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Consumption of carbonated soft drinks, fruits and vegetables and association with macroeconomic indicators: the analysis of students from seventy-four countries (2003–2015)

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Abstract

This study aimed to compare fruits and vegetables (FV), and carbonated soft drink (CSD) consumption among adolescents from seventy-four countries, according to macroeconomic indicators. This is an ecological study, developed with countries evaluated through the Global School-based Student Health Survey (2003–2014) and the National School Health Survey (PeNSE-Brazil, 2015). The percentages of students in each country who consumed CSD and FV daily and their association with the Human Development Index (HDI) and the Gross National Income per capita (GNIpc) were assessed. Scatter plots were constructed for each marker, and a multilevel model was tested to consider the effects of region in the associations. The overall prevalence of daily CSD consumption was 54·1 %. CSD consumption was positively associated with HDI and GNIpc through multilevel models, and Central and South America showed a considerable higher consumption compared with other regions. Overall, FV daily consumption was 67·9 % and 74·6 %, respectively, and no associations with macroeconomic indicators were found. The study shows concerning rates of CSD consumption among adolescents, and a trend of increased consumption with the improvement of the country's development and GNIpc. This points for the importance of public policies that regulate food and beverage industries to reduce CSD consumption and related co-morbidities among adolescents.

Key words: Adolescent nutrition: Nutrition surveys: Nutritional surveillance: Development indicators: Income: Economic indexes

It is well established that countries' wealth and welfare are associated with better health and nutrition outcomes among children and adults[1]. However, few studies have attempted to understand this association among adolescents[2,3], although like children, adolescents are among the most vulnerable to the effects of poverty and social and health inequalities. These may have an impact on adolescent's physical and psychosocial development, as well as influence their choices and health behaviours, with consequences that persist in adult life[3,4]. Thus, it is important to expand studies to this stage of life, having adolescence as a window of opportunity for the promotion of healthy behaviours and long-term impact on health and nutrition outcomes[3,4].

Adolescent health and nutrition are determined by multiple factors including proximal factors such as individual behaviours and friends and family influence, and distal factors such as education, national wealth and income inequality[2]. Despite the gap of studies examining adolescent health and distal factors, it is known that, usually, socio-economic disadvantages can limit food availability and access to health care and undermine people's participation in actions that promote healthy dietary habits and the consumption of healthy foods, such as fruits and vegetables (FV)[5,6].

In general, greater country economic development is related to greater food availability. However, the impact of food availability on diet quality varies across countries. In the most developed countries, rising incomes are often associated with increased food availability, to healthier and more diverse diets and better health care[7]. On the contrary, in developing

Abbreviations: CSD, carbonated soft drink; FV, fruits and vegetables; GNIpc, Gross National Income per capita; GSHS, Global School-based Student Health Survey; HDI, Human Development Index; AFR, Africa; AMR, Central and South America; EMR, Eastern Mediterranean; EUR, Europe; PeNSE, National School Health Survey; SEAR, Southeast Asia; WPR, Western Pacific.

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countries, rising incomes have been associated with increased consumption of ultra-processed food and animal products, contributing to unhealthy and less diverse diets[5–9]. Also, in these countries, increased national income tends to be followed by social and health inequalities, resulting in different effects in the population, depending on variables such as education. For instance, those with higher levels of education are more likely to pay for a diversified diet, while those in worst socio-economic conditions and lower levels of education have limited food choices and are more likely to pay for ultra-processed food[10].

The Human Development Index (HDI) and the Gross National Income per capita (GNIpc) are among the main macroeconomic indicators used to estimate countries' welfare and wealth, and they are potentially useful for international comparative analyses of countries' association with national food consumption profiles. However, studies on this subject are scarce, mostly using food balance sheets for the general population instead of providing more reliable information on food consumption patterns[7,11–19]. Another important gap is that none of the studies specifically evaluated these parameters among adolescents.

Evidence indicates that countries with higher Gross Domestic Product per capita have greater availability of both healthy food consumption markers, such as FV[13–15], and unhealthy food consumption markers, such as sugar[14] and typically Western foods, characterised by high energy density foods, large amounts of meat and animal fat and few whole grains[17,18]. A global study[20] that indicated higher fruit consumption in countries with higher Gross Domestic Product per capita also found a positive association between income and sweetened beverage consumption for Sub-Saharan Africa, suggesting variations in the association between macroeconomic indicators and food consumption by region. The same study also indicated differences in this association by sex and age when investigating adults and elderly.

Considering the complexity of adolescent dietary patterns, it is important to understand the association between macroeconomic indicators and food consumption in this age group to develop specific policies for the promotion of healthier habits among adolescents. Therefore, this study aimed to describe the consumption of healthy (FV) and unhealthy (carbonated soft drinks (CSD)) food markers among students from seventy-four countries, and its association with macroeconomic indicators.

Methods

Study design and sampling

This is an ecological study, using data from the Global School-based Student Health Survey (GSHS, 2003–2014), a collaborative surveillance project coordinated by the WHO with support from the Centers for Disease Control and Prevention. The GSHS is a nationally representative survey that has been largely applied in low–middle-income countries[3,21]. This study included seventy-four countries in the following regions: Africa (AFR: fourteen countries), Central and South America (AMR: twenty-three countries), Southeast Asia (SEAR: six countries), Europe (EUR: one country), Eastern Mediterranean (EMR: sixteen countries) and the Western Pacific (WPR: fourteen countries).

The GSHS focuses on students aged 13–17 years old[22,23] including different school grades according to the educational structure of each country[24–26]. The survey sampling plan was similar across countries, defined by a two-stage cluster design: first, the schools were selected and then the classes. All the students in the selected classes were invited to respond to the questionnaire[24–26]. The GSHS used a printed, self-administered questionnaire that was distributed during the classes. In the different countries investigated, specific questionnaires were used according to the local demands. The Centers for Disease Control and Prevention was responsible for digitising and processing the data[22,23].

Brazil was not included in the GSHS, and data from a national survey using comparable indicators, the National School Health Survey (*Pesquisa Nacional de Saúde do Escolar* – PeNSE 2015 – Sample 2), were used[27]. Questions about food groups were included in the same format adopted by the GSHS, precisely to enable comparison between the countries covered in this survey. PeNSE evaluated students enrolled in the final years of elementary and high school in Brazil following a three-stage sample design. Based on stratification by country region, groups of neighbouring municipalities were selected, followed by schools, and then classes. All students from these classes were invited to participate in the research. Data collection was conducted during school hours using a self-administered questionnaire applied through smartphones[27].

In the GSHS, the sample size varied between countries to ensure sufficient statistical power to estimate prevalence with accuracy equal to or greater than ± 5·0 % in each country. In PeNSE, the sample size was calculated to obtain an approximate error of 0·03 and a 95 % confidence level.

Investigated variables

The dependent variables analysed were the percentage of adolescents in each country who consumed CSD and FV daily. These food groups were chosen among all food consumption data collected by GSHS because they are part of the core questionnaire standardised for all countries, they are available in a considerable number of countries and they are routinely collected by other adolescent health surveillance systems, allowing for International comparison. Online Supplementary Fig. S1 shows the countries with information on CSD and FV consumption. The most recent data from each country were evaluated, considering all participants who were investigated (≥ 11 to ≤ 19 years).

The frequency of food consumption was assessed through common questions to both surveys, with reference to the last 30 days (answer options: *I did not drink carbonated soft drink/eat fruit/eat vegetables during the past 30 days; Less than one time/day; 1 time/day; 2 times/day; 3 times/day; 4 times/day; 5 or more times/day*)[21,27]. In view of the current recommendations for the consumption of ≥ 400 g/d of FV[7], and that daily consumption of CSD may be considered a marker of excessive consumption, the response options were recategorised into daily (≥ 1 times/d) and non-daily consumption.

The macroeconomic indicators evaluated included the HDI (2000–2015), a summarised measure of the fundamental

dimensions of human development (health, education and life standard) available at the United Nations Development Programme[28], and the GNIpc (Atlas Method; 2003–2015), a national wealth indicator used to divide countries into income groups available from the World Development Indicators, World Bank[29]. The HDI and GNIpc data used in this study were those in the closest years from the food consumption data (online Supplementary Fig. S1).

The independent variables in the study were the world regions (AFR, AMR, SEAR, EUR, EMR and WPR), continuous and categorised HDI (low: < 0·55; medium: 0·55 to < 0·7; high: 0·7 to < 0·8; very high human development: ≥ 0·8)[28] and continuous and categorised GNIpc (low income: ≤ US$1025·00; lower–middle-income: US$1026·00 to US$4035·00; upper–middle-income: US$4036·00 to US$12 475·00; high income: ≥ US$12 476·00 – according to World Bank income groups)[29].

Data analysis

Statistical tests were performed using SPSS software 17.0 for Windows (SPSS Inc.) and Stata (release 15; StataCorp LP). First, the countries databases were accessed individually to obtain their respective prevalence of CSD and FV daily consumption. Considering the representativeness of national data and its generalisation, the SPSS 'Complex sample' module was used, selecting the strata, clusters and sample weight variables specific to each country when carrying out the analysis. Then, information about the prevalence of food consumption was transferred to a new database, which aggregated this information and data on macroeconomic indicators for the set of countries investigated.

Descriptive analyses were conducted showing the prevalence, median and interquartile range data for food consumption by country. As the numerical variables did not have a normal distribution (Kolmogorov–Smirnov test), nonparametric analyses were adopted. The associations between the percentage of daily consumption and the world regions and human development and income groups were analysed using the Kruskal–Wallis test, followed by the Mann Whitney test adjusted by Bonferroni correction[30].

Scatter plots were constructed for each indicator as a continuous variable (HDI and GNIpc (logarithmic form)) and for the prevalence of daily consumption of each food marker, together with a correlation test. Four countries (Brunei Darussalam, Kuwait, Qatar and United Arab Emirates) were considered outliers and excluded from the GNIpc analysis due to their high values in comparison with other countries.

A multilevel model was tested between the variables with significant correlation to consider the effects of region in the association. Random Intercept Models were used, considering country as the level 1 and region as the level 2. A likelihood ratio test was used to compare the multilevel model with a single-level model. In addition, variance partition coefficients were calculated to show the proportion of total variance in the outcome due to differences occurring at each level. The models were controlled by sex (percentage of female);, year of data collection, Consumer Price Index for food indices and the Per capita Food Supply for human consumption (kcal/capita/d). Stepwise multilevel analyses were conducted, and none of the control variables was statistically significant.

Ethical standards

This study was developed from secondary data. Research used as a data source was conducted according to the guidelines established in the Declaration of Helsinki, and all procedures involving research study participants were approved by the WHO, Centers for Disease Control and Prevention (specific approval number for each country) and the National Research Ethics Committee of the Brazilian Ministry of Health (nº 1.006.467). Written informed consent was obtained from all subjects/patients.

Results

In the seventy-four countries, 257 770 students were evaluated, ranging from 578 in Nauru (WPR) to 28 368 in Argentina (AMR), with 70·3 % of countries having a sample size of at least 2000 students (median sample size = 2375·5). In the investigated countries, 50·2 % of the adolescents were male and 49·8 % were female (online Supplementary Table S1). The AMR region contained the largest proportion of countries surveyed (31·1 %, twenty-three countries). Over 70·0 % of the countries had medium-to-high HDI and half had low or lower–middle income (Table 1).

Table 1. General characteristics and socio-economic indicators in the seventy-four evaluated countries
(Number and percentages)

Variables	*n*	Values (%)
Region (%)		
Africa	14	18·9
Central and South America	23	31·1
Southeast Asia	6	8·1
Europe	1	1·4
Eastern Mediterranean	16	21·6
Western Pacific	14	18·9
Human Development Index (HDI)	72	
Median		0·70
IQR		0·58; 0·75
Human Development – HDI (%)*		
Low	14	19·4
Medium	21	29·2
High	32	44·4
Very high	5	6·9
Gross National Income per capita (GNIpc – US$)	74	
Median		3920·00
IQR		1792·50; 8587·50
Income groups according to GNIpc (%)†		
Low-income	11	14·9
Lower–middle-income	27	36·5
Upper–middle-income	24	32·4
High-income	12	16·2

IQR, interquartile range.
* Low human development: < 0·55; medium: 0·55 to < 0·7; high: 0.7 to < 0·8; very high: ≥ 0·8.
† World Bank Income groups according to GNIpc: low income: ≤ US$1025·00; lower–middle-income: US$1026·00 to US$4035·00; upper–middle-income: US$4036·00 to US$12 475·00; high income: ≥ US$12 476·00.

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Table 2. Prevalence of daily consumption of carbonated soft drinks, fruits and vegetables and macroeconomic indicators in the countries assessed, 2003–2015
(Numbers; median and interquartile range)

	Prevalence of daily consumption (%)											
	Carbonated soft drinks				Fruits				Vegetables			
Variables	*n*	Median	IQR	*P*	*n*	Median	IQR	*P*	*n*	Median	IQR	*P*
Countries with data available	50	54·1	41·6; 65·5		74	67·9	58·9; 73·3		54	74·6	64·6; 80·6	
World Regions (%)*				<0·001†				0·329†				0·417†
Africa	6	43·8	36·8; 57·1	‡,§	14	68·4	57·2; 74·5		14	75·6	65·2; 83·9	
Central and South America	20	65·6	58·5; 71·0	‡	23	70·4	63·5; 73·3		23	72·7	67·3; 75·5	
Southeast Asia	1	–		–	6	70·2	59·2; 74·8		6	85·6	71·6; 89·1	
Eastern Mediterranean	11	49·9	38·1; 59·9	‡,§	16	65·2	55·3; 74·2		16	66·9	60·8; 78·1	
Western Pacific	12	42·0	31·0; 50·1	‡,§	14	64·4	53·8; 69·9		14	76·2	64·8; 80·1	
Human Development – HDI (%)‖				0·006†				0·329†				0·817†
Low	6	39·5	34·2; 45·9	‡	14	66·0	56·4; 68·5		14	73·6	63·6; 83·9	
Medium	17	46·6	36·2; 58·8		21	70·4	65·1; 73·4		21	76·7	69·0; 81·8	
High	21	59·9	52·8; 72·3	‡	32	69·2	60·6; 75·0		32	74·8	67·1; 80·6	
Very High	5	60·3	44·8; 65·6		5	59·4	50·1; 69·7		5	65·2	60·2; 78·8	
Income groups according to GNIpc (%)¶				0·01†,**				0·177†				0·160†
Low-income	2	-			11	66·3	56·5; 73·4		11	74·8	64·1; 87·5	
Lower–middle-income	19	46·4	38·1; 56·3	‡	27	69·6	65·7; 75·2		27	78·3	69·2; 83·3	
Upper–middle-income	17	54·0	43·2; 64·8		24	69·8	60·3; 74·2		24	73·8	63·7; 79·5	
High-income	8	67·2	58·8; 73·0	‡	8	61·6	54·6; 70·2		8	67·8	61·6; 74·8	

IQR, interquartile range; HDI, Human Development Index; GNIpc, Gross National Income per capita.
* Europe was not included because it presented data only from North Macedonia. For carbonated soft drinks, Southeast Asia was not included because it had only data from Maldives.
† Kruskal–Wallis test, with Bonferroni correction.
‡ Categories that differed significantly from each other.
§ Difference in relation to Central and South America.
‖ Low human development: < 0·55; medium: 0·55 to < 0·7; high: 0·7 to < 0·8; very high: ≥ 0·8.
¶ Income groups according to GNIpc: low income: ≤ US$1025·00; lower–middle-income: US$1026·00 to US$4035·00; upper–middle-income: US$4036·00 to US$12 475·00; high-income: ≥US$12 476·00.
** For carbonated soft drinks, the low-income group was not included (only two countries with available data). Four countries (Brunei Darussalam, Kuwait, Qatar and United Arab Emirates) were excluded from this analysis due to extreme GNIpc values.

The median prevalence of daily CSD consumption was 54·1 % (range, 41·6–65·5 %) (Table 2). The lowest frequency was observed in Kiribati (22·2 %; WPR) and the highest in Suriname (80·4 %; AMR). Among the fifty countries with available CSD consumption data, thirty (60 %) had daily prevalence rates over 50·0 % (online Supplementary Table S2). Higher values of CSD consumption were identified in the AMR region compared with other regions (65·6 % in AMR *v.* 43·8 % in AFR, 49·9 % in EMR and 42·0 % in WPR; $P < 0·001$), in countries with high HDI compared with low HDI (59·9 % *v.* 39·5 %; $P = 0·006$) and in high-income countries compared with lower–middle income countries (67·2 % *v.* 46·4 %; $P = 0·010$) (Table 2).

The median daily fruit consumption was 67·9 % (range, 58·9–73·3 %) (Table 2). The lowest prevalence was identified in Libya (35·2 %, EMR) and the highest in the North Macedonia (83·7 %, EUR) (online Supplementary Table S2). The median daily vegetable consumption was 74·6 % (range, 64·6–80·6 %) (Table 2). The lowest value was in the Maldives (36·6 %, SEAR) and the highest value was in Algeria (91·8 %, AFR) (online Supplementary Table S2). There were no significant differences between the macroeconomic indicators and daily consumption of FV (Table 2).

When examining the association between the continuous variables, CSD consumption was positively associated with HDI (correlation = 0·446, $P = 0·001$, Fig. 1(a)), and with GNIpc (correlation = 0·491, $P < 0·001$, Fig. 2(a)). On the other hand, no significant correlations were found between macroeconomic indicators and the consumption of fruits or vegetables (Figs. 1(b) and (c), 2(b) and (c)).

A multilevel null model was estimated to check the variation of CSD consumption at the country and region levels. A likelihood ratio test was used to compare null models with and without a second level (region), showing that the two-level model offered a significant better fit to the data (likelihood ratio = 20·55). The variance partition coefficient showed that 39 % of the variance in the CSD consumption could be attributed to the differences between regions. In both models, HDI and GNIpc were positively associated with CSD consumption (Table 3). Graphs were produced with the predicted CSD consumption by HDI (Fig. 3(a)) and GNIpc (Fig. 3(b)) by region, in which the top line representing Central and South America showed a considerable higher CSD consumption compared with other regions.

Discussion

The median prevalence of daily consumption of CSD and FV by adolescents in the countries surveyed were over 50 %, with major differences between countries and regions. The daily consumption of CSD was highlighted due to its significant variation between regions, and country levels of human development and income. The daily consumption of CSD was higher in Central and South America when compared with Africa, Eastern

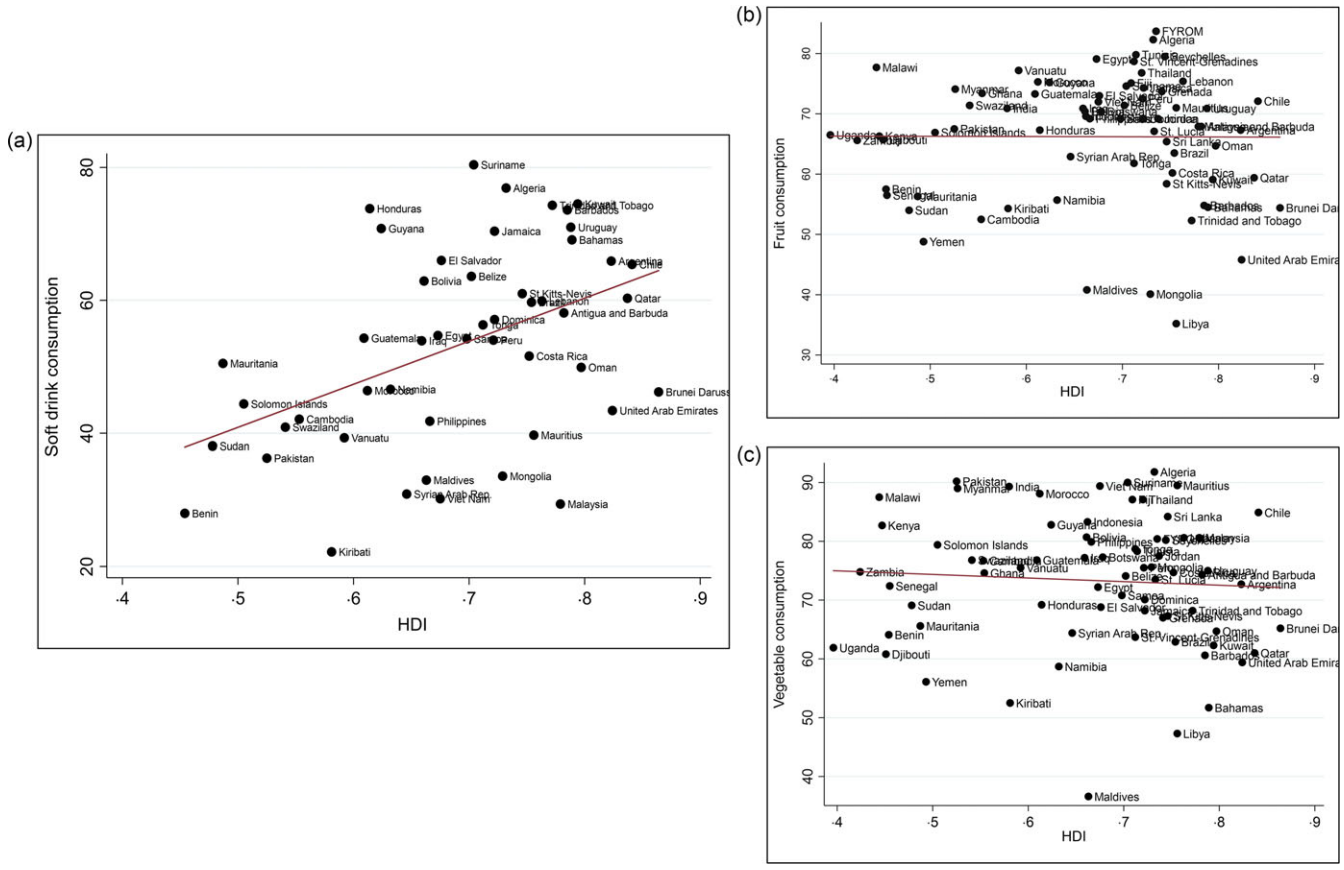

Fig. 1. Prevalence of daily carbonated soft drink, fruits and vegetables consumption among adolescents according to the Human Development Index in the analysed countries (2003–2015). (a) Carbonated soft drink consumption: correlation: 0·446; $P = 0·001$. (b) Fruits consumption: correlation: −0·004; $P = 0·970$. (c) Vegetables consumption: correlation: −0·064; $P = 0·592$. HDI, Human Development Index.

Mediterranean and Western Pacific, and among countries with higher HDI and GNIpc.

The comparison of our results with other adolescent health surveillance systems should be carried out with cautious, in view of the socio-cultural differences among the populations and the different methodologies adopted, including distinct time references to assess food consumption (last month or last week), established cut-off points and school grades. Taking this into consideration, adolescent health surveillance systems such as Health Behavior in School-aged Children (2014) in Europe and Canada[31] and the Youth Risk Behavior Surveillance System (2017)[32], in the USA (and some territories such as Guam and Puerto Rico) obtained markedly lower prevalence of daily CSD consumption compared with those found in this study: 19·0 and 18·7 %, respectively[31,32].

In Health Behavior in School-aged Children, the daily CSD consumption tended to be associated with worse socio-economic conditions[31], with the exception of some Eastern European countries. In these countries, with relatively lower HDI[28] and GNIpc[29] values compared with other European countries, CSD intake was higher among high-affluence adolescents[31]. These findings are consistent with the present work. Among countries with worse socio-economic conditions, it is assumed that as income increases and living conditions improve, the availability of ultra-processed foods, such as CSD, increases. This may be enhanced by the valuation of imported products and the gradual decrease in the price of these foods[33,34].

The high prevalence of daily CSD consumption shown in this study agrees with studies and reports that show an increasing trend in sweetened beverage consumption in countries with lower income[35–37]. A study evaluating CSD consumption specifically in low- and middle-income countries through GSHS data indicated a similar prevalence of daily consumption of CSD to this study (54·3 %) and showed that adolescents consumed CSD, on average, 1·39 times/d, with a lower consumption in SEAR and a higher consumption in AMR[38]. In Mexico, the average daily consumption of CSD among adolescents aged 12–19 years reached 229·9 ml/d[39].

Data from the National Health and Nutrition Examination Survey (2011–2014) in the USA showed that almost two-thirds of young people from 2–19 years old consumed at least one sugar-sweetened beverage per day (62·9 %)[40]. Still, it is important to note that in recent years, the prevalence of CSD consumption has been significantly reduced in high-income countries[36]. This scenario can be exemplified by data from the Health Behavior in School-aged Children, showing a reduction in daily CSD consumption of more than 20 % in countries such as Ireland, Israel, Slovenia, England and Scotland from 2002 to 2014[31]. Similarly, in Youth Risk Behavior Surveillance System, the

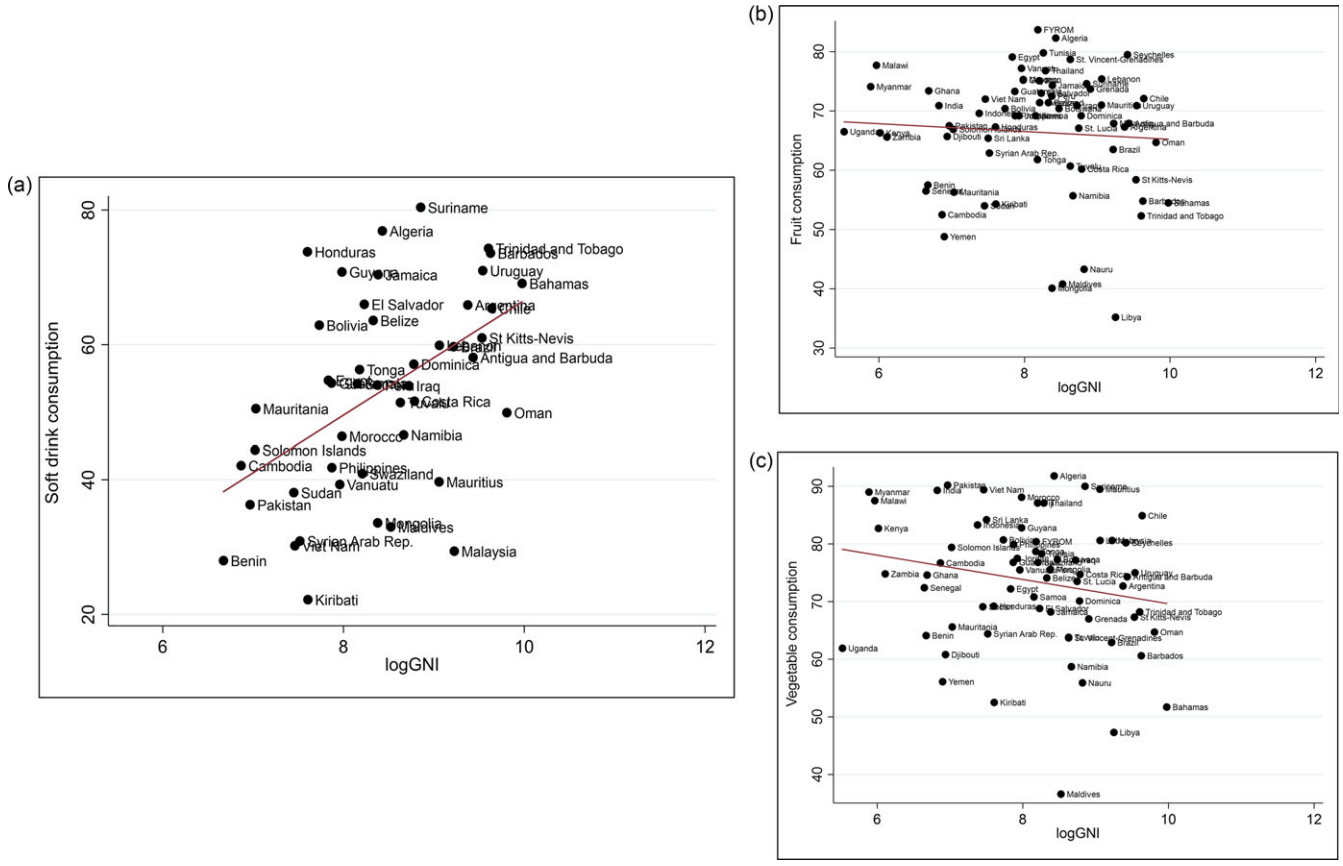

Fig. 2. Prevalence of daily carbonated soft drink, fruits and vegetables consumption among adolescents according to Gross National Income per capita in the analysed countries (2003–2015). (a) Carbonated soft drink consumption: correlation: 0·491; $P < 0·001$. (b) Fruits consumption: correlation: −0·067; $P = 0·580$. (c) Vegetables consumption: correlation: −0·197; $P = 0·101$. GNIpc, Gross National Income per capita presented in logarithmic form.

Table 3. Multilevel model for carbonated soft drink consumption and HDI and logGNIpc

	Null model†	Model HDI	Model GNI
Intercept	49·12	20·61	15·40
HDI		42·12*	
GNI			3·97*
Variance country	82·39	67·85	68·13
Variance region	118·52	103·73	100·94
Likelihood	−194·95	−175·80348	−175·80

HDI, Human Development Index; GNIpc, Gross National Income per capita.
* P value < 0·01.
† Likelihood ratio test between null multilevel model and single model = 20·55 (> 3·84).

percentage of adolescents who consumed CSD daily decreased from 33·8[32] to 18·7 %[41] (2007 to 2017). Although sales volumes in these countries remain high, these markets, in general, are saturated, which has led the CSD manufacturing industries to gradually shift and intensify their sales in middle- and low-income countries, especially in those whose economy is growing rapidly[35,36], as in Central and South American countries.

The high CSD consumption in Central and South American countries compared with other regions was clearly shown in this study, in agreement with the literature[3,35,42]. In this region, the expansion of large multinational companies, fast-food chains and supermarkets has led to a marked increase in the availability and consumption of ultra-processed foods, which tend to replace the healthy foods that are part of the local food culture[33,34,38]. Currently, three of the world's top five CSD countries consumers are in Central and South America region[43], which is considered the largest Coke producer in the world[36]. In this region, the aggressive advertising strategies coupled with the transformation of food systems and the nutrition transition from traditional to Western diets have occurred in an accelerated way, constituting satisfactorily lucrative markets[33,34,38]. This scenario makes AMR occupies a prominent position as a region of particular concern for policy makers[35].

No association was found between FV consumption and macroeconomic indicators, although a trend of lower FV consumption was observed in countries with very high HDI and high income. In contrast, findings from the Health Behavior in School-aged Children showed a positive association between the prevalence of daily fruit consumption and socio-economic conditions, reported by about a third of respondents (33·0 %)[31]. These differences might be influenced by the countries composing these researches. The group with very high HDI in this study includes wealthy countries from the Eastern Mediterranean regions, such as Qatar and United Arab Emirates, with known lower FV consumption among adolescents when compared with other regions[44]. For the analysis of GNIpc, most high-income

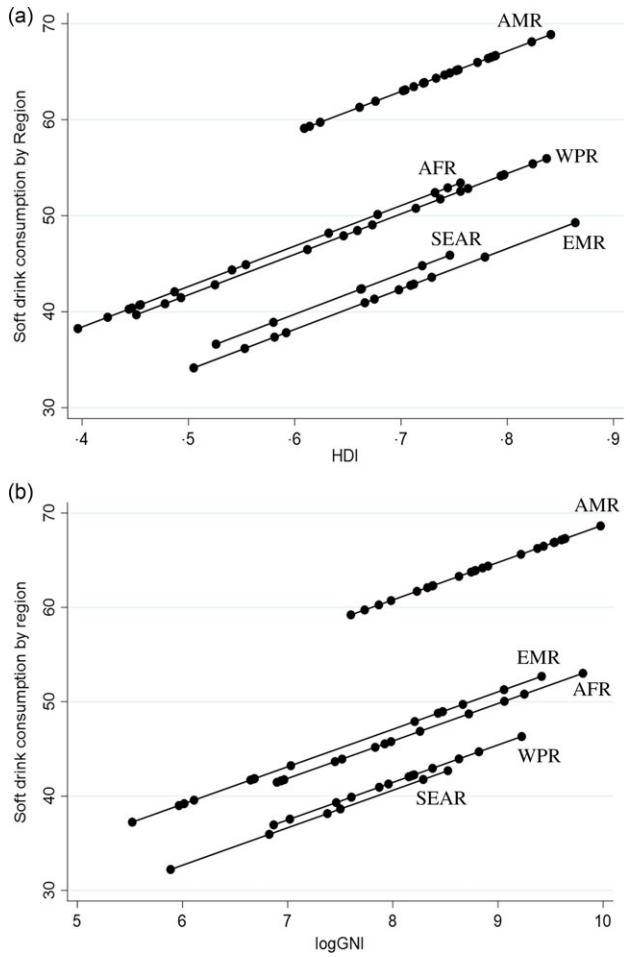

Fig. 3. Predicted carbonated soft drink consumption by Human Development Index and Gross National Income per capita by region. (a) HDI, Human Development Index. (b) logGNI, Gross National Income per capita in logarithmic form. AFR, Africa; AMR, Central and South America; SEAR, Southeast Asia; EUR, Europe; EMR, Eastern Mediterranean; WPR, Western Pacific.

countries are from the Caribbean, such as Bahamas, Trinidad and Tobago, and Barbados. Caribbean countries are more vulnerable to natural disasters and disruptions of agriculture and food production systems, and therefore, they have their largest source of food from imported foods rather than national food production[45,46]. This has contributed to the nutrition transition in these countries and the high import of ultra-processed foods, leading to some of the higher prevalence of obesity in the world. Also, these countries have high levels of income inequality and reduced food availability for some population groups[46].

In view of the nutrition transition and increased consumption of ultra-processed food, much has been discussed about ways to improve food and populations' lifestyle. Global guidelines have emphasised the importance of adequate consumption of natural and minimally processed foods, such as FV, and the need to reduce ultra-processed foods intake, such as CSD[36,47–50]. However, high rates of food inadequacy are still observed among adolescents, as indicated in this study. This scenario demands continuous attention to implement proposed guidelines and design new intersectoral and integrated strategies that contribute to improving adolescent living conditions.

To act effectively in this scenario, it is necessary to combine economic development programmes with political approaches aimed at improving the quality of food for individuals and populations. Among these, some measures are highlighted as options to prevent obesogenic environments through the regulation of food and beverage industries, such as the taxation of CSD; the regulation of publicity, especially those aimed at children and adolescents; the adoption of a front-of-pack food labelling that is easily understood by consumers and the regulation of ultra-processed foods in schools, limiting its commercialisation and advertising in their canteens and surroundings[10,20,38,51,52].

Moreover, there are actions to promote healthy environments such as the reduction of the stages of the food production chains; the incentive to FV consumption in schools; the provision of subsidies for the production and sale of fresh food, and when necessary, the strengthening of foods considered healthy imports[10,20,51]. These proposals reinforce the importance of adopting incisive political actions that in fact contribute to the improvement of the dietary pattern of the population in general, and especially among adolescents, which is reaffirmed by our results. Recent data show that adolescents living in countries with policies that encourage FV consumption are 1·48 times more likely to consume five portions of FV compared with adolescents in countries without such policies[51]. In addition, according to the WHO, the 20 % taxation on the costs of sweetened drinks can reduce consumption by about 20 %, with marked repercussions among families with lower socioeconomic conditions[53].

In Mexico, for example, in the first 2 years of taxing sugar-sweetened beverages (1 peso/l) there was a 7·6 % decrease in household purchases[54] with a greater reduction in households with children or adolescents[55] and among those with high purchases of these drinks before taxation[56]. Another example is Chile. One year after implementing the 5·0 % taxation of sugar-sweetened beverages, there was a 3·4 % decrease in volume purchased and 4·0 % decrease in energy content consumed[57]. In addition, a direct assessment of sales points indicated a 5·8 % reduction in the affordability (estimated from consumer's income, product and the price of other competing goods) of carbonated drinks after taxation[58]. Although initial, these results are very important for Public Health, indicating possible ways for other countries that, together with other interventions, can intensify their fiscal policies to decrease sugar-sweetened beverages consumption[59]. Continuous monitoring of purchases and consumption of these drinks will be essential to better understand the long-term impact of this intervention model on populations health and nutritional status[57–59].

Strengths

This study brings the novelty of a comparative evaluation of healthy and unhealthy food consumption markers among more than 250 thousand students from seventy-four countries in five different continents, and its association with different macroeconomic indicators. This study was conducted during school hours, which favoured higher response rates and greater knowledge

about health among adolescents, who are less likely to search for care in health services[46].

Furthermore, our results indicate the relevance of developing and maintaining health surveillance systems to monitor food consumption markers and other risk factors for non-communicable diseases among adolescents, contributing to global efforts to generate robust evidence regarding adolescent food and nutrition. They also highlight the need to prioritise intersectoral public policies, which act to reduce social inequities[33] and their potential consequences that contribute to disease prevention and health promotion in this population.

Study limitations

The study has some limitations that must be considered. First, the format of the GSHS consumption module responses (times/day in the last 30 d) may be difficult to respond, leading to overestimated answers. Second, the use of self-administered questionnaire may have caused underreporting or misunderstandings[60]. Still, it allows large-scale and fast data collection, which is important in international surveys. Third, the regions were not equally represented in the analysis due to the lack of data for macroeconomic indicators, and the lack of data on CSD consumption in twenty-four countries. Still, a significant association was found between CSD and macroeconomic indicators, showing the need to investigate this association in other populations and better qualify the data for more robust international comparisons.

Having this research performed in a school environment may had underrepresented adolescents in the most vulnerable situations and who are out of school, and therefore, data may be representative only of those who are regularly enrolled in schools[61]. Some regions have a significant proportion of adolescents out of school, and significant variations in school coverage (e.g. 39·7 % of adolescents do not attend school in West and Central Africa, and 7·5 % do not attend school in Latin America and the Caribbean)[62]. Nevertheless, school-based surveys produce valid information, allowing large populations to be included with lower costs and more feasible logistics. Structural political actions that contribute to raising enrollment and school retention rates could further improve school survey results[49].

Conclusion

There was a high prevalence of daily CSD consumption among adolescents from mainly low- and medium-income countries. This prevalence was positively associated with HDI and GNIpc values, and mostly prevalent in countries from the Central and South American region, which are highly targeted by CSD manufacturing industries and ultra-processed food industry. The prevalence of daily FV consumption, although not associated with macroeconomic indicators and considered higher than in other surveys, must still improve to achieve the recommendations. These results point for the importance of public policies that regulate food and beverage industries and prioritise the consumption of FV among adolescents to avoid the increased prevalence of obesity and non-communicable diseases among adolescents and other age groups. To guide effective policies, further research is needed to quantify factors that promote the consumption of CSD among adolescents in different countries and regions.

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Supplementary material

For supplementary materials referred to in this article, please visit https://doi.org/10.1017/S0007114521001914

References

1. Marmot M (2015) The health gap: the challenge of an unequal world. *Lancet* **386**, 2442–2443.
2. Viner RM, Ozer EM, Denny S, *et al.* (2012) Adolescence and the social determinants of health. *Lancet* **379**, 1641–1652.
3. Beal T, Morris SS & Tumilowicz A (2019) Global patterns of adolescent fruit, vegetable, carbonated soft drink, and fast-food consumption: a meta-analysis of global school-based student health surveys. *Food Nutr Bull* **40**, 44–59.
4. Currie C, Gabhainn SN, Godeau E, *et al.* (2008) *Inequalities in young people's health: Health Behaviour in School-aged Children (HBSC): International report from the 2005/2006 survey Health Policy for Children and Adolescents n. 5.* Copenhagen: WHO Regional Office for Europe.
5. Elgar FJ, Pförtner TK, White J, *et al.* (2016) Relative deprivation and risk factors for obesity in Canadian adolescents. *Soc Sci Med* **152**, 111–118.
6. Inchley J, Currie D, Young T, *et al.* (2016) Growing up Unequal: Gender and Socioeconomic Differences in Young People's Health and Well-Being. Health Behaviour in School-aged Children (HBSC) Study: International Report from the 2013/2014 survey (2016). Copenhagen: WHO Europe.
7. World Health Organization (2003) Food and Agriculture Organization of the United Nations Diet, nutrition and the prevention of chronic diseases. http://www.fao.org/3/ac911e/ac911e05.htm (accessed January 2020).
8. Ortiz-Hernández L & Gómez-Tello BL (2008) Food consumption in Mexican adolescents. *Rev Panam Salud Publica* **24**, 127–135.
9. Ochoa-Avilés A, Verstraeten R, Lachat C, *et al.* (2014) Dietary intake practices associated with cardiovascular risk in urban and rural Ecuadorian adolescents: a cross-sectional study. *BMC Public Health* **14**, 1–11.
10. Kearney J (2010) Food consumption trends and drivers. *Phi Trans R Soc B* **365**, 2793–2807.
11. Gerbens-Leenes PW, Nonhebel S & Krol MS (2010) Food consumption patterns and economic growth: increasing affluence and the use of natural resources. *Appetite* **55**, 597–608.

12. Michaelsen KF, Dewey KG, Perez-Exposito AB, *et al.* (2011) Food sources and intake of n-6 and n-3 fatty acids in low-income countries with emphasis on infants, young children (6–24 months), and pregnant and lactating women. *Matern Child Nutr* **7**, 124–140.
13. Siegel KR, Ali MK, Srinivasiah A, *et al.* (2014) Do we produce enough fruits and vegetables to meet global health need? *PLoS One* **9**, e104059.
14. Siervo M, Montagnese C, Mathers J, *et al.* (2013) Sugar consumption and global prevalence of obesity and hypertension: an ecological analysis. *Public Health Nutr* **17**, 587–596.
15. Asfaw A (2008) Fruits and vegetables availability for human consumption in Latin American and Caribbean countries: patterns and determinants. *Food Policy* **33**, 444–454.
16. Binh PNT, Soda K & Kawakami M (2010) Gross domestic product and dietary pattern among 49 western countries with a focus on polyamine intake. *Health* **2**, 1327–1334.
17. Oggioni C, Cena H, Wells JCK, *et al.* (2015) Association between worldwide dietary and lifestyle patterns with total cholesterol concentrations and DALYs for infectious and cardiovascular diseases: an ecological analysis. *J Epidemiol Glob Health* **5**, 315–325.
18. Oggioni C, Lara J, Wells JCK, *et al.* (2014) Shifts in population dietary patterns and physical inactivity as determinants of global trends in the prevalence of diabetes: an ecological analysis. *Nutr Metab Cardiovasc Dis* **24**, 1105–1111.
19. Sampaio MFA & Cardoso JL (2002) Comparative analysis of food consumption: Latin America and European Union. *Cad Debate* IX, 17–38. http://www.urbal.piracicaba.sp.gov.br/Italiano/download/Consumo%20de%20alimentos%20na%20Am%E9rica%20Latina%20e%20na%20Uni%E3o%20Europ%E9ia.pdf (accessed March 2017).
20. Muhammad A, D'Souza A, Meade B, *et al.* (2017) The Influence of income and prices on global dietary patterns by country, age, and gender. Economic Research Report. Department of Agriculture, Economic Research Service. https://www.ers.usda.gov/webdocs/publications/82545/err-225.pdf (accessed December 2016).
21. World Health Organization (2016) Chronic diseases and health promotion. Global school-based student health survey (GSHS). http://www.who.int/chp/gshs/en/ (accessed December 2016).
22. Centers for Disease Control and Prevention (2013) Global School-based Student Health Survey: 2013 GSHS Data User's Guide. Atlanta: CDC. http://www.cdc.gov/gshs/pdf/gshs-data-users-guide.pdf (accessed March 2015).
23. Centers for Disease Control and Prevention (2013) Global School-based Student Health Survey (GSHS): Overview. Atlanta: CDC. http://www.cdc.gov/gshs/pdf/GSHSOVerview.pdf (accessed March 2015).
24. Pierobon M, Barak M, Hazrati S, *et al.* (2013) Alcohol consumption and violence among Argentine adolescents. *J Pediatr* **89**, 100–107.
25. Brown DW, Rilley L, Butchart A, *et al.* (2009) Exposure to physical and sexual violence and adverse health behaviours in African children: results from the Global School-based Student Health Survey. *Bull World Health Organ* **87**, 447–455.
26. World Health Organization (2006) Global School-based Student Health Survey Country Report: Tajikistan. http://www.who.int/chp/gshs/UNICEF-GSHC-Report-Oct-07.pdf (accessed December 2016).
27. Instituto Brasileiro de Geografia e Estatística - IBGE (2016) National School Health Survey - 2015. Rio de Janeiro. https://biblioteca.ibge.gov.br/visualizacao/livros/liv97870.pdf (accessed December 2016).
28. United Nations Development Programme (2015) Human Development Index (HDI). http://hdr.undp.org/en/content/human-development-index-hdi (accessed December 2016).
29. The World Bank (2016) GNI per capita Atlas Method (current US$). http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GNP.PCAP.CD&country=# (accessed December 2016).
30. Field A (2009) *Discovering statistics using IBM SPSS Statistics*, 2nd ed. Porto Alegre: Artmed.
31. Inchley J (2017) *Adolescent Obesity and Related Behaviours: Trends and Inequalities in the WHO European Region, 2002–2014. Observations from the Health Behaviour in School-aged Children (HBSC) WHO Collaborative Cross-National Study*. Copenhagen: WHO Regional Office for Europe.
32. Kann L, McManus T, Harris WA, *et al.* (2018) Youth risk behavior surveillance — United States, 2017. *MMWR Surveill Summ* **67**, 1–114.
33. Monteiro CA, Moubarac JC, Cannon G, *et al.* (2013) Ultra-processed products are becoming dominant in the global food system. *Obes Rev* **14**, 21–28.
34. Reardon T & Timmer CP (2012) The economics of the food system revolution. *Annu Rev Resour Econ* **4**, 225–264.
35. Singh M (2017) Soda consumption among adolescents: implications for low and middle-income countries. *Am J Public Health* **107**, 1025–1027.
36. Center for Science in the Public Interest (2016) *Carbonating the World. The Marketing and Health Impact of Sugar Drinks in Low- and Middle-income Countries*. Washington, DC: Center for Science in the Public Interest.
37. United Nations Children's Fund - UNICEF (2019) *The State of the World's Children 2019. Children, Food and Nutrition: Growing well in a changing world*. New York: UNICEF.
38. Yang L, Bovet P, Liu Y, *et al.* (2017) Consumption of carbonated soft drinks among young adolescents aged 12 to 15 years in 53 low- and middle-income countries. *Am J Public Health* **107**, 1095–1100.
39. Malvido ME (2018) Adolescents' Soda Consumption in Mexico Before and After the Sugar-Sweetened Beverages Tax: Results from National Health and Nutrition Surveys. School of Public Policy Capstones. 48. https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1051&context=cppa_capstones (accessed August 2018).
40. Rosinger A, Herrick K, Gahche J, *et al.* (2017) *Sugar-Sweetened Beverage Consumption among US Youth, 2011–2014. NCHS Data Brief, nº 271*. Hyattsville, MD: National Center for Health Statistics.
41. Miller G, Merlo C, Demissie Z, *et al.* (2017) Trends in beverage consumption among high school students — United States, 2007–2015. *MMWR Morb Mortal Wkly Rep* **66**, 112–116.
42. Singh GM, Micha R, Khatibzadeh S, *et al.* (2015) Global, regional, and national consumption levels of sugar-sweetened beverages, fruit juice, and milk: a systematic assessment of beverage intake in 187 countries. *PLoS One* **10**, e0124845.
43. Popkin BM & Hawkes C (2016) Sweetening of the global diet, particularly beverages: patterns, trends, and policy responses. *Lancet Diabetes Endocrinol* **4**, 174–186.
44. Al Ani MF, Al Subhi LK & Bose S (2016) Consumption of fruits and vegetables among adolescents: a multi-national comparison of eleven countries in the Eastern Mediterranean Region. *Br J Nutr* **115**, 1092–1099.
45. Kelly JL & Pemberton C (2016) An Assessment of the Household Food Security Status and Local Foods Grown in Rural Bahamas. *Farm & Business* **8**, 82–96.
46. Food and Agriculture Organization of the United Nations - FAO (2015) *State of Food Insecurity in the CARICOM Caribbean*.

Meeting the 2015 hunger targets: Taking stock of uneven progress. Bridgetown: FAO.
47. Vereecken C, Pedersen TP, Ojala K, *et al.* (2015) Fruit and vegetable consumption trends among adolescents from 2002 to 2010 in 33 countries. *Eur J Public Health* **25**, 16–19.
48. World Health Organization (2004) Global Strategy on Diet, Physical Activity and Health. http://www.who.int/dietphysicalactivity/strategy/eb11344/strategy_english_web.pdf (accessed March 2020).
49. World Health Organization (2014) Health for the World's Adolescents: a second chance in the second decade. Geneva. www.who.int/adolescent/second-decade (accessed February 2020).
50. United Nations. General Assembly (2016) United Nations Decade of Action on Nutrition (2016–2025). http://www.un.org/ga/search/view_doc.asp?symbol=A/70/L.42 (accessed March 2020).
51. Darfour-Oduro SA, Andrade JE & Grigsby-Toussaint DS (2020) Do fruit and vegetable policies, socio-environmental factors, and physical activity influence fruit and vegetable intake among adolescents? *J Adolesc Health* **66**, 172–180.
52. Kessaram T, McKenzie J, Girin N, *et al.* (2015) Overweight, obesity, physical activity and sugar-sweetened beverage consumption in adolescents of Pacific islands: results from the Global School-Based Student Health Survey and the Youth Risk Behavior Surveillance System. *BMC Obes* **2**, 34.
53. World Health Organization (2016) *Taxes on sugary drinks: Why do it?* Geneva: WHO.
54. Colchero MA, Rivera-Dommarco J, Popkin BM, *et al.* (2017) In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. *Health Aff* **36**, 564–571.
55. Colchero MA, Molina M & Guerrero-López CM (2017) After Mexico implemented a tax, purchases of sugar-sweetened beverages decreased and water increased: difference by place of residence, household composition, and income level. *J Nutr* **147**, 1552–1557.
56. Ng SW, Rivera JA, Popkin BM, *et al.* (2018) Did high sugar-sweetened beverage purchasers respond differently to the excise tax on sugar-sweetened beverages in Mexico? *Public Health Nutr* **22**, 1–7.
57. Caro JC, Corvala´n C, Reyes M, *et al.* (2018) Chile's 2014 sugar-sweetened beverage tax and changes in prices and purchases of sugar-sweetened beverages: an observational study in an urban environment. *PLoS Med* **15**, e1002597.
58. Cuadrado C, Dunstan J, Silva-Illanes N, *et al.* (2020) Effects of a sugar-sweetened beverage tax on prices and affordability of soft drinks in Chile: a time series analysis. *Soc Sci Med* **245**, 1127082.
59. Sánchez-Romero LM, Canto-Osorio F, González-Morales R, *et al.* (2020) Association between tax on sugar sweetened beverages and soft drink consumption in adults in Mexico: open cohort longitudinal analysis of Health Workers Cohort Study. *BMJ* **369**, m1311.
60. Camelo LV, Rodrigues JFC, Giatti L, *et al.* (2012) Sedentary leisure time and food consumption among Brazilian adolescents: the Brazilian National School-Based Adolescent Health Survey (PeNSE), 2009. *Cad Saude Publica* **28**, 2155–2162.
61. Jacob L, Stubbs B, Firth J, *et al.* (2020) Fast food consumption and suicide attempts among adolescents aged 12–15 years from 32 countries. *J Affecct Disorders* **266**, 63–70.
62. United Nations Educational, Scientific and Cultural Organization - UNESCO & United Nations Children's Fund – UNICEF (2015) *Fixing the Broken Promise of Education for All: Findings from the Global*. Montreal: UNESCO & UNICEF.