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ORIGINAL ARTICLE

Comparison of intake of food groups between participants with normoglycemia, impaired fasting glucose, and type 2 diabetes in PURE Poland population

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Abstract

According to the World Health Organization, diabetes could be responsible for 1.5 mln deaths a year and prevalence of diabetes is still increasing. Improper diet is one of modifiable risk factors of type 2 diabetes. Because diabetes is a major health burden, research recognizing factors contributing to increased risk of type 2 diabetes is important. The aim of the study was conducting the comparison of intake of food groups between participants with normoglycemia, impaired fasting glucose (IFG), and type 2 diabetes of Prospective Urban and Rural Epidemiology (PURE) Poland population. Assessment of intake of food groups was conducted with the use of validated Food Frequency Questionnaire (FFQ) among 1654 participants of PURE Poland—baseline (2007–2009). Assessment of the differences between groups had been performed with the use of the Kruskal-Wallis test. The significance level was established to be $p \leq 0.05$. Participants with IFG in comparison to participants with diabetes consumed significantly more fruit juices, beverages with added sugar, sweets, honey, and sugar. Participants with IFG in comparison with normoglycemic participants consumed significantly more refined grains, fruit juices, lean meat, and processed meat and less nuts and seeds. Participants with diabetes in comparison to normoglycemic participants consumed significantly more lean meat and processed meat and less tea and coffee, alcohol, dried fruit, honey, sugar, and nuts. Especially participants with IFG, who consumed more products of high glycemic index should be the subject of intensive counseling and other prophylactic measures to reduce the risk of progression to type 2 diabetes.

Keywords Diabetes · Impaired fasting glucose · Diet · Food groups

Introduction

According to the World Health Organization (WHO), more than 422 mln people worldwide have diabetes and the prevalence of this disease have rapidly risen in the last decades [1]. Diabetes is the main cause of kidney failure, blindness, lower limb amputation, and stroke and contributes strongly to other cardiovascular diseases [1]. Impaired fasting glycemia (IFG) and impaired glucose tolerance (IGT)—conditions preceding full-symptomatic type 2 diabetes—are considered

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independent risk factors for cardiovascular diseases [2], though according to recent meta-analyses, this association is rather moderate in comparison with diabetes [3]. There have been evidence that endothelial dysfunction caused by hyperglycemia and macrovascular lesions occur much earlier than previously thought—endothelial dysfunction develops already in prediabetic state [4]. According to the WHO, the modifiable risk factors that contribute to the development of diabetes can be included: tobacco smoking, overweight and obesity, low physical activity, and improper diet [1]. So-called *western diet*, rich in, e.g., saturated fatty acids, trans-unsaturated fatty acids, and refined grains, is associated not only with cardiovascular diseases but also with type 2 diabetes [5, 6], whereas Mediterranean diet is associated with much lower risk of those conditions [7]. Progression of impaired fasting glycemia and impaired glucose tolerance to full-symptomatic type 2 diabetes is not inevitable. Early behavioral intervention, like improving physical activity and changing dietary habits, can slow down or even cease the process of progression to type 2 diabetes [8]. Standards for diabetes management, not only Polish [9] but also international (e.g., Standards of American Diabetes Association [10]), emphasize the need for implementing intensive counseling regarding changing the lifestyle in prediabetic patients. Nutritional intervention includes, e.g., changing the quality of dietary fat, increased intake of wholegrain, high-fiber carbohydrate products and decreased intake of additionally sweetened beverages, sweets, and high processed products. The influence of consumption of individual food groups on the risk of type 2 diabetes differ from one group to another, as it was observed in many studies [11]. The aim of the study was to compare the intake of groups of dietary products between individuals with normoglycemia, impaired fasting glucose, and type 2 diabetic patients in the population of Prospective Urban and Rural Epidemiology (PURE) study.

Material and methods

Prospective Urban and Rural Epidemiology study engages 21 countries of different status of economic development and more than 150,000 participants worldwide. The study is designed to collect data in 3 years and intervolves and is planned for 12 years in total [12]. The Polish arm of the PURE study was established in 2007 at Wroclaw Medical University. The baseline cohort included 2036 participants, aged between 30 and 85 years, both from urban and rural area. All participants were examined according to the international PURE project protocol [13]. The paper presents the results of PURE Poland study—baseline, covering the group of 1654 participants, who completed the Food Frequency Questionnaire (FFQ) and had the blood test performed.

The Food Frequency Questionnaire consists of 154 dietary products, characteristic for Polish dietary habits. The FFQ was collected by trained staff and referred to dietary habits of 1 year prior to the interview. The FFQ was specially developed and validated for Polish population [14]. One hundred fifty-four dietary products were divided in 26 food groups (Table 1). The criteria for such specific division were not only dietary recommendations for general Polish population [15] but also standards for nutrition therapy in diabetes [9, 10]. We had taken into consideration, e.g., the glycemic index of the dietary products, the content of fiber, and quality of dietary fat. We gathered soups in one independent food group, because of their traditional and Polish-specific ingredients and way of preparation. Other traditional Polish dishes were included in the "mixed dishes" group. Because of different glycemic index and fiber content, we divided grains into "whole grains" and "refined grains," similarly, fruits and vegetables were divided into "raw," "cooked," "dried," and "juices." Due to the quantity and quality of dietary fat, but also recommendations for Mediterranean diet, we divided dairy products into "low-fat" and "full-fat," moreover, meats were divided into "lean meat," "red meat," and "processed meat." Participants whose calorie intake assessed by FFQ was < 500 kcal/day or > 5000 kcal/day were excluded from analysis due to presumably unreliable interview.

Overall analysis concerned 1654 eligible participants: 992 with normoglycemia, 464 with IFG, and 198 with diabetes. People, whose fasting plasma glucose was between 100 mg/dL (5.6 mmol/L) and 125 mg/dL (6.9 mmol/L) were included into the group of participants with IFG. In the group of diabetes, there were included people whose fasting plasma glucose was ≥ 126 mg/dL (7.0 mmol/L), or those who had already been diagnosed with diabetes in the past and had been undergoing treatment ever since. Participants with normal fasting plasma glucose (70–99 mg/dL, 3.9–5.5 mmol/L) and who were declared with no diabetes diagnosed in the past were included into the group of normoglycemia. A trained health professional, who performed examination, verified whether fasting prior to the examination lasted at least 8 h. Enzymatic hexokinase method was used to measure the fasting plasma glucose from venous blood with the use of Cobas machine and reagents (Roche Diagnostics).

Statistical analysis was performed with the use of Statistica 12.0 PL computer program. Assessment of the differences between groups had been performed with the use of the Kruskal-Wallis test. The significance level was established to be $p \leq 0.05$.

Results

Study population consists of 1654 eligible participants: 36.2% of men and 63.8% of women (Table 2). Overall, 992

Table 1 Characteristic of food groups

Lp.	Food groups	FFQ dietary products
1.	Low-fat dairy products	Milk 1–2% fat
		Buttermilk 0.5% fat
		Cocoa w/ milk 1–2% fat
		Cottage cheese
		Low-fat yoghurt
		Kefir
2.	Full-fat dairy products	Milk 3.2% fat
		Milk 3.2% fat (from mixed dish—oatmeal w/ milk)
		Feta Greek cheese
		Granulated cottage cheese w/ sour cream
		Cheese
		Edam cheese
		Fromage cheese
		Yoghurt 2–8% fat
		Sour cream 12% fat
		Sour cream 18% fat
		Sour cream 18% fat (from mixed dish—salad w/sour cream)
3.	Whole grains	Whole-meal rye bread
		Mixed bread w/ rye and wheat flour w/ sunflower seeds
		Buckwheat groats, boiled
		Barley groats, boiled
		Pasta w/ durum, boiled
		Oatmeal (from mixed dish—oatmeal w/ milk)
4.	Refined grains	Wheat bread, white
		White rice, boiled
		Wheat roll, white
		Mixed bread w/ rye and wheat flour, white
		Cornflakes
5.	Fats w/o oils	Butter
		Lard
		Fat spread w/ butter
		Mayonnaise
		Margarine, soft
6.	Raw fruit	Apple
		Banana
		Grapefruit
		Grapes
		Mandarin
		Strawberries
		Kiwi fruit
		Lemon
		Orange
		Pear
		Peach
		Prunes
		Raspberries
7.	Fruit juices	Orange juice
		Raspberry juice
		Carrot juice
		Apple juice
		Grapefruit juice
		Black currant juice
		Multifruit juice (local fruits)
		Multifruit juice (exotic fruits)
8.	Raw vegetables	Cabbage red, raw
		Chinese cabbage, raw
		Cabbage white, raw
		Carrot, raw
		Cauliflower, raw
		Chives
		Cucumber, raw
		Garlic cloves, raw
		Salad, leaves
		Onion, raw
		Parsley, leaves
		Horseradish
		Red pepper, raw
		Radish
		Tomato, raw
		Sauerkraut salad
		Chinese cabbage salad w/ mayonnaise
		Salad (from mixed dish—salad w/ sour cream)
9.	Cooked vegetables	Kidney beans, cooked
		Beetroot, cooked
		Broccoli
		Cabbage white, cooked
		Carrot, cooked
		Cauliflower, cooked, w/butter
		Mushrooms, fried
		Red pepper, cooked
		Tomatoes, cooked
		Tomato passata
		Spinach, cooked
		Zucchini, cooked
		Green beans, cooked
		Corn, canned
		Peas, canned
		Salad of mixed cooked vegetables w/ mayonnaise
10	Potatoes	Potatoes, boiled
		Potatoes, mashed
		French fries
11.	Lean meat	Chicken w/ skin boiled/fried
		Chicken w/o skin boiled/fried

Table 1 (continued)

Lp.	Food groups	FFQ dietary products
		Turkey, roasted
12.	Red meat	Beef, cutlets
		Beef ham, boiled
		Pork, bacon
		Cutlets of ground beef and pork, fried
		Offal
13.	Meat w/ breadcrumbs	Chicken nuggets
		Pork chops, w/ breadcrumbs
14.	Processed meat/charcuterie	Chicken ham
		Sausage
		Luncheon meat, pork
		Pork ham
		Sausage, pork, smoked (traditional polish)
		Sausage, mixed beef/pork, smoked (traditional polish)
		Sausage, pork, white, boiled (traditional polish)
		Turkey ham
		Turkey sausage ham
		Brawn
		Chicken pâté
15.	Eggs	Eggs, boiled/fried
16.	Fish	Codfish, fried, w/ breadcrumbs
		Herring, w/ cream
		Mackerel, smoked
17.	Mixed dishes	Baked beans w/ tomato sauce
		Meat and rice stuffed cabbage w/ tomato sauce
		Dumplings w/ meat, boiled
		Dumplings w/ potatoes and cottage cheese, boiled
		Sauerkraut and meat stew
18.	Beverages w/ added sugar	Fruit drink
		Soft drink w/ added sugar
19.	Low-calorie beverages	Low-calorie soft drink
20.	Tea, coffee	Coffee
		Tea, black
		Tea, green/herb
21.	Alcohol	Beer
		Wine
		Vodka
22.	Sweets	Milk chocolate
		Dark chocolate
		Tea biscuit
		Yeast cake
		Shortbread cake
		Gingerbread
		Pound cake
		Cheesecake
		Halvah
		Caramel candy
		Other sweets
		Candy
		Ice cream
23.	Honey and sugar	Honey
		Sugar
24.	Dried fruits	Raisins
25.	Nuts and seeds	Walnuts
		Other nuts
		Seeds
26.	Soups	Broth
		Sour rye soup
		Vegetable soup
		Barley soup
		Tomato soup
		Bean soup
		Sauerkraut soup

w/, with; *w/o*, without

participants had normoglycemia (34.6% of men and 65.4% of women). Overall, 464 participants had IFG (37.1% of men and 62.9% of women). Overall, 198 participants had diabetes (41.9% of men and 58.1% of women).A total of 17.5% of participants overall were < 45 years old (73.4% and normoglycemia, 21.7% had IFG, and 4.8% had diabetes). Age group between 45 and 64 years old was the largest group: 66.9% of participants overall (57.8% with normoglycemia, 29.6% with IFG, and 12.6% with diabetes). Of the participants, 15.5% were older than 64 years (54.1% with normoglycemia, 28.4% with IFG and 17.5% with diabetes). A total of 55.9% of participants were urban dwellers and 44.1% were rural dwellers. Among urban dwellers, 69.0% had normoglycemia, 22.7% had IFG, and 8.3% had diabetes. Among rural dwellers, 48.6% had normoglycemia, 34.8% had IFG, and 16.6% had diabetes. Overall, 15.3% participants had primary education (46.6% with normoglycemia, 31.2% with IFG, and 22.1% with diabetes). Overall, 16.6% of participants had vocational education (53.5% with normoglycemia, 32.4% with IFG, and 14.2% with diabetes), while 39.0% of participants had secondary education (60.2% with normoglycemia, 28.8% with IFG, and 11.0% with diabetes). Total of 29.1% of participants had university degree (70.5% with normoglycemia, 22.9% with IFG, and 6.7% with diabetes).

Average BMI in groups of normoglycemia, IFG, and diabetes was 27.2, 29.2, and 31.6 kg/m^2 respectively. The analysis revealed statistically significant differences in distribution of body weight between participants with normoglycemia, IFG, and diabetes ($p < 0.000$) (Table 3). The largest group

Table 2 Characteristics of 1654 participants of PURE Poland study population

	Total		
Men *n* (%)	598 (36.2%)		
Women *n* (%)	1056 (63.8%)		
	Normoglycemia (70–99 mg/dL)	Impaired fasting glucose (IFG) (100 and 125 mg/dL)	Type 2 diabetes (≥ 126 mg/dL or previously diagnosed)
Total *n* (%)	992 (59.9%)	464 (28.1%)	198 (11.9%)
Men *n* (%)	343 (57.4%)	172 (28.8%)	83 (13.9%)
Women *n* (%)	649 (61.5%)	292 (27.7%)	115 (10.9%)
Age			
< 45 years	213 (73.4%)	63 (21.7%)	14 (4.8%)
45–64 years	640 (57.8%)	328 (29.6%)	139 (12.6%)
> 64 years	139 (54.1%)	73 (28.4%)	45 (17.5%)
Place of residence			
Urban *n* (%)	638 (69.0%)	210 (22.7%)	77 (8.3%)
Rural *n* (%)	354 (48.6%)	254 (34.8%)	121 (16.6%)
Education level			
Primary *n* (%)	118 (46.6%)	79 (31.2%)	56 (22.1%)
Vocational *n* (%)	147 (53.5%)	89 (32.4%)	39 (14.2%)
Secondary *n* (%)	388 (60.2%)	186 (28.8%)	71 (11.0%)
Higher *n* (%)	339 (70.5%)	110 (22.9%)	32 (6.7%)
BMI			
Average BMI [kg/m^2]:			
M ± *SD*	27.2 ± 4.7	29.2 ± 5.1	31.6 ± 5.9
Min-Max	15.0–47.1	17.8–46.9	19.8–49.2

with normal body weight was participants with normoglycemia (34.3 vs. 20.3% participants with IFG and 12.1% participants with diabetes) (Table 3). Obesity was more prevalent in participants with IFG (40.3%) and diabetes (57.6%), than in participants with normoglycemia (23.8%).

The analysis revealed statistically significant differences in consumption of 12 out of 26 food groups (Table 4). Participants with IFG in comparison to participants with diabetes consumed statistically significantly more fruit juices, beverages with added sugar, sweets, and honey/sugar. Participants with IFG in comparison with normoglycemic participants consumed significantly more refined grains, fruit juices, lean meat, and processed meat/charcuterie and significantly less nuts/seeds. Participants with diabetes in comparison to normoglycemic participants consumed significantly more lean meat, processed meat/charcuterie, and soups, while on the other hand, significantly less tea/coffee, alcohol, dried fruit, nuts/seeds, and honey/sugar. Simplified results of post hoc analyses are presented in Table 5.

Discussion

The comparison between consumption of food groups between participants with normoglycemia, IFG, and type 2 diabetes revealed significant differences in 12 out of 26 food groups.

Participants with IFG consumed more refined grains than normoglycemic participants. Refined grains are characterized by high glycemic index and deprivation of most of the dietary fiber and are not recommended, especially in the prevention and treatment of diabetes. According to the guidelines, whole grains should be the main source of carbohydrates [10]. Alminger et al. [16] observed that the intake of whole grains in comparison to refined grains is associated with much lower rise of postprandial glucose and insulin level. According to Wirström et al. [17], consumption of whole grains lowers the risk of development of prediabetes. Meta-analysis conducted by Yao et al. [18] concludes that increased intake of dietary fiber is associated with lower risk of development of type 2 diabetes. In a randomized, double-blind study conducted by Dainty et al. [19], participants who consumed bagels rich in resistant starch in comparison with participants who consumed regular bread were characterized by lower fasting and postprandial insulin levels and lower fasting insulin resistance. Participants with IFG consumed more fruit juices than either normoglycemic or diabetic participants.

It is already known that higher consumption of fruit and vegetables is associated with lower risk of metabolic diseases. Recently published meta-analysis, by Wang et al. [20],

Table 3 Population characteristics according to BMI

	Underweight (BMI < 18.5 kg/m^2) *n* (%)	Normal body weight (BMI 18.5–24.9 kg/m^2) *n* (%)	Overweight (BMI 25.0–29.9 kg/m^2) *n* (%)	Obesity (BMI > 30.0 kg/m^2) *n* (%)	*p* value*
Normoglycemia (70–99 mg/dL)	9 (0.9)	340 (34.3)	407 (41.0)	236 (23.8)	0.000
Impaired fasting glucose (IFG) (100 and 125 mg/dL)	3 (0.6)	94 (20.3)	180 (38.8)	187 (40.3)	
Type 2 diabetes (≥ 126 mg/dL or previously diagnosed)	0 (0.0)	24 (12.1)	60 (30.3)	114 (57.6)	

*With exclusion of underweight group due to insufficient number of participants

concludes that higher intake of raw fruit and vegetables (especially green leafy, yellow, and cruciferous vegetables) is associated with lower risk of type 2 diabetes. On the other hand, fruit juice is characterized by higher content of monosaccharides and lower content of fiber than raw fruit, which also results in higher glycemic index. Moreover, fruit juice frequently contains artificially added glucose-fructose syrup (or high-fructose corn syrup), which is cheaper than saccharose, in order to improve the taste of the juice. Meta-analysis performed by Imamura et al. [21], who assessed impact of consumption of soda and fruit juices on the risk of type 2 diabetes, adjusted for adiposity and calorie intake, concluded that both soda and fruit juices increase the relative risk for diabetes. In fact, increasing the intake of fruit juice by one serving a day was associated with 7% greater risk of type 2 diabetes. On the contrary, meta-analysis recently conducted by Wang et al. [22] provides no hard evidence for association between consumption of fruit juices and diabetes. Either way, overconsumption of fructose could be deleterious for the metabolic health. Although fructose has lower glycemic index than glucose, it is speculated that its consumption promotes deposition of lipids in visceral abdominal tissue and decreases glucose tolerance and insulin sensitivity especially in overweight persons [23]. To sum up, excessive consumption of fruit juices, especially those with added sugar or glucose-fructose syrup, should not be recommended in patients with metabolic disorders. Consumption of highly sweetened beverages is one of the risk factors for overweight and obesity and is strongly unrecommended [1]. The herein analysis revealed increased consumption of beverages with added sugar by participants with IFG in comparison to diabetic patients. Meta-analysis of 11 cohort studies, performed by Malik et al. [24], concludes that among participants who consumed the highest amounts of sweetened beverages (one to two servings a day), the risk of development of type 2 diabetes was higher by 26%. Moreover, the Framingham Offspring Cohort study provided an observation that consumption of sweetened beverages increased the risk of development of prediabetes and insulin resistance by 46% in comparison to the risk of those who did not consume such beverages [25]. In the presented paper, participants with IFG consumed more sweets and honey/sugar than diabetic patients. Because of increasing consumption of sugar worldwide and association of higher consumption of sugar with increased risk of overweight/obesity and non-communicable diseases, the World Health Organization strongly recommends to limit consumption of free sugars to 10% of total energy intake (and states that ideal intake is below 5% of total energy intake) [26].

Either participants with IFG or diabetes consumed more processed meat and charcuterie than normoglycemic participants. Meta-analysis conducted by Feskens et al. [27] concluded that increased consumption of red meat and processed meat increases the risk of type 2 diabetes. According to the meta-analysis conducted by Micha et al. [28], every additional serving of processed meat per day increases the risk of diabetes by 19%. Possibly, the high content of saturated fatty acids and trans-unsaturated fatty acids in processed meat is a factor responsible for such association. Analysis performed by Guess et al. [29] concludes that higher consumption of saturated fatty acids is associated with higher fasting plasma glucose, hepatic insulin resistance, and higher plasma glucose after 2 h in oral glucose tolerance test (OGTT). Further non-nutritive compounds (differentiating processed meat from red meat), like sodium or nitrosamines, are candidate factors affecting metabolic disorders.

According to the herein findings, diabetic participants consumed significantly less alcohol than normoglycemic participants. As stated in recommendations for diabetic patients by the American Diabetes Association [10], excessive alcohol consumption should be strictly avoided (no more than two servings per day for men and no more than one serving per day for women). The findings presented in this paper suggest that it is possible that counseling introduced after diagnosis of diabetes influenced decreased consumption of alcohol. Excessive consumption of alcohol can increase the risk of delayed hypoglycemia in diabetic patients, especially those who use insulin [10]. Excessive consumption of alcohol should be avoided not only by diabetic patients but also by healthy population. According to findings from the Northern Swedish Cohort study [30], a 27-year prospective cohort study, increased consumption of alcohol and binge drinking

Table 4 Differences in consumption of food groups between participants with normoglycemia, IFG, and type 2 diabetes—result of analyses with the use of the Kruskal-Wallis test

Food groups	Normoglycemia[a]			Impaired fasting glucose (IFG)[b]			Diabetes[c]			*p*
	Mean [g/day]	Median	SD	Mean [g/day]	Median	SD	Mean [g/day]	Median	SD	
Low-fat dairy products	147.08	82.29	169.74	134.60	81.35	141.05	129.78	77.30	149.10	0.500
Full-fat dairy products	120.95	69.42	139.79	139.16	71.59	172.88	132.50	68.32	151.43	0.490
Whole grains	62.53	47.40	48.10	61.75	47.40	43.61	70.22	48.08	57.10	0.560
Refined grains	75.56	59.91[b]	63.95	87.56	83.57[a]	64.15	78.59	78.66	68.72	0.001
Fats w/o oils	20.33	15.98	16.29	21.48	17.14	16.31	21.23	17.82	16.22	0.170
Fruit raw	300.15	235.41	211.56	285.18	223.91	205.97	288.86	234.17	217.65	0.310
Fruit juices	152.69	107.14[b,c]	148.88	173.83	137.00[a,c]	162.11	138.18	84.89[a,b]	163.70	0.000
Vegetables raw	172.45	142.05	115.25	162.72	137.04	100.26	167.45	141.84	105.35	0.670
Vegetables cooked	148.92	120.82	116.45	134.97	117.28	90.44	141.19	121.30	99.89	0.430
Potatoes	87.24	71.82	58.95	93.34	78.71	58.85	94.25	78.71	52.24	0.017
Lean meat	19.78	15.08[b,c]	15.96	21.82	15.08[a]	16.79	21.98	16.25[a]	14.50	0.003
Meat w/ breadcrumbs	21.97	20.84	15.31	22.86	20.84	15.95	22.56	20.84	15.65	0.750
Red meat	22.89	17.70	20.61	24.70	19.88	22.14	21.51	18.06	16.10	0.120
Processed meat/charcuterie	60.02	47.90[b,c]	44.92	68.46	52.95[a]	47.47	75.09	63.36[a]	49.88	0.000
Eggs	15.29	19.28	13.65	16.79	19.28	16.49	16.90	19.28	17.56	0.560
Fish	13.49	13.11	10.98	14.35	13.11	10.29	14.72	13.11	10.95	0.035
Mixed dishes	25.71	26.22	18.49	26.79	26.22	18.96	27.69	26.22	17.80	0.180
Beverages w/ added sugar	40.32	0.00	93.04	45.51	0.00[c]	100.86	36.24	0.00[b]	89.11	0.027
Low-calorie beverages	156.47	0.00	343.44	122.07	0.00	320.84	146.07	0.00	374.32	0.050
Tea, coffee	970.88	910.71[c]	463.22	939.58	891.39	439.76	866.33	883.19[a]	491.06	0.035
Alcohol	56.23	12.13[c]	127.30	49.59	9.31	104.04	52.64	0.00[a]	144.12	0.006
Sweets	42.87	35.40	35.20	45.16	38.16[c]	32.15	37.37	31.08[b]	33.18	0.004
Honey, sugar	17.94	15.71[c]	16.39	17.32	15.42[c]	15.53	12.03	3.90[a,b]	15.08	0.000
Dried fruit	5.68	4.91[c]	10.86	4.57	4.91	9.31	2.95	0.00[a]	4.44	0.000
Nuts, seeds	9.22	5.57[b,c]	15.13	8.19	5.44[a]	14.60	7.14	4.91[a]	12.22	0.000
Soups	242.61	221.53[c]	140.61	252.75	228.57	138.02	270.27	250.11[a]	134.40	0.003

Results of post hoc analyses were marked with the upper indexes [a], [b], and [c]. Upper indexes indicate between which groups significant differences occurred

IFG, impaired fasting glucose; *w/o*, without; *w/*, with; *[g/day]*, grams per day; *SD*, standard deviation

behavior were associated with higher values of fasting plasma glucose among adult women. These findings were consistent with findings obtained by Baliunas et al. [31] in the meta-analysis of cohort studies. According to this meta-analysis, moderate consumption of alcohol decreases the risk of type 2 diabetes among women, but excessive consumption of alcohol significantly increases the risk of diabetes.

In the herein study, it was also observed that participants with diabetes consumed less tea and coffee than normoglycemic participants. There is evidence that drinking unsweetened tea and coffee can improve health status, presumably due to the high content of antioxidative compounds. However, the association between consumption of tea and coffee and incidence of type 2 diabetes needs further investigation, but there have been some observations that have emerged. Meta-analysis conducted by Yang et al. [32] concluded that consumption of at least three cups of tea per day can contribute to lower risk of type 2 diabetes. According to van Dieren et al. [33] and the Dutch arm of EPIC-NL study, which investigated more than 40,000 participants over a 10-year period, consuming at least three cups of tea or coffee decreased the risk of type 2 diabetes by 42%.

According to our findings, participants with diabetes consumed significantly less nuts and seeds than normoglycemic participants. It is not clear why diabetic participants consumed less of those products, but one of the reasons for such behavior could be an attempt to reduce the overall energy intake, since nuts and seeds are rather calorie-dense products. On the other hand, such behavior can deprive of some essential nutrients provided by nuts and seeds, e.g., polyunsaturated fatty acids.

Table 5 Summary of results of post hoc analyses

Groups of participants	Results
IFG vs. normoglycemia	↑Refined grains
	↑Fruit juices
	↑Lean meat
	↑Processed meat and charcuterie
	↓Nuts and seeds
IFG vs. diabetes	↑Fruit juices
	↑Beverages w/ added sugar
	↑Sweets
	↑Honey and sugar
Diabetes vs. normoglycemia	↑Lean meat
	↑Processed meat and charcuterie
	↑Soups
	↓Tea and coffee
	↓Alcohol
	↓Dried fruit
	↓Nuts and seeds
	↓Honey and sugar

Results obtained within the Nurse's Health Study [34] suggest that higher consumption of nuts is associated with lower risk of type 2 diabetes among adult women, though findings from the Physician's Health Study found no such association among adult men [35]. A meta-analysis conducted by Wu et al. [36] also failed to find an association between consumption of nuts and risk of type 2 diabetes. On the other hand, the role of polyunsaturated fatty acids prevalent in nuts and seeds in lowering the risk of cardiovascular diseases is well established [37]. Since diabetic patients are at high risk of developing cardiovascular complications, including nuts and seeds in the diet is recommended in order to lower the risk of metabolic complications [38].

The participants with IFG consumed more food groups characterized by higher glycemic index in comparison with the participants with diabetes (fruit juices, beverages with added sugar, sweets) and normoglycemia (refined grains, fruit juices). On the other hand, diabetic participants were characterized by lower consumption of high glycemic index food groups, e.g., alcohol. These findings can suggest that dietary counseling introduced after diabetes diagnosis is—at least partially—effective and influences dietary choices of the participants. There is evidence in the literature that dietary counseling is effective not only in promoting diabetes management but also preventing progression to full-symptomatic diabetes [8]. According to the standards of diabetes care, both Polish [9] and American [10], intensive dietary and behavioral counseling should be introduced in prediabetic patients as soon as possible in order to prevent deterioration of glucose tolerance. Nevertheless, not all prediabetic patients are referred to dietary counseling. According to Ginde et al. [39], only 10% of the patients with incidentally diagnosed IFG or IGT in emergency ward received information about their condition and 6% were referred for further management. According to the results of NHANES study [40], 43.6% of patients with prediabetes and 10% of normoglycemic patients were informed about health risks of type 2 diabetes.

What is more, analysis revealed that obesity was more common in participants with IFG and diabetes than in normoglycemic participants, in fact there was a gradual increase in percentage of obese individuals along with deterioration of glucose metabolism (23.8% of individuals with normoglycemia, 40.3% with IFG, and 57.6% with diabetes were obese). Obesity is a major risk factor of type 2 diabetes, cardiovascular diseases [41], and cancer [42]. Both higher consumption of unrecommended food groups and high prevalence of obesity in IFG participants are alarming risk factors of metabolic deterioration.

Conclusion

The diets of participants with IFG were characterized by higher content of unrecommended food groups. The prevalence of obesity was much higher among participants with IFG and diabetes than participants with normoglycemia. Because of high risk of further metabolic deterioration, individuals with IFG should be the group of the highest priority for dietary and behavioral counseling in order to prevent progression to full-symptomatic type 2 diabetes.

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Study limitations Food Frequency Questionnaire is an acknowledged method of assessment of nutritional habits and intake of nutritional products but has its limitations. FFQ assesses the intake of nutrients retrospectively and depends entirely on participant's memory and judgment, which supposedly can contribute to overestimation of consumption of recommended food groups and underestimation of consumption of unrecommended food groups. Categorization of participants into groups of normoglycemia, IFG, and diabetes was made only on the basis of fasting glucose levels (in the case of diabetes, also on self-reported disease and taking glucose-lowering agent). Mentioned methodology could possibly cause some underestimation in IFG and diabetes prevalence (neither hemoglobin A_{1c} was measured nor OGTT was performed), but this is a methodology implemented in the PURE study worldwide [43]. Dietary data was only recorded, and participants did not receive any dietary counseling following the examination.

Author's contributions AB – manuscript preparation, literature search, manuscript editing
DR –concept and design, manuscript review
KPZ – statistical analysis
MW – data acquisition
AS – manuscript final approval
KZ – concept and design, manuscript review, manuscript guarantor
All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study. All human studies have been reviewed by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in an appropriate version of the 1964 Declaration of Helsinki (Positive opinion of bioethical committee of Wroclaw Medical University nr KB-443/2006).

Abbreviations IFG, impaired fasting glucose; FFQ, Food Frequency Questionnaire; WHO, World Health Organization; IGT, impaired glucose tolerance; PURE, Prospective Urban and Rural Epidemiology study; OGTT, oral glucose tolerance test

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