

Relationship of Soft Drink Consumption to Global Overweight, Obesity, and Diabetes: A Cross-National Analysis of 75 Countries

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Obesity and associated diabetes rates are rising worldwide.¹⁻³ More than 1.5 billion people worldwide are now overweight, and at least 1 in 20 adults now have diabetes.^{2,3} Globally, obesity has doubled since 1980, such that most of the world's population now lives in countries where there are more deaths attributable to being overweight than to being underweight.³ The prevalence of diabetes among adults aged 20 to 79 years rose from 5.5% in 2000 to 7.0% in 2010; 60% of people with diabetes live in low- or middle-income countries.²

These adverse trends are often attributed to changing patterns of nutrition and decreased physical activity, in association with broader socioeconomic changes, such as economic development, urbanization, and aging.⁴ There is controversy whether increasing consumption of so-called “Western” foods, such as soft drinks and processed foods, is a contributing factor to obesity outside of the United States and Western Europe.⁵⁻⁷ In the United States, consumption of sugar-sweetened beverages, particularly soft drinks, has been associated with rising obesity and diabetes.⁸⁻¹¹ Sugar-sweetened beverages contain large amounts of refined sugars, conferring a high glycemic load while having poor satiating properties, which is believed to contribute to excessive weight gain, the metabolic syndrome, and insulin resistance.¹²⁻¹⁴

There have been few empirical studies of the role of soft drinks on the epidemiology of obesity and diabetes in low- and middle-income countries.^{15,16} Major increases in soft drink consumption have occurred not only in the United States and Western Europe but also in other countries; three fifths of global consumption now occurs outside of Western countries. However, evidence to test the hypothesis that such consumption is related to obesity and obesity-related health outcomes has been limited for 2 reasons. First, there has

Objectives. We estimated the relationship between soft drink consumption and obesity and diabetes worldwide.

Methods. We used multivariate linear regression to estimate the association between soft drink consumption and overweight, obesity, and diabetes prevalence in 75 countries, controlling for other foods (cereals, meats, fruits and vegetables, oils, and total calories), income, urbanization, and aging. Data were obtained from the Euromonitor Global Market Information Database, the World Health Organization, and the International Diabetes Federation. Bottled water consumption, which increased with per-capita income in parallel to soft drink consumption, served as a natural control group.

Results. Soft drink consumption increased globally from 9.5 gallons per person per year in 1997 to 11.4 gallons in 2010. A 1% rise in soft drink consumption was associated with an additional 4.8 overweight adults per 100 (adjusted B; 95% confidence interval [CI] = 3.1, 6.5), 2.3 obese adults per 100 (95% CI = 1.1, 3.5), and 0.3 adults with diabetes per 100 (95% CI = 0.1, 0.8). These findings remained robust in low- and middle-income countries.

Conclusions. Soft drink consumption is significantly linked to overweight, obesity, and diabetes worldwide, including in low- and middle-income countries. (*Am J Public Health.* 2013;103:2071–2077. doi:10.2105/AJPH.2012.300974)

been a lack of consistent, comparable data on obesity and related health outcomes in low- and middle-income countries; only recently have international efforts been made to systematically estimate body mass index and diabetes prevalence worldwide.^{2,3} Second, there has been a lack of data to reflect the actual consumption of soft drinks in these countries. Although the Food and Agricultural Organization publishes data describing the availability of different commodities, industry data on actual consumer-level purchasing only recently has become available in a systematically collected, comparable format.¹⁷

In this study, we drew upon recently published overweight, obesity, and diabetes prevalence data, and compared these data with new industry data sources to test the hypothesis that soft drink consumption was related to population-level rates of overweight, obesity, and diabetes worldwide.

METHODS

Industry data on soft drink sales were obtained from the EuroMonitor Passport Global Market Information Database (2011 edition). These data contained industry records of soft drink sales in 79 countries from 1997 to 2010.¹⁷ Data included per capita annual purchases of carbonated soft drinks (excluding bottled still or carbonated water, fruit or vegetable juices, coffee, tea, or sports drinks) in US gallons, including both imported drinks and those manufactured domestically (e.g., franchises of multinational beverage companies).

Comparable age-standardized overweight prevalence data were obtained from the World Health Organization's Global Database on Body Mass Index (2011 edition),³ reflecting the best available population-representative, survey-based estimates of the percentage of adults aged 20 years and older in each country who had a body mass index (BMI, defined as weight in

kilograms divided by the square of height in meters) of 25 kg/m² or greater. The database similarly included estimates of obesity prevalence (percentage of adults older than 20 years with BMI ≥ 30 kg/m²) for 88 countries.³ Diabetes prevalence data for adults aged 20 to 79 years were obtained from the International Diabetes Federation's survey-based estimates for 202 countries for 2007, the year with the most data and for which the most extensive checking and validation exercises were performed.^{2,18} Table 1 further describes the data and their summary statistics among countries in different income groups.

To adjust for potential confounding factors in all regressions, we controlled for gross domestic product (GDP) per capita (expressed in constant 2005 international dollars purchasing power parity for comparability), population aging (the percentage of the population older than 65 years), and urbanization (the percentage of the population living in urban areas), all from the World Bank World Development Indicators Database (2011 edition).¹⁹ To further isolate the effect of soft drink consumption, we incorporated a series of nutritional controls into all of the regressions. Specifically, we used the food balance sheets from the United Nations Food and Agricultural Organization's FAOSTAT database (2011 edition), for all available food categories, reflecting the market sizes of cereals, fruits and vegetables, meats, oils, and total food overall (expressed in terms of kcal/person/day) for each of the countries in the analysis. As a "control group," bottled water consumption (from the

EuroMonitor database) was incorporated into all regressions because we did not expect bottled water consumption to relate significantly to weight or diabetes after adjusting for potentially confounding factors, such as the GDP.

Our analysis proceeded in 2 steps. First, we assessed global trends and variation in soft drink consumption. Second, we evaluated the relationship between soft drink consumption and overweight, obesity, and diabetes prevalence using multivariate linear regression models that included data from multiple countries (cross-national regression). The following linear regression models were specified:

$$(1) \text{ OVERWEIGHT}_i = \text{BSODA}_i + \text{BCEREAL}_i + \text{BFRUITVEG}_i + \text{BMEAT}_i + \text{BOIL}_i + \text{BTOTAL}_i + \text{BELDER}_i + \text{BGDP}_i + \text{BURBAN}_i + \text{BWATER}_i + \varepsilon$$

$$(2) \text{ OBESE}_i = \text{BSODA}_i + \text{BCEREAL}_i + \text{BFRUITVEG}_i + \text{BMEAT}_i + \text{BOIL}_i + \text{BTOTAL}_i + \text{BELDER}_i + \text{BGDP}_i + \text{BURBAN}_i + \text{BWATER}_i + \varepsilon$$

$$(3) \text{ DIABETES}_i = \text{BSODA}_i + \text{BCEREAL}_i + \text{BFRUITVEG}_i + \text{BMEAT}_i + \text{BOIL}_i + \text{BTOTAL}_i + \text{BELDER}_i + \text{BGDP}_i + \text{BURBAN}_i + \text{BWATER}_i + \varepsilon$$

In the preceding equations, *i* designates each country; OVERWEIGHT, OBESE, and

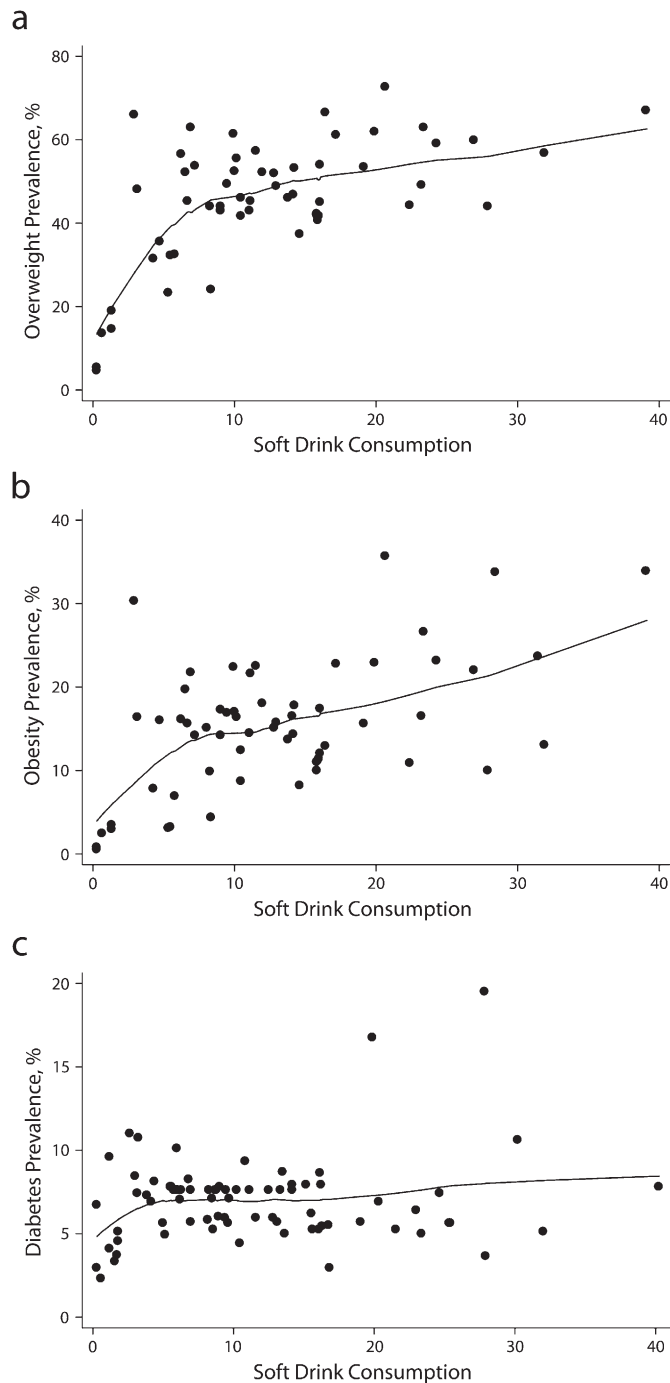
DIABETES refer to the prevalence rates of these 3 conditions (percentage of adults); SODA refers to the gallons per capita per year of soft drink consumption; CEREAL refers to consumption of cereals in kilocalories per capita per day, and the subsequent food-related variables similarly reflect consumption of fruits and vegetables (FRUITVEG), meats (MEAT), oils (OIL), and overall total calories (TOTAL) in kilocalories per capita per day. ELDER refers to the percentage of the population older than 65 years; GDP is the gross domestic product per capita; URBAN refers to the percentage of the population living in urban areas; WATER refers to bottled water consumption in gallons per person per year; and ε is the error term. We further assessed the relationships between soft drink consumption and overweight, obesity, and diabetes using locally weighted regression, which is a nonparametric smoothing technique using the Stata *lowess* command (StataCorp, College Station, TX; Figure 1).

We computed the average of annual soft drink consumption per capita from 1997 to 2007 in each country to capture that overweight and diabetes risks were related to sustained exposures to unhealthy foods (i.e., a cumulative and lagged effect, not an instantaneous one).⁸ We similarly calculated the average annual consumption of other foods over the same period to capture their lagged and cumulative exposure effects. Regressions were weighted by country population. Log transformations were performed on skewed variables, and robust standard errors were

TABLE 1—Descriptive Statistics of the Study Sample

Variable	Description	Low- and Middle-Income Countries, No. (Mean ±SD)	High-Income Countries, No. (Mean ±SD)
Soft drink consumption, 1997–2010	US gallons of carbonated soft drinks sold in each country by year, excluding bottled water, fruit or vegetable juices, coffee, tea, or sports drinks, but including both imported drinks and those manufactured domestically (e.g., through franchising)	38 (7.2 ±4.9)	41 (14.4 ±8.7)
Overweight prevalence (aged ≥ 20 y), 2008	Population-based age-standardized survey estimates of the percentage of adults older than 20 y in each country who have a BMI ≥ 25 kg/m ²	34 (38.1 ±20.1)	48 (52.2 ±12.5)
Obesity prevalence (aged ≥ 20 y), 2008	Population-based age-standardized survey estimates of the percentage of adults older than 20 y in each country who have a BMI ≥ 30 kg/m ²	37 (14.4 ±12.6)	51 (19.7 ±12.9)
Diabetes prevalence (aged 20–79 y), 2007	Population-based age-standardized survey and interpolated estimates of the percentage of adults aged 20–79 y in each country who meet international criteria for diabetes based on blood glucose testing	118 (5.9 ±2.6)	84 (7.8 ±3.3)

Note. BMI = body mass index. Both soft drink consumption and diabetes prevalence data were available for 75 countries, including 37 low- and middle-income nations; both soft drink consumption and BMI data were available from 58 countries, including 22 low- and middle-income nations; largest analytical sample reported for each row.



Note. The curves on the graphs are the product of a robust locally weighted nonparametric regression describing the smoothed relationship between the x- and y-axis variables. The locally weighted regression is performed with the Stata *lowess* algorithm in which $\text{bandwidth} \times N$ observations are used to calculate a smoothed value for each point in the curve; the default bandwidth is 0.8 and $n = 79$ countries. Consumption is the annual average from 1997 to 2007 to reflect both the lagged and cumulative impact of consumption on body mass and diabetes. Y-axis variables are unadjusted in these figures. Bandwidth = 0.8.

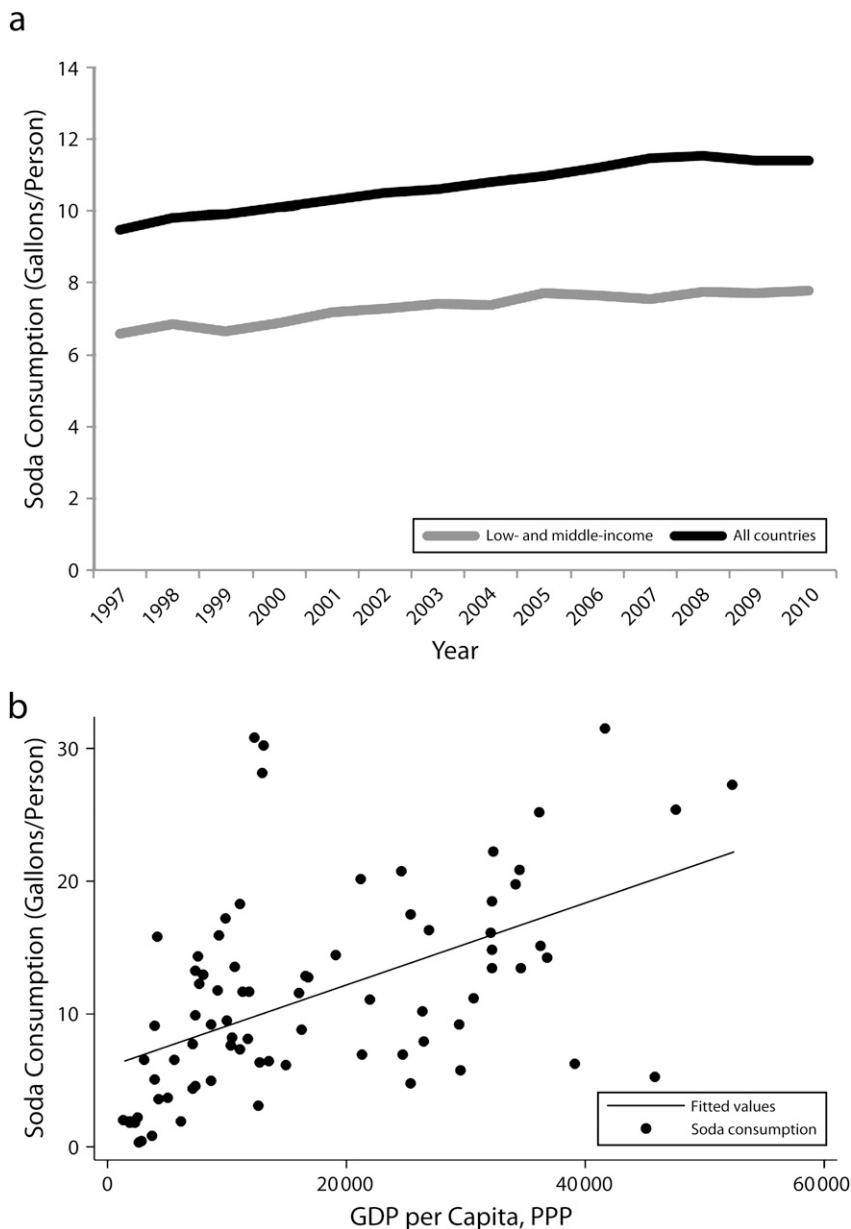
FIGURE 1—Relationship of soft drink consumption to the prevalence of (a) overweight among adults older than 20 years, (b) obesity among adults older than 20 years, and (c) diabetes among adults aged 20–79 years.

calculated for all models.²⁰ Statistics were calculated in StataSE version 10.1 (StataCorp.).

RESULTS

Soft drink consumption averaged 10.7 US gallons per capita per year from 1997 to 2010 (SD 7.6) in the 79 countries for which data were available. Average consumption worldwide increased from 9.5 gallons per person per year in 1997 to 11.4 gallons per person per year in 2010 (Figure 2a). An estimated 54% of soft drink consumption occurred in low- and middle-income countries from 1997 to 2010. The average consumption in these countries increased from 6.6 gallons per person in 1997 to 7.8 gallons in 2010. The increase of soft drink consumption in low- and middle-income countries from 1997 to 2010 (ratio 7.8:6.6 gallons = 1.19) was higher than the increase in high-income countries (ratio 14.8:14.4 gallons = 1.03; $P < .05$ by paired *t*-test), indicating a difference in time trends in soft drink consumption among countries at different levels of income.

Soft drink consumption generally increased with income (Figure 2b). On average, a 10-times increase in per capita GDP was associated with a 5.1-times increase in the annual number of gallons of soft drinks consumed per person (95% CI = 3.8, 6.4; estimated by linear regression of GDP on soft drink consumption). As shown in Figure 2b, however, there was great variability among countries in how much soft drink consumption occurred at different levels of per capita GDP, with higher variation at higher income levels. The highest consumption among all countries from 1997 to 2010 was observed in the United States in the year 1998 (37.8 gallons per capita), after which consumption in the United States decreased to 31.2 gallons per capita in 2010. This was followed by Mexico, where 31.7 gallons of soft drinks per person were consumed in 2007, decreasing only to 31.5 gallons in 2010 (higher than in the United States that year). Among all countries in 2010, Mexico's rate of consumption was followed by the United States, then Argentina (30.6 gallons per capita per year), Chile (28.8 gallons), and the United Arab Emirates (27.3 gallons). Among low- and middle-income countries (those with GDP per capita less than \$12 275, which Mexico exceeds), Venezuela



Note. GDP = gross domestic product; PPP = purchasing power parity. GDP per capita is expressed in 2005 international dollars PPP for comparability between countries. Bandwidth = 0.8.

FIGURE 2—Soft drink consumption in US gallons per capita per year worldwide (a) over time and (b) vs GDP for the year 2010.

led the list of consumers (at 18 gallons per capita per year), followed by Serbia (16.7 gallons), Brazil (16.5 gallons), Guatemala (16.0 gallons), and the Dominican Republic (14.8 gallons).

Several neighboring countries with otherwise similar economic, social, and cultural characteristics had vastly different soft drink consumption profiles and correspondingly divergent rates of

obesity. For example, although Bulgarians drank 9.5 gallons per person per year on average between 1997 and 2007 and exhibited a 12.4% prevalence of adult obesity in 2008, neighboring Serbians drank an average of 14.3 gallons and had a 17.4% prevalence of obesity. Indonesians drank 0.6 gallons and had a 2.4% obesity rate, whereas Thais drank 4.2 gallons

and had a 7.8% obesity rate. Italians drank 8.2 gallons and had a 9.8% obesity rate, whereas Spaniards drank 19 gallons and had a 15.6% obesity rate. Peruvians drank 10.8 gallons and had a 16.3% obesity rate, whereas neighboring Chileans drank 25.4 gallons and had a 21.9% obesity rate.

Soft Drink Consumption and Overweight and Obesity Prevalence

As shown in Figure 1a and 1b, soft drink consumption was strongly and positively correlated with the prevalence of overweight (BMI ≥ 25 kg/m²; unadjusted $r = 0.62$; $P < .001$) and obese adults (BMI ≥ 30 kg/m²; unadjusted $r = 0.55$; $P < .001$). An inflection point was observed in the dose-response relationship between soft drink consumption and overweight and obesity prevalence, such that the rate of increase in overweight and obesity prevalence was greater at lower levels of soft drink consumption than at higher levels. At levels of annual consumption of less than 6 gallons per person per year, each 1 gallon increase in per capita annual soft drink consumption related to 5 more overweight adults per 100 among all nations (and 8 more per 100 among low- and middle-income nations) and 1 more obese adult per 100 among all nations (4 more per 100 among low- and middle-income nations). At levels of annual consumption of more than 6 gallons per person per year, each 1 gallon increase in per capita annual soft drink consumption related to 0.5 more overweight adults per 100 among all nations (and 0.4 more per 100 among low- and middle-income nations) and 0.6 more obese adults per 100 among all nations (0.1 more per 100 among low- and middle-income nations). However, when tested using parametric piecewise linear regression (data available as a supplement to the online version of this article at <http://www.ajph.org>) rather than nonparametric locally weighted regression, these changes in the effect size of soft drinks with consumption level were not significant. Within the global sample, the 25th percentile of soft drink consumption (5.9 gallons per person per year) corresponded to a 38% overweight and a 12% obesity prevalence, whereas the 75th percentile of consumption (16 gallons per person per year) corresponded to a 50% overweight and a 17% obesity prevalence.

TABLE 2—Associations between Soft Drink Consumption and Overweight, Obesity, and Diabetes Prevalence

Determinant	Overweight Prevalence (BMI > 25 kg/m ²)			Obesity Prevalence (BMI > 30 kg/m ²)			Diabetes Prevalence		
	Low- and Middle-Income Countries, B (95% CI)	All Countries, B (95% CI)	Low- and Middle-Income Countries, B (95% CI)	All Countries, B (95% CI)	Low- and Middle-Income Countries, B (95% CI)	All Countries, B (95% CI)	Low- and Middle-Income Countries, B (95% CI)	All Countries, B (95% CI)	
Soft drinks	0.034* (0.006, 0.063)	0.048*** (0.031, 0.065)	0.023* (0.002, 0.044)	0.023*** (0.011, 0.035)	0.0050* (0.0001, 0.0090)	0.003* (0.001, 0.008)	0.0050* (0.0001, 0.0090)	0.003* (0.001, 0.008)	
Fruits and vegetables	0.00002 (-0.00176, 0.00181)	0.00002 (-0.00176, 0.00181)	0.00002 (-0.00176, 0.00181)	0.00002 (-0.00176, 0.00181)	0.000005 (-0.00013, 0.00014)	0.00006 (-0.00005, 0.00017)	0.000005 (-0.00013, 0.00014)	0.00006 (-0.00005, 0.00017)	
Cereals	-0.019 (-0.074, 0.037)	-0.004 (-0.020, 0.012)	0.005 (-0.020, 0.029)	0.002 (-0.008, 0.011)	0.000 (-0.004, 0.004)	0.001 (-0.002, 0.004)	0.000 (-0.004, 0.004)	0.001 (-0.002, 0.004)	
Meats	-0.060 (-0.140, 0.015)	-0.021 (-0.049, 0.007)	-0.014 (-0.048, 0.021)	-0.005 (-0.023, 0.012)	-0.008* (-0.015, -0.002)	-0.008*** (-0.013, -0.004)	-0.008* (-0.015, -0.002)	-0.008*** (-0.013, -0.004)	
Oils	-0.079 (-0.210, 0.052)	-0.012 (-0.043, 0.019)	-0.008 (-0.062, 0.047)	-0.004 (-0.020, 0.013)	-0.003 (-0.013, 0.007)	-0.007* (-0.013, -0.001)	-0.003 (-0.013, 0.007)	-0.007* (-0.013, -0.001)	
Total calories	0.037 (-0.052, 0.130)	0.015 (-0.003, 0.034)	0.003 (-0.031, 0.037)	0.005 (-0.005, 0.014)	0.002 (-0.002, 0.006)	0.001 (-0.001, 0.004)	0.002 (-0.002, 0.006)	0.001 (-0.001, 0.004)	
Age (% of population ≥ 65 y)	0.280 (-1.238, 1.798)	0.280 (-1.238, 1.798)	0.280 (-1.238, 1.798)	0.280 (-1.238, 1.798)	0.0879 (-0.0740, 0.250)	-0.176 (-0.357, 0.0053)	0.0879 (-0.0740, 0.250)	-0.176 (-0.357, 0.0053)	
GDP per capita	0.0014 (-0.0019, 0.0047)	0.0014 (-0.0019, 0.0047)	0.0014 (-0.0019, 0.0047)	0.0014 (-0.0019, 0.0047)	0.00003 (-0.00023, 0.00029)	0.00007 (-0.00003, 0.00018)	0.00003 (-0.00023, 0.00029)	0.00007 (-0.00003, 0.00018)	
Urban population (% of total population)	-0.0334 (-0.532, 0.465)	-0.0334 (-0.532, 0.465)	-0.0334 (-0.532, 0.465)	-0.0334 (-0.532, 0.465)	-0.0292 (-0.0900, 0.0316)	-0.0004 (-0.0534, 0.0525)	-0.0292 (-0.0900, 0.0316)	-0.0004 (-0.0534, 0.0525)	
Bottled water	-0.322 (-5.628, 4.984)	-0.322 (-5.628, 4.984)	-0.322 (-5.628, 4.984)	-0.322 (-5.628, 4.984)	-0.205 (-1.140, 0.730)	0.878 (-0.0275, 1.728)	-0.205 (-1.140, 0.730)	0.878 (-0.0275, 1.728)	
Countries, no.	21	54	22	58	37	75	37	75	
R ²	0.810	0.675	0.580	0.498	0.364	0.413	0.364	0.413	

Note. BMI = body mass index; CI = confidence interval; GDP = gross domestic product. Adjusted B's are listed with confidence intervals in parentheses, calculated using robust standard errors and adjusted for all variables listed in the first column. Soft drink and bottled water consumption variables are regressed in terms of annual average US gallons/person/year from 1997 to 2007 to reflect the impact of lagged and cumulative exposure effects. Other food items are regressed as kcal/person/day on average from 1997 to 2007. The table displays the change in outcome variables with a 1% rise in the independent variables. GDP per capita is expressed in purchasing power parity in constant 2005 international dollars for comparability.
P* < .05; *P* < .01; ****P* < .001.

Table 2 presents the results of our multivariate statistical models that examined the effect of soft drink consumption on overweight and obesity prevalence. We found that each 1% rise in soft drink consumption was significantly associated with an additional 4.8 per 100 adults being overweight (95% CI = 3.1, 6.5), after correcting for potential confounders, including GDP per capita, aging, urbanization, other food products, and total calories. No significant difference in the magnitude of association was observed among low- and middle-income countries compared with high-income countries. When analyzing only the subset of countries that were low- and middle-income, a 1% rise in soft drink consumption was related to an additional 3.4 cases of overweight per 100 adults (95% CI = 0.6, 6.3) when controlling for the same confounders.

Similarly, we found that a 1% rise in soft drink consumption was significantly associated with an additional 2.3 cases of obesity per 100 adults, after controlling for other foods (including total calories and bottled water), GDP per capita, urbanization, and aging (Table 2; 95% CI = 1.5, 4.4). Again, there was no significant difference across country income levels of the estimated effect size.

Soft Drink Consumption and Diabetes Prevalence

For diabetes prevalence, we found that the observed relationships between soft drink consumption and diabetes prevalence among low- and middle-income countries paralleled those between soft drink consumption and overweight and obesity prevalence. As shown in Figure 1c, there was a similar inflection point in the locally weighted regression curve between annual soft drink consumption and diabetes prevalence after about 6 gallons per person of consumption. Each gallon increase in per capita consumption corresponded to an additional 0.5 cases of diabetes per 100 adults aged 20 to 79 years in low- and middle-income countries (data available as a supplement to the online version of this article at <http://www.ajph.org>), but the curve among all countries was less pronounced (Figure 1c), suggesting that the association of soft drink consumption with diabetes prevalence among wealthier countries was less clear than among poorer ones (although this was still in a generally upward direction).

In the multivariate regression analysis, each 1% increase in soft drink consumption was significantly associated with a rise in diabetes prevalence by 0.5 cases per 100 adults among the 37 low- and middle-income countries for which data were available, after controlling for other foods (including total calories), GDP per capita, urbanization, and aging (Table 2; 95% CI=0.01, 0.9). A 1% rise in soft drink consumption was also significantly correlated with an additional 0.3 cases per 100 adults among the overall country dataset of 75 countries after the controls were incorporated (95% CI=0.1, 0.8).

Robustness Checks and Sensitivity Analyses

We assessed whether there were differences in the regression results from low- and middle-income countries, or from low- and middle-income countries combined and high-income countries, and did not find substantial differences between the 2 country groups in the regressions ($P > .05$ when testing effect heterogeneity). We ran an interaction specification, in which a country dummy was used to represent only low-income countries, then only low- and middle-income countries, and in which the dummy variable interacted with soft drink consumption. We found that the coefficient on this term was always nonsignificant and near zero, suggesting no statistical evidence for significant heterogeneity in the relationship of soft drink consumption with overweight and obesity and diabetes between country income groups.

Bottled water consumption increased in parallel to soft drink consumption over time (from an average of 5.7 gallons per capita in 1997 to 11.3 in 2010) and rose 4.3-times with each 10-times increase in GDP (95% CI=2.7, 5.9), exhibiting a similarly scattered distribution of consumption among countries of different income levels as soft drink consumption (see data available as a supplement to the online version of this article at <http://www.ajph.org>). No significant relationship, however, was observed between bottled water consumption and overweight, obesity, or diabetes prevalence (Table 2 and data available as a supplement to the online version of this article at <http://www.ajph.org>).

To test the assertion that soft drink consumption might pose greater risks of obesity and diabetes among women than among men for

unclear reasons,^{21,22} we disaggregated the statistical models by gender. Several countries had estimates among women rather than among all adults (i.e., 9 additional countries' data were available for overweight and obese female prevalence only than for prevalence among all adults). None of the results was qualitatively changed, nor was significant heterogeneity of effect observed by gender ($P > .05$ in effect heterogeneity test), but the association between soft drink consumption and obesity and overweight prevalence among men in the subset of low- and middle-income countries fell from significance because of low statistical power (see data available as a supplement to the online version of this article at <http://www.ajph.org>).

DISCUSSION

Our study analyzed the relationship between soft drink consumption and prevalence of overweight, obesity, and diabetes. We found that soft drink consumption was significantly associated with population-level rates of overweight, obesity, and associated diabetes worldwide, including in low- and middle-income countries.

Industry analysts suggest that soft drink consumption is expected to rise by 15.7% over the next 5 years in low- and middle-income countries and 9.5% worldwide.¹⁷ To put the magnitude of the associations we found into perspective, this projected rise in soft drink consumption would correspond to an additional 2.3 billion adults who are overweight, 1.1 billion adults who are obese, and 192 million new cases of diabetes worldwide over the next 5 years, with at least 60% of the burden falling on low- and middle-income countries.

Study Limitations

Our analysis, however, had several caveats. First, the available industry data on soft drink consumption included all carbonated soft drinks. This class of soft drinks might include some "diet" sodas that might have lower calories and a lower glycemic index than regular soft drinks. Although diet drinks are less commonly available and more expensive than their sugar-sweetened counterparts in most countries,¹⁷ their presence would dilute the association between soft drink consumption and health outcomes, making our results conservative. Second, the soft drink consumption dataset did

not include fruit drinks that were independently related to the risk of diabetes, likely because of their high sugar content.^{14,23} Third, soft drink consumption data were industry estimates based on consumer purchasing, and some soft drink purchases might not result in full consumption (as a result of wastage), potentially overestimating consumption levels in some areas. Related to this issue, the soft drink data included consumption among children, whereas the overweight and obesity and diabetes data were only on adults; this would tend to understate the impact of soft drink consumption on the health outcomes. Of note, the industry sources used in this analysis provided higher estimates of soft drink consumption than self-reported data used in other analyses,²⁴ potentially reflecting the underestimation of individuals in their degree of consumption or wastage between purchased products and consumed products. Similarly, the Food and Agricultural Organization data reflecting other food sources corresponded to the market availability of these food types rather than recorded consumption. This would tend to overestimate the consumption of other foods, leading us to make conservative estimates of the impact of soft drink consumption. Fourth, we used diabetes prevalence data that were estimated from available surveys, but in several countries such survey data were incomplete, and therefore, were interpolated, particularly among sub-Saharan African nations. These data also reflected total diabetes rates as disaggregated rates for only type 2 diabetes (thought to be obesity-related) and were unavailable; however, it was widely agreed upon that more than 90% of these diabetes cases were type 2 diabetes.² Similarly, data on the distribution of BMI and the relationship between individual-level BMI and soft drink consumption remained unavailable and would be an important area for further research to reduce the likelihood of the ecological fallacy (i.e., to test whether those consuming the most soft drinks are in fact those with the highest BMI). Panel data analysis (longitudinal time-series analysis) should be performed to verify our results once comparable long-term data on weight and diabetes become available and once it is physiologically clear what the time delay is between consumption and weight change or development of diabetes.

As with any observational study, association did not necessarily indicate causation, and

using population-level data offered the potential for ecological fallacies. Nevertheless, we observed a consistent and strong association between soft drink consumption and cross-sectional overweight, obesity, and diabetes prevalence, even after correcting for other types of foods available on the market and for plausible controls, including income, urbanization, and aging. As a further indicator of specificity, we did not find an effect of bottled water consumption on overweight, obesity, or diabetes prevalence, suggesting that the observed effects were likely not the result of other unobserved lifestyle changes associated with economic growth besides the metabolic and nutritional effects of soft drinks themselves.

Our study has important implications for future research. There is a clear need to better understand the marked variations in population-wide consumption of soft drinks. Several countries, particularly Mexico, Argentina, and Chile, experienced much higher consumption of soft drinks for their levels of GDP per capita than others, such as Singapore, Korea, and Malaysia. Furthermore, the observation that countries with high levels of GDP had widely varying levels of soft drink consumption, with some having less than a gallon per person per year of average consumption, suggests that higher soft drink consumption is not an inevitable result of economic growth.

It will be important to identify what strategies maintained a lower level of soft drink consumption in some high-income nations; such strategies might help prevent the further rise of obesity and diabetes in low- and middle-income nations. Although individual-level analyses and controlled trials are useful in investigating detailed mechanisms relating food consumption to obesity and diabetes, the advantage of an ecological study such as this one was that by comparing many countries, we could investigate population-wide factors that might have had the greatest potential to contribute to disease. These strategies might be particularly important as countries' markets become more integrated into the international economic system, a process that is expected to increase the probability of importing soft drinks and developing franchise arrangements with large multinational soft drink manufacturers and distributors.

Conclusions

Overall, our study indicated that soft drink consumption was significantly associated with obesity and diabetes prevalence worldwide, even in low- and middle-income countries. Thus, the continued rise of soft drink consumption poses a global public health risk of worsening obesity and diabetes. ■

About the Authors

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Contributors

S. Basu created the study, conducted the analysis, and wrote the first draft of the article. D. Stuckler reviewed the study methodology and confirmed the statistical results. All of the authors edited the article.

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