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Sucrose in the diet of 3-year-old Finnish children: sources, determinants and impact on food and nutrient intake

Maijaliisa Erkkola[1,2]*, Carina Kronberg-Kippilä[1], Pipsa Kyttälä[1,3], Jenni Lehtisalo[1,2], Heli Reinivuo[1], Heli Tapanainen[1], Riitta Veijola[4], Mikael Knip[5,6], Marja-Leena Ovaskainen[1] and Suvi M. Virtanen[1,3,6]

[1]*Unit of Nutrition, Department of Health Promotion and Chronic Disease Prevention, National Public Health Institute, Mannerheimintie 166, FIN-00300 Helsinki, Finland*

[2]*Division of Nutrition, Department of Applied Chemistry and Microbiology, PO Box 66, FIN-00014 University of Helsinki, Finland*

[3]*Tampere School of Public Health, FIN-33014 University of Tampere, Finland*

[4]*Department of Paediatrics, Box 5000, FIN-90014 University of Oulu, Finland*

[5]*Hospital for Children and Adolescents, PB 281, FIN-00029 HUS, Finland*

[6]*Department of Paediatrics and Research Unit, Tampere University Hospital, FIN-33014 University of Tampere, Finland*

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The aim was to identify the important sources of added sucrose and determinants of high intake, and to evaluate what impact a high proportion of energy from added sucrose has on the intake of foods and nutrients. The subjects consisted of children invited to the nutrition study within the Type 1 Diabetes Prediction and Prevention birth cohort and born in 2001 (*n* 846). Of these, 471 returned 3 d food records at 3 years of age. The average daily intake of added sucrose was 35 (SD 17) g (11·3 % of energy intake) and that of total sucrose was 41 (SD 18) g (13·3 % of energy intake). Sucrose added by manufacturers accounted for 82 %, naturally occurring sucrose for 15 % and sucrose added by consumers for 3 % of the total sucrose. Juice drinks, yoghurt/cultured milks, and chocolate and confectionery were the main contributors to added sucrose intake. Consumption of rye bread, porridge, fresh vegetables, cooked potatoes, skimmed milk, hard cheeses, margarine and fat spread as well as intake of most nutrients decreased across the quartiles of added sucrose ($P < 0·05$). Being cared for at home, having a father with a vocational school degree, having at least two siblings and a milk-restricted diet increased the risk for a high-sucrose diet. The study implied that a high proportion of added sucrose in the diet had mainly an unfavourable impact on the intake of recommended foods and key nutrients in Finnish children. The rationale for the recommendation to reduce the intake of refined sugars to ensure adequate intakes of nutrients seems reasonable.

Added sucrose: Nutrient intake: Food intake: Children

The added sugar intake in relation to energy is, in general, higher among children than in other population groups and commonly above the limit of 10 % of energy intake[1,2]. Studies among children have shown that some micronutrients tend to correlate inversely with sugar consumption[3–6]. Even though evidence suggests that a broad range of sugar intake has no detrimental effects on micronutrient intakes in most populations, it is acknowledged that the true risk of deficiencies can only be assessed using biological indicators[1]. Foods simultaneously fortified with vitamins and minerals and sweetened with added sugars could mask nutrient dilution[7]. The association of added sugar intake with fat intake has turned out to be inverse (sugar–fat see-saw phenomenon) in children, indicating that added sugar intake at least partially replaces fat intake[3–5]. The majority of epidemiological studies have not demonstrated correlations between sugar consumption and obesity[1]. However, consumption of sugar-sweetened drinks could lead to obesity, due to imprecise and incomplete compensation for energy consumed in liquid form[8–10]. Dietary data on Finnish children are dispersed and sparse. The sugar intake has been presented only as total sugars or total sucrose[11–13]. Food preferences, which could become determined already by the age of 2–3 years, are strongly influenced by social, demographic and lifestyle factors related to the family, particularly to the mother [14–16]. However, sociodemographic factors determining the consumption of added sugars are not well known among children.

In the present study the objective was to identify the most important sources of naturally occurring and added sucrose among 3-year-old children, and the most important determinants of high intake. Furthermore, we evaluated whether a high proportion of energy from added sucrose has an impact on the intake of foods and nutrients. In the present study, the term ‘added sucrose’ is used in reference to added sucrose eaten separately at the table or used as an ingredient in processed or prepared foods. It does not include naturally occurring sucrose which is calculated separately.

Abbreviations: DIPP, Type 1 Diabetes Prediction and Prevention; HLA, human leucocyte antigen.

* **Corresponding author:** Dr Maijaliisa Erkkola, fax +358 9 191 58269, email maijaliisa.erkkola@helsinki.fi

Subjects and methods

The subjects in the present study belong to the Type 1 Diabetes Prediction and Prevention Study (DIPP) cohort[17] (http://research.utu.fi/dipp/index.php). Written consent for screening of genetic susceptibility to type 1 diabetes of their newborn infant was obtained from the parents. The subjects carrying the high- or moderate-risk human leucocyte antigen (HLA) class II genotypes were observed for diet, growth, viral infections and type 1 diabetes-associated auto-antibodies at 3- to 12-month intervals. The study was approved by the ethics committees of the participating hospitals. The present series comprises the at-risk children born in 2001 in Tampere and Oulu University Hospitals.

A total of 471 families (56 % of those 846 invited, and 61 % of those 773 who started in the DIPP Nutrition study) returned the structured dietary questionnaire and the 3 d food record at the age of 3 years of the child. For seven children (1·5 % of all) food records were kept for only 1 d and for twenty children (4 %) for 2 d. The background information was obtained from a questionnaire completed at 3 months after delivery. Data on gestation and delivery were obtained from the Medical Birth Registries of the Oulu and Tampere University Hospitals and from the National Research and Development Centre for Welfare and Health.

Dietary data

Structured dietary questionnaire at age 3 years and 3 d food records. Data on the child's food consumption were obtained by a 3 d food record completed close to the child's third birthday. The 3 d food record comprised two consecutive weekdays and one weekend day. Additional questions about special diets were attached. A separate food record was given to day-care personnel if the child was cared for outside the home during the recording days. The families and day-care personnel received written instructions to record (type, brand and preparation method) with household measures all the foods the child consumed and vitamin and mineral supplements used. Trained study nurses checked the questionnaire and food record during the respective visits.

The food consumption data were analysed using a software program developed at the National Public Health Institute (www.ktl.fi). The food composition database of the National Public Health Institute, called Fineli[18] (www.fineli.fi), is continuously updated and is the most comprehensive database in Finland. The analytical nutrient values in the database are mostly based on Finnish studies. In addition, complementary data are obtained from the Finnish food industry and international food composition tables. The system is able to accommodate the creation or modification of specific recipes, and personal recipes were used whenever possible.

For food consumption and nutrient intake, an estimate of average daily intake was calculated. Accordingly, the data on nutrient intake were analysed by food-use groups. The food-use groups were reclassified according to quantity and quality of sucrose (see the classification in Table 1). Sucrose use per child per d was calculated producing four different variables: naturally occurring sucrose, sucrose added by manufacturers, sucrose added by the consumer, and total sucrose (the sum of the aforementioned). In most of the analyses, added sucrose from manufacturers and sucrose from consumer sources were combined and named as added sucrose. The term 'naturally occurring sucrose' is used in reference to intrinsic sucrose that is enclosed in the cell in whole fruits and berries and naturally occurring sucrose in the products made out of fruits and berries (for example, fruit juices).

Statistical analysis

The dietary variables were log-transformed when necessary to meet the assumptions of normal distribution. Adjustment for

Table 1. The average contribution of food groups to the intake of different sucrose classes among the children (*n* 471)

Contributing food group*	Proportion of users (%)	Added sucrose		Naturally occurring sucrose	
		g/d	% of total	g/d	% of total
Bread and savoury bakery	98	0·1	<1	0·3	4
Breakfast cereals and porridge	91	0·6	2	0·5	8
Sweet bakery	86	3·9	11	0·1	2
Chocolate and confectionery	82	4·2	12†	–	
Fresh fruits and berries	82	–		2·3	38†
Juice drinks‡	79	9·5	27†	< 0·1	< 1
Ice cream, milk desserts	73	4·1	12	0·1	1
Yoghurt, cultured milks	68	4·6	13†	0·1	1
Fruit and berry salads and soups	55	2·9	8	0·3	5
Fruit and berry juices	47	–		1·4	23†
Condiments	46	0·4	1	–	
Sugar, syrup and honey (added by the consumer)	42	1·2	3	–	
Soft drinks with sugar	34	1·5	4	–	
Fruit and berry jams	32	1·0	3	< 0·1	< 1
Fruit and berry purées for children	18	< 0·1	<1	0·1	2
Other foods*	100	1·0	3	0·9	15†
Sum		34·7	100	6·1	100

* The food groups are based on quantity and quality of sucrose. Other foods include all other foods which are not mentioned in the Table, such as meat, fish, etc.
† Three main contributors.
‡ Berry- or fruit-based drinks that contain naturally occurring and added sucrose.

total energy intake was made using Willett's[19] residual method. Differences between means by sociodemographic characteristics were tested with the independent-samples *t* test (for two groups of cases) or ANOVA (for more than two groups of cases). The paired-samples *t* test was used to compare the means of sucrose intake on weekdays *v.* holidays. Pearson's correlation coefficients were used to study associations between fat and different types of sucrose (in % of energy intake). Children were divided into quartiles of proportion of energy from added sucrose. Differences between nutrient quartiles were assessed by one-way ANOVA. Differences in food intake between the quartiles were tested with the non-parametric Mann–Whitney *U* test (lowest and highest quartiles) and the Kruskal–Wallis test (all quartiles). A linear regression analysis was applied to study the intake of the proportion of energy from added sucrose in relation to selected sociodemographic characteristics. Sociodemographic characteristics were categorised as shown in Table 2. A *P* value of less than 0·05 was considered statistically significant. The SPSS 12.0 statistical package for Windows (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses.

Results

The mean daily energy intake was 5353 (SD 988) kJ for boys and 5066 (SD 981) kJ for girls ($P=0{\cdot}002$). Protein accounted for 16 (SD 3) %, fat for 31 (SD 6) % and total carbohydrates for 53 (SD 6) % of the total energy intake. The energy-adjusted food consumption in boys and girls differed from each other mainly with regard to less frequently used food groups (tea, pulses, and snacks) and that of nutrient intake with regard to Fe and fluoride, which were higher among boys. No significant difference was seen in energy intake between the quartiles of added sucrose as a % of energy intake (Table 3).

On average, the children consumed 41 (SD 18, range 6–109) g sucrose/d, accounting for 13·3 (SD 5) % of energy intake. Total sucrose intake was higher during the weekend days; the mean sucrose intake during the weekend days was 45 *v.* 39 g/d on weekdays ($P<0{\cdot}001$). The average intake of added sucrose by manufacturers and consumers was 35 (SD 17, range 1·5–102) g, accounting for 11·3 (SD 4·8, range 0·5–32) % of the energy intake (Table 2). Quartile points of added sucrose intake were 23, 34, and 44 g/d; and 7·8, 11·0 and 14·6 % of the energy

Table 2. Proportion of energy from naturally occurring and added sucrose by sociodemographic variables*
(Mean values and standard deviations)

			Proportion of energy from added sucrose (% of energy intake)			Proportion of energy from naturally occurring sucrose (% of energy intake)		
Characteristic†	*n*	%	Mean	SD	*P*	Mean	SD	*P*
Sex					0·521			0·789
Girls	237	50	11·5	4·8		2·0	1·2	
Boys	234	50	11·2	4·9		2·0	1·2	
Region					0·145			0·005
Southern Finland	297	63	11·1	4·6		2·1	1·3	
Northern Finland	174	37	11·8	5·2		1·8	1·2	
Maternal age (years)					0·850			0·388
Less than 25	79	17	11·3	4·6		1·8	1·4	
25–29	184	39	11·2	4·8		2·0	1·1	
30 or more	208	44	11·5	5·0		2·0	1·2	
Number of siblings per family					0·002			0·015
None	217	46	11·2	4·9		2·2	1·3	
One	145	31	10·7	4·4		1·9	1·1	
Two or more	94	20	12·3	5·0		1·7	1·1	
Missing information	15	3	14·3	5·2		2·1	1·1	
Maternal professional education					0·115			0·503
No vocational education	35	7	11·3	3·9		1·8	1·1	
Vocational school or course	134	29	12·1	5·4		1·9	1·3	
Upper secondary vocational education	179	38	11·2	4·5		2·0	1·2	
University education	112	24	10·7	4·8		2·1	1·2	
Missing information	11	2	11·6	5·9		2·2	1·1	
Paternal professional education					0·018			0·004
No vocational education	20	4	11·0	4·5		1·6	0·8	
Vocational school or course	176	38	12·1	5·1		1·8	1·2	
Upper secondary vocational education	154	33	11·0	4·6		2·1	1·3	
University education	105	22	10·4	4·5		2·3	1·2	
Missing information	16	3	13·3	5·6		2·2	0·9	
Type of day-care					<0·001			0·943
Home	287	61	12·0	5·1		2·0	1·3	
Small-size day-care outside home	50	11	10·2	3·8		1·9	1·0	
Pre-school or kindergarten	134	28	10·3	4·3		2·0	1·2	
All children	471	100	11·3	4·8		2·0	1·2	

* Differences between means by sociodemographic characteristics were tested with the independent-samples *t* test (for two groups of cases) or ANOVA (for more than two groups of cases).
† At the time of the birth of the child.

Table 3. Intake of energy-yielding nutrients by quartiles of energy from added sucrose*
(Mean values and standard deviations)

	Quartiles of energy from added sucrose									
	I (*n* 117)		II (*n* 118)		III (*n* 118)		IV (*n* 118)			
Nutrient	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value for the difference between all quartiles†	Recommendation‡
Energy (kJ)	5108	972	5146	1014	5225	950	5209	1032	0·235	–
Protein (% of energy intake)	17	3	16	2	15	2	14	2	< 0·001	15
Carbohydrate (% of energy intake)	49	6	52	5	54	5	58	5	< 0·001	55
Total sugar (g)§	69	19	81	21	94	21	107	24	< 0·001	–
Sucrose (g)	22	7	34	8	46	10	61	15	< 0·001	–
Added sucrose (g)	17	6	29	7	39	8	55	15	< 0·001	
Added sucrose (% of energy intake)	5·6	1·8	9·5	1·0	13	1	18	3	< 0·001	Maximum 10
Fibre (g)	10·2	2·9	9·2	2·8	9·5	3·0	8·4	3·0	< 0·001	–
Fat (% of energy intake)	32	6	31	5	31	5	28	4	< 0·001	Maximum 30
Saturated + *trans*-fatty acids (% of energy intake)	13	3	13	3	13	3	12	3	0·067	Maximum 10
MUFA (% of energy intake)	11	3	10	2	10	2	9	2	< 0·001	10–15
PUFA (% of energy intake)	4·3	1·4	3·7	1·0	3·8	1·2	3·4	1·1	< 0·001	5–10
n-3 Fatty acids (% of energy intake)	1·0	0·4	0·8	0·3	0·8	0·3	0·7	0·3	< 0·001	1

* Sum of sucrose added by manufacturers and consumers. For the lowest quartile, energy intake from added sucrose was < 7·85 % and for the highest quartile, energy intake from added sucrose was > 14·5 %.
† Differences between nutrient quartiles were assessed by one-way ANOVA.
‡ Finnish Nutrition Recommendations, which are based on Nordic Nutrition Recommendations.
§ Total sugar = sucrose, fructose, lactose, maltose, galactose.

intake respectively. More than half of the children (59 %; *n* 279) had a mean % of the energy intake of added sucrose below the limit of 10 % of energy intake. In 5 % (*n* 23) of the children, the proportion exceeded 20 % of energy intake; in three children, the proportion exceeded 25 % of energy intake. The average intake of naturally occurring sucrose was 6 (SD 3·8, range 0·3–22) g/d, accounting for 2 (SD 1·2) % of the energy intake (Table 2).

The major contributor to the total sucrose intake was sucrose added by manufacturers, with 82 % of the total sucrose among the children Tables 1 and 2. Naturally occurring sucrose contributed 15 % and sucrose added by consumers 3 % of total sucrose in all children studied. The food groups entitled 'juice drinks', 'yoghurt and cultured milks' and 'chocolate and confectionery' were the main contributors to added sucrose intake followed by 'ice cream and milk desserts'. In all children, fresh fruits and berries contributed most to naturally occurring sucrose (Table 1).

Food and nutrient intake by quartiles of sucrose intake as percentage of energy intake

The consumption of rye bread, porridge, fresh vegetables, cooked potatoes, skimmed milk, hard cheeses and margarine and fat spread decreased across the quartiles of added sucrose as a % of energy intake (Table 4). In contrast, the consumption of sweet bakery, biscuits, breakfast cereals, fruit and berry soups, ice cream, milk desserts, yoghurt, juice drinks, confectionery and chocolate increased across the quartiles. However, the differences close to the mean (quartiles II and III) were not always clear. The difference in food consumption between the lowest and highest quartile of added sucrose ranged from 28 % for breakfast cereals to 381 % for juice drinks.

Fat intake as a % of energy intake was inversely associated with sucrose intake as a % of energy intake (for total sucrose as a % of energy intake, r −0·32; for naturally occurring sucrose as a % of energy intake, r −0·29; for added sucrose as a % of energy intake, r −0·26; $P<0·01$ for all). Intake of protein and fat was highest in the lowest quartile of added sucrose as a % of energy intake and carbohydrate intake in the highest quartile (Table 3). Across the quartiles of added sucrose as a % of energy intake from the lowest to the highest, there was a decrease in intake of all analysed nutrients, except for vitamin A, pyridoxine, vitamin C and Cu (Table 5). The difference in micronutrient intake from food between the lowest and highest quartile of added sucrose was on average 16 %, ranging from 8 % for pyridoxine to 26 % for vitamin D. Among the children, 222 (47 %) used vitamin D supplements during the recording days. There was no difference in the proportion of supplement users between the quartiles. However, intake of vitamin D from supplements was highest in the lowest quartile of sucrose as a % of energy intake, and significantly so when only supplement users were compared (Table 5).

Factors associated with high sucrose intake

Intake of added sucrose as a % of energy intake differed significantly when the following were taken into consideration: number of siblings, paternal professional education, and type of day-care (Table 2). The children who followed a special diet because of milk allergy or lactose intolerance (*n* 58; 12 % of all) had higher added sucrose intake as a % of energy intake compared with others (12·6 *v.* 11·2 % energy intake; $P=0·032$). When all relevant characteristics are included in a linear regression model, type of day-care (home *v.* pre-school

Table 4. Total daily food intake by quartiles of energy from added sucrose*
(Mean values and standard deviations)

	Quartiles of energy from added sucrose (g/d)									*P* value for the difference across the quartiles‡	
	I (*n* 117)		II (*n* 118)		III (*n* 118)		IV (*n* 118)				
Food group	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Q1 – Q4 (% of difference)†	Crude variables	Energy-adjusted § variables
Rye bread	16	18	11	13	12	12	10	14	38	0·033	0·032
Porridge	148	132	126	105	122	114	97	108	34	0·007	0·005
Sweet bakery	2·9	7·8	5·7	9·9	5·0	10	11	21	279	0·015	0·014
Biscuits	4·5	6·6	6·9	8·4	7·8	12	8·9	9·5	98	< 0·001	< 0·001
Breakfast cereals	3·9	7·1	5·8	7·8	5·6	7·6	5·0	8·2	28	0·015	0·014
Vegetables	33	41	24	31	27	33	19	26	42	0·001	0·001
Cooked potatoes	68	71	57	51	49	45	46	44	32	0·051	0·015
Fruit and berry soups	20	35	39	63	38	59	53	69	165	0·004	0·004
Milks, skimmed	159	226	172	200	124	141	91	150	43	0·003	0·004
Hard cheeses	9·5	11	7·8	11	9·0	10	5·8	9·3	39	0·005	0·005
Ice cream	12	16	16	19	22	27	20	24	67	0·014	0·021
Milk desserts	10	25	15	35	19	33	22	38	120	0·004	0·004
Yoghurt	40	56	51	63	62	68	68	77	70	0·008	0·016
Juice drinks	42	54	89	83	131	95	202	160	381	< 0·001	< 0·001
Confectionery	2·5	4·1	5·4	8·5	8·2	12	12	13	380	< 0·001	< 0·001
Chocolate	2·0	5·5	3·6	5·9	4·2	6·6	6·1	11	205	0·002	0·002
Margarine and fat spread	5·3	7·5	4·1	5·1	3·8	5·3	3·4	5·0	36	0·051	0·044

* Sum of sucrose added by manufacturers and consumers. For the lowest quartile, energy intake from added sucrose was < 7·85 % and for the highest quartile, energy intake from added sucrose was > 14·5 %.
† Percentage difference between Q1 and Q4 in micronutrient intake ((Q1 − Q4)/Q1).
‡ Differences between the quartiles were tested with the non-parametric Kruskal–Wallis test.
§ The dietary variables were log-transformed and adjusted for total energy intake using Willett's residual method[19].

Table 5. Intake of selected vitamins and minerals by quartiles of energy from added sucrose*
(Mean values and standard deviations)

	Quartiles of energy from added sucrose										
	I (*n* 117)		II (*n* 118)		III (*n* 118)		IV (*n* 118)				
Nutrient	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*P* value for the difference between all quartiles†	Q1 – Q4 (% of difference)‡	Recommendation§
Vitamin A (μg)	476	700	333	375	467	640	386	609	0·152	19	350
Vitamin D from food (μg)	4·6	2·1	4·2	1·9	3·8	1·6	3·4	2·2	< 0·001	26	7·5
Vitamin D from supplements among users (μg)‖	7·4	3·1	5·6	2·4	6·7	2·9	5·8	2·7	0·006	22	¶
Vitamin D from supplements among all children (μg)	3·8	4·4	2·5	3·3	3·0	3·9	2·8	3·4	0·238	26	¶
Vitamin E (mg)	5·7	2·3	5·1	1·7	5·3	1·8	4·7	1·5	0·001	18	5
Thiamin (mg)	0·9	0·3	0·8	0·3	0·8	0·3	0·7	0·2	< 0·001	22	0·6
Riboflavin (mg)	1·6	0·5	1·5	0·5	1·5	0·4	1·3	0·4	< 0·001	19	0·7
Niacin (mg)	17·3	4·0	16·7	3·9	16·0	3·6	14·2	3·5	< 0·001	18	9
Pyridoxine (mg)	1·2	0·3	1·2	0·3	1·3	0·4	1·3	0·4	0·498	8	0·7
Folate (μg)	131	46	118	34	123	34	111	41	0·001	15	80
Vitamin B_{12} (μg)	4·5	2·7	4·1	1·7	4·0	2·0	3·5	2·3	0·005	22	0·8
Vitamin C (mg)	57	30	54	34	61	38	51	33	0·125	11	30
Ca from food (mg)	949	359	907	325	865	271	777	270	< 0·001	18	600
P (mg)	1104	302	1047	260	1015	228	925	222	< 0·001	16	470
K (mg)	2453	619	2320	565	2276	542	2062	505	< 0·001	16	1800
Mg (mg)	211	49	199	44	199	44	184	44	< 0·001	13	120
Fe (mg)	6·8	1·8	6·6	1·8	6·6	1·9	6·1	1·8	0·030	10	8
Zn (mg)	7·4	1·8	7·2	1·7	6·9	1·7	6·1	1·4	< 0·001	18	6
Cu (mg)	0·9	0·4	0·9	0·5	0·9	0·4	0·8	0·4	0·221	11	0·4
I (μg)	188	60	176	51	169	45	151	41	< 0·001	20	90
Se (μg)	36	10	34	8	33	9	30	8	< 0·001	17	30

* Sum of sucrose added by manufacturers and consumers. For the lowest quartile, energy intake from added sucrose was < 7·85 % and for the highest quartile, energy intake from added sucrose was > 14·5 %.
† Differences between nutrient quartiles were assessed by one-way ANOVA.
‡ Percentage difference between Q1 and Q4 in micronutrient intake ((Q1 − Q4)/Q1).
§ Finnish Nutrition Recommendations, which are based on Nordic Nutrition Recommendations.
‖ Number of users: 60, 53, 52 and 57 in quartile groups I, II, III and IV respectively.
¶ Children < 3 years, 5–6 μg/d all year round or 10 μg/d if on milk-restricted diet; 3-year-olds, 5–6 μg/d during October–March.

or kindergarten) and paternal professional education (vocational school v. academic education) were the strongest determinants of energy intake from added sucrose (Table 6).

Discussion

In the present study, sucrose added by manufacturers accounted for 82 %, naturally occurring sucrose for 15 % and sucrose added by consumers for 3 % of total sucrose in the diet of the children studied. Juice drinks, yoghurt and cultured milks, and chocolate and confectionery were the key contributors to the intake of added sucrose; fresh fruits and berries and fruit and berry juices were the key contributors to the intake of naturally occurring sucrose. A high proportion of added sucrose in the diet had an unfavourable impact on the intake of recommended foods and key nutrients in 3-year-old Finnish children. The type of day-care, paternal professional education and a milk-restricted diet were the strongest determinants of high added sucrose intake.

The majority of added sugars in the diet comprise of sucrose, but fructose, glucose as well as different syrups are also found in this group. Added sucrose calculated in the present study is, therefore, an underestimate of the total amount of added sugars, and is not directly comparable with studies providing estimates for added sugars. However, the consumption of added sucrose reliably predicts the total consumption of added sugars. In a German study[20] the mean contribution of sucrose to total energy intake in children aged 4–6 years was 14 %, of which 15–25 % was assumed to be accounted for by naturally occurring sucrose. In the present study, naturally occurring sucrose contributed 15 % to the total sucrose intake. About half of the children maintained their added sucrose intake below the recommended limit of 10 % energy intake[21]. Since the recommendation applies to all ‘refined sugars’ (not only sucrose), the real proportion of children meeting the recommended limit is smaller.

The average total sucrose intake in the present study was remarkably higher than in the Finnish STRIP-intervention study in the 1990s[12,13] but lower than in Finnish 1–3-year-olds in a survey from the late 1980s[11]. Between-country comparisons regarding the actual intake of added sugars are difficult and partly inaccurate due to discrepancies in the calculation or mode of expression. The proportion of added sugars from total energy in the diet of children was above 10 % of energy intake in studies in Denmark[22], Norway[6], Germany[5], UK[3] and the USA[4,23]. The consequence of this high intake on diet quality is still unclear. The lack of measurement and reported intake precision complicates further analyses on the health effects of high added sugar intake. There might only be a long-term effect, which is difficult to measure, that only appears later on in life when the habit of a high-sucrose diet is established.

As observed by others in cross-sectional surveys[3–5], the effect of added sugar intake on fat intake was inverse, supporting the ‘sugar–fat see-saw phenomenon’. Energy intake did not differ with added sucrose intake, which supports earlier notions that the intake of added sucrose, at least partially, replaces fat intake in children’s diets[6]. Most of the micronutrients were inversely related to added sucrose intake as has also been observed in earlier studies[3,4,6,7]. Among the children in the lowest quartile of added sucrose as a % of energy intake, the mean intake of most nutrients came closest to the recommended levels. However, intakes of most nutrients were adequate regardless of the level of added sucrose intake.

All groups had a mean of vitamin D (from food) and Fe intake that did not meet the Nordic Nutrition Recommendations[21], supporting earlier studies that found a shortfall of these nutrients among Finnish children[24–26]. The nutritional consequences of an increased added sucrose intake are, therefore, most critical for decreased intakes of vitamin D and Fe. The differences in vitamin D and Fe intakes between the four quartiles of added sucrose as a % of energy intake are partly

Table 6. Family characteristics associated with energy intake from added sucrose in linear regression models in 3-year-old children

(β Coefficients and 95 % confidence intervals)

	Energy intake from added sucrose		
	B Coefficient	95 % CI	P
Intercept (α)			< 0·001
Characteristic*			
Number of siblings at the time of birth			
1 *v.* 0	−0·35	−1·35, 0·64	0·484
2 or more *v.* 0	1·06	−0·11, 2·22	0·075
Paternal professional education			
No professional education *v.* academic education	0·51	−1·73, 2·76	0·653
Vocational school or course *v.* academic education	1·59	0·45, 2·73	0·007
Upper secondary vocational *v.* academic education	0·49	−0·68, 1·65	0·415
Type of day-care			
Home *v.* pre-school or kindergarten	1·49	0·48, 2·51	0·004
Small-size day-care outside home *v.* pre-school or kindergarten	−0·09	−1·66, 1·48	0·910
Fit of the model			
r^2 0·060			
$F = 4·075$			
$P < 0·001$			
n 471			

* The model included all covariates presented in the Table.

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explained by a decreased consumption of fortified liquid milk products and margarines (vitamin D) and rye (Fe).

In the present study, the main food groups contributing to sucrose intake were 'juice drinks', 'yoghurt and cultured milks', 'chocolate and confectionery' and 'ice cream and milk desserts'. These are the same as have been found in other child populations[5,6,13,22]. For vegetables there was a 42 % decrease in intake from the low to the high quartiles of added sucrose as a % of energy intake. Øverby *et al.* [6] found a very similar 45 % decrease among Norwegian 4-year-old children. The consequence of decreasing vegetable intake is critical, as Finnish children are known to consume remarkably low amounts of vegetables and fruits[27].

Having a milk-restricted diet seems to endow a Finnish 3-year-old child with greater odds for a high added sucrose intake. A substantial proportion of changes in the added sucrose intake by children can be attributed to changes in their beverage consumption patterns. Inverse associations between added sucrose intake and riboflavin and Ca point to a reduction in milk consumption, as shown earlier as well[7]. It is an enormous challenge to replace milk in a child's diet with a drink providing similar nutrients without any increase in added sucrose intake.

It is valuable to speculate why the added sucrose intake was higher in children cared for at home. A snack-dominated meal pattern might be higher when cared for at home. Snacks appear to be associated with higher sucrose intake and lower intake of micronutrients[28]. The observed increased sucrose intake during weekends is another facet of the same issue. Compared with the present results, the difference in sucrose intake between the weekends and weekdays was even higher in 3–5-year-old Swedish children[29]. The difference may be due to differences in meal habits at home compared with day-care, or to different meal habits during weekends as compared with weekdays. In addition, there is an established tradition of 'Saturday sweets' for children in both Finnish and Swedish families.

Interestingly, we found an association between paternal, but not maternal, education and the intake of both naturally occurring and added sucrose by 3-year-old children. Paternal, but also maternal, education determined the sucrose intake in an earlier Finnish study[13]. An association between mothers', but not fathers', education and 4-year-olds' intake of sugar was found in an earlier Norwegian study[6]. Overall, the impact of the paternal education on the eating pattern and dietary quality in the offspring is not as widely studied as is maternal education. It is important to note that naturally occurring and added sucrose related differently to the background variables. An overall, high intake of naturally occurring sucrose seems to be more related to better overall dietary quality than a high intake of added sucrose, which is clearly explained by their main dietary sources. Including sugars which occur naturally in fruit juices within the group of added sugars, as in the WHO statement[30], is questionable when estimating an overall effect of added sucrose on the dietary quality.

Certain limitations of the present study should be considered when interpreting the findings. The 3 d food records give an accurate estimate of usual intake for most frequently used foods such as porridge, milk and bread spreads. However, for occasionally used foods, many more days are required. The same applies to nutrients. In the present study with 3 d of diet records, the correlation coefficients between observed and true intake of nutrients ranged from 0·16 for vitamin A to 0·98 for Fe, being 0·65 for sucrose and 0·61 for added sucrose (M Erkkola, unpublished results; for the method, see Nelson *et al.* [31]). A 7 d diet record would have been needed to achieve $r \geq 0{\cdot}8$ (18 d for $r \geq 0{\cdot}90$) between observed and true sucrose intake. The 'Saturday sweets' habit contributes to daily variation in sucrose intake, and, consequently, a child's average sucrose intake could differ according to the type of days recorded. The families were advised to record two consecutive weekdays and one weekend day in order to obtain the influence of day of the week in sucrose intake. However, the small number of records may provide a standard deviation that is greatly overestimated. Furthermore, measurements of associations are substantially weakened.

We did not exclude potential under-reporters from the analysis. Diet during childhood tends to be highly variable from day to day, and the identification of reliable under-reporters is difficult. Ideally, we would have included anthropometric data, so that we had something against which to check reliability of reporting. However, data on children's weight and height were not available. One fourth of boys (26 %) and girls (25 %) had their average daily energy intake below the FAO, WHO & United Nations University energy requirements computed for moderate levels of physical activity (2–3-year olds: boys 4·7 and girls 4·4 MJ/d)[32]. Based on within- and between-individual variability of energy among the subjects in the present study, 5 d of diet records are needed to achieve $r \geq 0{\cdot}8$ (12 d for $r \geq 0{\cdot}9$) between observed and true energy intake. In the present study, diet was recorded for 3 d, so $r = 0{\cdot}72$.

In a Norwegian validation study among 2-year-old children, the food items under-reported were typically sucrose-rich foods such as cake, soft drinks and sweets, while the over-reported foods were more healthy foods such as bread, fruit and potatoes[33]. In the present study, this could imply that the subjects in the top quartile of the added sucrose distribution were more likely to under-report their consumption of sucrose-rich foods than subjects in other quartiles. The true association could then be obscured and the influence of the consumption of added sucrose on intake of nutrients would be stronger than that observed.

Although the present cohort carries increased HLA-conferred susceptibility to type 1 diabetes, the children are expected to be representative of the general population of young Finnish children. Almost 20 % of the Finnish population have increased HLA-conferred predisposition to type 1 diabetes, while only 3–4 % of those actually progress to clinical disease[34]. The distribution of subjects by sociodemographic characteristics was comparable with the Finnish 3-year-olds in general[35].

In conclusion, the primary rationale for the recommendation to reduce the intake of refined sugars, to ensure adequate intakes of Fe and other essential nutrients as well as dietary fibre, seems reasonable. The recommendation for increased use of vegetables and whole-grain food products should also be promoted, not only to prevent extra added sucrose intake, but as an overall base for preventing obesity and chronic diseases.

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