Salt Intake Is Related to Soft Drink Consumption in Children and Adolescents

A Link to Obesity?

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***Abstract*—**Dietary salt is a major determinant of fluid intake in adults; however, little is known about this relationship in children. Sugar-sweetened soft drink consumption is related to childhood obesity, but it is unclear whether there is a link between salt and sugar-sweetened soft drink consumption. We analyzed the data of a cross-sectional study, the National Diet and Nutrition Survey for young people in Great Britain. Salt intake and fluid intake were assessed in 1688 participants aged 4 to 18 years, using a 7-day dietary record. There was a significant association between salt intake and total fluid, as well as sugar-sweetened soft drink consumption ($P<0.001$), after adjusting for potential confounding factors. A difference of 1 g/d in salt intake was associated with a difference of 100 and 27 g/d in total fluid and sugar-sweetened soft drink consumption, respectively. These results, in conjunction with other evidence, particularly that from experimental studies where only salt intake was changed, demonstrate that salt is a major determinant of fluid and sugar-sweetened soft drink consumption during childhood. If salt intake in children in the United Kingdom was reduced by half (mean decrease: 3 g/d), there would be an average reduction of ≈2.3 sugar-sweetened soft drinks per week per child. A reduction in salt intake could, therefore, play a role in helping to reduce childhood obesity through its effect on sugar-sweetened soft drink consumption. This would have a beneficial effect on preventing cardiovascular disease independent of and additive to the effect of salt reduction on blood pressure. **(*Hypertension*. 2008;51:629-634.)**

Key Words: salt intake ■ soft drink consumption ■ obesity ■ children and adolescents

In adults, the quantitative relationship between salt intake and fluid consumption is well documented by both observational epidemiological studies and controlled trials where salt intake was altered.[1,2] It has been estimated that reducing salt intake by half, eg, from the current intake of ≈10 g/d to the World Health Organization recommended level of 5 g/d, would reduce fluid intake by ≈350 mL/d per person.[1] However, there are no studies in children that have looked at the relationship between salt intake and fluid consumption.

In nearly all of the developed and many developing countries, childhood obesity and subsequent diabetes are major public health problems.[3] Intervention strategies, eg, changing diet and increasing physical activity levels, could reduce obesity. However, few have been proven to be effective,[4,5] and, indeed, in most countries the prevalence of obesity is rapidly increasing.[3] Some studies have also highlighted the difficulty of changing diet and lifestyles in young individuals.[6]

Sugar-sweetened soft drink consumption is an important source of calorie intake in children and is also claimed not to give rise to any feeling of satiety and is, therefore, linked to obesity.[7] In adults, it has been shown that a reduction in salt intake reduces fluid intake[1] and would lead to a concomitant reduction in soft drink consumption. In children, sugar-sweetened soft drinks are an important component of total fluid intake. A reduction in salt intake might, therefore, be important in reducing sugar-sweetened soft drink consumption and, thus reducing childhood obesity. Compared with other diet and lifestyle changes, a modest reduction in salt intake is easier to make as, in most developed countries, ≈80% of salt intake now comes from salt hidden in food[8] and can be done by slow but progressive reductions in the amount of salt added to food by the food industry without necessarily informing the consumers. Such a policy has been adopted in the United Kingdom, and a recent study has shown that salt intake has already been reduced as a result of this strategy and, importantly, without consumers having to change what they eat.[9]

To study the relationship between salt intake and total fluid consumption, as well as the consumption of sugar-sweetened soft drinks, we analyzed the data from a large cross-sectional study, the National Diet and Nutrition Survey for young people in Great Britain, which was carried out in 1997 in a nationally representative sample of individuals aged between 4 and 18 years.[10]

Methods

We obtained the data of the National Diet and Nutrition Survey for young people from the United Kingdom Data Archive.[11] The

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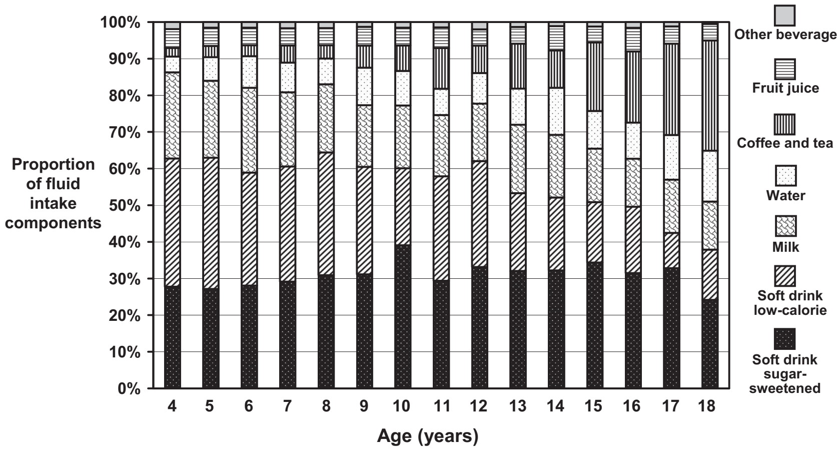

Figure 1. Proportion of fluid intake components by age group.

methods used in the National Diet and Nutrition Survey for young people are reported in detail elsewhere,[10] and only methods relevant to the current analysis are reported in brief here. The survey was carried out in 1997 by the Social Survey Division of the Office for National Statistics and the Medical Research Council Human Nutrition Research on behalf of the Ministry of Agriculture, Fisheries, and Food and the Department of Health. The data are Crown copyright. The main aim of the survey was to provide detailed information on the dietary habits and nutritional status of young people in Great Britain. A nationally representative sample of 2672 individuals aged 4 to 18 years was identified from a postal sift of addresses selected from the Postcode Address File. An interview, which was the first stage of the full survey protocol, was completed by 2127 young people. The survey protocol was approved by National Health Service local research ethics committees in the areas where fieldwork took place, and informed consent was obtained from the young person and/or the person with parental responsibility.[10]

A weighted dietary record of all of the food and drink consumed over 7 consecutive days was kept by the parent and/or young person, depending on age. Each participant was issued with a set of accurately calibrated Soehnle Quanta digital food scales to weigh food and drinks. Drinks consumed were, therefore, recorded in grams rather than in milliliters. Sugar-sweetened soft drinks included all types of non-low-calorie–concentrated, carbonated and ready to drink soft drinks. Low-calorie soft drinks included all low-calorie, no added sugar, and sugar-free types of concentrated, carbonated, and ready-to-drink soft drinks.[10] A total of 1688 participants (63% of those identified and 79% of those who completed the interview) had both salt intake and fluid consumption recorded and were included in our analysis.

For young persons aged 7 to 18 years, detailed information on their daily activities was collected over the same 7-day period as the dietary record. Moderate-intensity physical activity was defined as activity usually equivalent to brisk walking, which might be expected to leave the participant feeling warm and slightly out of breath, eg, physical education or gymnastics. Vigorous intensity physical activity was defined as activity usually equivalent to at least slow jogging, which might be expected to leave the participant feeling out of breath and sweaty, eg, playing rugby.[10]

Results were reported as mean±SD. Multiple linear regression analysis was performed to examine whether there was a significant relationship between dietary salt intake and fluid consumption, as well as sugar-sweetened soft drink consumption, with adjustment for potential confounding factors, including age, sex, and body weight. Additional adjustment of hours spent on moderate and vigorous physical activities was made for participants aged ≥7 years in whom the data on physical activities were recorded. From the multiple regression analyses, we reported partial correlation coefficient (partial r) and regression coefficient (b), as well as the standard error of b. All of the statistical analyses were carried out using SPSS.

Results

Salt Intake and Total Fluid Consumption

Among the 1688 participants included in our analysis, there were 851 boys and 837 girls. The mean age was 11±4 years, ranging from 4 to 18 years. The average salt intake, which did not include salt added during cooking or at the table, was 4.6±1.5 g/d at the age of 4 years. With increasing age there was an increase in salt intake, and by the age of 18 years, salt intake was 6.8±2.1 g/d.

The mean fluid consumption varied between age groups, with the lowest intake being 978±336 g/d for 6-year–old subjects and the highest intake being 1291±648 g/d for 17-year-old subjects, although in general there was a trend of increase in total fluid consumption with increasing age from 4 to 18 years. Figure 1 shows the proportion of fluid intake components by age group. Taking all of the participants together, 56% of total fluid intake was in the form of soft drinks, of which 55% were sugar sweetened and 45% were low in calorie. In other words, 31% of total fluid intake was in the form of sugar-sweetened soft drinks in children and adolescents. Milk accounted for 18% of total fluid consumption; coffee and tea, 11%; water, 9%; fruit juice, 5%; and other beverages, 1%.

There was a highly significant association between salt intake and fluid consumption (r=0.40, b=108±6 [±SE] g/d of fluid consumption per gram per day of salt intake; P<0.001; Figure 2). This quantitative association was still significant after adjusting for age, sex, and body weight (partial r=0.33; b=100±7; P<0.001). From this analysis, it was predicted that a reduction of 1 g/d in salt intake would reduce total fluid consumption by 100 g/d. Additional adjustment of hours spent on moderate and vigorous physical activities was made for participants aged ≥7 years, and the quantitative relationship between salt intake and fluid consumption did not change greatly (partial r=0.34; b=104±8; P<0.001).

Subgroup Analysis by Age and Sex

To further minimize any potential confounding effect of age and sex on the relationship between salt intake and fluid consumption, we grouped participants into 2-year age groups, except for the participants aged 4 to 6 years, in whom

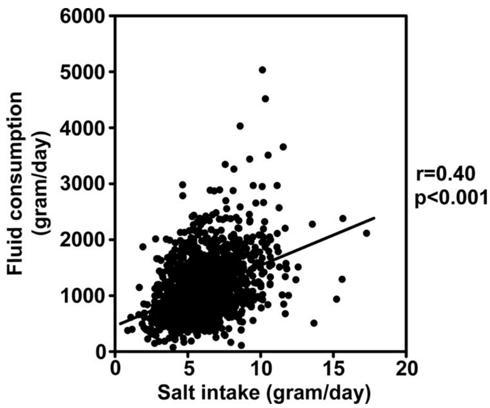

Figure 2. Relationship between salt intake and fluid consumption in children and adolescents.

physical activity levels were not recorded and who were combined as 1 group. Further analyses were performed by these age groups for boys and girls separately.

Table 1 shows the average fluid consumption and the proportion of fluid intake components by age and sex. Soft drinks, including sugar-sweetened and low-calorie drinks, accounted for the largest proportion of total fluid consumption in all of the age groups for both boys and girls. For boys, on average, 57% of the total fluid intake was in the form of soft drinks, of which 56% were sugar-sweetened and 44% were low in calorie, meaning that sugar-sweetened soft drinks made up 32% of total fluid intake. For girls, 54% of the total fluid intake was in the form of soft drinks, of which 54% were sugar-sweetened and 46% were low in calorie, meaning that sugar-sweetened soft drinks made up 29% of total fluid intake. With increasing age there was a trend of decrease in the consumption of low-calorie soft drinks and milk and an increase in the consumption of coffee, tea, and water for both boys and girls. There were only small variations between age groups in the consumption of sugar-sweetened soft drinks, fruit juice, and other beverages. As shown in Table 2, there was a significant association between salt intake and fluid consumption in all of the subgroups except 1 after adjusting for body weight and hours spent on moderate and vigorous physical activities.

Salt Intake and Sugar-Sweetened Soft Drink Consumption

Sugar-sweetened soft drinks are an important component (ie, 31%) of total fluid intake in children, and other studies have shown that the consumption of sugar-sweetened soft drinks is related to childhood obesity.[7] We, therefore, performed a separate analysis to determine whether salt intake was related to sugar-sweetened soft drink consumption. Taking all of the participants together, there was a highly significant association between salt intake and sugar-sweetened soft drink consumption (r=0.18; b=34±5; P<0.001). This quantitative association was attenuated slightly after adjusting for age, sex, and body weight (partial r=0.12; b=27±5; P<0.001). Additional adjustment of hours spent on moderate and vigorous physical activities for participants aged ≥7 years of age did not change this quantitative relationship (partial r=0.13; b=29±6; P<0.001).

From the multiple regression analysis, it was predicted that a reduction of 1 g/d in salt intake would reduce sugar-sweetened soft drink consumption by 27 g/d per child. If salt intake was reduced by half in all children aged 4 to 18 years in the United Kingdom (ie, a mean decrease of 3 g/d), there would be an average reduction of 81 g/d in the consumption of sugar-sweetened soft drinks per child, which is equivalent to a reduction of 2.3 soft drinks per week (assuming that the average size of a soft drink is ≈250 g). This reduction in

Table 1. Fluid Consumption and Proportion of Fluid Intake Components in Children and Adolescents

		Milk		Fruit Juice		Beverage		Coffee and Tea		Water		Soft Drink, Sugar Sweetened		Soft Drink, Low Calorie		Total Fluid Consumption	
Age, y	N	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%	Mean±SD, g/d	%
Boys																	
4	183	247±159	23	49±91	5	17±42	2	28±61	3	70±103	7	292±295	28	360±411	34	1062±410	100
7	128	219±136	19	52±98	5	18±44	2	41±81	4	87±151	8	353±365	31	373±428	33	1143±472	100
9	128	217±146	19	49±83	4	15±41	1	71±117	6	100±147	9	405±375	36	266±321	24	1122±453	100
11	127	211±157	18	54±96	5	23±83	2	103±165	9	78±143	7	382±339	33	324±485	28	1176±544	100
13	106	230±163	19	60±103	5	17±47	1	107±189	9	113±155	10	387±374	33	267±312	23	1183±526	100
15	101	208±161	15	64±128	5	16±47	1	235±395	17	115±183	8	493±544	36	240±432	18	1370±750	100
17	78	221±169	15	67±114	5	8±23	1	324±333	23	205±356	14	481±550	34	122±221	9	1428±646	100
All boys	851	224±155	19	55±100	5	17±51	1	109±222	9	102±178	9	385±400	32	295±397	25	1186±544	100
Girls																	
4	172	205±134	22	51±86	5	16±38	2	31±75	3	67±116	7	265±260	28	315±344	33	950±347	100
7	97	198±119	20	50±83	5	18±58	2	50±83	5	74±108	7	292±284	29	328±415	32	1011±455	100
9	127	150±119	14	59±82	6	15±40	1	71±134	7	112±148	11	357±371	34	276±310	27	1041±419	100
11	123	138±124	14	56±96	6	14±37	1	100±170	10	89±137	9	289±247	29	295±411	30	981±449	100
13	111	162±141	16	62±105	6	10±32	1	137±200	14	135±206	13	316±318	31	183±228	18	1004±412	100
15	109	137±113	12	69±117	6	18±46	2	234±323	21	132±180	12	325±370	30	187±318	17	1103±473	100
17	98	139±129	12	51±81	5	13±66	1	363±368	32	131±166	12	270±288	24	164±350	14	1131±575	100
All girls	837	164±129	16	57±93	6	15±45	1	129±234	13	103±155	10	301±307	29	256±348	25	1024±444	100

Table 2. Correlation Between Salt Intake and Fluid Consumption

	Boys		Girls	
Age, y	*r* (*P*)	Partial *r*, Controlling for Body Weight and Hours Spent on Moderate and Vigorous Activities (*P*)	*r* (*P*)	Partial *r*, Controlling for Body Weight and Hours Spent on Moderate and Vigorous Activities (*P*)
4	0.230 (0.002)	0.232 (0.002)*	0.231 (0.002)	0.166 (0.031)*
7	0.317 (<0.001)	0.254 (0.005)	0.445 (<0.001)	0.410 (<0.001)
9	0.293 (0.001)	0.234 (0.009)	0.287 (0.001)	0.256 (0.005)
11	0.462 (<0.001)	0.434 (<0.001)	0.384 (<0.001)	0.369 (<0.001)
13	0.315 (0.001)	0.308 (0.002)	0.212 (0.026)	0.242 (0.015)
15	0.427 (<0.001)	0.414 (<0.001)	0.183 (0.057)	0.167 (0.094)
17	0.448 (<0.001)	0.449 (<0.001)	0.394 (<0.001)	0.415 (<0.001)

*Data are controlling for body weight only, because physical activities were not recorded in this group of children.

sugar-sweetened soft drinks would result in a decrease in sugar intake by 61 g/wk (assuming that 1 soft drink contains ≈26.5 g of sugar[12]), equivalent to a reduction in calorie intake of 244 kcal/wk for each child (1 gram of sugar provides 4 kcal).

In the United Kingdom, there are ≈11 million individuals aged between 4 and 18 years.[13] If all of these children reduced their salt intake by half, the consumption of sugar-sweetened soft drinks would be reduced by ≈3.5 million per day, which would result in a decrease of ≈95 tons/d in sugar intake. This amounts to a reduction of ≈1 billion soft drinks per year and a decrease of ≈35 000 tons of sugar intake per year in the United Kingdom alone. In the United States, the amount of sugar-sweetened soft drink consumption per child is very similar to that in the United Kingdom[14]; however, the population in the United States is much larger (over 60 million individuals aged between 4 and 18 years)[15]; therefore, the same reduction in salt intake could lead to a much larger decrease in total soft drink sales and sugar intake. It is estimated that, in the United States, if salt intake was reduced by half, ie, a mean decrease of 3 g/d, for all children aged 4 to 18 years this could result in a decrease of ≈7 billion soft drinks per year and ≈190 000 tons/y in sugar intake.

Discussion

Salt Intake and Total Fluid Consumption

Our analysis is the first to show a significant relationship between salt intake and fluid consumption in children and adolescents. Although no cause-effect relationship can be drawn from a cross-sectional study, our finding, in conjunction with other evidence, particularly that from experimental studies where only salt intake was changed,[1] demonstrates that salt intake is an important determinant of fluid consumption during childhood.

It has long been known from animal experiments that salt intake is a major determinant of fluid consumption.[16] However, the number of studies in humans is very limited. Nevertheless, a large cross-sectional study and a well-controlled trial where only salt intake was changed have consistently shown that salt intake is an important factor in determining fluid consumption in adult humans.[1] In an experimental study, 104 individuals with untreated essential hypertension were studied on the fifth day of a high-salt and a low-salt intake. When salt intake was reduced from 16.3 to 1.2 g/d, as measured by 24-hour urinary sodium, which is the most accurate method to estimate dietary salt intake, fluid intake was decreased from 2.2 to 1.3 L/d, as measured by 24-hour urine volume. There was a significant relationship between the reduction in salt intake and the decrease in fluid consumption; a 1-g/d reduction in salt intake would reduce fluid consumption by 63 mL/d. A large cross-sectional study, the International Study of Salt and Blood Pressure, which enrolled 10 074 individuals, also showed a significant association between salt intake and fluid consumption, as measured by 24-hour urinary sodium and volume, on an individual's usual diet.[1] A difference of 1 g/d in salt intake was related to a difference in fluid consumption of 65 mL/d in hypertensive subjects and 69 mL/d in normotensive subjects. Importantly, for a given difference in salt intake, the difference in fluid consumption in the cross-sectional study was almost identical to that predicted from the experimental study where salt intake was changed. These consistent findings, from a well-controlled trial of altering only salt intake and a cross-sectional study of a large number of people on their usual diet, demonstrate that dietary salt is a major factor in determining fluid intake in free-living individuals.

Salt Intake and Sugar-Sweetened Soft Drink Consumption

Our analysis shows that, in children and adolescents, more than half of total fluid consumed is in the form of soft drinks, and more than half of these soft drinks are sugar sweetened. In other words, sugar-sweetened soft drinks contribute to approximately one third of total fluid intake. At the same time, our study demonstrates a direct relationship between salt intake and sugar-sweetened soft drink consumption. These findings clearly suggest that a reduction in salt intake would reduce not only total fluid but also sugar-sweetened soft drink consumption. From our analysis, we estimate that, if salt intake was reduced by half in all children aged 4 to 18 years in the United Kingdom (ie, mean decrease of 3 g/d), there would be an average reduction of >2 sugar-sweetened soft drinks per week per child, which would result in a decrease in calorie intake of 244 kcal/wk for each child. This, in the long-term, could have a significant impact on reducing overweight and obesity during childhood. Recently, Wang et al[17] calculated that an excess calorie intake of 110 to 165 kcal/d was sufficient to account for the excess weight gain observed in US children.

A number of observational epidemiological studies have shown a link between sugar-sweetened soft drink consumption and obesity in children.[7,18] For instance, in a prospective study, Ludwig et al[7] followed up 548 school children aged 11 to 12 years for 19 months and showed that the consumption of sugar-sweetened beverages was an independent risk factor for obesity in children. For each additional can of sugar-sweetened drink consumed daily, there was a 60% increase in the development of obesity. Two randomized trials have studied the effect of reducing soft drink consumption on body mass index (BMI) or obesity. Ebbeling et al[19] carried out a pilot study in 103 individuals aged 13 to 18 years. Participants were randomly allocated to either the intervention or control group. In the intervention group, sugar-sweetened soft drinks were replaced with noncaloric beverages for a period of 25 weeks. Participants in the control group were asked to continue their usual beverage consumption habits throughout the study. The results showed that consumption of sugar-sweetened beverages decreased by 82% in the intervention group and did not change in the control group. Among the individuals in the upper-baseline BMI tertile, there was a significant reduction in BMI (decreased by 0.75 ± 0.34 kg/m^2) in the intervention group compared with the control group. However, among the subjects in the middle- and lower-baseline BMI tertiles, there was no significant difference in BMI between the intervention and control group. The other randomized trial was carried out by James et al[20] in 6 primary schools with 644 children aged 7 to 11 years for 1 school year. The intervention was to reduce the consumption of carbonated drinks, including both sugar-sweetened and low-calorie carbonated drinks. After 1 year of intervention, there was a reduction of $\approx$1.5 carbonated soft drinks per week per child in the intervention group compared with the control group. This reduction in carbonated soft drinks, although small, resulted in a significant decrease in the number of overweight and obese children by 7.7%.[20] From these data, it is predicted that reducing children's salt intake by half could lead to a reduction of $>$15% in overweight and obese children, because the number of total soft drinks (including both sugar-sweetened and low-calorie soft drinks) that would be reduced by halving salt intake was more than twice the reduction achieved in the above trial.

Strengths and Potential Limitations of Our Analysis

Our analysis has 2 strengths: the data were from a large, nationally representative sample of free-living young people in Great Britain, and salt and fluid intake were estimated from a 7-day detailed dietary record with all foods and drinks weighted before and after consumption. This method is likely to characterize individuals' usual intake more accurately than a single measurement or other dietary methods.

The limitation of our analysis is that the salt intake estimated from the National Diet and Nutrition Survey for young people underestimated the actual amount of salt consumed by children, because it did not include salt added during cooking or at the table. However, generally in most developed countries, the amount of salt discretionarily added to food is small, and the majority of salt intake is from salt already hidden in food, ie, added by the food industry,[8] and this salt consumption is clearly related to fluid and sugar-sweetened soft drink consumption, as demonstrated by our analysis.

Public Health Implications

The attraction of reducing salt as a public health measure in developed countries is that, because $\approx$80% of the salt is hidden in food before either children or adults consume it and they have no say over how much salt is added, it can be reduced if the food industry is prepared to slowly reduce the amount of salt they add to food. This policy of small reductions in the salt content, ie, 10% to 20% reductions, which cannot be detected by the human salt taste receptors[21] and do not cause any technological or safety problems either, are currently being carried out in the United Kingdom on a voluntary and collaborative basis with the food industry. Such a policy could easily be adopted by other developed countries worldwide. Furthermore, it has already been demonstrated that salt intake, as measured by 24-hour urinary sodium, is falling in adults in the United Kingdom.[9] A slow but persistent reduction in the amount of salt that is added, in particular, to children's products by the food industry will also reduce salt intake in children, as is occurring in adults. This, according to our current analysis, would result in a decrease in both fluid and sugar-sweetened soft drink consumption in children and is likely to cause a big decrease in the number of children developing obesity, which is an important risk factor for high blood pressure, type 2 diabetes, and cardiovascular disease.[3] Furthermore, a modest reduction in salt intake has already been shown to cause a fall in blood pressure in children,[22] which may, by itself, prevent the development of high blood pressure and, therefore, cardiovascular disease later in life.

Since the early 1970s, Finland has had a policy of reducing salt intake in the whole population.[2] The strategy has been a community-based collaboration with the food industry to develop reduced-salt food products, in combination with a public awareness program on the harmful effects of salt on health. During the past 30 years, salt intake has been reduced by one third.[23] This is accompanied by a fall of $>$10 mm Hg in both systolic and diastolic blood pressure and a pronounced decrease of 75% to 80% in both stroke and coronary heart disease mortality.[2] The reduction in salt intake is the major contributory factor for these results, particularly the fall in blood pressure, because both BMI and alcohol consumption have increased during the same period. An increase in potassium intake via the use of reduced-sodium, potassium- and magnesium-enriched salt; an increased consumption of fruit and vegetables; and a reduction in fat intake also play a part in the fall in cardiovascular disease.

Among all of the dietary changes to try to prevent cardiovascular disease, a reduction in salt intake is the easiest to make, because it can be done without the individual's knowledge but requires cooperation from the food industry. Some members of the food industry outside the United Kingdom have been reluctant to reduce the salt content of their food products for purely commercial reasons, one of which is to protect soft drink sales, because some soft drink companies own large snack companies that specialize in highly salted snacks. However, they should not be allowed to stand in the way of a reduction in salt intake, because this reduction would have major benefits to the health of the whole population and, particularly, to children in potentially preventing the development of high blood pressure and obesity, thereby reducing the appalling burden of cardiovascular disease later in life.

Perspectives

Our analysis of the data from the National Diet and Nutrition Survey for young people shows that, in a free-living population of British children and adolescents, differences in salt intake are associated with differences in total fluid, as well as sugar-sweetened soft drink consumption. Our results, in conjunction with other evidence, particularly that from experimental studies where only salt intake was changed,[1] demonstrate that salt intake is an important determinant of fluid and sugar-sweetened soft drink consumption during childhood. Currently, in most countries, salt intake in young people is unnecessarily high due to hidden salt added to food by the food industry.[8] A modest reduction in salt intake has been shown to cause a fall in blood pressure in children.[22] According to our present analysis, it would also reduce sugar-sweetened soft drink consumption and, therefore, play an important role in helping to reduce childhood obesity and diabetes. This would have a beneficial effect on preventing cardiovascular disease independent of and additive to the effect of salt reduction on blood pressure.

Acknowledgments

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Disclosures

None.

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