

Sweetened beverage consumption is a risk factor for depressive symptoms among adolescents living in Boston, Massachusetts, USA

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Abstract

Objective: To investigate the relationship between sweetened beverage consumption and depressive symptoms among adolescents.

Design: In a cross-sectional study, adolescents were asked how often they drank soda and fruit drinks in the past 7 d. Depressive symptoms were measured using a brief adapted version of the Modified Depression Scale. Summation scores were standardized using the Z-transformation. We used multilevel multiple linear regression models to estimate the association between soda and fruit drink consumption and depressive symptoms.

Setting: The 2008 Boston Youth Survey.

Subjects: Adolescents (*n* 1878), high-school students in grades 9–12 of Boston public schools, Massachusetts, USA.

Results: Compared with those who never drank soda in the past 7 d, those who consumed soda 2–6 times/week ($\beta=0.18$; 95% CI 0.04, 0.32) or ≥ 1 times/d ($\beta=0.29$; 95% CI 0.13, 0.45) had higher depressive symptoms. Similarly, those who consumed fruit drinks 2–6 times/week ($\beta=0.14$; 95% CI 0.00, 0.28) and those who consumed ≥ 1 times/d ($\beta=0.22$; 95% CI 0.04, 0.40) had higher depressive symptoms.

Conclusions: Frequent consumption of both soda and fruit drinks is associated with greater depressive symptoms among adolescents.

Keywords

Soda and fruit drink consumption
Depressive symptoms
Adolescents

Depression among teens is a major public health concern in the USA. According to recent evidence, the prevalence of a lifetime major depressive episode among adolescents aged 12–17 years is 7.7 (95% CI 7.3, 8.2)% and 18.2 (95% CI 17.5, 18.9)% among boys and girls, respectively⁽¹⁾. Furthermore, an estimated 30% of adolescents reported experiencing symptoms of depression, such as feeling sad or hopeless⁽²⁾. Girls, in comparison to boys, are more likely to experience depression⁽¹⁾. In comparison to white students, Hispanic students are more likely to report depressive symptoms, while black students are less likely⁽³⁾. Teens from lower socio-economic status backgrounds are more likely to experience depression⁽⁴⁾. For example, the population-attributable risk for income and education on depression is 26% and 40%⁽⁵⁾, respectively. Public health impacts include suicide, which was the second leading cause of death among adolescents aged 12–17 years in 2010⁽¹⁾.

Sugar-sweetened beverages are those that contain caloric sweeteners and typically include soft drinks, soda, pop, soda pop, fruit juices and fruit drinks. A soft drink is a beverage that typically contains carbonated water, a sweetener, and a natural or artificial flavouring. The terms 'sodas' and 'pops' have been used interchangeably with 'soft drinks'. Fruit juices contain 100% fruit juice and provide essential vitamins and minerals. Fruit drinks do not contain very much fruit juice and do not contain vitamins and minerals. Recent evidence identifies that regular soda consumption has been increasing among children in the USA and Europe^(6–10). Furthermore, the proportion of daily energy from sweetened beverages increased significantly from 11.8% in 1965 to 21.0% in 2002 in the USA. This has led health professionals to recommend that children limit intake of beverages high in sugar such as regular soda and fruit juices from their daily dietary intake⁽⁶⁾. In the USA,

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researchers have observed associations between soda consumption and adverse behavioural problems among children and adolescents^(11–13). For example, soda consumption was associated with withdrawn behaviour and aggression in 5-year-olds⁽¹³⁾ and with violence perpetration and suicidal behaviour among adolescents^(11,12).

Sugar consumption has been identified as a risk factor for depression⁽¹⁴⁾. One theoretical biological mechanism by which sugar leads to depression involves the reduction of brain-derived neurotrophic factor^(15,16). Previous studies have identified the relationship between soda consumption and depression, specifically among adults^(17–19). However, research is limited in adolescence, a particular period when the human brain is undergoing development and might be sensitive to high sugar intake. Additionally, the relationship between the consumption of other sweetened beverages, such as fruit drinks, and depressive symptoms has yet to be investigated. An observed association could highlight the importance of recognizing that fruit drinks, even though perceived to be healthy, can be detrimental to the mental health of adolescents.

Although several studies have identified high soda consumption as a risk factor for depression among adults^(17–19), limited evidence exists that identifies this relationship among adolescents. To our knowledge, only one study has investigated this relationship among adolescents⁽²⁰⁾. In a study among Norwegian adolescents, researchers observed a J-shaped relationship between soda consumption and mental distress⁽²⁰⁾. More studies among adolescents are warranted, especially among US teens, where the prevalence of daily soda consumption is high in comparison to other OECD (Organisation for Economic Co-operation and Development) countries. Furthermore, the association between mental health and sources of sweetened beverages other than sodas, such as fruit drinks, needs to be investigated. One previous study identified different socio-demographic characteristics associated with differing sweetened beverages⁽²¹⁾. For example, children from lower socio-economic backgrounds were significantly more likely to consume sodas in comparison to those from high socio-economic backgrounds, and girls were significantly less likely to consume soft drinks than boys⁽²¹⁾. However, sex and socio-economic status were not associated with fruit juice consumption⁽²¹⁾.

The current study addresses the dearth in the literature by conducting analyses among adolescents to identify the association between soda and fruit drink consumption and depressive symptoms. We hypothesize that students who consume high amounts of soda and fruit drinks have higher depressive symptoms.

Methods

Data come from the 2008 Boston Youth Survey (BYS), a biennial survey of high-school students in grades 9–12 in

Boston public schools ($n = 31$)^(22,23), Massachusetts, USA. Of the eligible schools, twenty-two agreed to participate (71%). The final sample of schools was representative of all public schools in the Boston area in terms of race/ethnicity of the students, school drop-out rates and other variables⁽²⁴⁾.

A unique list of classrooms was obtained from each school and classrooms stratified by grade were randomly selected for participation in the BYS until 100–120 students in each school were identified. All students in randomly selected classrooms were invited to participate⁽²⁴⁾. We used passive parental consent and students were also free to decline to participate at any time before or during the survey administration. The response rate was 69%, reflecting primarily students who were absent on the day of administration, which yielded a sample size of 1878 students. Of the 1878 students, complete data were available for $1314/1878 = 70.0\%$ of students. We used multiple imputations to replace missing individual-level data. Students who did not provide their residential location were excluded. As a result, complete data within the imputed data set were available for $1611/1878 = 85.8\%$ of students. We imputed missing values within five copies of the data set. We then used multilevel regression analyses to fit the model of interest to each of the imputed data sets. Next, we averaged the estimates to obtain estimated associations⁽²⁵⁾. Those with missing data were more likely to be male, black, older and to have immigrated to the USA within the last 4 years.

Data collection

The BYS team of investigators developed the questionnaire, using reliable and valid scales to measure behaviours. We emphasized violence exposure. During the spring of 2008, a paper-and-pencil survey was administered in classrooms by trained staff. The Office of Human Research Administration at the Harvard School of Public Health approved all data collection procedures.

Study variables

Individual-level covariates in the study were students' gender, age, nativity (US born, foreign born arrived ≤ 4 years, foreign born arrived > 4 years) and race/ethnicity (white, black, Asian, Hispanic, other).

Depressive symptoms were measured using a brief adapted version of the Modified Depression Scale (MDS), which has been described elsewhere⁽²⁶⁾. Briefly, students were asked to report the frequency of five symptoms in the past month: 'In the past month, how often ...': (i) '... were you very sad?'; (ii) '... were you grouchy or irritable or in a bad mood?'; (iii) '... did you feel hopeless about the future?'; (iv) '... did you sleep a lot more or less than usual?'; and (v) '... did you have difficulty concentrating on your school work?'. Response options included 'never' (= 1), 'rarely' (= 2), 'sometimes' (= 3), 'often' (= 4) and 'always' (= 5). Total scores were calculated by summing

items among participants who had complete responses for all five items (range: 5–25). Scores were standardized using the *Z*-transformation. BYS data were used to evaluate psychometrics (Cronbach's $\alpha = 0.79$), reliability and known-group validity⁽²⁶⁾.

Sweetened beverage consumption

The BYS collected information on soda and sweet drink consumption, but NOT fruit juice consumption. For both soda (not including diet soda) and sweetened fruit drink consumption, students were asked: 'In the past 7 days, how often did you drink ... (1 can or glass; count 20 oz bottles as 2 cans)?'. Response options included 'never or less than 1 can', '1 can in the past 7 days', '2–4 cans in the past 7 days', '5–6 cans in the past 7 days', '1 can per day', '2 cans per day' and '3 or more cans per day'. Response options were categorized into never, 1 time/week, 2–6 times/week and ≥ 1 times/d.

Area-level economic deprivation

Since individual-level income information was not collected, we used an area-level approximation of the socio-economic environment. Students were asked the nearest cross-street of their residence for geocoding to US Census tracts. Data from the US Census American Community Survey in 2008 were used to characterize neighbourhood clusters of Census tracts. These neighbourhood clusters were formed by working with key informants from Boston to identify thirty-eight socially meaningful neighbourhood clusters.

Economic deprivation, which is a socio-economic score, was created using principal components analysis. US Census indicators included for this score were the proportion of residents living below the poverty level, the proportion of households receiving public assistance and the proportion of families with a female head of household (Cronbach's $\alpha = 0.84$). A higher score was indicative of greater economic deprivation or poverty. Tertiles of the neighbourhood economic deprivation were used to categorize economic deprivation into low, moderate and high.

Statistical analysis

Since students were nested within neighbourhoods, we used multilevel modelling to investigate the relationship between sweetened beverage consumption and depressive symptoms. Multilevel models are a generalization of the linear model used in traditional analysis. Further information regarding the use of this analysis in public health research is available⁽²⁷⁾.

To determine whether there were sociodemographic differences associated with soft drink and fruit drink consumption, multilevel logistic regression models were run to determine the relationships of gender, age, race, nativity and neighbourhood deprivation with daily consumption of soda, daily consumption of fruit drinks, no consumption of soda and no consumption of fruit drinks.

To investigate the association of soda and fruit drink consumption with depressive symptoms, a sequence of multilevel linear models was conducted. First, a set of analyses involved estimating the null model. The null model allowed us to calculate the intraclass correlation coefficient, which allowed us to determine the proportion of variance explained at the neighbourhood and at the individual levels. Then potential confounders were added. Cross-level economic deprivation \times sweetened beverage consumption, race \times sweetened beverage consumption and gender \times sweetened beverage consumption interaction terms were added to determine if the association between sweetened beverage and depressive symptoms differed across socio-economic groups and gender. Since interaction terms were not significant, findings were not presented. We ran the analyses twice, first using the case-complete data set and second with the multiply imputed data set. Since the results in the case-complete analyses were consistent with the analysis using the multiply imputed data set, only results from the latter analyses are presented.

Results

The characteristics of the students participating in the BYS are found in Table 1. Characteristics of the case-complete and imputed samples are provided. Overall, the sample had 53.4% females, 42.6% were black and 69.4% were born in the USA. The mean depressive symptom score was 13.3 (SD 4.3) and ranged from 5.0 to 25.0. The mean economic deprivation score was 0.02 (SD 1.01) and the range was -1.79 to 2.42.

When identifying correlates of sweetened beverage consumption (Table 2), older students (aged 17–19 years) in comparison to younger students (aged 14–6 years) were more likely to drink soda daily. Asians in comparison to whites, and immigrants who arrived >4 years ago in comparison to US-born students, were significantly less likely to consume soda daily. When identifying correlates for fruit drink consumption, black, Hispanic and students from other racial backgrounds, in comparison to white students, were significantly more likely to consume fruit drinks daily. When identifying correlates of no sweetened beverage consumption, immigrants who arrived >4 years ago, in comparison to US-born students, were significantly more likely to consume no soda in the previous week. Students who immigrated to the USA >4 years ago in comparison to US-born students, and those from moderately deprived neighbourhoods in comparison to those from low deprived neighbourhoods, were significantly more likely to consume no fruit drinks. These findings provide support that the demographic profiles of soda and fruit drink consumers differ.

The results of models for the relationship between soda/fruit drink consumption and depressive symptoms are presented in Table 3. When soda consumption was the

main exposure of interest, the adjusted model using imputed data indicated that compared with those who reported never consuming soda, there was no significant

Table 1 Characteristics of the adolescents participating in the Boston Youth Survey 2008, Massachusetts, USA

	Case-complete		Imputed	
	<i>n</i>	Proportion (%)	<i>n</i>	Proportion (%)
Gender				
Male	579	44.1	736	45.7
Female	735	55.9	875	54.3
Race				
White	126	9.6	136	8.4
Black	544	41.4	683	42.4
Asian/South Asian	109	8.3	130	8.1
Hispanic	443	33.7	549	34.1
Other	92	7.0	113	7.0
Nativity				
New immigrant	107	8.1	157	9.7
Settled immigrant	263	20.0	332	20.6
Born in USA	944	71.8	1122	69.6
Age (years)				
13 or 14	107	8.1	133	8.3
15	262	19.9	316	19.6
16	357	27.2	438	27.2
17	356	27.1	422	26.2
18	178	13.6	225	14.0
19	178	13.6	77	4.8
Soda consumption				
Never	307	23.4	346	21.5
1 time/week	287	21.8	334	20.7
2–6 times/week	424	32.3	597	37.1
≥1 times/d	296	22.5	334	20.7
Fruit drink consumption				
Never	248	19.1	276	17.1
1 time/week	196	15.1	242	15.0
2–6 times/week	474	36.5	636	39.5
≥1 times/d	382	29.4	457	28.4

Table 2 The relationship of sociodemographic characteristics with beverage consumption among adolescents (*n* 1611) participating in the 2008 Boston Youth Survey, Massachusetts, USA

	Daily soda consumption		Daily fruit drink consumption		No daily soda consumption		No daily fruit drink consumption	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Gender								
Male (ref.)		1.00		1.00		1.00		1.00
Female	0.89	0.69, 1.14	0.95	0.75, 1.21	1.23	0.94, 1.60	1.28	0.97, 1.68
Age (years)								
14–16 (ref.)		1.00		1.00		1.00		1.00
17–19	1.32	1.05, 1.66*	1.24	1.01, 1.52*	0.82	0.65, 1.02	0.67	0.52, 0.85*
Race								
White (ref.)		1.00		1.00		1.00		1.00
Black	1.00	0.68, 1.47	3.80	2.61, 5.53*	0.54	0.35, 0.83*	0.23	0.15, 0.34*
Hispanic	1.02	0.71, 1.46	1.96	1.37, 2.81	0.36	0.25, 0.53*	0.27	0.19, 0.40*
Asian	0.25	0.14, 0.44*	0.57	0.33, 1.00	1.38	0.86, 2.21	1.05	0.66, 1.65
Other	0.82	0.48, 1.42	2.21	1.30, 3.76*	0.71	0.44, 1.14	0.32	0.17, 0.58*
Nativity								
US-born (ref.)		1.00		1.00		1.00		1.00
Arrived >4 years ago	0.68	0.49, 0.96*	0.71	0.53, 0.94*	1.47	1.09, 1.99*	1.53	1.13, 2.07*
Arrived ≤4 years ago	0.75	0.51, 1.12	0.74	0.49, 1.12	1.43	0.93, 2.20	1.38	0.88, 2.17
Neighbourhood deprivation								
Low (ref.)		1.00		1.00		1.00		1.00
Moderate	1.08	0.81, 1.43	0.90	0.73, 1.11	1.23	0.98, 1.53	1.38	1.03, 1.84*
High	0.90	0.64, 1.27	1.13	0.91, 1.42	1.18	0.92, 1.50	1.00	0.76, 1.30

Ref., reference category.

*Indicates a significant predictor at $P < 0.05$.

difference in depressive scores among those who consumed soda 1 time/week ($\beta = -0.04$; 95% CI $-0.18, 0.10$). However, those who consumed soda 2–6 times/week ($\beta = 0.18$; 95% CI $0.04, 0.32$) and ≥1 times/d ($\beta = 0.29$; 95% CI $0.13, 0.45$) had significantly greater depressive scores. A marginally significant linear trend between amount of soda consumed and depressive scores was observed ($P = 0.09$; Fig. 1(a)).

When fruit drink consumption was the main exposure, similar findings were obtained. For example, in comparison to students who reported never consuming fruit drinks, those who drank fruit drinks 2–6 times/week ($\beta = 0.14$; 95% CI $0.00, 0.28$) and ≥1 times/d ($\beta = 0.22$; 95% CI $0.04, 0.40$) had significantly greater depressive scores. A significant positive linear trend was observed ($P = 0.02$; Fig. 1(b)).

Neither race × sweetened beverage consumption, gender × sweetened beverage consumption, nor the cross-level economic deprivation × sweetened beverage consumption interaction terms were significant (data not shown). Therefore, the association between sweetened beverage consumption and depressive symptoms did not differ across racial groups and genders.

Discussion

The current investigation is one of the first to investigate the association between sweetened beverage consumption and depressive symptoms among adolescents. These findings are consistent with other studies among adults^(17–19) and with studies that indicate increased sugar intake is related to an increased risk of depression^(28–32).

Table 3 The relationship of soda, fruit drink and overall sweetened beverage consumption with depressive symptoms among adolescents (*n* 1611) participating in the 2008 Boston Youth Survey, Massachusetts, USA

	Soft drink consumption				Fruit drink consumption				Sweetened beverage consumption			
	Crude		Adjusted		Crude		Adjusted		Crude		Adjusted	
	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Consumption												
Never (ref.)		1.00		1.00		1.00		1.00		1.00		1.00
1 time/week	-0.05	-0.21, 0.11	-0.04	-0.18, 0.10	0.06	-0.12, 0.24	0.03	-0.15, 0.21	0.00	-0.22, 0.22	-0.01	-0.02, 0.42
2-6 times/week	0.15	0.01, 0.29*	0.18	0.04, 0.32*	0.08	-0.06, 0.22	0.14	0.00, 0.28*	0.14	-0.05, 0.33	0.20	-0.02, 0.42
≥1 times/d	0.25	0.09, 0.41*	0.29	0.13, 0.45*	0.17	0.01, 0.33*	0.22	0.04, 0.40*	0.25	0.05, 0.44*	0.31	0.09, 0.54*
Gender												
Male (ref.)				1.00				1.00				1.00
Female			0.47	0.38, 0.56			0.47	0.27, 0.67*			0.47	0.38, 0.57*
Age (years)												
14 (ref.)				1.00				1.00				1.00
15			0.14	-0.06, 0.34			0.15	-0.01, 0.31			0.15	0.01, 0.30*
16			0.23	0.05, 0.41*			0.25	0.11, 0.39*			0.24	0.11, 0.38*
17			0.17	-0.01, 0.35			0.18	0.04, 0.32*			0.18	0.05, 0.31*
18			0.27	0.07, 0.47*			0.28	0.14, 0.42*			0.29	0.15, 0.42*
19			0.40	0.13, 0.67*			0.41	0.06, 0.76*			0.41	0.06, 0.77*
Race												
White (ref.)				1.00				1.00				1.00
Black			0.02	-0.16, 0.20			-0.03	-0.23, 0.17			-0.04	-0.23, 0.16
Hispanic			0.08	-0.10, 0.26			0.07	-0.13, 0.27			0.06	-0.15, 0.26
Asian			0.1	-0.14, 0.34			0.07	-0.20, 0.34			0.09	-0.19, 0.36
Other			0.2	-0.04, 0.44			0.17	-0.08, 0.42			0.17	-0.05, 0.14
Nativity												
US-born (ref.)				1.00				1.00				1.00
Arrived >4 years ago			0.05	-0.07, 0.17			0.04	-0.06, 0.14			0.04	-0.05, 0.14
Arrived ≤4 years ago			-0.04	-0.22, 0.14			-0.05	-0.23, 0.13			-0.04	-0.22, 0.13
Neighbourhood deprivation												
Low (ref.)				1.00				1.00				1.00
Moderate			-0.07	-0.21, 0.07			-0.06	-0.18, 0.06			-0.06	-0.18, 0.07
High			-0.09	-0.23, 0.05			-0.09	-0.21, 0.03			-0.09	-0.21, 0.02

Ref., reference category.

*Indicates a significant predictor at $P < 0.05$.

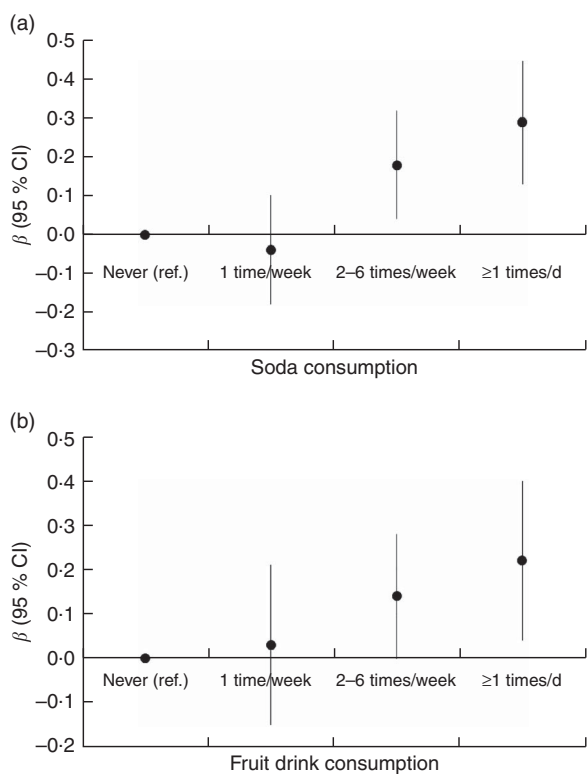


Fig. 1 The relationship of (a) soda consumption and (b) fruit drink consumption with depressive symptoms, controlling for individual and neighbourhood-level confounders, among adolescents (n 1611) participating in the 2008 Boston Youth Study, Massachusetts, USA. Values are β estimates with their 95% confidence intervals represented by vertical bars (ref., reference category)

We found that there were some differences in socio-demographic characteristics between soda and fruit drink consumers. However, more frequent soda and fruit drink consumption were both associated with higher depressive symptoms after controlling for confounding variables. Overall, our results indicate that sweetened beverage consumption, which accounts for a high proportion of daily energy intake among US adolescents, might not only be detrimental to physical health, but also harmful to mental health.

Our investigation is consistent with several studies conducted among adults that indicate consumption of sweetened beverages is associated with depression^(17–19) as well with studies conducted among adolescents that indicate high intake of foods high in refined sugar is associated with increased risk for depression^(28–32). Our study adds to the literature because it is one of the first studies to identify the relationship of both soda and fruit drink consumption with depressive symptoms among adolescents. Adolescence is an important stage in human development and restricting sugar-sweetened beverage consumption may help healthy adolescent development.

Sweetened beverages contain high levels of refined sugar. Although public health professionals have focused mainly on sweetened beverage consumption and

increased risk for obesity^(33–35), adverse effects of these beverages on other health outcomes have not been sufficiently addressed. The present results suggest that high consumption of sweetened beverages may also be associated with higher risk for depression. Two possible biological mechanisms have been proposed. First, refined sugar has been shown to suppress the growth hormone brain-derived neurotrophic factor, a decrease in normal functioning of which has been linked with depression^(15,16). Second, sugar consumption impairs glucose and lipid metabolism and promotes inflammation, which disrupts the normal functioning of the immune system and may lead to a greater risk for depression^(36–38). Sweetened beverage consumption increases risk for obesity, diabetes and other chronic illnesses, which in turn are risk factors for depression^(39,40).

Public health professionals should not only emphasize the adverse risk of obesity that comes along with sweetened beverage consumption, but also warn parents, adolescents and policy makers about the potential negative effects these beverages can have on mental development and health. Policies that restrict the availability of sweetened beverages within schools and community and recreation centres while promoting the consumption of water might be beneficial to adolescent health. Since the sociodemographic profiles of soda and fruit drink consumers differ, public health practitioners could better identify those who are at greater risk of consuming different types of sweetened beverages.

These findings should be interpreted in light of the limitations of the present study. We used cross-sectional data to help us investigate the relationship between sweetened beverage consumption and depressive symptoms and therefore the temporality of main exposure and outcome could not be identified. However, our hypotheses and directionality have intuitive appeal and are based on previous work. Since individual-level covariates, such as household income, parental education or occupation, were not collected, residual confounding might be an issue. Furthermore, we did not measure dietary intake and therefore intake of foods high in refined sugar could not be accounted for. However, dietary behaviours tend to cluster and sweetened beverage consumption might be a good marker for overall dietary intake. Finally, we might be able to generalize the results to urban centres similar to Boston but not necessarily to non-urban areas.

An alternative explanation for the relationship between soft drink consumption and depression could be that it is the caffeine found within these beverages and not the sugar that increases the risk for depression. Several studies have identified caffeine consumption as related to depression. Researchers theorize that caffeine interferes with the dopaminergic and glutamatergic systems, which can lead to mood disorders^(41–43). Since the BYS did not distinguish between which beverages contained caffeine and which ones did not, we were not able to determine

whether the sugar or caffeine was responsible for the relationship between sweetened beverages and depressive symptoms. However, we measured soda and fruit drink consumption separately. Since fruit drinks do not contain caffeine and consumption of these drinks was associated with increased depressive symptoms, we can deduce that our study contributed evidence to the possibility that sugar intake is associated with increased depressive symptoms.

Conclusion

In conclusion, findings from the present study suggest that sweetened beverage consumption is associated with depressive symptoms among adolescents living in an urban setting. Sweetened beverage consumption is potentially harmful to the development and mental health of adolescents. Further investigation should include longitudinal studies to determine whether sweetened beverage consumption is a predictor of depression among adolescents as they age into adulthood.

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