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Original article

Relationships between food choices, physical activity, glycated haemoglobin and Body Mass Index in type 1 diabetes patients treated with personal insulin pumps - what else can surprise?

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Abstract. *Background and aim:* The aim of the study was to find the relationship between food choices and physical activity, glycated haemoglobin and body mass index among people with type 1 diabetes without complications treated with personal insulin pumps. *Methods:* A cross-sectional study was conducted using a Beliefs and Eating Habits Questionnaire with additional follow-up questions. The data from the questionnaire and the last glycated haemoglobin from the patient file were used. *Results:* We included 116 patients with type 1 diabetes and founded the relationship between physical activity at leisure and snacking in the subgroup of men (p=0.009). Overweight was more common among men. It has been shown that people with glycated haemoglobin over 7% (53 mmol/mol) preferred light products (p=0.003). In the univariate logistic regression model the choice of light products was influenced by gender, age, glycated haemoglobin level and physical activity at leisure. The statistically significant relationship was found between the physical activity at leisure and the frequency of white bread and rolls (p=0.016). *Conclusions*: We found that men with low and moderate physical activity snack more between meals. Light products were significantly associated with higher level of glycated haemoglobin and weight. Despite good glycaemic control, patients should be reminded and educated about proper nutrition and the selection of good products during physical activity at work and at leisure, taking into account the parameter such as Body Mass Index.

Key words: Diabetes type 1, Dietary Assessment, Food Choices, Insulin Infusion Systems, Physical Activity

Introduction

Type 1 diabetes mellitus (T1DM) develops as a result of an autoimmune process, which leads to destruction of the pancreatic beta cells and thus to absolute insulin deficiency (1-3).

The main treatment for T1DM is to replace insulin made by the pancreas with exogenous insulin, administrated in most patients by means of a multiple daily insulin injections (MDI) or a personal continuous subcutaneous insulin infusion (CSII) insulin pump (1,2). An individually selected diet and physical activity are the key components of modern diabetes treatment (1-3).

Eating habits should be adapted to the physical activity during the day, but also to the patient's state of health. Our cross-sectional study aimed to assess the impact of food choices and physical activity on glycated

haemoglobin level (HbA_{1c}) and BMI in patients with T1DM treated with personal insulin pumps.

Material and methods

The study was approved by the Bioethics Committee [removed for blind peer review].

The study included 116 adult patients (55% of the group were women) with T1DM treated with personal insulin pumps, under the constant care at the department [removed for blind peer review] (single-centre study).

The surveyed population was characterised by an average age of 26.5 ± 5 years, an average BMI 23.7 ± 2.9 kg/m^2 and mean HbA_{1c} level 7.2 ± 1.1% (55.8 ± 12.8 mmol/mol). All were dwellers of region [removed for blind peer review]: 37% lived in the country, 8% in towns below 20,000 residents, 14% in city from 20,000 to 100,000 residents and 41% in a city of over 100 inhabitants.

The exclusion criteria were: pregnancy, treatment with multiple insulin injections, i.e. pens, presence of advanced late complications of diabetes, i.e. retinopathy, nephropathy or neuropathy.

No additional patient education was provided prior to the study.

Questionnaire data and the last available HbA_{1c} were analysed during the study.

In this study we used 40 questions derived from the KomPAN questionnaire, which is an improved and extended version of the QEB (Beliefs and Eating Habits Questionnaire) and was created by Behavioural Conditions of Nutrition Team, Committee of Human Nutrition Science, Polish Academy of Science. For the purpose of this study the questionnaire had been extended with 13 additional, original questions (questionnaire available in appendices) (4-6). Among additional questions, a distinction was made between the categories of physical activity: at work and duration, and at leisure (cycling, running, aerobics, swimming, etc.) (7).

Physical activity at work and its duration has been divided into three categories: low physical activity (more than 70% of the time sitting), moderate physical activity (approximately 50% of the time sitting and approximately 50% of the time moving) and high physical activity (about 70% of the time in motion or physical work involving strenuous exercise) (7).

Physical activity at leisure has been divided into three categories: low physical activity (predominance of sitting, watching TV, reading the press, books, light housework, walking 1-2 hours a week), moderate physical activity (walking, cycling, gymnastics, gardening or other light physical activity 2-3 hours a week), high physical activity (cycling, jogging, working on a plot or in the garden and other recreational sports activities requiring physical effort performed over 3 hours a week) (7).

In order to comprehensively evaluate the quality of the diet, two diet indexes were calculated:

- Index of a healthy diet (pHDI-10, Prohealthy-Diet-Index-10) calculated by summing the frequency of consumption (multiplicity / day): fruit, vegetables, wholemeal bread, milk (including flavoured milk), milky fermented beverages (like yoghurts, kefirs), curd cheese (including homogenised cheese), fish products and dishes, legume dishes, thick milled buckwheat cereal products, oatmeal, whole-grain pasta and other coarse groats and dishes from the so-called white meat, e.g. chicken, turkey, rabbit (6);
- Index of unhealthy diet (nHDI-14, Non-Healthy-Diet-Index-14) calculated by summing the frequency of consumption (times / day): confectionery: fried dishes, alcoholic drinks, sweetened carbonated beverages, meat, powder soups and ready-to-eat soups, fast food and energy drinks, light breads, "white" cereal products - white rice, plain pasta or small groats, semolina, couscous; butter, lard, yellow cheese, red meat dishes, veal, mutton, lamb, beef, pork or venison (6).

Body weight and height provided by the patients into the questionnaire were used to calculate BMI.

The PS Imago Pro 6 (version 26, 2019, IBM Corporation) was used for statistical analysis. To check if the variables have a normal distribution, the Shapiro-Wilk test was used. The t-Student test and its non-parametric counterpart, the Mann-Whitney

test, were used to analyse quantitative variables in two subgroups, the ANOVA was used to analyse quantitative variables in three and four subgroups and the chi2 test was used to analysed qualitative data. A univariate logical regression was performed in two cases. Statistically significant results were those of $p < 0.05$.

We present the most interesting results in the next section.

Results

Table 1 presents the characteristics of the studied group (for the whole population and with respect to gender).

The ANOVA result turned out to be on the verge of statistical significance when an attempt was made to check whether the average nHDI-14 differs depending on the place of residence (p=0.066).

The average HbA_{1c} level and pHDI-10 did not differ depending on the place of residence and education.

However, we found relationship between gender and BMI in two categories (normal and overweight; we did not have underweight patients in the study) (p=0.01). The correct BMI was found in 62% of women, and only 38% of men. 64.5% of men were overweight, while only 35.5% of women.

In the studied population, 2% of people consumed only 2 meals a day, 26% consumed 3 meals, 52% - 4 meals, and just 21% consumed 5 or more meals a day. Only 21% of respondents ate all meals at regular times, 52% regularly consumed some meals, the rest ate irregularly. 74.1% of diabetics declared that they eat between the main meals. No relationship was found between gender and snacking, and between physical activity at leisure and snacking, as well as between BMI and snacking. However, when statistical analysis was performed in the subgroups of men and women, a relationship was found between physical activity at leisure and snacking in the subgroup of men (p=0.009); for women, this relationship was not statistically significant (p=0.450). In the group of men with low physical activity, 100% of respondents snack between meals. Among men with moderate physical activity, as many as 88% ate snacks. Only 52% men who showed high physical activity ate snacks between meals.

Figure 1 presents what products patients consume between main meals. Patients most often chose fruit, sweet snacks (such as candies, cakes, bars, wafers) and nuts, almond, seeds and pips.

The statistical analysis demonstrated that there was a relationship between two HbA_{1c} groups (both groups did not differ statistically significantly in age - p=0.180 and BMI - p=0.05): 'group 1' – $HbA_{1c} \leq 7\%$ (N=56 - 48.3% of the study group) and 'group 2' – $HbA_{1c} > 7\%$ N=58 – 50.0% of the study group) and the choice of light products ('Yes' or 'No') (p=0.003). Additionally, a univariate logistic regression was performed and results showed a similar effect (Table 2).

Table 1. Characteristics of the study population with respect to gender.

	Overall		Men		Women		p-value
	Mean	SD	Mean	SD	Mean	SD	
BMI [kg/m^2]	23.65	2.88	24.27	2.66	23.14	2.98	**0.016**
Age [year]	26.46	5.17	25.00	3.00	28.00	6.00	0.055
pHDI-10 [points]	22.43	10.54	18.74	7.14	25.43	11.88	**0.001**
nHDI-14 [points]	17.26	7.79	18.64	7.92	16.15	7.55	0.161
HbA_{1c} [%] [mmol/mol]	7.2 55.8	1.1 12.8	7.1 54.2	1.0 11.0	7.3 57.0	1.2 13.9	0.777

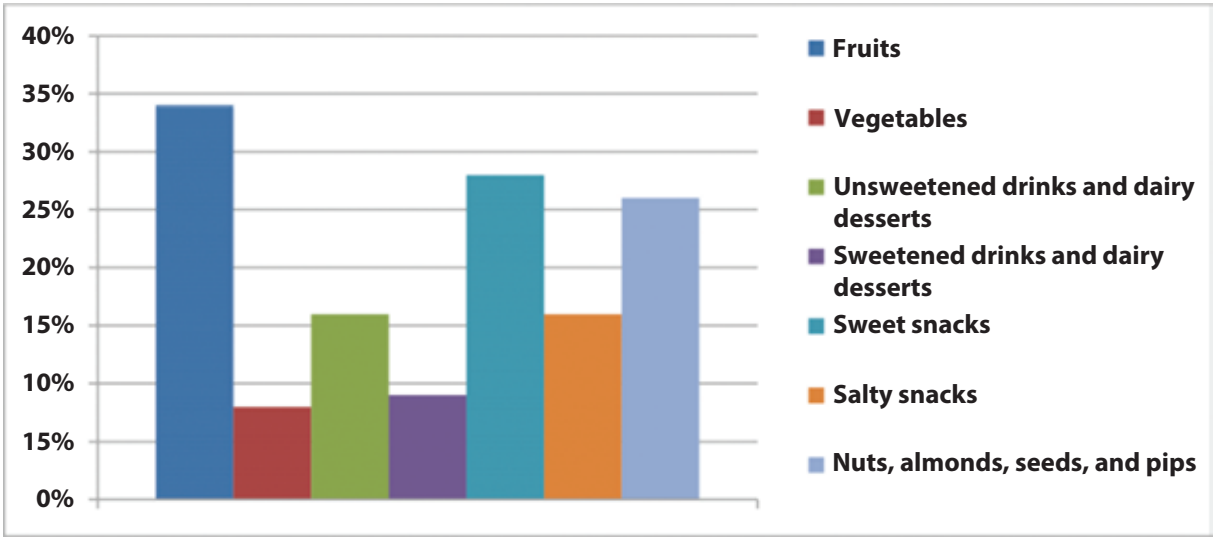

Figure 1. Products chosen as snacks by people with type 1 diabetes treated with personal insulin pumps.

Table 2. Influence of various variables on the selection of light products (p=0.007).

	B	p-value
Gender	-1.157	**0.034**
Age [Year]	-0.143	**0.017**
Bmi [Kg/m^2]	-0.039	0.678
Phdi [Points]	0.026	0.256
Nhdi [Points]	0.024	0.472
Hba$_{1c}$ [%]	0.729	**0.002**
Country	ref.	ref.
City Below 20,000 Residents	1.890	0.076
City From 20,000 To 100,000 Residents	0.131	0.858
City Above 100,000 Residents	0.723	0.220
Higher Education	ref.	ref.
Primary Education	-1.566	0.251
Basic Vocational Education	-1.528	0.278
Secondary Education	0.106	0.852
Smoking	0.520	0.479
Low Physical Activity At Leisure	ref.	ref.
Moderate Physical Activity At Leisure	-1.141	0.080
High Physical Activity At Leisure	-1.804	**0.013**

According to the univariate logistic regression model, the choice of light products was influenced by gender, age, HbA_{1c} level and physical activity at leisure.

The Figure 2 shows the light products chosen by people with T1DM treated with personal insulin pumps, divided into two groups with HbA_{1c} up to 7% and HbA_{1c} over 7%.

Light or "0%" dairy products and mayonnaise are low-fat products.

Sodas and chocolate light are sugar-free products.

In further analysis we focused on physical activity among patients with T1DM. There was a significant relationship between gender and physical activity in two categories: "at work and duration study" and "at leisure". No relationship has been found between increased physical activity, BMI, pHDI-10, nHDI-14, and HbA_{1c} level.

The analyses showed that physical activity at work differed between men and women (p=0.001). 61.5% of men spend more time in a sitting position during physical activity at work, while among women only 42.2% of the respondents declared such a situation.

This was followed by the analysis of the relationship between physical activity at work and the frequency of consumption of selected food products.

The consumption of fish differed in the three categories of physical activity at work (p=0.020). In the

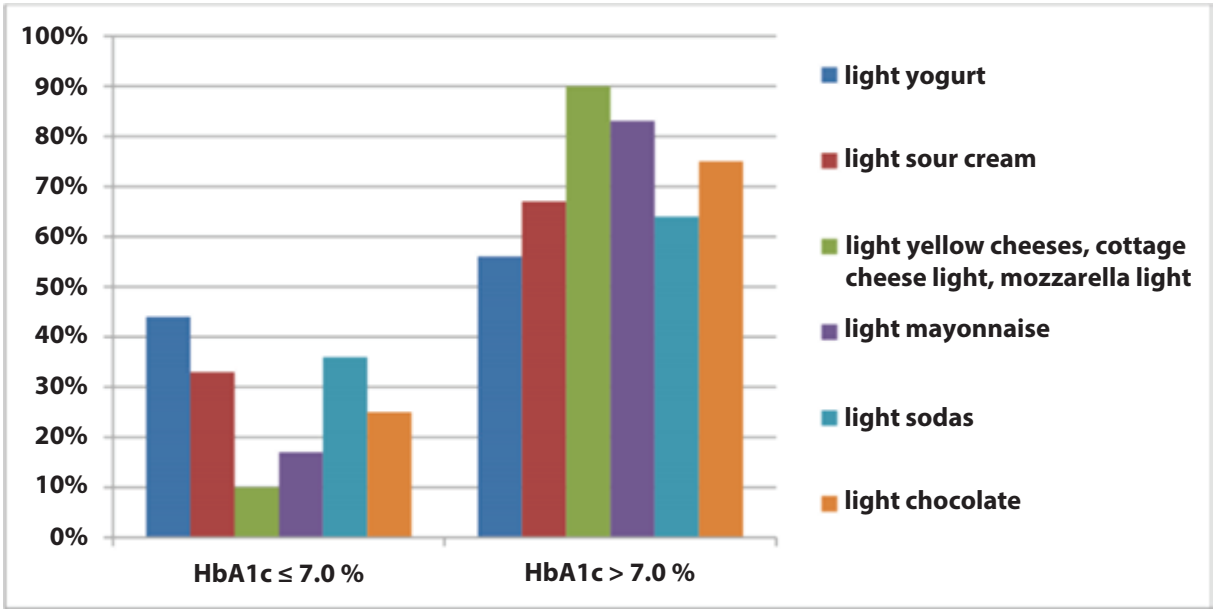

Figure 2. Selection of individual groups of light products.

group with low physical activity, the consumption of fish was 58% ate rarely or never, and 42% ate at least once a week. In the group with moderate physical activity, the consumption of fish was 34% ate rarely or never, and 66% ate at least once a week. In the group with high physical activity, the consumption of fish was 32% ate rarely or never, and 68% ate at least once a week.

The statistically significant relationship was found between the physical activity at work and frequency of canned meat, fish, vegetables and meat (p=0.023). In the group with low physical activity, the consumption of canned food was 93% ate rarely or never, and 7% ate at least once a week. In the group with moderate physical activity, the consumption of this type of food was 95% ate rarely or never, and 5% ate at least once a week. In the group with high physical activity, the consumption of canned food was 74% ate rarely or never, and 26% ate at least once a week.

The frequency of eating out differed in terms of physical activity at work (p=0.016). In the group with low physical activity, 46% were eating out rarely or never, and 54% ate out at least once a week. In the group with moderate physical activity, 76% ate out rarely or never, and 24% ate out at least once a week. In the group with high physical activity, 63% were eating out rarely or never, and 37% ate out at least once a week.

The analyses showed that free time physical activity differs between men and women (p=0.004). 48.1% of men declared moderate physical activity and 44.2% - high physical activity. Among women, 50% chose moderate physical activity, and high physical activity - 21.9%.

The next analyses were made to check whether there is a relationship between physical activity at leisure and the frequency of consumption of selected food products.

The results showed relationship between physical activity at leisure and 2 groups of BMI (normal and overweight observed (p=0.032). 17% of people with a normal BMI were low-activity, 57% were moderately active, while the remaining 27% were highly active. 26% of people with excess body weight had low activity, 29% were moderately active, while as many as 45% declared high activity.

The statistically significant relationship was found only between the physical activity at leisure and the frequency of white bread and rolls (p=0.016). Additionally, a univariate logistic regression was performed and results showed a similar effect (Table 3).

According to the univariate logistic regression model, the choice of white bread was influenced by gender, BMI index, education, smoking and physical activity at leisure.

Table 3. Influence of various variables on the selection of white bread (p<0.001).

	B	p-value
Gender	-1.157	**0.028**
Age [Year]	-0.143	0.400
Bmi [Kg/m^2]	-0.039	**0.036**
Phdi [Points]	0.026	0.109
Nhdi [Points]	0.024	**0.006**
Hba$_{1c}$ [%]	0.729	0.261
Country	ref.	ref.
City Below 20,000 Residents	1.890	0.977
City From 20,000 To 100,000 Residents	0.131	0.717
City Above 100,000 Residents	0.723	0.379
Higher Education	ref.	ref.
Primary Education	-1.566	0.465
Basic Vocational Education	-1.528	0.308
Secondary Education	0.106	**0.040**
Smoking	0.520	**0.020**
Low Physical Activity At Leisure	ref.	ref.
Moderate Physical Activity At Leisure	-1.141	**0.028**
High Physical Activity At Leisure	-1.804	0.163

Discussion

The study investigated the relationship between food choices and physical activity, glycated haemoglobin and body mass index among people with T1DM treated with personal insulin pumps. The selected results indicate the need for continuous analysis of the food choices of patients with type 1 diabetes.

Our study concerned a specific sub population of patients with T1DM. It was based exclusively on a homogeneous group of patients being treated with personal insulin pumps. They were characterised with normal BMI (despite the statistical difference in the average BMI for men and women) and relatively good metabolic control as measured with HbA_{1c}. A similar result was shown in the study by Matejko et al. 2015 (8). Statistical analysis of two groups of BMI index by gender showed that men are more often included in the category of being overweight, but this cannot be directly related to the risk of obesity. A similar result was shown in the study by Swasey et al. 2018 (9). It should be noted that BMI is calculated on the basis of body weight and height without any additional fat mass analysis (10). The meta-analysis by Ostman et al. 2017 indicated that exercise had no significant effect on BMI in post-2000 studies (11). This assumption shows the important role of the additional factor which is diet. When looking at nutritional indicators, the opposite picture can be observed, as men tend to choose unhealthy food more than women, which can be the factor connected with their excess weight, despite being more active.

The dietary habits in the studied individuals were far from being optimal. The study showed a difference in pHDI-10 (Prohealthy-Diet-Index-10) between men and women. Women had higher score in the index of a healthy diet than men. There was no statistically significant correlation for the nHDI-14 index. Nevertheless, the indicators for gender should be interpreted: the diet of the studied group was characterised by a low intensity of pro-health features and a low intensity of unhealthy features. Similar results were shown by the study by Hawrysz et al. 2016 (12). Compared to our previous study, which was conducted on a

slightly larger group, the current diet indicators turned out to be worse. In the previous analyses the pHDI-10 was 24.22 ± 10.28 point, now was 22.43 ± 10.54 point and then he nHDI-14 was 15.56 ± 7.61 and currently it was 17.26 ± 7.79 (4). According to norms, in overall the results for the pHDI index should aim for more points, while the nHDI should aim for the fewest points (6).

Almost 3/4 of patients declared eating between the main meals. A similar frequency of snacking was observed in the study by Schübert et al. 2019 who indicated that 70.5% patient with type 1 diabetes ate snacks (13). To quote a study by Heller et al. 2014, most people with insulin-treated diabetes, including the group with T1DM, consume snacks voluntarily, not on the medical indications (14). Eating snacks with high fat, sugar and salt such as salty snacks, sweetened drinks and milk desserts or sweet snacks may contribute to deposition of fatty tissue in the body and worsen the metabolic control (15,16). The results showed that men are more physically active, in addition, in this subgroup, the analysis showed that the greater the physical activity at leisure, the less frequent the decision to choose snacks. It can be concluded that the higher the physical activity, the greater the awareness of its influence on glycaemia. Perhaps the increased frequency, extended duration and increased intensity of physical activity affect the planning of meals before physical activity, which reduces the frequency of snacking in health focused individuals (17).

The results suggest that patents with higher the level of HbA_{1c} more often chose light products. "0%" or light dairy products can be associated with products that reduce the risk of hypertension, dyslipidaemia, atherosclerosis, which were healthier (18). Light or "0%" dairy products and mayonnaise are products often fortified with sugar or modified starches, to maintain flavour while reducing the fat content of the product (19,20). These various additions to low-fat version of the dairy products may result in higher blood glucose levels. Sodas and chocolate light are products which transform sugar into sweeteners or other sugar substitutes (21). Reaching for these foods may be the result of the current marketing of these products as healthy, because this type of food was associated with a reduced risk of metabolic syndrome (22). The results of the univariate logistic regression analysis showed that HbA_{1c} statistically significantly predicts whether or not a patient chooses light products. This choice is additionally influenced by gender, age, HbA_{1c} level and physical activity at leisure.

This relationship may result from poor nutritional education about the composition of light products.

The study also showed that more fish and canned food are consumed by people who declare high physical activity at work or at school / university. We may suspect that more physically active patients had less free time, and therefore used canned products more often.

What is more, people who declared low physical activity at work ate meals more often outside home. This relationship could have been due to their lower nutritional knowledge. Eating out has been linked to poor diet quality and weight gain (23) – it was usually high in energy and fat but low in micronutrients, such as calcium, vitamin C, and iron (24). The effects of advertising, promotion and pricing on nutrition as well as physical activity have long been discussed. Current trends, including eating out, are also affecting patients with type 1 diabetes.

In the further part of the result analysis, it was shown that different intensity of physical activity is associated with BMI level. Overweight was more common among people with low physical activity, but also among people with high physical activity. Generally the observational studies have shown that people who do comparatively more physical activity have a lower BMI than less active people (25). Looking at the overall results, men were characterised by a higher BMI and greater physical activity, but showed a diet with a low level of pro-health features.

More frequent consumption of white bread is associated with higher physical activity at leisure. Univariate logistic regression showed that other parameters such as gender, BMI index, education, smoking influence the choice of white bread. On the basis of analyses from previous publications, white bread can be seen a standard food (26,27). Therefore, it was the product that patients ate more often, especially from the region [removed for blind peer review] (26). In case of the prediction of hypoglycemia, the recommendation would be to eat a bedtime snack containing

carbohydrates (28). White bread as a standard food, being the source of monosaccharide, may be associated by patients with a solution to avoid hypoglycaemia. However, it is known from many studies that this is a mistaken assumption of patients (29). It should be noted, however, that white bread is never eaten on its own. Composing a meal with white bread and products that lower the glycaemic index may be the reason for such a decision among the examined patients (30).

This study has several limitations: in the case of the data on the basis of which the BMI was calculated, there is a risk of error on the part of the respondent, because the patients themselves filled in the anthropometric data gap in the survey. In addition, in the statistical analyses the influence of each product (its frequency) was artificially checked, regardless of its consumption with other food products, which could have some influence on the results Another limitation is the fact that this study was observational in nature, in order to be able to draw cause-and-effect conclusions, it is necessary to plan randomised trials. There did not analyse psychological aspects in this study and data from insulin pumps.

Conclusions

To summarise, the obtained results show the food choices of adult patients with T1DM treated with a personal insulin pump. We found that men with low and moderate physical activity snack more between meals. The light product was significantly associated with higher level of HbA_{1c} and weight. The results of this observational study suggest that, despite good glycaemic control, this population should pay careful attention to the selection of health-promoting product groups especially during physical activity. It seems that broad education (counting carbohydrates, principles of healthy eating), including physical activities at work and at leisure, is necessary to maintain proper eating habits among patients with type 1 diabetes.

Conflict of Interest: No potential conflict of interest relevant to this article was reported by the authors.

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