

Dietary Intake of 10- to 16-Year-Old Children and Adolescents in Central and Northern Europe and Association with the Incidence of Type 1 Diabetes

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Key Words

Type 1 diabetes · Type 1 diabetes incidence · Type 1 diabetes, risk factors · Adolescents · Dietary intake · Nutrients · Food

Abstract

Background/Aims: The highest incidence of type 1 diabetes is among 10- to 15-year-old adolescents. The aim of this study was to investigate a possible relationship between the dietary intake of this group and the incidence of type 1 diabetes. **Methods:** Dietary intake data of 10- to 16-year-old adolescents ($n = 4,701$) from 11 European countries and the incidence rates of type 1 diabetes were used to examine the relation between food and the disease. **Results:** The incidence of type 1 diabetes correlated with the consumption of total fat ($r = 0.674$; $p = 0.023$), saturated fatty acids ($r = 0.714$; $p = 0.047$) and the intake of fruits and vegetables ($r = 0.786$; $p = 0.036$). Fruit intake or vegetable intake alone did not correlate with the incidence. Cow's milk and animal product consumption correlated with the incidence when Icelandic data were excluded ($r = 0.829$; $p = 0.042$ and $r = 0.999$; $p = 0.001$). A negative correlation of borderline significance was found between sugar intake and the incidence of type 1 diabetes ($r = -0.721$; $p = 0.068$). **Conclusion:** The results indicate for the first time that an adolescent's diet high in fat and fruits and vegetables is associated with an

increased risk of type 1 diabetes. Fruit or vegetable intake separately was not associated with type 1 diabetes. It is important to characterize and minimize diabetogenic factors in fruits and vegetables as the general health benefits of a diet rich in fruits and vegetables are well known and such a diet is therefore recommended. This study supports previous research about the importance of cow's milk and animal products in the aetiology of type 1 diabetes.

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Introduction

A multifactorial aetiology with hereditary and environmental components has been proposed in type 1 diabetes, where environmental factors may play a leading role, as only a minority of genetically predisposed people develop type 1 diabetes, whereas the majority (>90) does not [1]. These proportions may differ between countries, depending on environmental circumstances, such as food. The wide range of the incidence of type 1 diabetes within Central and Northern European countries (e.g., Switzerland, 7.9/100,000 persons per year, and Finland, 40.2/100,000 persons per year [2]) and steadily increasing incidence rates, which have been observed since the 1970s [3], can only be explained by an increase in exposure to potential risk factors [3] or by a decrease in exposure to protective

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factors as the genetic predisposition will not have changed during the last 30 years. Many environmental factors have been suggested to play a role in the type 1 diabetes pathogenesis [4]. The 'gross domestic product' (GDP), as a measure of wealth and living standard, correlates positively with the incidence of type 1 diabetes [5, 6].

Results from epidemiological studies and ecological and animal research have indicated possible connections between the intake of certain food items or nutrients and the incidence of type 1 diabetes. The intake of animal food [6], cow's milk [7–12], meat [6, 13] and nitrate [14–16] has been positively related to the incidence of type 1 diabetes; the intake of fish oil [17], vitamin E [18], vitamin D [19, 20] and zinc [21] has been related negatively to the disease. The most thoroughly investigated food, i.e. cow's milk, has been found to vary in its diabetogenicity depending on its protein composition [22, 23].

Many observed relationships between nutrients and the incidence of type 1 diabetes are based on the availability of food or a nutrient rather than the actual intake of a certain group of the population. Food supply, per capita intake and balance sheet data overestimate real intakes [6] and furthermore cannot be used to estimate the dietary intake of a certain group, such as children and adolescents. It is important for the further exploration of dietary risk factors of type 1 diabetes to study the dietary intake of adolescents as this age group has the highest incidence of type 1 diabetes [24]. It is of special interest for the investigation of risk factors to include data from countries with different incidences of type 1 diabetes, despite geographic, socioeconomic and genetic similarities, e.g., the Nordic countries, where Iceland has a considerably lower incidence of type 1 diabetes compared with Finland, Norway and Sweden [2]. The dietary intake of children and adolescents in this age group has never been linked with the incidence of type 1 diabetes.

The aim of this study was to investigate the food and nutrient intake of 10- to 16-year-olds by using available data of 4,701 children and adolescents of this age and the incidence of type 1 diabetes in 11 Central and North European countries. A further aim was to determine or reconfirm the risk and protective factors in the European population that have been suggested in previous studies. The countries compared have similar living standards, expressed as GDP [25]. Despite similar western lifestyles, there is considerable variation in the incidence of type 1 diabetes between these countries that might be attributed to differences in the food intake of children and adolescents in the population studied.

Subjects and Methods

Data from 11 European countries were used for calculations: Austria, Belgium, Denmark, Finland, Germany, Iceland, Ireland, Northern Ireland, Norway, Sweden and Switzerland. It is important for the interpretation of the results that the available data of food consumption, nutrient intake and incidence of type 1 diabetes are of a high quality. Nine of the dietary surveys investigated more than 200 individuals and two more than 90, utilizing well-trained researchers employing accepted dietary intake methods [26–39]. The standardized, average annual incidence rates of childhood diabetes (mostly between 1990 and 1994) in the countries were derived from the EURODIAB ACE Study Group, whose centres have to fulfil well-defined quality criteria [2]. Irish data was derived from Roche et al. [24]. The incidence rates for boys and girls separately were derived from Karvonen et al. [24], except for Island and Switzerland, where separate data have not been published. The standardized, average annual incidence rates of childhood diabetes as well as the incidence for boys and girls were used for calculations.

The food and nutrient intake data were obtained from scientific publications and national nutrition reports. The intake data were from a sample of the entire nation at the relevant age or covered regional areas. Dietary intake was described based on the intake of food items/food groups and single nutrients (table 1). The daily intakes were expressed as means and medians. The dietary intake data according to sex as well as the arithmetic mean calculated from girls' and boys' intakes were used for the calculations. Seven investigations used dietary records 3–7 days in length to collect the dietary data; two used validated food frequency questionnaires; one used a 48-hour recall in combination with an open-ended interview, and one investigator used a 24-hour recall (see table 2). The methods used are well known and deemed to be valid and reliable, so the dietary survey methods give comparable results on the intake of food and nutrients for the groups [41, 42].

The data in the EURODIAB ACE Study Group are collected prospectively by a physician on the basis of the clinical diagnosis of idiopathic diabetes and give the annual incidence of type 1 diabetes per 100,000 persons, aged 0–14 years. These diabetes registers provide data from several counties/regions or from the entire nation [2].

The food and nutrient intake data were tested for correlation with the incidence of type 1 diabetes. Calculations were carried out when the intake data were available for at least five countries. Spearman's nonparametric correlation was used to express the relation between a certain nutrient or food item and the incidence of type 1 diabetes. $p < 0.05$ was regarded as statistically significant.

Results

Great differences in the daily food or nutrient intake of 10- to 16-year-olds (mean \pm SD: 12.7 \pm 0.7 years) could be observed between the countries of Europe with similar living standards. The lowest and highest intakes of some food items and nutrients and the corresponding countries are shown in table 3.

The daily intake of total fat of 10- to 16-year-old children (fig. 1a), saturated fatty acids (SFA) (fig. 1b) and

Table 1. Intake of food items and nutrients used for calculation

Food items	Energy and energy-giving nutrients	Vitamins	Trace element
Bread and cereal products	total energy	vitamin E	zinc
Milk and milk products	total fat	vitamin D	
Eggs	total protein		
Meat and meat products	total carbohydrates		
Vegetables and potatoes	percent of fat		
Fruits	percent of protein		
Fish and fish products	percent of carbohydrates		
	dietary fibre		
	total sugar		
	percent of sugar		
	total SFA		
	total monounsaturated fatty acids		
	total polyunsaturated fatty acids		

Table 2. Characteristics of dietary intake data

Country	Subjects	Method of dietary assessment	References
Iceland	386	24-hour recall and FFQ amount evaluated	26
Sweden	97	7 days' dietary history	27
Norway	1,705	FFQ	28
Denmark	334	7 days' estimated dietary record	29
Finland	324	48-hour recall	30
Austria	400	7 days' weighed food record	31
Ireland	207	7 days' dietary history	32
Northern Ireland	509	open end interview, diet history method	33–34
Belgium	401	24-hour estimated food record	35
Germany	92	3-day weighed record	36–38
Switzerland	246	3-day weighed record	39

Table 3. Range of food, energy and nutrient intake

Food item, nutrient or energy	Lowest daily intake		Highest daily intake	
	country	amount	country	amount
Milk, g	Switzerland	341	Iceland	917
Vegetables and potatoes, g	Iceland	117	Finland	224
Fruits and berries, g	Iceland	74	Norway	283
Fish, g	Germany	0	Norway	39
Energy, kcal	Switzerland	2,075	Norway	3,086
Protein, g	Germany	64	Norway	103
Carbohydrates, g	Germany	240	Norway	426
Fat, g	Switzerland	86	Northern Ireland	103
SFA, g	Belgium	35.5	Finland	48
Sugar, % of total energy	Finland	9.7	Iceland	15.3
Vitamin E, mg	Denmark, Sweden	7	Austria	10.9

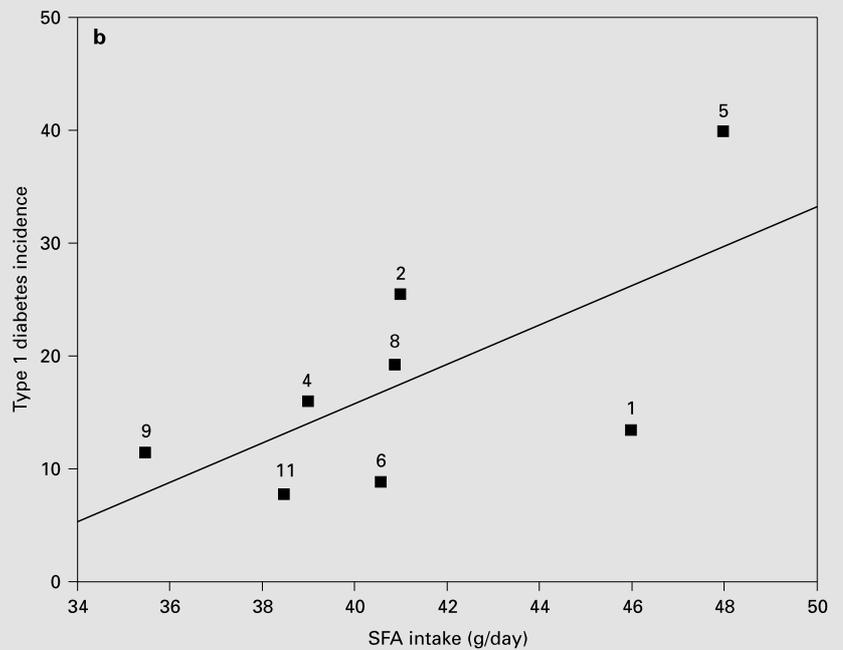
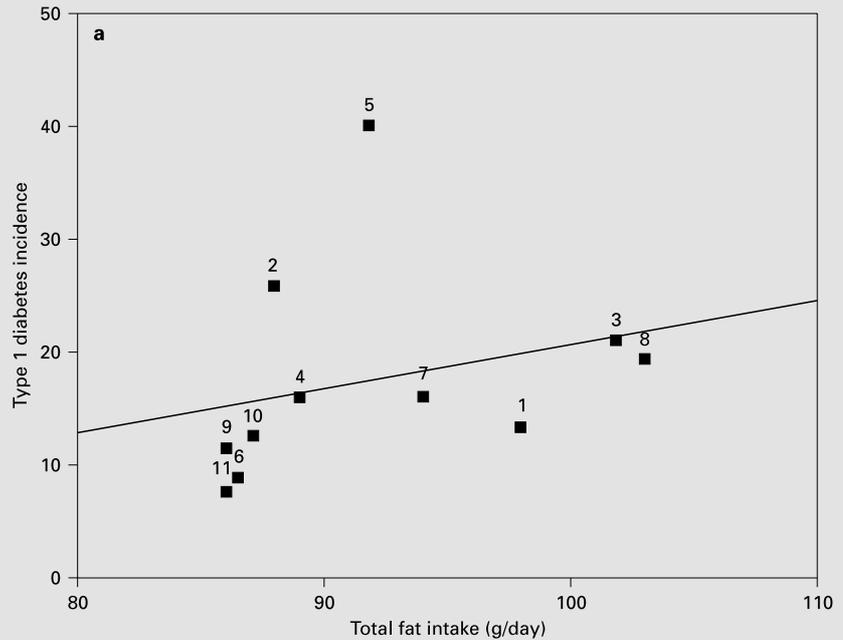


Fig. 1. a Association between standardized incidence rate (per 100,000 person-years) and total fat intake: $r = 0.674$, $p = 0.023$; total $n = 4,701$ children, number of countries = 11. **b** Association between standardized incidence rate (per 100,000 person-years) and SFA intake: $r = 0.714$, $p = 0.047$; total $n = 2,697$ children, number of countries = 8. 1 = Iceland; 2 = Sweden; 3 = Norway; 4 = Denmark; 5 = Finland; 6 = Austria; 7 = Ireland; 8 = Northern Ireland; 9 = Belgium; 10 = Germany; 11 = Switzerland.

pooled 'fruit and vegetable' consumption (fig. 2) correlated positively with the incidence of type 1 diabetes. Fruit intake or vegetable intake alone did not correlate with the incidence. A significant positive correlation between daily milk intake (fig. 3a) or daily intake of animal

products (milk, meat and eggs, fig. 3b) and the incidence of type 1 diabetes could be seen only when the Icelandic data were excluded from the calculations.

A negative correlation of borderline significance was found between sugar intake as a percentage of total energy

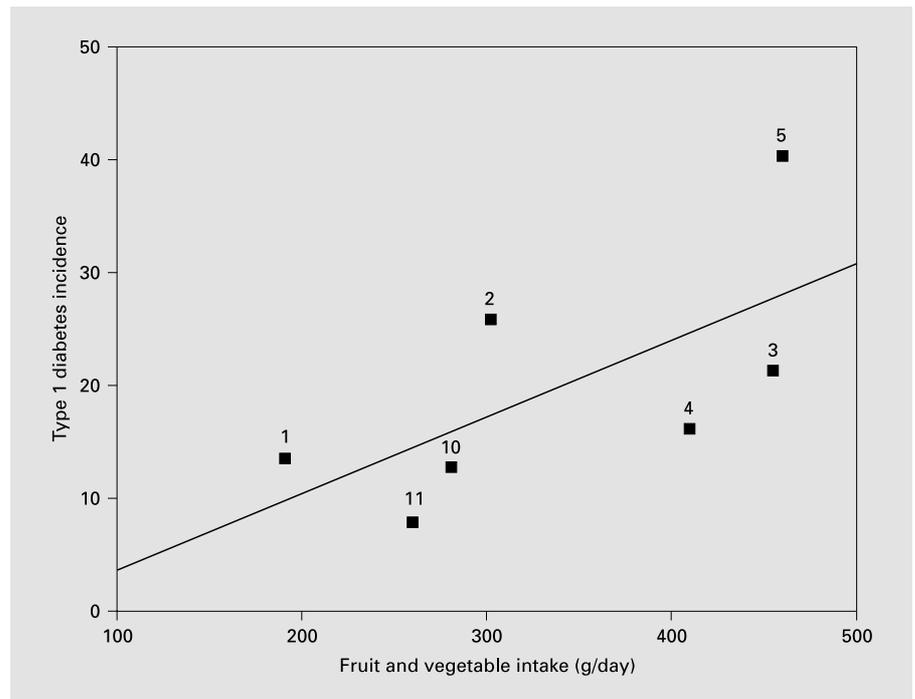


Fig. 2. Association between standardized incidence rate (per 100,000 person-years) and consumption of fruits and vegetables: $r = 0.786$, $p = 0.036$; total $n = 3,184$ children, number of countries = 7. Numbers are explained in legend to figure 1.

and the incidence of type 1 diabetes (fig. 4). No significant correlations between the incidence of type 1 diabetes and the consumption of cereals, energy intake, protein intake or the intake of the fat-soluble vitamins D and E could be seen.

When the data were analyzed separately for boys and girls, similar results were obtained (table 4), although some correlations were gender-specific. The correlation between milk intake and incidence of the disease was seen in both genders; the same could be observed for milk, meat and egg intake together. The fruit and vegetable intake correlated with the incidence in both genders, although this was of borderline significance in boys. The negative association between percent sugar intake and diabetes was only seen in girls. A higher total fat intake was only associated with a higher incidence in boys. SFA intake did not correlate with the incidence of the disease.

Discussion

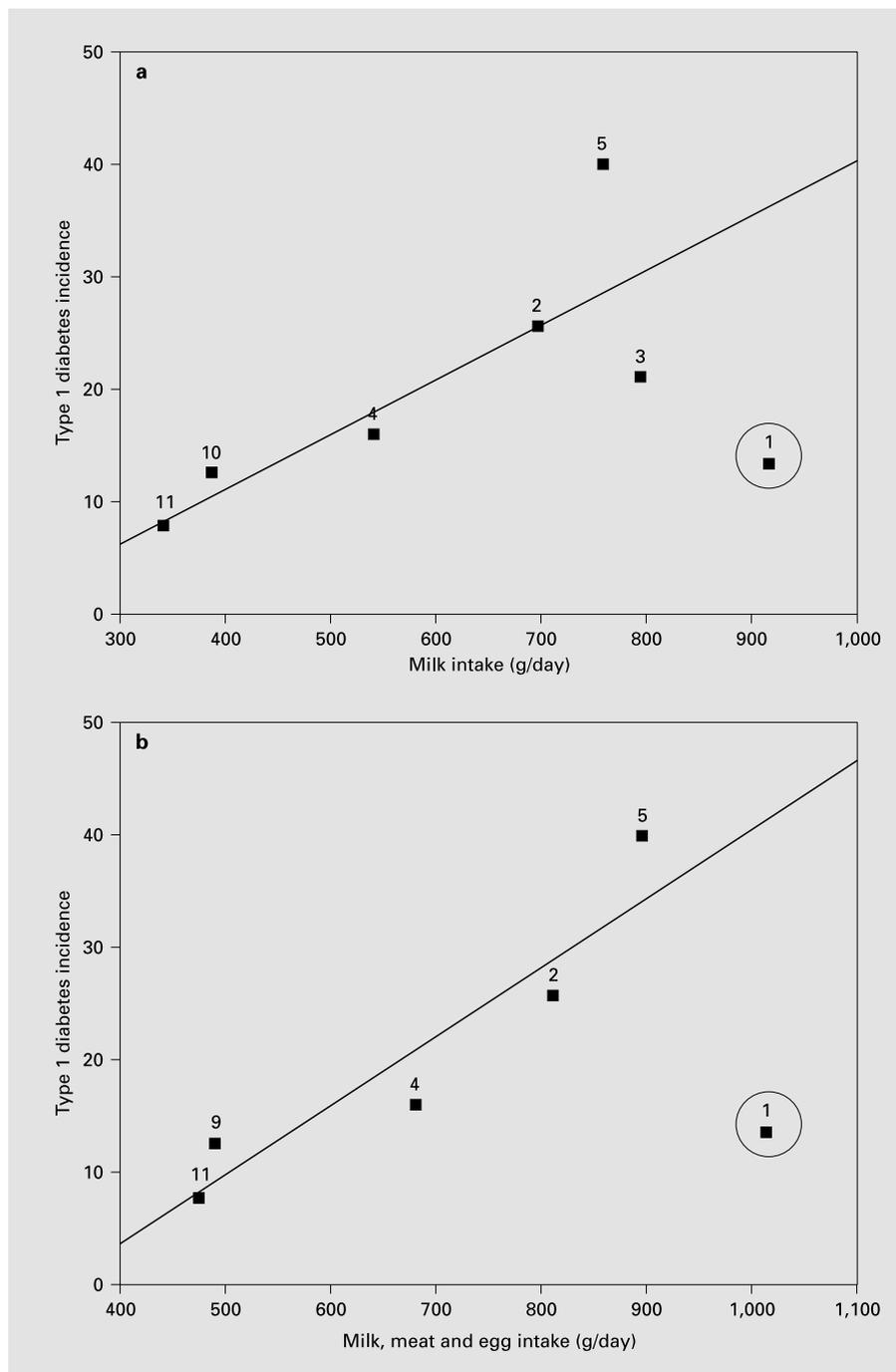
As expected, there were greater differences in food consumption and vitamin intake than in energy and macronutrient intake. The intakes of nutrients were within the normal range. Therefore, the variation of the food groups reveals that the nutrient intakes are achieved by different

dietary patterns. The fruit and vegetable intake in Iceland is below 200 g a day; the fish intake in Germany in this age group is close to zero.

The milk intake of children was significantly associated with the incidence of type 1 diabetes when the Icelandic data were excluded from the calculations. The exclusion of the Icelandic data was due to the earlier reported lower diabetogenicity of Icelandic cow's milk compared to milk from other countries due to its different protein composition [22, 23]. In contrast to many other studies in Europe, a study in Iceland [22] did not find a difference in dairy consumption in infancy between diabetic children and healthy controls. In other countries the consumption of dairy products in childhood has repeatedly been related to type 1 diabetes [7–12].

The intake of animal products (milk, meat, eggs) taken together was significantly related to the incidence of type 1 diabetes (without Icelandic data). This confirms the results from Muntoni et al. [6], who recently found a positive correlation between the availability of animal products and the risk of type 1 diabetes, comparing data from FAO balance sheets with the incidence of type 1 diabetes in 34 countries.

A positive correlation between the combined consumption of fruits and vegetables and the incidence of type 1 diabetes has not been described before. It might



reflect the fact that certain fruits and vegetables contain potent diabetogenic compounds. These sorts of fruits and vegetables might provide varying amounts of diabetogenic compounds in the diet of the adolescents, explaining the observed relation. Very recent research suggests that virus-infected vegetables provide a dietary source of a dia-

betogenic toxin [43]. Additionally, fruits and vegetables can contribute considerably to the nitrate intake, which has been discussed as a diabetogenic factor [14–16]. It has been suggested that these components initiate or hasten the pathogenesis process via several mechanisms, e.g., beta cell stress or immune response activation. Fruit

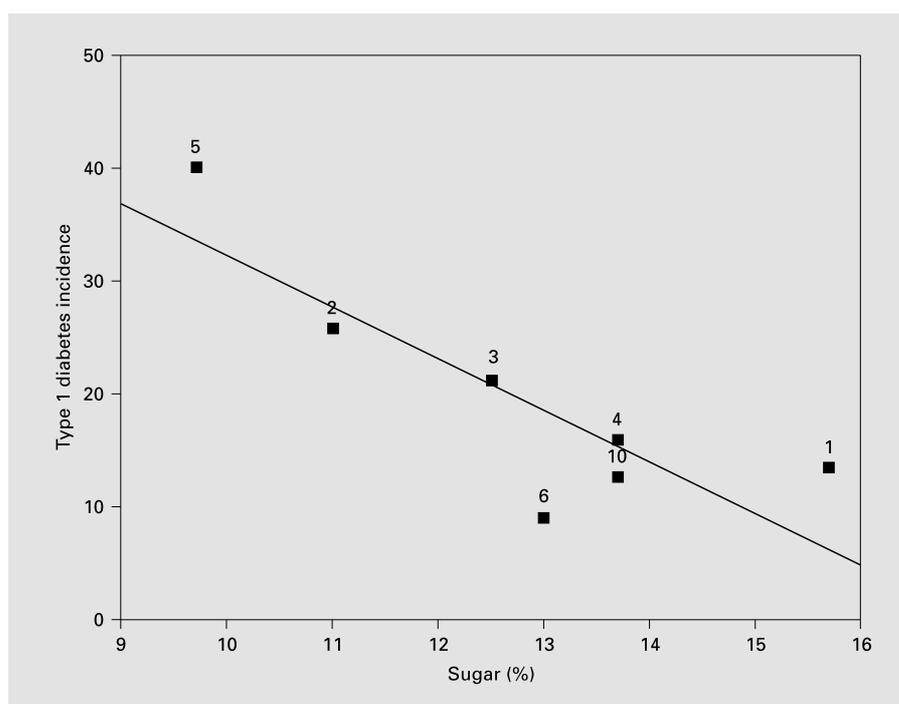


Fig. 4. Association between standardized incidence rate (per 100,000 person-years) and percent of sugar intake: $r = -0.721$, $p = 0.068$; total $n = 3,338$ children, number of countries = 7. Numbers are explained in legend to figure 1.

intake or vegetable intake separately was not significantly associated with type 1 diabetes. It is important to characterize diabetogenic factors in fruits and vegetables to modulate and minimize their amount in this food group as the general health benefits associated with a diet rich in fruits and vegetables are well known, and such a diet is therefore recommended [44].

A significantly positive correlation between fat intake and an even greater correlation between SFA intake and the incidence of type 1 diabetes were observed. This association can be explained by the fact that a high consumption of whole milk and meat goes along with high-fat and SFA intake. Also a more causative role of high-fat intake is possible, as fat micelles, which emerge during fat digestion, facilitate the absorption of whole dietary proteins, which could act as dietary triggers of the beta cell destruction [45]. Results from animal research suggest that the 'immunological potential' of cow's milk depends on its fat content. Increasing fat content in milk resulted in increased anaphylactic reactions in mice, which had been sensitized with various types of bovine milk before [46]. When the data were analyzed separately by gender, an association between fat intake and diabetes incidence could only be observed in boys, but not in girls. Other results, i.e. the results for milk as well as meat and egg, were similar for the genders, but the association between

Table 4. Correlations between standardized incidence rate (per 100,000 person-years) and dietary intake in boys and girls

	Boys		Girls	
	rho	p value	rho	p value
Total fat intake (n = 11)	0.629	0.038	0.297	0.375
SFA intake (n = 8)	0.635	0.091	-0.216	0.608
Fruit and vegetable intake (n = 7)	0.714	0.071	0.786	0.036
Milk intake (n = 6)	0.829	0.042	0.943	0.005
Milk, meat and egg intake (n = 6)	0.829	0.042	0.943	0.005
Sugar intake in % (n = 5)	-0.700	0.188	-0.900	0.037

fruit and vegetable intake and the incidence of type 1 diabetes was of borderline significance in boys.

The incidence of type 1 diabetes in Finland is higher than would be predicted on the basis of total fat, SFA and pooled 'fruit and vegetable' consumption according to the correlations shown in figures 1a, b and 2. This is especially true for total fat intake, which would predict an incidence of less than 20; the actual incidence in Finland is more than 40 (fig. 1a). In contrast, the Icelandic incidence of type 1 diabetes is much lower than would be expected, based on the SFA intake. The SFA intake greatly overestimates the incidence of type 1 diabetes in Iceland (esti-

mated 26/100,000 person-years vs. the actual 13.5/100,000 person-years, fig. 1b).

Unexpectedly, sugar intake (expressed as a percentage of total energy) was negatively correlated with the incidence of type 1 diabetes. High sugar intake might reflect an avoidance of foods high in fat, which is significantly associated with a higher risk. When analyzed separately, this association was significant for girls, but not for boys. The reason for the gender differences observed is not known, but might be related to hormonal differences.

No protective roles of high vitamin D and vitamin E intake in infancy [18–20] were observed in this study of 10- to 16-year-old children and adolescents. It is possible that the protective properties of these nutrients might only work earlier or in infancy or even during fetal life.

Caution is needed in the interpretation of an ecological analysis, as used in the present study. Different lifestyles and living standards (e.g., infection, microbial exposure, household size) might influence the type 1 diabetes incidence rate. In our study the countries investigated have similar living standards expressed as GDP [25] and have not faced dramatic changes in life style compared to, for example, countries of the former eastern block, which were not included in this analysis. The similarity in the living standard between the populations studied might be more important than increasing the number of cases. This has the disadvantage of there being few cases for the correlation analysis. In the present study individual food intake values were not available for all countries, but the main results were most likely not affected.

It could also be suggested that the association between nutrition and incidence found could be a marker of other disease-related factors rather than a causal association. It is difficult to exclude this problem in epidemiological and ecological research. However, pathophysiological mechanisms have been proposed for the associations observed in the literature; thus causes of possible interactions between disease and nutrients remain less speculative. The dietary intake data used in the present study were collected with both pro- and retrospective methods. It was

not possible to find dietary intake data of European countries which have used only one type of assessment. But it is unlikely that the differences found in food intake and associations between food and type 1 diabetes are methodological artefacts, because the methods are judged valid for the measurement of dietary intake of different groups [41, 42]. No systematical over- or underestimation of pro- or retrospective methods could be observed. A comparison of techniques for estimating nutrient intake showed that estimates of group mean intake from the 24-hour recall and 3-day records were similar in both women and men with differences of less than 10% for most nutrients [47]. Similarly, food frequency questionnaires showed good agreement with food intakes of a group with a reference method (i.e., 7-day weighed food record) [41]. Comprehensive reviews of dietary surveys indicate that there is no perfect method for assessing dietary intake in children, although it is important to refine and improve upon those methods that work well, which is essential for further research, policy decisions and nutrition interventions [48]. It is of considerable importance to use the available data collected with the most accepted methods for large groups to study a possible relation between food intake and health. It is possible to obtain valid surveys and information on diet and diseases without accurate data assessment at the individual level, and data at the group level is sufficient for examination for epidemiological and ecological research [49].

Overall, the results of this study suggest that there is an association between food consumption or nutrient intake in adolescents and the incidence of type 1 diabetes. As certain nutrients (e.g., vitamin D, E), which were reported to be protective in previous studies, showed no association with the incidence of type 1 diabetes in this research, it is assumed that these factors might work in an age-dependent way. It is concluded that a diet of 10- to 16-year-olds high in fat, especially saturated fat, and fruits and vegetables, is associated with an increased risk of type 1 diabetes.

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