Glycemic index in the diet of European outpatients with type 1 diabetes: relations to glycated hemoglobin and serum lipids[1–3]

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ABSTRACT

Background: Little is known about the variation of the glycemic index (GI) in the diet of European outpatients with type 1 diabetes and how the GI of a commonly consumed diet is associated with metabolic control.

Objective: The present study examined the calculated dietary GI of European outpatients with type 1 diabetes for possible relations to glycated hemoglobin (Hb A_{1c}) and serum lipid concentrations.

Design: The relation of the GI (calculated from a 3-d dietary record) to Hb A_{1c}, serum cholesterol (total, LDL, and HDL), and fasting triacylglycerol was analyzed in 2810 people with type 1 diabetes from the EURODIAB Complications Study.

Results: The GI was independently related to Hb A_{1c} ($P = 0.0001$). Compared with the highest GI quartile (median GI: 89), adjusted Hb A_{1c} in the lowest GI quartile (median GI: 75) was 11% lower in patients from southern European centers and 6% lower in patients from northern, western, and eastern European centers. Of the serum lipids, only the HDL cholesterol in patients from these European centers was independently related to the GI ($P = 0.002$). In southern European centers, the consumption of pasta, temperate-climate fruit, white bread, and potatoes largely determined the patients' dietary GI, whereas in the northern, western, and eastern European centers, consumption of bread, potatoes, and temperate-climate fruit was most relevant.

Conclusions: This study in European patients with type 1 diabetes showed that a lower dietary GI is related to lower Hb A_{1c} concentrations, independently of fiber intake. The consumption of bread and pasta had the biggest effect on the overall dietary GI of European outpatients. *Am J Clin Nutr* 2001;73:574–81.

KEY WORDS Glycemic index, type 1 diabetes, glycated hemoglobin, Hb A_{1c}, LDL cholesterol, HDL cholesterol, triacylglycerol, Europe, carbohydrate sources

INTRODUCTION

In the 1980s the glycemic index (GI), a means of ranking carbohydrate-supplying foods according to their glycemic effects, was proposed to help patients with diabetes to minimize their postprandial rise in blood glucose (1–5). Since then, several crossover studies in people with diabetes have shown that medium-term consumption (2–12 wk) of a diet with a low GI was associated with sustained modest improvements in glycemic control (6–12). Furthermore, some clinical studies suggested that the serum lipid profile benefited with consumption of a low-GI diet for a longer period (7–12). However, few medium-term studies included persons with type 1 diabetes (7, 8, 13).

The implementation of the GI concept has been controversial. Some authors have criticized the system as being too complex for most patients with diabetes, claiming that its application may eventually limit food choices (14, 15). Other groups believe that a lower GI can be achieved by only a few substitutions and that incorporating low-GI foods into the diet increases the variety of foods consumed (16–18). From a clinical viewpoint, little is known about the extent to which a diet commonly consumed by European outpatients with type 1 diabetes varies in its GI and how diets with a lower or a higher GI are realized in everyday life.

Food selection in the Mediterranean countries traditionally differs from that in other European countries (19, 20). Although these differences in food consumption patterns have lessened in the past decades (21, 22), we showed that persons with type 1 diabetes from the southern European EURODIAB centers still maintained some features characteristic of a traditional Mediterranean diet (23). In addition, we observed a beneficial effect of dietary fiber on glycated hemoglobin (Hb A_{1c}) that was particularly pronounced in patients from southern European centers (24). Thus, potential associations between the GI of the diet consumed by people with type 1 diabetes and measures of metabolic control may also be different for persons from the southern European centers.

This study examined the calculated dietary GI of European outpatients with type 1 diabetes for possible relations to Hb A_{1c}

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and serum lipid concentrations. Furthermore, we determined whether the potential associations differed between persons from southern European centers and people from northern, western, and eastern European centers.

SUBJECTS AND METHODS

Subjects

The EURODIAB IDDM Complications Study was a cross-sectional, clinic-based study that included 3250 individuals with type 1 diabetes from 31 European centers. The study measured the prevalence of diabetic complications and examined established and putative risk factors associated with these complications. In each center a random sample of individuals aged 15–60 y with type 1 diabetes was selected from defined strata in relation to sex, age, and the duration of diabetes. Details on the patient selection procedure were published previously (25). Type 1 diabetes was defined as diabetes diagnosed before the age of 36 y with a continous need for insulin 1 y after diagnosis (25).

In total, 3002 of the 3250 patients with type 1 diabetes provided adequate 3-d dietary records. Of these, 38 patients had missing demographic data. Furthermore, data from one center (96 persons) were excluded because only 18% of the patients from that center had recorded plausible energy intakes (23). A ratio of reported energy intake to estimated basic metabolic rate >1.06 in each individual's actual diet was considered plausible during the 3 d of recording (26, 27). Overall, 89% of the 2868 patients with type 1 diabetes included in all subsequent nutritional analyses reported a plausible energy intake (28).

For the present analysis, patients taking lipid-lowering medication, oral hypoglycemic agents, or both in addition to insulin (n = 58) were excluded. Because some Hb A_{1c} concentrations were missing from all centers, only 2054 patients with type 1 diabetes could be included in the study of the relation between GI and Hb A_{1c}. Models of total cholesterol were based on measurements in 2746 patients and analysis for HDL cholesterol included 2708 subjects. Because nonfasting blood samples were collected in 8 of the 31 study centers, models for triacylglycerols were based on only 1851 patients. Subsequently, LDL-cholesterol data could be calculated for a total of 1801 patients with type 1 diabetes. The study conformed with the Declaration of Helsinki, and the study protocol was approved by local ethical committees in each center. Informed consent was given by all patients with type 1 diabetes.

Methods

Nutritional intake was determined by a standardized 3-d dietary record. Details of the specific assessment procedure are presented elsewhere (23, 26). In brief, the dietitian at each local center instructed each patient with type 1 diabetes to record detailed descriptions of all foods and beverages consumed (ingredients, methods of preparation, and whether the food was cooked) on 2 workdays and a Sunday. The patients were asked to give quantities by using weights or household measures from a standardized list of portion sizes and household measures provided. When completed, the local dietitian carefully checked the diary together with the patient to ensure completeness (eg, whether all spreads and dressings were recorded) and quantification of all items. The diaries were then coded by the dietitian with use of a centrally prepared EURODIAB food list and were rechecked and computed at the Nutrition Co-Ordinating Center in Düsseldorf, Germany. Dietary records were analyzed for intakes of fat (total fat, saturated fat, monounsaturated fat, and polyunsaturated fat) and cholesterol, protein, carbohydrate, fiber, alcohol and energy.

For the present analysis, published GIs (29–33) were appended to the previously used EURODIAB nutrient database. White bread is the standard food on which all GIs are based. Values in the literature relating to the glucose standard were transformed into GIs relating to white bread by multiplying the indexes by 1.42 (32). GIs of foods for which no published data were available were estimated as suggested by Wolever et al (12): jam and ketchup were assigned the GI of sucrose (GI: 89), dairy products were given the mean GI of whole and skim milk (GI: 48), and fruit was assigned an estimate based on the GIs of apples, oranges, raisins, or bananas. Because few data are available for vegetables (one would have to eat large amounts of vegetables to ingest 50 g carbohydrate), we used the mean of published indexes for carrots, green peas, and pumpkin (GI: 92) (32). The GI of the individual's diet was determined by multiplying the carbohydrate content (in g) of each food consumed during the day by the food's GI. The sum of these products was then divided by the total daily carbohydrate intake (34). To determine the food selection pattern, median carbohydrate intake was calculated for different carbohydrate sources.

Hb A_{1c} concentrations were measured in a central laboratory in London (Royal London Hospital) by an enzyme immunoassay, with a notably low reference range of 2.9–4.8% (35). Total cholesterol, HDL cholesterol, and triacylglycerol were determined by using standard enzymatic methods (Guy's Hospital Medical School, London). LDL-cholesterol concentrations were calculated with use of the Friedewald equation (36). A questionnaire completed by all patients with type 1 diabetes provided information on smoking habits.

Statistical analysis

Mean daily intakes of energy and nutrients were calculated from the 3-d record of each patient. Because the distributions for Hb A_{1c}, total cholesterol, LDL cholesterol, and triacylglycerol were skewed, these variables were log transformed for analysis.

Least-squares regression was used to analyze the GI for potential relations with concentrations of Hb A_{1c} or serum lipids. The distribution of the GI was grouped into quartiles and least-squares means of Hb A_{1c} and serum lipids were calculated for each quartile. Trend testing was performed across quartiles of GI: each individual was assigned to the corresponding quartile (1, 2, 3, or 4) and the t test was performed to test whether the parameter estimate obtained for this categorical variable was significantly different from zero (P < 0.05) (37). In the multivariate analyses, mean Hb A_{1c} concentrations were adjusted for intakes of total energy (in kJ) and fiber (in g/d), self-reported alcohol consumption (none, <20, and ≥ 20 g/d), sex, age, presence of overweight [body mass index (BMI; in kg/m^2) > 25], and smoking status (never, past, or current). Mean concentrations of serum lipids were adjusted for total energy intake (in kJ), fiber intake (in g/d), sex, age, and presence of overweight (BMI > 25) (38). In addition, self-reported alcohol intake (none, >0 but <20, or ≥ 20 g/d) was also accounted for in models for HDL cholesterol and triacylglycerol. The adjusted means were the least-squares means predicted by the model when the other variables were held at their mean values. Colinearity diagnostics were performed in all

TABLE 1
Characteristics of the 2810 European patients with type 1 diabetes

	All (n = 2810)	Southern Europe (n = 1144)	Northern, western, and eastern Europe (n = 1666)
Age (y)	32.9 ± 10.2[1]	32.0 ± 10.2	33.2 ± 10.1[2]
Duration of diabetes (y)	14.6 ± 9.3	14.0 ± 8.9	15.0 ± 9.6[2]
Sex (% male)	50.8	51.1	50.7
Glycated hemoglobin (%)	6.4 (1.9–15.5)[3]	6.5 (2.8–15.0)	6.2 (1.9–15.5)[4]
Total cholesterol (mmol/L)	5.24 (1.75–12.38)	5.15 (2.31–12.38)	5.31 (1.75–11.34)[4]
LDL cholesterol (mmol/L)	3.26 (0.93–9.72)	3.22 (0.93–9.72)	3.32 (0.32–8.40)[4]
HDL cholesterol (mmol/L)	1.44 (0.27–3.70)	1.44 (0.27–3.70)	1.43 (0.28–3.67)
Triacylglycerol (mmol/L)	0.93 (0.12–12.64)	0.87 (0.22–12.64)	0.99 (0.12–8.58)[4]
Glycemic index (%)	81.5 (58.2–111.5)	80.1 (60.4–108.5)	82.6 (58.2–111.5)[4]
Fiber intake (g/d)	17.5 (2.6–63.4)	17.5 (2.6–63.4)	17.6 (2.9–57.8)
Energy intake (kJ)	9610 (2148–26 875)	9083 (2145–21 090)	9970 (2805–26 875)[4]
Carbohydrate intake (% of energy)	42.5 (19.2–74.7)	43.0 (19.2–74.7)	42.2 (19.4–71.4)[4]
Self-reported alcohol intake			
None (%)	51.7	48.3	54.1[5]
<20 g/d (%)	36.9	40.2	34.7[5]
≥20 g/d (%)	11.4	11.5	11.2
BMI > 25 kg/m² (%)	26.7	21.9	30.0[5]
Number of daily insulin injections			
1 or 2 times/d (%)	50.1	51.8	48.9
≥3 times/d (%)	49.9	48.2	51.1
Current smokers (%)	33.4	31.9	34.5
Exsmokers (%)	17.3	16.4	17.9

[1] $\bar{x}$ ± SD.
[2] Significantly different from southern Europe, $P < 0.05$ (unpaired t test).
[3] Median; range in parentheses.
[4] Significantly different from southern Europe, $P < 0.05$ (Mann-Whitney U test).
[5] Significantly different from southern Europe, $P < 0.05$ (chi-square test).

multivariate models with use of the Belsley-Kuh-Welch-criteria (39). Colinearity did not occur in any of the models.

For region-specific analyses, the participating centers were grouped as in previous analyses (24, 40). The southern European centers were Athens, Bari, Cagliari, Lisbon, Milan, Perugia, Pisa, Rome, Turin, Thessaloniki, and Verona; the northern, eastern, and western European centers were Bucharest, Budapest, Cork, Düsseldorf (2 centers), Gent, Helsinki, Krakow, Leiden, London, Luxembourg, Manchester, Munich, Paris, Sheffield, Valenciennes, Vienna, Wolverhampton, and Zagreb. All statistical analyses were carried out with use of the SAS program (41).

RESULTS

The characteristics of the total cohort of European patients with type 1 diabetes and of the subgroups from the different European centers are shown in **Table 1**. Patients from the southern European centers had higher Hb A_{1c} concentrations but lower total cholesterol, LDL cholesterol, and fasting triacylglycerol concentrations than did those from the northern, western, and eastern European centers. Furthermore, the GI was lower in the southern European diet.

The associations between the GI and measures of metabolic control are shown in **Table 2** and **Table 3**. Hb A_{1c} increased significantly as dietary GI increased (Table 2). This relation was maintained after adjustment for potential confounding factors. Lower adjusted Hb A_{1c} concentrations were observed especially in individuals in the lowest quartile of GI (median GI: 75): the adjusted Hb A_{1c} concentrations in these individuals were 8% lower than those of persons in the highest GI quartile (median GI: 89). Total and LDL-cholesterol concentrations were not associated with dietary GI (Table 3). HDL cholesterol tended to decrease as GI increased; however, this trend was explained partly by potential confounders. Also, in the bivariate model a higher GI was associated with higher concentrations of fasting triacylglycerol, but this relation was largely attributable to confounders (Table 3).

The relation of dietary GI with Hb A_{1c} concentrations is compared between southern European centers and northern, western, and eastern European centers in **Figure 1**. The tendency of Hb A_{1c} to be higher in higher quartiles of GI was found in both regions but was particularly pronounced in the southern European centers, where the mean adjusted Hb A_{1c} in the lowest GI quartile was 11% lower than in the highest quartile.

TABLE 2
Glycated hemoglobin (Hb A_{1c}) concentrations in quartiles of glycemic index in 2054 European patients with type 1 diabetes[1]

Median glycemic index (range)	Hb A_{1c}: Bivariate analysis[2]	Hb A_{1c}: Full model[2,3]
	%	
74.9 (58.2–77.7)	6.04 (5.90, 6.19)	6.05 (5.91, 6.20)
79.8 (77.6–81.5)	6.24 (6.08, 6.40)	6.27 (6.11, 6.43)
83.6 (81.5–85.5)	6.60 (6.43, 6.77)	6.59 (6.43, 6.76)
88.5 (85.5–111.5)	6.60 (6.44, 6.77)	6.55 (6.38, 6.72)

[1] Geometric $\bar{x}$ (95% CI).
[2] P for trend = 0.0001.
[3] Adjusted for energy and fiber intake (g/d), self-reported alcohol consumption (none, <20, or ≥20 g/d), sex, age, presence of overweight [BMI > 25 (in kg/m²)], and smoking status (never, past, or current).

TABLE 3
Serum lipid concentrations in quartiles of glycemic index in European patients with type 1 diabetes[1]

Median glycemic index (range)	Total cholesterol (n = 2746)		LDL cholesterol (n = 1801)		HDL cholesterol (n = 2708)		Triacylglycerol (n = 1851)	
	Bivariate analysis	Full model[2]	Bivariate analysis	Full model[2]	Bivariate analysis	Full model[2]	Bivariate analysis	Full model[2]
	mmol/L							
74.9 (58.2–77.7)	5.20 (5.12, 5.29)	5.20 (5.12, 5.28)	3.22 (3.14, 3.31)	3.24 (3.16, 3.32)	1.54 (1.50, 1.57)	1.50 (1.47, 1.53)	0.95 (0.91, 0.99)	0.98 (0.93, 1.02)
79.8 (77.6–81.5)	5.27 (5.18, 5.35)	5.27 (5.19, 5.35)	3.26 (3.17, 3.35)	3.26 (3.17, 3.34)	1.50 (1.47, 1.53)	1.49 (1.46, 1.52)	0.98 (0.94, 1.03)	0.99 (0.94, 1.03)
83.6 (81.5–85.5)	5.22 (5.14, 5.30)	5.20 (5.13, 5.28)	3.20 (3.12, 3.29)	3.19 (3.10, 3.27)	1.44 (1.41, 1.47)	1.45 (1.42, 1.48)	1.06 (1.02, 1.11)	1.05 (1.01, 1.10)
88.5 (85.5–111.5)	5.17 (5.09, 5.25)[3]	5.18 (5.10, 5.26)[4]	3.27 (3.18, 3.36)[5]	3.26 (3.17, 3.36)[6]	1.44 (1.41, 1.47)[7]	1.47 (1.44, 1.51)[8]	1.01 (0.96, 1.06)[9]	0.98 (0.94, 1.03)[3]

[1] $\bar{x}$ (95% CI).
[2] Adjusted for energy and fiber intake (g/d), sex, age, and presence of overweight [BMI > 25 (in kg/m^2)]. Models for HDL cholesterol and triacylglycerol also include self-reported alcohol consumption (none, <20, or ≥20 g/d).
[3] P for trend = 0.4.
[4] P for trend = 0.5.
[5] P for trend = 0.7.
[6] P for trend = 1.0.
[7] P for trend = 0.0001.
[8] P for trend = 0.1.
[9] P for trend = 0.01.

An independent association of the GI with HDL-cholesterol concentrations, confined to patients with type 1 diabetes from the northern, western, and eastern European centers, was observed (**Figure 2**). Mean adjusted HDL-cholesterol concentrations of northern, western, and eastern European patients in the lowest quartile were 6% higher than those of patients in the highest GI quartile. This association was maintained when Hb A_{1c} concentrations were accounted for. In neither European region was an independent relation of GI with total cholesterol, LDL cholesterol, or fasting triacylglycerols observed (data not shown). All results were comparable when analyses were repeated with inclusion of further terms for the frequency of insulin injections or vigorous exercise at least once per week (data not shown).

The median carbohydrate intake from different sources between persons consuming a low-GI diet (lowest quartile) and those consuming a high-GI diet (highest quartile) for both European regions is compared in **Figure 3**. Outpatients from the southern European centers who consumed a low-GI diet ate more carbohydrate from pasta and temperate-climate fruit and less carbohydrate from white bread and potatoes than did patients in the highest GI quartile. In the northern, western, and eastern European centers, patients in the lowest GI quartile ingested more carbohydrate from whole-meal or whole-grain bread and from temperate-climate fruit and less carbohydrate from white bread and potatoes than did patients consuming a high-GI diet. Most patients with type 1 diabetes from the northern, western, and eastern European centers did not consume pasta during the 3 d of recording, regardless of their dietary GIs. In both regions, patients in the lowest and the highest GI quartiles had similar intakes of carbohydrate from breakfast cereals and rice.

DISCUSSION

Currently, persons with type 1 diabetes who receive intensified insulin treatment are trained to familiarize themselves with their short-term glycemic response to a carbohydrate meal by appropriate self-monitoring of blood glucose and to adjust their doses of short- or rapid-acting insulins accordingly (42). In view

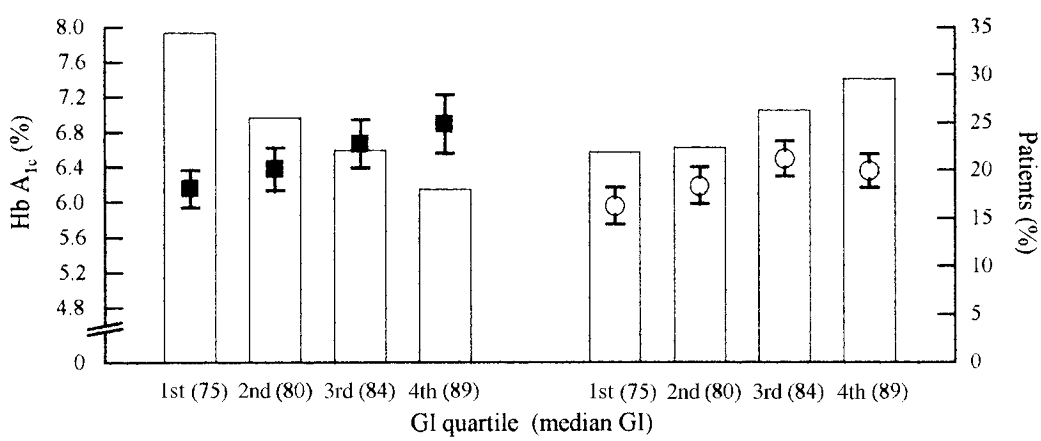

FIGURE 1. Mean glycated hemoglobin (Hb A_{1c}) concentrations (with 95% CIs) in relation to quartiles of glycemic index (GI) of patients with type 1 diabetes from southern European centers (■; n = 933; P for trend = 0.0001) compared with patients from northern, western, and eastern European centers (○; n = 1121; P for trend = 0.002). Hb A_{1c} is adjusted for energy and fiber intake (in g/d), self-reported alcohol consumption (none, >0 but <20, or ≥ 20 g/d), sex, age, presence of overweight [BMI > 25 (in kg/m^2)], and smoking status (never, past, or current). Columns indicate the percentage of patients in each quartile.

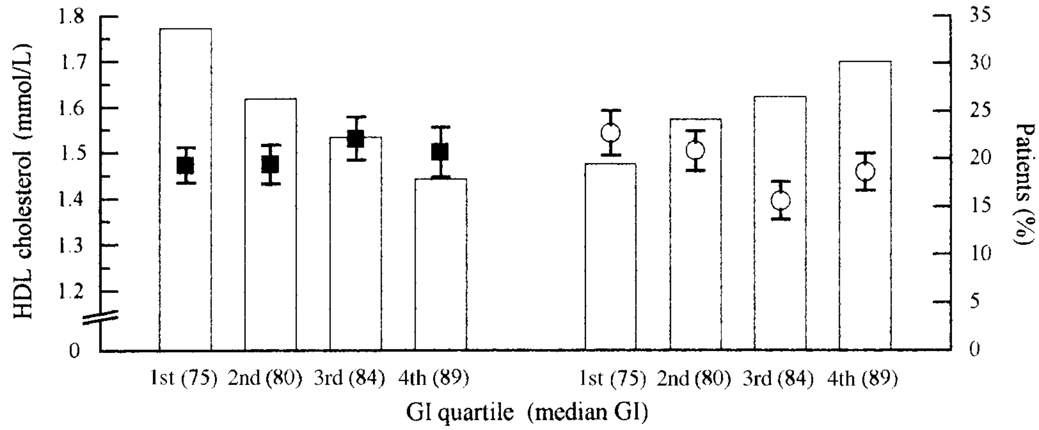

FIGURE 2. Mean HDL-cholesterol concentrations (with 95% CIs) in relation to quartiles of glycemic index (GI) of patients with type 1 diabetes from southern European centers (■; n = 1136; P for trend = 0.2) compared with patients from northern, western, and eastern European centers (○; n = 1572; P for trend = 0.02). HDL cholesterol is adjusted for energy and fiber intake (in g/d), self-reported alcohol consumption (none, >0 but <20, or ≥ 20 g/d), sex, age, and presence of overweight [BMI > 25 (in kg/m^2)]. Columns indicate the percentage of patients in each quartile.

of this therapeutic approach, the potential to reduce postprandial blood glucose peaks by selecting the optimal carbohydrate sources appears to be of secondary relevance (15, 43, 44).

Nevertheless, the present epidemiologic study showed that a lower GI in the diet of European outpatients with type 1 diabetes was associated with significantly lower Hb A_{1c} concentrations. This is of interest because any further reduction in glycemia will effectively lower the risk of microvascular and neuropathic complications in patients with type 1 diabetes (45–47). The notable differences in adjusted Hb A_{1c} between the highest and the lowest GI quartiles (11% in patients from the southern European centers and 6% in patients from the northern, eastern, and western European centers) are within the range of reductions in Hb A_{1c} or fructosamine (3–18%) observed in most medium-term clinical studies (2–12 wk), when patients with diabetes switched from a high-GI diet (GI: 82–92) to a low-GI diet (GI: 54–77) (6–12, 48). People with type 1 diabetes from the northern, western, and eastern EURODIAB centers gained less in terms of Hb A_{1c} from a diet with a lower GI. This could be attributable partly to the lower overall Hb A_{1c} concentrations in these patients, which may in turn mean that self-monitoring had already become more established in many northern and western European centers by the 1980s.

The results of the present study cannot be simply generalized to people with type 1 diabetes who are receiving intensive insulin treatment. At the time of the evaluation, many of the study participants still injected insulin only once or twice daily and insulin analogs were not yet used. Although fast-acting insulins and insulin analogs can help people with type 1 diabetes to efficiently counteract short-term peaks in postprandial blood glucose concentrations, the use of these insulins does not result in a perfect matching of insulin concentration to glycemic response. Because the incorporation of low-GI foods into the diet reduces incremental glycemic responses, we believe that, even in the context of modern insulin treatments, a low-GI diet will beneficially affect long-term glycemic control.

A low-GI diet has also been suggested as beneficially affecting the serum lipid profile in people with diabetes (11, 12, 38). However, for people with type 1 diabetes, clinical studies showed lower concentrations of triacylglycerol only after the diet's GI was reduced (7, 8), a change presumably associated with the simultaneous improvement in glycemia. In the present cohort, which was not characterized by severe derangements in serum lipid profiles, benefits of a low-GI diet for LDL cholesterol and fasting triacylglycerols were not significant. Instead, we observed higher concentrations of HDL cholesterol in patients from the northern, eastern, and western European centers who were consuming a low-GI diet. Similarly, a recent reanalysis of the 1986–1987 Survey of British Adults found a significant association of the dietary GI with HDL cholesterol only (49). Why the beneficial effects of a lower GI was not be seen in the HDL cholesterol of patients with type 1 diabetes from the southern European centers cannot be answered by this study.

This large epidemiologic study is the first to statistically disentangle the effects of the dietary GI and dietary fiber intake on the metabolic control of people with type 1 diabetes. The observed relations of the dietary GI with Hb A_{1c} and HDL-cholesterol concentrations were both independent of dietary fiber intake. Interestingly, the overall effect of a lower dietary GI on Hb A_{1c} was bigger than the relations shown previously with dietary fiber intake in this cohort (24). However, an increased fiber intake was associated with more pronounced beneficial alterations of the serum cholesterol pattern (50).

The feasibility of the low-GI diets (GI: 54–77) used in medium-term studies (2–12 wk) in which the dietary GI was reduced by 13–28 (6–8, 10–12) has been questioned for everyday life (14, 15). In the present study, the GI of the diet commonly consumed by European outpatients with type 1 diabetes varied considerably and 25% of the patients achieved a low dietary GI (≈75).

Clinical studies often emphasize the consumption of legumes as a means of achieving a low-GI diet (11, 12, 48, 51) or strongly encourage the consumption of breakfast cereals with a low GI (6, 11, 12). In a US nondiabetic population, the consumption of potatoes, beverages, white bread, muffins, white rice, and cold breakfast cereals largely determined the GI of the diet, whereas pasta consumption was low in all GI quintiles (52). However, for European patients with type 1 diabetes, the present study showed that breakfast cereals, rice, pulses, and beverages are generally of limited relevance for the dietary GI and that the pattern of

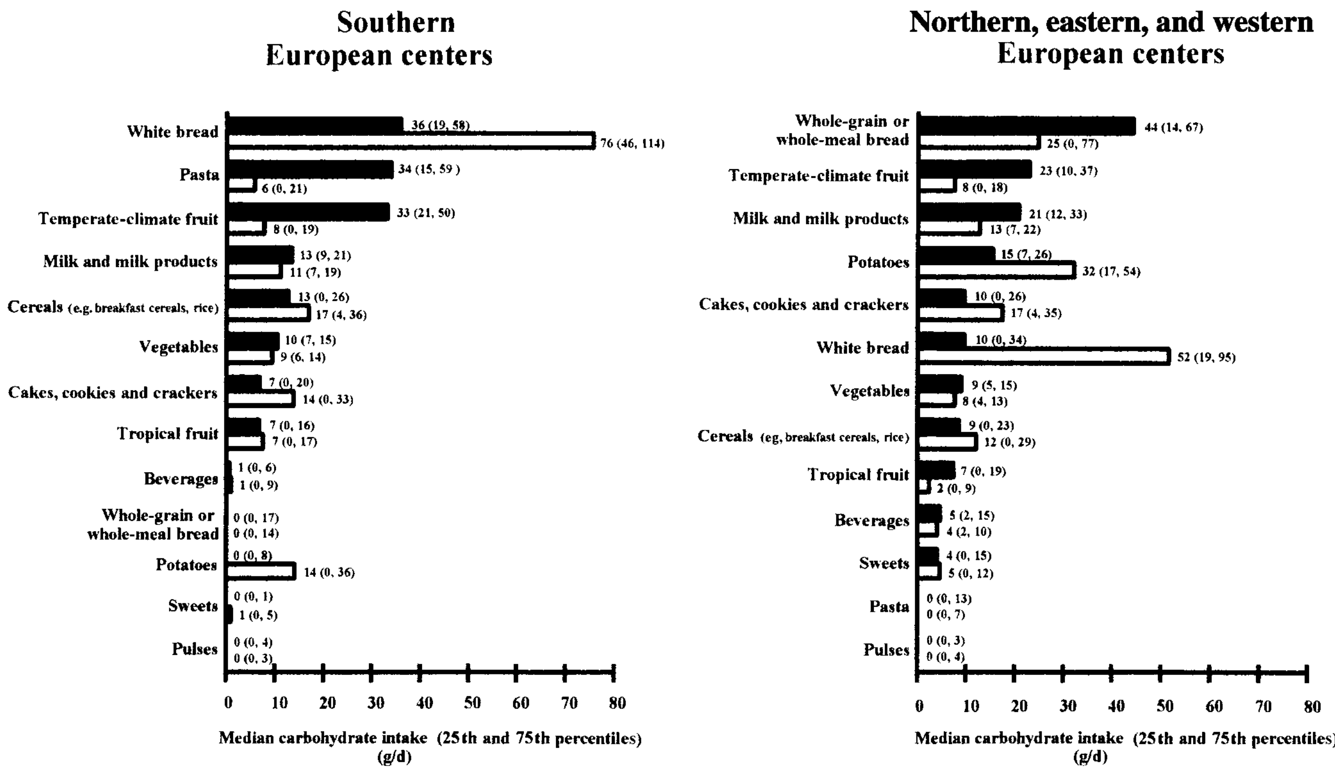

FIGURE 3. Median carbohydrate intake (25th and 75th percentiles) from different carbohydrate sources in diets with a low (first quartile; ■) or high (fourth quartile; □) glycemic index of patients with type 1 diabetes from southern European centers and patients from northern, western, and eastern European centers. $n = 355$ in the first quartile and 323 in the fourth quartile in the southern European centers, and 348 in the first quartile and 479 in the fourth quartile in the northern, eastern, and western European centers.

carbohydrate sources by which a lower GI was achieved differed between European regions. It appears that individuals from southern European centers can best realize a lower dietary GI by increasing their consumption of pasta and temperate-climate fruit and reducing their intake of white bread, whereas, for persons from the northern, western, and eastern European centers, a substitution of whole-grain bread for white bread accompanied by an increase in consumption of temperate-climate fruit and a reduction in potato intake seem to have the biggest effect on the diet's overall GI.

In conclusion, European patients with type 1 diabetes improved their glycemic control as a result of preferred consumption of low-GI foods, irrespective of their fiber intake. In addition, a low-GI diet may have beneficial effects on HDL-cholesterol concentrations. Overall, a diet with a lower GI can be achieved by exploiting the potential of regional dietary habits in Europe.

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