000	.44 (0.029) kg/m ² p<0.000	.41 (0.029) kg/m ² p<0.000	.35 (0.029) kg/m ² p<0.000
DZ	.65 (0.027) kg/m ² p<0.000	.44 (0.028) kg/m ² p<0.000	.41 (0.028) kg/m ² p<0.000	.32 (0.028) kg/m ² p<0.000

Soda consumption transformed to continuous variable using midpoint values for ordinal response category. For example, if the ordinal response range was 1-2 sodas, we this value with 1.5 sodas. For the final category in ordinal responses, 5+ sodas per day, was assigned the “midpoint” value of 8. This is based on data from the National Health and Nutrition Examination Survey suggesting that 68% of the U.S. adults who drink 5+ sodas per day drink an average of 5.5-10.5 sodas per day. Therefore, we chose a midpoint of 8 sodas per day. +). ^aChange in BMI with each ordinal category increase in soda consumption compared to reference value of no sodas/day; SE = Standard Error. ^bModel A unadjusted. ^cModel B adjusted for income and education. ^dModel C additionally adjusted for smoking status. ^eModel D additionally adjusted for physical activity.

FIGURE 1. Density plot of body mass index (kg/m^2) for each level of soda consumption

