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Exploring the relationship between sugars and obesity

Winsome Parnell[1,*], Noela Wilson[2], Donnell Alexander[3], Mark Wohlers[2], Micalla Williden[2], Joel Mann[1] and Andrew Gray[4]

[1]Department of Human Nutrition, University of Otago, PO Box 56, Dunedin, New Zealand: [2]LINZ® Activity and Health Research Unit, University of Otago, Dunedin, New Zealand: [3]Network Communications Ltd, Auckland, New Zealand: [4]Preventive and Social Medicine, University of Otago, Dunedin, New Zealand

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Abstract

Objective: Investigate the relationship between body mass index (BMI) and intake of sugars and fat in New Zealand adults and children.
Design: Secondary analyses of National Nutrition Survey (1997) and Children's Nutrition Survey (2002) data for the New Zealand population. BMI calculated from height and weight; fat, sugars and sucrose (used as a surrogate for added sugars) intakes estimated from 24-hour diet recall. Ethnic-specific analyses of children's data. Relationships (using linear regression) between BMI and sugars/sucrose intakes; per cent total energy from fat; mean total energy intake from sucrose. Subjects classified into diet-type groups by levels of intake of fat and sucrose; relative proportions of overweight/obese children in each group compared with that of normal weight subjects using design-adjusted χ^2 tests.
Setting: New Zealand homes and schools.
Subjects: 4379 adults (15+ years); 3049 children (5–14 years).
Results: Sugars (but not sucrose) intake was significantly lower among obese compared to normal weight children. In adults and children, those with the lowest intake of sugars from foods were significantly more likely to be overweight/obese. Sucrose came predominantly from beverages; in children, 45% of this was from powdered drinks. Sucrose intake from sugary beverages was not related to BMI. Per cent total energy (%E) from sucrose was significantly inversely related to %E from fat among adults and children. Proportions of overweight/obese adults or children in each diet-type group did not differ from that of normal weight individuals.
Conclusions: Current sugars or sucrose intake is not associated with body weight status in the New Zealand population.

Keywords
Obesity
Sugars
Sucrose
New Zealand
Body mass index

Rates of overweight and obesity have increased worldwide over the last three decades and while genetic factors may play a part in the development of obesity, the recent dramatic increase in rates of obesity suggests that environmental and behavioural factors have contributed to this problem[1]. Specifically, diminished physical activity and an increase in the availability and consumption of energy-dense foods are suggested to be important factors in the development of overweight and obesity[2,3]. In recent times, there has been significant interest in the role of sugar in the development of obesity, both worldwide[4] and in New Zealand[5]. What has been lacking from this debate is objective data on exactly how much sugar New Zealanders consume and if in New Zealand there is a relationship between sugar intake and body weight status.

While it is generally accepted that overconsumption of high-fat foods can contribute to excess energy in the diet (and subsequent weight gain)[6], the relationship between the consumption of sugars from all sources or added sugar (that not occurring naturally in foods) and body weight is less clear. Cross-sectional studies have shown either no association[7] or a negative association[4,8] between body mass index (BMI) and current consumption of sugars in adults and children. There has also been significant debate about whether intake of sugars from beverages, as opposed to foods, may have the greater effect on BMI. There is some support for the hypothesis that beverages may not promote the same level of satiety as solid food and therefore consumers may not adjust their overall intake to compensate for the energy in sugar-sweetened beverages[9].

Those who consume high-fat diets tend to have lower intakes of sugars and vice versa, a phenomenon commonly referred to as the 'fat–sugar see-saw'[8]. It is therefore interesting to speculate whether overall diet

*Corresponding author: Email winsome.parnell@otago.ac.nz

type (with respect to both sugars and fat intake) has an association with BMI.

The aims of the present study were to conduct a secondary analysis of National Nutrition Survey data from New Zealand adults and children and examine the association between weight status and sugars and sucrose intake and whether they were sourced from beverages or foods; to examine the association between fat intake and sucrose intake as per cent of total energy; and to examine the relationship between BMI and type of diet, with respect to both fat and sugars.

Methods

Data derived from the National Nutrition Survey of 1997 (NNS97) and the 2002 Children's Nutrition Survey (CNS02), including nutrient intakes from 24-hour diet recall and height and weight measurements, were used in secondary data analyses. In summary, the NNS97 was a voluntary cross-sectional survey of New Zealanders aged 15 years and above ($n = 4636$) and was a subsample of the 1996/1997 NZ Health Survey with an oversampling of NZ Māori and Pacific people. The CNS02 was a voluntary cross-sectional school-based survey of New Zealand children aged 5–14 years ($n = 3275$), with oversampling of NZ Māori and Pacific children. The group NZ Māori are indigenous New Zealanders and the group Pacific includes New Zealand born and migrant people from Pacific countries including Samoa, Tonga, the Cook Islands and Nuie. The details of design, recruitment and collection procedures of these surveys have been described previously[10,11].

'Sugars' is the term used for 'total sugars' in the diet, and includes all mono- and disaccharides from foods and beverages, whether intrinsic (e.g. lactose from dairy products and sugars from fruit) or added sugars. While 'sucrose' is a specific disaccharide and occurs both intrinsically or added to foods and beverages, in these analyses it is considered the best available surrogate for 'added sugars'. With respect to beverages (as a major source of sucrose), New Zealand adults and children choose fruit drinks where sucrose is 'added' more frequently than fruit juices where the sucrose would be intrinsic[11]. As high-fructose corn syrups are not used as food or beverage sweetners in this country, fructose present in foods will be intrinsic, i.e. naturally present in the juice, fruit or other food.

BMI, weight (kg)/[height^2 (m^2)], was calculated and used to classify adult participants into the following four weight categories: underweight (BMI $< 18.5\,\mathrm{kg\,m^{-2}}$); normal weight (BMI $= 18.5$ to $< 25\,\mathrm{kg\,m^{-2}}$); overweight (BMI $= 25$ to $< 30\,\mathrm{kg\,m^{-2}}$); and obese (BMI $\geq 30\,\mathrm{kg\,m^{-2}}$). Age- and sex-specific BMI cut-offs established by Cole *et al.*[12] were used to classify children as normal weight, overweight or obese.

Children were assigned to one of three ethnic groups: Māori, Pacific, or New Zealand European and Others (NZEO), based on a hierarchical system[11].

Statistical analysis

Mean daily intakes of sugars and sucrose and per cent of total energy (%E) from sugars and sucrose were calculated for BMI categories within different age and gender groups. Mean daily intakes of sucrose from 'foods' and 'beverages' were calculated as follows:

- 'Foods' included the following groups: breakfast cereals, biscuits, cakes and muffins, puddings, ice-cream, yoghurt, snack foods, sugar/sweets, snack bars.
- 'Beverages' included the following groups: hot drinks, fruit and vegetable juices, cordials and fruit drinks, regular soft drinks, sports drinks, energy drinks (e.g. Milo, Nesquik), powdered drinks (fruit-flavoured powdered sucrose), plain milk, flavoured milk or milkshakes and alcoholic beverages (adults only).

The relationships between sugars and sucrose intakes and weight status were examined using linear regression, adjusting for gender, age, ethnic group (in children) and energy intake. Adjusted Wald tests were also used to examine the overall or main effect of age, ethnic group and BMI category on sugars and sucrose intakes. If these were significant, differences within the groups were examined. Because of the number of statistical tests carried out, only differences where $P < 0.01$ were considered significant.

To examine the relationship between the proportions of fat and sucrose in the diet, the population was divided into quartiles by per cent energy (%E) coming from fat and the mean %E from sucrose consumed by each resultant quartile was calculated. A linear regression was calculated, adjusting for age, gender and energy intake, and a value of $P < 0.01$ was considered significant.

To determine whether obese or overweight individuals were more likely to consume a particular diet, the sample of adults and children was divided into four diet types: low fat, low sucrose (LFLS); low fat, high sucrose (LFHS); high fat, low sucrose (HFLS); and high fat, high sucrose (HFHS). The cut-off used to define individuals as high or low fat consumers was the New Zealand Nutrition Taskforce Guidelines goal of no more than 33% total energy from fat[13]. The cut-off used to define high or low sucrose consumers was the World Health Organization (WHO) recommendation of no more than 10% total energy coming from sucrose (as a proxy for added sugar)[14]. The proportion of overweight/obese children and adults consuming each diet type was compared with the proportion of normal weight children and adults. Differences were determined using a design-adjusted χ^2 test.

The statistical package STATA 8.0 was used to carry out the analyses, adjusting for the complex survey design[15].

All data presented were weighted to provide NZ population estimates.

Results

Prevalence of obesity

The proportion of Pacific children (both boys and girls) who were obese was higher than both Māori and NZEO children (Table 1). This difference was significant. Obesity levels in adults peak in the 45–64 year group for both males (23%) and females (27%) (Table 2). Data for the underweight category for adults (BMI $< 18.5\,kg\,m^{-2}$) could not be reported as numbers were too small.

Daily intake of sugars and sucrose

Mean daily intake of sugars (g), sucrose (g) and %E from sugars and sucrose (Tables 3 and 4) were significantly different across age groups in adults with those aged 15–24 years consuming more sugars than older adults, but were not related to weight status or gender. For children there were no significant differences by gender or age group and there was a significant relationship between intake of sugars (but not sucrose) and weight status (Tables 5 and 6). Obese children had a significantly lower intake of sugars ($P < 0.001$) and %E from sugars ($P < 0.001$) than normal weight children (Table 5). Pacific children had significantly lower intakes of both sugars ($P < 0.001$) and sucrose ($P < 0.001$) than either NZEO or Māori children (Tables 5 and 6).

Daily intakes of sucrose by quartile of fat intake

Both for men and women ($P < 0.001$) and for boys and girls ($P < 0.001$), there was a significant difference in %E from sucrose by quartile of %E from fat (Figs 1–4). Pacific children also had significantly lower %E from sucrose across all fat intake quartiles than Māori children ($P < 0.0001$).

Choice of different diet types

The predominant diet type of adults was a HFLS diet (40%), whereas for children the predominant diet type was LFHS (35%). In both adults and children, there were no significant differences between overweight/obese and normal weight individuals with respect to choice of diet type.

Daily intake of sucrose from foods

Obese adults and obese children both had significantly lower daily intakes of sucrose (adults $P = 0.001$ and children $P < 0.0001$), and lower %E from sucrose sourced from sugary foods, than normal weight adults and children (adults $P = 0.008$ and children $P < 0.0001$).

Table 1 Weight status of children by gender, age and ethnicity

	Ethnicity								
	Māori			Pacific			New Zealand European and Others		
Age (years)	5–6	7–10	11–14	5–6	7–10	11–14	5–6	7–10	11–14
Boys*									
n	128	262	179	119	197	160	93	226	200
Normal weight (%)	65	65	65	48	38	38	83	80	71
Overweight (%)	17	19	22	31	36	33	14	16	23
Obese (%)	18	16	14	21	26	29	3	4	6
Girls*									
n	116	269	164	86	195	238	76	186	155
Normal weight (%)	52	53	52	44	39	29	83	72	75
Overweight (%)	33	30	30	33	30	36	16	20	18
Obese (%)	15	16	18	23	31	35	1	8	6

*Weight classification based on Cole *et al.*[12] cut-offs for body mass index.

Table 2 Weight status of adults by gender and age

	Men					Women				
Age (years)	15–24	25–44	45–64	65–74	75+	15–24	25–44	45–64	65–74	75+
n	244	737	568	206	102	318	1105	643	279	177
Normal weight* (%)	64	46	29	28	53	60	55	36	28	44
Overweight† (%)	25	39	48	58	39	20	26	37	47	33
Obese‡ (%)	6	14	23	14	7	12	17	27	22	17

*Body mass index (BMI) = 18.5 to $<25\,kg\,m^{-2}$.
†BMI = 25 to $<30\,kg\,m^{-2}$.
‡BMI $\geq 30\,kg\,m^{-2}$.

Table 3 Adults' mean daily intake of sugars (g) and per cent total energy (%E) from sugars by gender, age* and weight status

	Age (years)									
	15–24		25–44		45–64		65–74		75+	
	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)
Men										
Normal weight†	165	20.9	153	19.2	131	18.6	115	19.6	99.5	20.8
Overweight‡	176	25.1	154	19.0	121	16.7	120	19.4	99.4	19.3
Obese§	143	20.6	129	18.2	102	16.8	116	19.8	91.8	16.3
Mean¶	167	21.8	150	19.0	118	17.1	118	19.4	98.3	19.8
Women										
Normal weight†	138	23.0	103	20.2	95.7	20.4	83.8	20.1	85.0	22.1
Overweight‡	124	23.6	106	21.3	101	22.1	92.9	21.5	82.4	20.0
Obese§	132	27.6	99.3	18.8	87.3	19.8	88.4	20.1	72.2	19.3
Mean¶	133	24.2	106	20.6	94.9	20.8	88.6	20.9	81.9	21.0

*Sugars intakes (g) and per cent total energy (%E) from sugars are significantly different across age groups, ($P<0.0001$) and the 15–24-years age group significantly higher than all others.
†Body mass index (BMI) = 18.5 to $<25\,kg\,m^{-2}$.
‡BMI = 25 to $<30\,kg\,m^{-2}$.
§BMI $\geq 30\,kg\,m^{-2}$.
¶Mean values for the age and sex group.

Table 4 Adults' mean daily sucrose intake (g) and per cent total energy (%E) from sucrose by gender, age* and weight status

	Age (years)									
	15–24		25–44		45–64		65–74		75+	
	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)
Men										
Normal weight†	80.1	10.1	79.7	9.7	65.0	9.3	55.5	9.4	50.4	10.5
Overweight ‡	91.1	11.9	78.7	9.6	54.3	7.4	56.5	8.9	44.5	8.5
Obese§	76.7	10.8	62.9	8.8	46.9	7.9	53.4	8.8	35.6	6.4
Mean¶	83.2	10.6	77.0	9.6	54.8	8.0	55.6	9.1	46.3	9.3
Women										
Normal weight†	72.6	12.0	46.4	9.0	41.7	8.7	36.4	8.5	36.3	9.4
Overweight‡	62.0	11.5	52.8	10.4	45.2	9.8	36.6	8.3	35.9	8.5
Obese§	68.2	14.2	48.2	8.9	39.9	8.7	37.7	8.4	30.7	8.0
Mean¶	69.3	12.3	50.1	9.5	42.2	9.0	36.8	8.5	35.2	8.9

*Sucrose intakes (g) and per cent total energy (%E) from sugar ($P<0.0001$) are significantly different across age groups, with the 15–24 year age group significantly higher than all others.
†Body mass index (BMI) = 18.5 to $<25\,kg\,m^{-2}$.
‡BMI = 25 to $<30\,kg\,m^{-2}$.
§BMI $\geq 30\,kg\,m^{-2}$.
¶Mean values for the age and sex group.

Table 5 Children's mean daily intake of sugars (g) and per cent of total energy (%E) from sugars by gender, ethnicity, age and weight status

Ethnicity	Māori						Pacific*						NZEO					
Age (years)	5–6		7–10		11–14		5–6		7–10		11–14		5–6		7–10		11–14	
	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)
Boys†																		
Normal	125	23.5	130	23.1	156	22.2	109	23.4	106	20.6	124	20.9	109	24.4	129	23.6	149	22.5
Overweight	104	20.3	129	20.7	158	23.4	116	22.9	106	19.6	121	20.5	99.3	23.1	146	25.7	143	21.5
Obese‡	119	20.0	122	19.4	127	18.4	97.4	19.7	121	19.7	120	23.5	79.3	20.4	127	19.5	124	20.2
Mean	122	22.4	131	22.3	148	21.8	108	22.3	110	20.0	122	19.8	106	23.9	132	23.8	145	22.5
Girls†																		
Normal	93.9	22.3	127	24.1	144	25.7	86.6	21.0	99.5	21.1	122	20.8	107	26.6	114	24.4	121	23.8
Overweight	124	24.7	120	22.5	148	28.8	95.6	23.4	103	22.1	105	22.1	126	23.8	112	20.7	110	24.7
Obese‡	106	20.2	123	21.4	116	23.1	95.5	24.1	99.0	19.5	115	19.5	92.9	15.8	128	25.2	88.8	18.0
Mean	105	22.6	123	23.1	138	24.3	91.0	22.2	100	21.0	113	20.2	108	26.4	118	24.1	118	23.8

NZEO – New Zealand European and Others.
*Sugars intake (g) and per cent total energy (%E) from sugars are significantly different ($P<0.0001$) between ethnic groups, with Pacific children having significantly lower intakes than Māori or New Zealand European and Others children.
†Weight classification based on Cole *et al.*[12] cut-offs for BMI.
‡Sugars intake (g) and %E from sugars are significantly different ($P<0.0001$) between body mass index (BMI) category with obese children having significantly lower intakes than children in the normal BMI category.

Table 6 Children's mean daily intake of sucrose (g) and per cent of total energy (%E) from sucrose by gender, ethnicity, age* and weight status

Ethnicity	Māori						Pacific*						NZEO					
Age (years)	5–6		7–10		11–14		5–6		7–10		11–14		5–6		7–10		11–14	
	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)	(g)	(%E)
Boys†																		
Normal	71.4	13.3	70.9	12.5	87.6	12.3	55.9	11.8	57.3	11.0	66.4	11.0	56.7	12.5	70.5	12.8	78.2	11.8
Overweight	55.6	10.7	74.9	11.9	93.3	13.4	65.8	12.7	56.2	10.3	61.9	10.4	51.7	12.1	73.9	12.9	77.1	11.5
Obese	59.3	9.9	68.6	10.8	73.6	11.1	53.1	10.6	71.3	11.2	62.5	9.2	51.3	13.1	87.2	13.4	64.7	12.3
Mean	67.4	12.3	73.1	12.3	83.2	12.0	57.9	11.8	60.9	10.9	63.8	10.2	55.2	12.4	71.1	12.8	76.8	11.8
Girls†																		
Normal	52.0	12.3	71.5	13.5	81.7	14.5	44.2	10.7	53.0	11.0	70.7	11.8	53.0	13.3	62.2	13.1	62.9	12.2
Overweight	69.0	13.5	64.3	12.5	86.3	13.8	50.9	12.0	56.6	12.0	57.5	11.1	71.6	16.6	61.6	12.1	55.4	12.7
Obese	60.3	11.3	74.0	13.0	60.2	11.4	53.9	13.6	53.7	10.4	65.3	11.0	62.2	10.6	78.1	15.5	41.8	8.3
Mean	59.3	12.6	69.1	13.0	78.0	13.6	48.0	11.7	54.5	11.2	63.6	11.2	55.3	13.6	63.3	13.1	60.3	12.2

NZEO – New Zealand European and Others.
*Sucrose intakes (g) and per cent total energy (%E) from sucrose are significantly different ($P < 0.0001$) between ethnic groups, with Pacific children having significantly lower intakes than Māori or New Zealand European and Others children.
†Weight classification based on Cole *et al.*[12] cut-offs for body mass index.

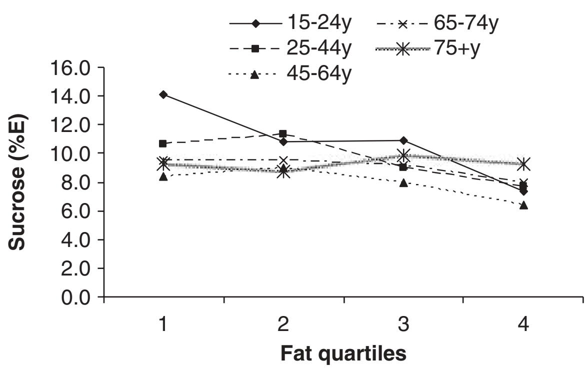

Fig. 1 Per cent of energy (%E) from sucrose for men, with increasing intakes of fat

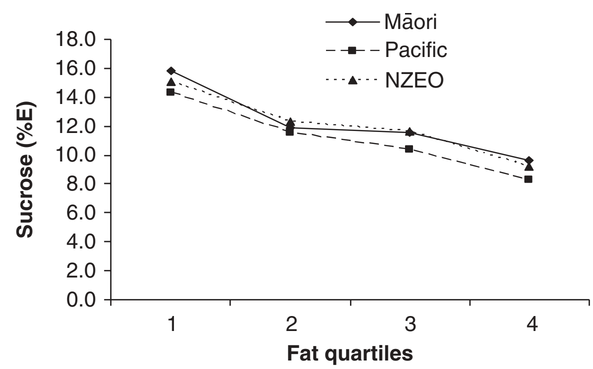

Fig. 3 Per cent of energy (%E) from sucrose for boys, with increasing intakes of fat (NZEO – New Zealand European and Others)

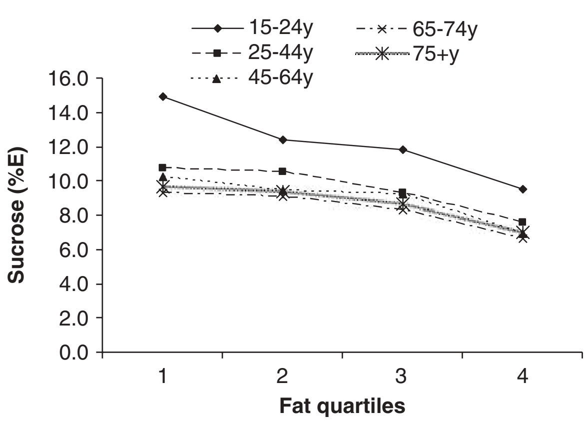

Fig. 2 Per cent of energy (%E) from sucrose for women, with increasing intakes of fat

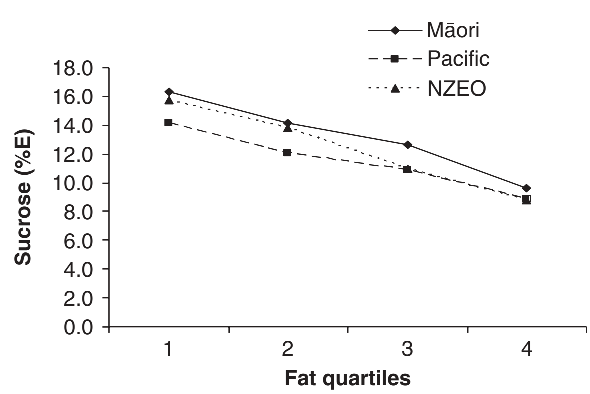

Fig. 4 Per cent of energy (%E) from sucrose for girls, with increasing intakes of fat

Pacific children had significantly lower daily intakes of sucrose (($F2, 168) = 5.81$; $P = 0.004$) and %E from sucrose ($P = 0.001$) from sugary foods than both Māori and NZEO children.

Daily intakes of sucrose from beverages

There was no significant relationship between sucrose and %E from sucrose sourced from beverages (including alcohol) and weight status for either adults or children.

Beverages were however the predominant source of sucrose (26%) among children. Of these, powdered drinks were the main source (45%), followed by soft drinks (33%) and cordials and fruit drinks (15%).

Discussion

These cross-sectional data reported here demonstrate that overweight or obese adults in New Zealand did not have a higher intake of sugars or sucrose (either considered as absolute intake in grams or as a proportion of energy) than normal weight adults. In addition, obese children consumed significantly less sugars than overweight or normal weight children.

Other studies using the 24-hour diet recall methodology (to assess current sugar intake in relation to body weight status) have similar findings to these NZ data. These results are congruent with those reported from the Australian National Nutrition Survey, where the intakes for total, natural and added sugars were not associated with BMI in either adults or children[7].

On the other hand, Bolton-Smith and Woodward[8] described a negative association between BMI and intake of total and intrinsic sugars in Australian adults aged 25–64 years using data from a qualitative food-frequency questionnaire, and in the Dietary and Nutrition Survey of British Adults (using 7-day diet records), Macdiarmid *et al.*[4] found a negative association between the %E from sugars and BMI in men, but not in women.

The findings of this study are in agreement with those of Gibson[16], who found no evidence that overweight or obese people in the United Kingdom were more likely to be consuming a diet high in both fat and sucrose. This was a large study, involving more than 2000 men and women whose dietary intake was assessed by 7-day diet records. People who are overweight or obese may be restricting their intake of high-fat and high-sugar foods in an effort to reduce their weight, and respondents may not be able to describe the type of diet that contributed to their weight gain. Compared to adults, overweight children, however, may be less likely to actively restrict or modify their dietary intake due to the fact that they are still growing.

Although obese individuals are more likely to under-report their actual energy intake than those of lower weight status, it is not possible to account for this in a meaningful way in these analyses, particularly as younger children are less likely to under-report than adults[17]. With respect to the issue of which foods or nutrients might be more likely to be under-reported, the authors have no reason to believe that sugary foods were more likely than others to be under-reported in general, or by any subgroup. At the time of data collection for the NNS97 and CNS02, 'fatty foods' rather than 'sugary foods or beverages' were considered unhealthy in New Zealand. Therefore the possibility of differential under-reporting as being part of the explanation for the lack of association found here between sucrose intake and body weight status is acknowledged.

The trend for %E from sucrose to decrease as %E from fat increases provides evidence for the 'fat–sugar see-saw' phenomenon in this population. This illustrates the possibility that sucrose might displace fat in the diet rather than more desirable complex carbohydrate, sourced from foods that are also rich in dietary fibre. For both adults and children in this study, there was no evidence to suggest that overweight or obese individuals were currently choosing foods with more sugar.

Because energy consumed in a liquid form (especially when consumed between meals) may not produce the same level of satiety as would solid food[18], beverages have often been targeted as an energy source to be restricted in order to achieve weight reduction/maintenance[5,19]. In this study, there were no significant differences in intake of sucrose (amount or %E) coming from beverages between normal and overweight/obese adults or children. While studies by Berkey *et al.*[20] in adolescents, and Forshee and Storey[21] in children, have had similar findings, the opposite trend was shown by Ludwig *et al.*[22] Rajeshwari *et al.*[23] recently described an increase in the mean BMI over a period of 21 years (from 1973 to 1994) for a cohort of children in Los Angeles, while the per cent consuming sweetened beverages declined over that time. Therefore, the influence of intake of sweet beverages on weight status is still open to question.

The finding that Pacific children consumed significantly less sugars than children in other ethnic groups is interesting considering the higher prevalence of overweight and obesity among Pacific children[11]. While there are likely to be a number of contributing factors to the higher body weight among Pacific children, these data do not suggest a greater influence of the intake of sugars on the prevalence of overweight and obesity in this ethnic group.

These data from the NNS97 are cross-sectional in nature and therefore the question of association of body weight status with the habitual intake of sugars cannot be addressed. The use of sucrose intake as a surrogate for 'added' sugars can be criticised. However, for the NZ population, only about one-third of sucrose intake comes from the fruits and from beverages[11,24]. Beverages (non-alcoholic) are an important source of sucrose to the diets of adults and children, providing 23% and 26%, respectively. However, within the beverage category, fruit juice, which does provide some non-extrinsic sugars, is chosen much less often than fruit drinks. Overestimation of added sugars does occur but we believe to a lesser extent than in most Western countries. It is not possible using food composition data (derived from chemical analysis of a product) to separate the sucrose in the fruit drinks into 'added sucrose' or intrinsic sucrose. Furthermore, 'sucrose' is the sweetner of choice in NZ-manufactured foods and not high-fructose corn syrups. The authors therefore conclude that it is appropriate to examine the relationships between sucrose intake and body weight status estimating that in NZ the greatest part of sucrose would have been 'added' to foods and beverages consumed in manufacture or preparation.

While these data cannot ascertain whether overweight individuals (adults or children) may or may not have modified their intake in response to their body weight status, these cross-sectional New Zealand population data do not provide evidence of a positive association between their current sugars and sucrose intake and body weight status.

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