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Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Osijek, Croatia

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NUTRITION STATUS AND BOWEL HABITS IN COLORECTAL CANCER PATIENTS BEFORE AND AFTER NUTRITION COUNSELING

Nevena Ćorić^{1,2*}, Ines Banjari^{2,3}, Inga Marijanović^{1,4}, Ljubica Vazdar^{5,6}, Ilijan Tomaš^{7,8}

¹University Clinical Hospital Mostar, Ulica Kralja Tvrtka bb, 88000 Mostar, Bosnia and Herzegovina

²University of Mostar, Faculty of Agriculture and Food Technology, Biskupa Čule bb 88000 Mostar, Bosnia and Herzegovina

³Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 18, 31000 Osijek, Croatia

⁴University of Mostar, School of Medicine, Bijeli Brijeg bb, 88000 Mostar, Bosnia and Herzegovina

⁵University Hospital Center "Sestre Milosrdnice", Vinogradska cesta 29, 10000 Zagreb, Croatia

⁶University of Zagreb, School of Medicine, Šalata 3, 10000 Zagreb, Croatia

⁷University Hospital Center Osijek, Josipa Huttlera 4, 31000, Osijek, Croatia

⁸Josip Juraj Strossmayer University of Osijek, Faculty of Medicine, Josipa Huttlera 4, 31000 Osijek, Croatia

original scientific paper

Summary

The aim of this study was to examine the nutritional status and bowel habit before and after nutrition counseling in CRC patients. The study included 43 CRC patients (22 females and 21 males) with a mean age of 61.23±9.22. All participants received nutritional counseling, which included dietary guidelines for managing defecation during treatment (constipation or diarrhea). Nutritional status included anthropometric measurements: height and weight, body mass index, waist, hip, waist to hip ratio, and mid-upper arm circumference. For the bowel habit, a questionnaire examines bowel habits including bowel movement frequency, consistency, quantity, feeling of discomfort during bowel movement, and laxative use. Anthropometric measurements and questionnaires were performed at the initial nutritional counseling - prior to the start of treatment, and after a minimum of 6 months. Results show that 65.1% of CRC patients experienced weight loss in the three months prior to the initial nutrition counseling (base line). At endpoint, more patients were categorized as overweight (39.5%) or obese (23.3%) than at baseline. A statistically significant difference was observed between the baseline and endpoint measurements for all anthropometric variables, including weight, BMI, waist and hip circumference, and MUAC. Means of weight, BMI, waist and hip circumference, and MUAC were higher at the endpoint and after the nutrition education. There was a statistically significant difference in stool frequency in CRC patients at baseline and at the endpoint of the study. A larger number of patients (60.5%) had stool daily at the end point and after nutrition counseling than at baseline (48.8%). Also, the proportion of cases having at least 2–3 stools per day, at baseline was higher (44.2%) than at endpoint (32.6%). No statistically significant differences were observed in stool consistency, quantity, or discomfort during the follow-up. This study found pre-treatment weight loss in CRC patients, followed by significant weight regain and improvements in bowel function, potentially due to individualized nutritional education, though further research is needed to confirm these effects.

Keywords: colorectal cancer, nutritional status, bowel habits, defecation

Abbreviations:

BMI - Body mass index

ICD - International classification of disease

CRC - Colorectal cancer

RCRC - Right sided colorectal cancer

LCRC - Left sided colorectal cancer

MUAC - Mid upper arm circumference

WHR - Waist to hip ratio

Introduction

Colorectal cancer (CRC) represents a significant global health burden, impacting millions of lives each year. In 2022, GLOBOCAN reported that colorectal cancer was the third most common cancer globally, with 1 926 425 (9.6%) new cases, and the second leading cause of cancer-related deaths, totaling 904 019 (9.3%) (Globocan, 2022). According to the latest available data from the International Agency for Research on Cancer, in Bosnia and Herzegovina CRC is the second most

common cancer, after lung cancer, with an incidence of 26.3 per 100,000 inhabitants (Ferlay et al., 2024).

This is a multifactorial disease (Negrichi and Taleb, 2020) which includes non-modifiable and modifiable risk factors. Non-modifiable risk factors include age (40 to 50 years), gender (the incidence is higher in males), genetics, personal history of cancer and polyps, inflammatory bowel disease and race ethnicity. Modifiable risk factors include diet, physical inactivity, obesity, smoking, alcohol use, diabetes and insulin resistance (American Cancer

Society, 2024). This is the only cancer with an extremely high correlation with diet quality, and it is also believed that dietary and lifestyle habits (such as physical activity) have a greater influence than genetic predisposition (Banjari, 2018).

While extensive research has demonstrated the preventive role of specific dietary and lifestyle factors on CRC, the impact of nutritional status and dietary interventions on CRC treatment outcomes remains relatively unexplored (Martinis et al., 2023).

The nutritional status of patients with CRC significantly influences clinical outcomes, with malnourished and obese individuals exhibiting higher mortality rates compared to those with normal nutritional status (Negrichi and Taleb, 2020). Cancer stage, comorbidities, dietary and lifestyle factors, type of treatment, and treatment-related side effects, including appetite loss, nausea, vomiting, diarrhea, and constipation, collectively contribute to the patient's nutritional status. The body's response to cancer often involves inflammation, which can lead to muscle wasting or cachexia, specific for cancer patients (Zietarska et al., 2017). While many CRC patients maintain or even gain weight (Zietarska et al., 2017), the aforementioned metabolic and nutritional changes can adversely impact quality of life, life expectancy and the development of complications.

Malnutrition, a state of suboptimal nutritional status, arises from an imbalance between nutrient intake (macronutrients or micronutrients) and physiological demands, leading to compromised health. This imbalance can manifest as undernutrition, overnutrition, or micronutrient deficiencies. Under- and overnutrition can coexist, creating a dual burden of malnutrition (Himmelgreen and Miller, 2018). Nutritional status encompasses a range of indicators reflecting nutritional, physical, and health conditions, assessed through various methods. These include anthropometric measurements of body size and composition, biochemical analysis, dietary intake assessment, physical examination, and physical activity measurement (Himmelgreen and Miller, 2018).

Previous studies on CRC patients have demonstrated that many of them suffer from severe long-term bowel dysfunction and that the symptom pattern differs between patients undergoing right and left-sided colon resection (Bräuner et al., 2023). Due to the tumor's location in the large intestine and the type of treatment, which may involve surgical resection alongside radiotherapy or chemotherapy, patients may encounter a range of bowel complications. Typical symptoms of bowel dysfunction are diarrhea, urge for defecation, fecal incontinence, bloating, constipation and difficulties with evacuation (Borre et al., 2022; Lai et al., 2013). They result with discomfort,

embarrassment, and social isolation, worsening a patient's quality of life. Additional deterioration of the quality of life is present in patients with stoma.

Consequently, nutrition of CRC patients should be adjusted to their condition and individual needs (Lewandowska et al., 2022). However, the dietary information provided often lacks clarity, consistency, and supporting evidence. Some information can lead to confusion among patients, like in case of increased fiber intake (Borre et al., 2022). Previous findings indicate that CRC patients would benefit from dietary guidance during the immediate post-treatment period to alleviate symptoms and address concerns about food choices (Anderson et al., 2013).

The aim of this study was to examine the nutritional status and bowel habits before and after nutrition counseling in CRC patients.

Participants and methods

The research was conducted between August 2021 and June 2024 at the University Clinical Hospital Mostar, Bosnia and Herzegovina. This study was approved by the Ethics Committee of the University Clinical Hospital Mostar, Bosnia and Herzegovina (Decision No. 1013/21, September 20, 2021). All patients diagnosed with C18-C21 (according to the international classification of diseases) were recruited at the Oncology Clinic during their initial consultation with an oncologist. Patients were enrolled in the study either prior to the initiation of oncology therapy or during their first therapy session, following any surgical procedures. All patients signed informed consent to participate in the study.

First part of the study-specific questionnaire was collected via direct interview at baseline. It included general questions (age, gender), data on sociodemographic characteristics (e.g. place of residence, number of household members, working status, education, average monthly income), and single focused question about weight loss in the last three months, questions regarding general dietary and lifestyle habits e.g. number of meals per day, skipping meals, individual food preference, avoidance, and tolerance for spicy foods, smoking and alcohol consumption. The dietary assessment of patients, including energy, macronutrient, and micronutrient intake, was conducted using a 24-hour dietary recall and a food frequency questionnaire (FFQ). However, the results of this analysis are not presented within the scope of this study.

Data regarding the diagnosis of CRC (e.g. date of diagnosis, type of treatment) were collected from personal health charts.

Anthropometric measurements and bowel habit questionnaire were collected at baseline and after a minimum of 6 months follow-up (endpoint). Nutrition education was performed at baseline and after 3 months (midpoint) post diagnosis.

Nutritional status included anthropometric measurements: body height and weight, waist, hip, waist to hip ratio (WHR) and mid-upper arm circumference (MUAC). Digital column scale Seca 769 (Hamburg, Germany) was used to measure body height (in meters) and weight (in kilograms; ± 0.5 kg), with patients being barefoot and dressed in lightweight clothing and head positioned in the Frankfurt Horizontal.

Body mass index (BMI) was calculated as a person's weight in kilograms (kg) divided by the height in meters squared (kg/m^2). The plastic non-elastic measuring tape was used to measure waist, hip and MUAC. Waist circumference was measured with the subject standing, positioning the measuring tape horizontally just above the navel. The values were recorded in centimeters, rounded to whole numbers. Hip circumference was measured by placing the tape around the widest part of the hips. WHR was calculated dividing the circumference of waist by the circumference of the hip. For MUAC, the measurement was taken on a relaxed, non-dominant arm extended along the body, with the tape positioned horizontally 1 cm above the midpoint of the upper arm. This measurement was recorded in centimeters, rounded to one decimal place.

Patients were divided into four categories depending on their calculated BMI: underweight (less than $18.5 \text{ kg}/\text{m}^2$), normal ($18.5\text{--}24.9 \text{ kg}/\text{m}^2$), overweight ($25.0\text{--}29.9 \text{ kg}/\text{m}^2$), and obese ($\geq 30 \text{ kg}/\text{m}^2$), based on WHO 2008 classification.

For the bowel habit, a questionnaire from the European Prospective Investigation Into Cancer and Nutrition (EPIC) study was used (Park et al., 2009), translated into Croatian language. It examines bowel habits including bowel movement frequency, consistency, quantity, feeling of discomfort during bowel movement, and laxative use. Participants categorized bowel movement frequency into seven groups (more than six times daily, four or five times daily, two or three times daily, daily, every three or four times a week, two or three times a week and less than once a week), consistency into three levels (hard, soft, loose), and quantity into three categories (small, medium, large). Discomfort during bowel movements (no, yes) and laxative use were also recorded, with frequency ($<1/\text{d}$, daily, and $>1/\text{d}$) and brands of laxatives specified if applicable.

Nutritional counseling was conducted at the Department of Nutrition of the University Clinical Hospital Mostar by a nutritionist/ dietician.

The nutritional education was specifically designed to be in line with all current recommendations for CRC survivors (Fretwell et al., 2024; Rock et al. 2022; WCRF/ AICR, 2018.; Van Blarigan and Meyerhardt, 2015). The nutritional education for the CRC patients emphasized maintaining body weight. Recommendations included avoiding alcohol and processed meats and other processed food with monosodium glutamate, moderating red meat consumption (2 times per week), increasing intake of vegetables, fruits, whole grains, and legumes, in a form in which the patient will tolerate it (boiled and/or mashed) and consuming at least two servings of dairy daily or other calcium-rich foods, and at least two servings of fish per week. Easily digestible food was recommended without hot and strong spices. Also, it was recommended to increase food rich in omega-3 fatty acids, such as fish, flax, chia and other seeds and nuts, olive, flaxseed and other cold pressed plant oils. Nutritional education was further individualized based on each patient's specific conditions, with particular attention to their nutritional status and defecation patterns.

For example, during radiotherapy greater attention was paid on consuming cooked vegetables, pureed when necessary, and maintaining a moderate fiber intake.

The education was conducted in a one-on-one counseling session with provision of written materials patients were bringing home for their personal use. All patients also received a weekly meal plan.

Statistical analysis

The results were analyzed using IBM SPSS for Windows, version 25 [IBM Corp., Armonk, NY, USA]. For categorical variables, results are expressed as percentages, mean and standard deviation. To assess the normality of the investigated variables and select the appropriate statistical test, the Shapiro-Wilk test was used. For variables such as weight, BMI, waist and hip circumference, and MUAC, the distribution was found to be normal, enabling the use of paired samples t-tests. Categorical data with repeated measures were analyzed using Chi square test. For all analyses, p-value <0.05 was considered statistically significant.

Results and Discussion

A total of 43 individuals with CRC of all clinical stages were included, with 21 (48.8%) men and 22

(51.2%) women. The average age of all patients was 61.23 years (SD=9.22). Sociodemographic characteristics are shown in Table 1. Average monthly income of participants, was 355,41 EUR (SD=210,74).

Out of the total number of respondents, 9.3% have RCRC (1 female, 3 males), 58.1% have LCRC (13 females and 13 males) 32.6% patients (8 females and

5 males) have an unspecified type of CRC (ICD: C18.9). The RCRC include cecum, appendix, ascending colon, hepatic flexure and proximal two thirds of the transverse colon. The LCRC includes the left side of the colon, more precisely transverse colon, splenic flexure, descending colon, sigmoid colon and rectum (Baran et al., 2018) and its incidence has been higher than the RCRC (Lee et al., 2015).

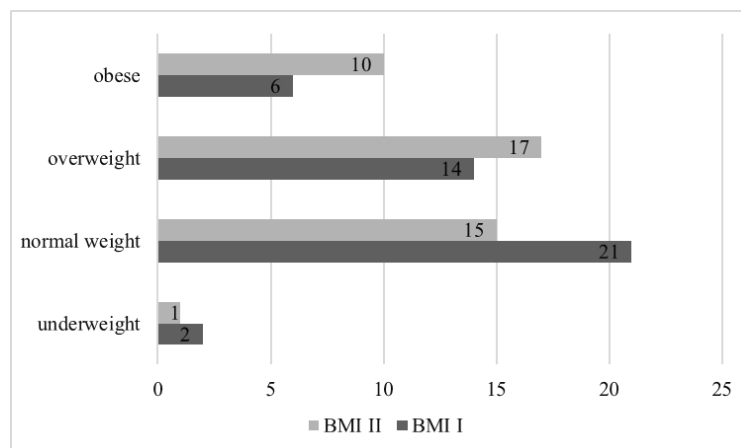
Table 1. Sociodemographic characteristics of CRC patients (N=43)

	n (%)
Marital status	
Married	36 (83.7%)
Single	7 (16.3%)
Work status	
Employed	7 (16.3%)
Unemployed	14 (32.6%)
Retired	22 (51.2%)
Education level	
Primary school	4 (9.3%)
Secondary school	26 (60.5%)
Non-university degree	5 (11.6%)
University degree	8 (18.6%)
Number of household members	
	9 (20.9%)
1	13 (30.2%)
2	14 (32.6%)
3	7 (16.3%)
>4	
Residential status	
Homeowner	42 (97.7%)
Living with family	1 (2.3%)

Change in nutritional status

Weight loss 3 months prior to the initial nutrition counseling (baseline) was reported by 28 (65.1%)

patients, while 7 (16.3%) patients reported gaining weight during the same period. In the following 6 months, a substantial number of patients gained weight (Figure 1).



*BMI I - baseline; BMI II - endpoint

Figure 1. Change of BMI in CRC patients

At the endpoint, according to the calculated BMI, significantly more patients ($p=0.000$) were categorized as overweight (39.5%) or obese (23.3%) than at baseline (32.6% and 14.0%) (Figure 1). During the six-month follow-up period, 10 (23.3%) patients experienced weight loss, 19 (44.2%) patients gained up to 5 kg of weight, and 14 (32.6%) gained more than 5 kg of weight. Changes in all anthropometric variables between the two time points were statistically significantly different (Table 2). Between

gender, statistically significant difference was observed between weight ($p=0.002$) and waist circumference ($p=0.000$), as also between WHR ($p=0.000$). On average, women exhibited a greater increase in body mass (84.36 ± 12.57 at baseline to 86.59 ± 12.57 compared to males 96.76 ± 11.72 to 100.75 ± 11.73), while men experienced a more pronounced increase in waist circumference (84.605 ± 16.41 to 87.98 ± 15.38 compared to women 67.25 ± 12.47 to 71.64 ± 13.38).

Table 2. Anthropometric measurement at baseline and endpoint in CRC patients (N=43)

	Mean ± SD	<i>p</i>	<i>t</i>
Weight (kg)			
Weight I	75.7 ± 16.8	0.000	-3.996
Weight II	79.6 ± 16.4		
BMI (kg/m²)			
BMI I	25.4 ± 5.3	0.001	-3.625
BMI II	26.7 ± 5.0		
Waist circumference (cm)			
Waist I	89.8 ± 13.6	0.002	-3.305
Waist II	92.6 ± 13.9		
Hip circumference (cm)			
Hip I	103.7 ± 9.9	0.003	-3.230
Hip II	106.4 ± 10.1		
WHR			
WHR I	0.85 ± 0.07	0.000	-0.894
WHR II	0.86 ± 0.08		
MUAC (cm)			
MUAC I	29.4 ± 4.3	0.035	-2.185
MUAC II	30.2 ± 3.4		

*"I" refers to baseline values and "II" refers to endpoint values after the nutrition education

We hypothesized that weight gain may be attributed to increased food intake to compensate for nutritional loss and a decrease in physical activity following surgery. Yet, BMI at the time of diagnosis has been identified as an independent prognostic factor in patients with early-stage CRC who underwent primary tumor resection and received adjuvant chemotherapy with curative intent (Renfro et al., 2016). Study by Lee et al. (2020) showed that obesity has a negative prognostic role in CRC patients undergoing adjuvant chemotherapy. Also, according to Meyerhardt et al. (2017) the impact of obesity on cancer outcomes is inconsistent according to sex, where obesity (BMI > 30 kg/m²) was associated with poor survival in women but not in men. In analysis by Sinicrope et al. (2013) based on 25,291 patients from the ACCENT (Adjuvant Colon Cancer End Points) database, during a median follow-up of 7.8 years, obese and underweight patients with stage II or III disease had significantly poorer survival compared with overweight and normal-weight patients. For metastatic CRC, BMI was a prognostic factor for the overall survival and progression-free survival, with an L-shaped pattern. Risk of progression and/or death was greatest for low BMI, risk decreased as BMI increased to approximately 28 kg/m², and then it plateaued (Renfro et al., 2016).

The evaluation of waist circumference to assess the risks associated with obesity or overweight is supported by research (WHO, 2011). A 2-cm increase in waist circumference, a measure of central obesity,

was associated with a 4% greater risk of CRC (Moghaddam et al., 2007). Waist circumference and waist to hip ratio could also be a predictor of mortality and morbidity after colorectal surgery, and according to Kartheuser et al. (2013) even better than BMI or body surface area. Abdominal obesity is linked to insulin resistance, abnormal blood lipid levels, and widespread inflammation, all of which are associated with an increased risk of CRC. Visceral adiposity, along with its aggravation, is associated with colorectal adenoma, which can progress to CRC (Gonzalez-Gutierrez et al., 2024). BMI, waist circumference, and increased waist-to-hip ratio are associated with significant increases in CRC in men and this association appears to be less strong in women, probably because of the protective effect of estrogens (Gonzalez-Gutierrez et al., 2024), and higher percentage of visceral fat in men (Chaplin et al., 2022). Our results are in line with literature evidence. This could also explain results from this research, where men experienced a more pronounced increase in waist circumference.

Change in bowel habits

At baseline, eight patients already had a colostomy, and two more patients till the endpoint. Among patients with stomas, only one had RCRC, the remaining patients had LCRC. Bowel habits of CRC patients at baseline and at the endpoint are presented in Table 3.

Table 3. Bowel habits in CRC patients at baseline and at endpoint, after nutrition counseling (N=43)

<i>Bowel movement</i>	I	II	<i>p</i>
Frequency			
≤ 3-4 stool/week	3 (7.0%)	3 (7.0%)	0.049
7 stools/week (daily)	21 (48.8%)	26 (60.5%)	
≥ 2-3 stool/day	19 (44.2%)	14 (32.6%)	
Consistency			0.682
Hard	11 (25.6%)	6 (14.0%)	
Soft	27 (62.8%)	35 (81.4%)	
Loose	5 (11.6%)	2 (4.7%)	
Quantity			0.662
Small	14 (32.6%)	6 (14.0%)	
Medium	25 (58.1%)	36 (83.7%)	
Large	4 (9.3%)	1 (2.3%)	
Feeling			0.966
No discomfort	31 (72.1%)	36 (83.7%)	
Discomfort	12 (27.9%)	7 (16.3%)	
Laxative use			0.005
No	38 (88.4)	42 (97.7%)	
Yes	5 (11.6%)	1 (2.3%)	

**"I" refers to baseline values and "II" refers to endpoint values after the nutrition education

There was a statistically significant difference ($p=0.049$) in stool frequency in CRC patients during the follow-up. More patients (60.5%) reported regular bowel movement (daily) at the endpoint as compared to the baseline (48.8%). The number of patients having at least 2–3 stools per day diminished from 44.2% at baseline to 32.6% at endpoint. This reduction was particularly observed in LCRC patients, though it was not statistically significant. Laxative use was significantly reduced during the study; from 11.6% at baseline to 2.3% at endpoint ($p=0.005$). Laxatives used by those patients were non-fiber laxatives (one commercial, herbal preparations and fruits).

Stool consistency, quantity, or discomfort during defecation did not change significantly during the follow-up. However, almost 20% of patients reported a shift in stool consistency during the study. Specifically, a smaller number of patients experienced harder stools and fewer reported discomfort during bowel movements at endpoint (Table 3). Larger number of patients with LCRC had hard stool at both study points, which is consistent with the study of Brauner et al. (2023).

A significant number of patients reported heightened sensitivity to some foods (18 patients; 41.9%) particularly legumes (beans and lentils), as well as peppers, onions, and milk, which exacerbated their gastrointestinal symptoms. Preference towards hot and spicy food was reported by 17 (39.5%) patients. The most common foods they avoided even before their first nutritional education were sweets and soft and fizzy drinks (17 patients; 37.2%).

Given that all CRC patients treated at the University Clinical Hospital Mostar, were included in the study, the method of treatment and its influence on defecation were not taken into account. The basic treatment of CRC is classical or laparoscopic resection of the tumor with the removal of the surrounding lymph nodes (Lewandowska et al., 2022). Chemotherapy or chemoradiation is advised for patients with unresectable tumors or who are medically unfit for surgery. Adjuvant chemotherapy is recommended for post-surgical patients with stage III or high-risk stage II disease. Pre-operative neoadjuvant therapy may be administered to patients with resectable high-stage colonic disease (T4 tumors) in order to downstage the tumor (Szymańska, 2018), so this explains why some patients had a stoma implanted at endpoint.

Bowel dysfunction, characterized by changes in bowel frequency, incontinence, abnormal sensations, and evacuation difficulties, is particularly prevalent among patients with rectal cancer. These problems are mostly pronounced within the initial year post-

diagnosis, especially during the first six months (Lai et al., 2013).

Findings from the prospective study by Citronberg et al. (2014) suggest that the risk of CRC increases with non-fiber laxative use and decreases with fiber laxative use. Overall, despite the common use of laxatives among patients undergoing treatment, current research on this subject is still limited. Also, studies on the association between spicy food intake and cancer risk have reported inconsistent results. Various *in vitro* studies have demonstrated anticancer activity of chemicals present in spices. A review by Mani et al. (2020) showed significant negative correlation between spice intake and CRC risk, indicating their potentially preventive effect, possibly even risk-lowering agents in populations at higher risk of CRC. A study by Mahfouz et al. (2014) showed that higher consumption of spicy foods, as well as red meat, preserved foods, artificial sweeteners, fast foods, soft drinks, and processed meat, were significantly related to onset of CRC. Baseline assessments of general dietary habits, including preferences, food avoidance, and tolerance, revealed that a significant proportion of CRC patients had already modified their diets to manage bowel function, avoiding certain foods even before receiving nutritional education. This aligns with findings from the study by Borre et al. (2022) which showed that food categories such as fatty foods, spices, sweets, meat, and alcohol were most frequently reported as having a negative impact on bowel function, while vegetables, fruits, and dairy were commonly perceived to improve it. The dietary and bowel symptom information provided to patients can significantly influence their perception of diet and bowel-related symptoms (Borre et al., 2022).

Conclusion

Results from this study showed pre-treatment weight loss among CRC patients, likely attributable to surgical resection of the tumor, preoperative preparation, or diagnostic procedures. At the endpoint, a significant proportion of patients regained their initial weight, with notable increases in body weight and other anthropometric measures such as BMI, waist and hip circumference, and MUAC.

In regard to bowel dysfunction, a greater proportion of patients exhibited a normalization of bowel habits, characterized by daily stool passage and an improvement in stool consistency. The observed improvements may be attributed to the effectiveness of individualized nutritional education. However, further research is required to validate this hypothesis, as this study does not address the impact of treatment techniques on defecation patterns or stool characteristics.

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USPOREDBA PREHRAMBENIH NAVIKA OBOLJELIH OD PARKINSONOVE BOLESTI U ODNOSU NA ZDRAVU POPULACIJU

Barbara Kolarić¹, Svetlana Tomić^{2,3}, Ines Banjari^{1*}

¹Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek, Franje Kuhača 18, 31000 Osijek, Hrvatska

²Klinički bolnički centar Osijek, Josipa Huttlera 4, 31000 Osijek, Hrvatska

³Sveučilište Josipa Jurja Strossmayera u Osijeku, Medicinski fakultet Osijek, Josipa Huttlera 4, 31000 Osijek, Hrvatska

izvorni znanstveni rad

Sažetak

Parkinsonova bolest (PB) jedna je od neurodegenerativnih bolesti multifaktorijalne etiologije koja najčešće pogađa osobe u dobi od 60 i više godina, pretežito muškarce. Zbog velikog broja simptoma koji prethode postavljanju dijagnoze PB, a očituju se kao različiti gastrointestinalni simptomi, smatra se da prehrana ima vrlo važnu ulogu u razvoju i progresiji bolesti. Napravljena je usporedba prehrambenih navika oboljelih od PB-a i zdrave populacije iste dobi, s posebnim naglaskom na usklađenost prehrane principima mediteranske prehrane (MeDi), prehrane za kontrolu hipertenzije (DASH) i prehrane za neuroprotekciju (MIND). Analizirani su odgovori 33 zdrave osobe i 16 oboljelih od PB u dobi od 60 godina. Prehrana oboljelih od PB ima više pozitivnih karakteristika u odnosu na zdrave osobe; imaju veći broj obroka u danu ($p=0,031$), rjeđe preskakuju obroke (75 % nikada ne preskače obrok) i prehrana im je u većoj mjeri usklađena s MeDi, DASH i MIND principima, no usklađenost je i dalje iznimno loša. Potreba za edukacijom oboljelih od PB o prilagodbi prehrane je neophodna kako bi se osigurali bolji ishodi liječenja i progresije bolesti.

Ključne riječi: Parkinsonova bolest, prehrambene navike, mediteranska prehrana, DASH prehrana, MIND prehrana

Uvod

Parkinsonova bolest (PB) je idiopatski, sporoprogresivni degenerativni poremećaj središnjeg živčanog sustava koji se manifestira sporošću i siromaštvom pokreta, mišićnim rigiditetom, tremorom u mirovanju i nestabilnošću pri održavanju položaja tijela (Kouli i sur., 2018). Riječ je o bolesti starije životne dobi, prosječna dob u kojoj se bolest javlja je 60 godina i češće se javlja u muškaraca nego u žena (Beitz, 2014). Rezultat je nedostatka dopamina, koji je uzrokovan smrću živčanih stanica u mozgu koje ga proizvode. Bez dopamina, pokreti postaju sporiji, te osobama koje boluju od PB treba duže vremena za obaviti određene radnje (Kouli i sur., 2018).

Etiologija PB je multifaktorska i iako nije još uvijek u potpunosti razjašnjena, smatra se da bolest uključuje kompleksnu interakciju genetskih i okolišnih čimbenika (Kouli i sur., 2018). Teški metali, insekticidi, herbicidi, toksini, bunarska voda, stanja nakon traume mozga, život na selu, bavljenje poljoprivredom, korištenje nesteroidnih protuupalnih lijekova i narkotika, povećana tjelesna masa i nedostatak tjelesne aktivnosti opisani su kao okolišni čimbenici koji mogu uzrokovati bolest (Telarović, 2013; Kenborg i sur., 2015).

Epidemiološke studije pokazuju da je pušenje povezano s nižom incidencijom PB. Ovaj nalaz je važan jer bi mogao pružiti tragove o terapijskim strategijama za zaštitu od ovog poremećaja kretanja. Dim sadrži brojne kemikalije koje bi mogle biti odgovorne za zaštitni učinak. Veliku ulogu ima nikotin, jer ova kemikalija potiče dopaminergički sustav te također ima neuroprotektivno svojstvo (Moccia i sur., 2015).

Pretpostavlja se da zbog genskih i okolišnih čimbenika dolazi do povećanog stvaranja slobodnih radikala i nastanka oksidativnog stresa što uzrokuje neurodegeneraciju. Substancija nigra je izrazito bogata željezom što ju čini pogodnom za nastanak slobodnih radikala. U sklopu PB također dolazi do smanjenja količine glutationa i oksidativnog oštećenja bazalnih ganglija pa se i oksidativna hipoteza spominje u kontekstu mogućih objašnjenja nastanka bolesti (Telarović, 2013). Dosadašnji rezultati pokazuju kako prehrana izravno sudjeluje u povećanju rizika za PB, uglavnom u pogledu visokih unosa životinjskih masti (Powers i sur., 2003) i mliječnih proizvoda (Chen i sur., 2007; Hughes i sur., 2017). Neke od teorija povezanosti konzumacije mliječnih proizvoda i PB proizlaze iz činjenica da smanjuju mokraćnu kiselinu u organizmu, a niska razina mokraćne kiseline povezuje se s većom incidencijom i bržom progresijom PB, povećana potrošnja mliječnih proizvoda u odsustvu dovoljne količine laktaze može dovesti do upale i povećane propusnosti crijeva što se također može povezati s etiologijom PB (Seifar i sur., 2022).

Ispitanici i metode

Cilj rada bio je usporediti prehrambene navike oboljelih od PB sa zdravom populacijom iste dobi.

Ispitanici

Provedeno je opažajno istraživanje na populaciji starijoj od 45 godina s područja Republike Hrvatske. Istraživanjem je obuhvaćeno 33 zdrave osobe i 16 osoba s dijagnozom PB.

Primjenom metode intervjua prikupljeni su podaci od samih bolesnika ili njihovih skrbnika u ambulanti za Neurologiju Kliničkog bolničkog centra Osijek i u Udruzi bolesnika oboljelih od Parkinsonove bolesti „Buđenje“ u Osijeku. Zdravi ispitanici prikupljeni su s područja Osječko-Baranjske, Virovitičko-Podravske i Varaždinske županije.

Istraživanje je odobrilo Etičko povjerenstvo Kliničkog bolničkog centra Osijek.

Upitnik

Upitnik kreiran specifično za potrebe istraživanja sastojao se iz dva dijela. Prvi dio je obuhvatio pitanja o ekonomskim i socijalnim karakteristikama ispitanika, masi i visini, zdravstvenom stanju, simptomima, konzumaciji lijekova i općenitim prehrambenim navikama. Drugi dio ankete je bio semi-kvantitativni upitnik o učestalosti konzumacije hrane (SFFQ) kojim je prikupljena informacija o učestalosti konzumacije namirnica/skupina namirnica koje usklađene s radom Morris i suradnika (2015). Upitnik je uključivao 69 namirnica/skupina namirnica, 8 vremenskih kategorija o učestalosti konzumacije (2+ x/dan, 1x/dan, 3-5x/tjedan, 2-3x/tjedan, 1x/tjedan, 2-3x/mjesec, 1x/mjesec i rjeđe) te dijela o količini koji se sastojao od tri veličine porcije (srednje S, male M i velike porcije V) s točno navedenim količinama srednje porcije za lakšu usporedbu.

Morris i suradnici (2015) su razvili tri bodovna sustava (DASH, MeDI i MIND) prema kojima je napravljena procjena kvalitete prehrane ispitanika.

Za MeDI dijetu, bodovi za količinu porcija su uzeti iz tradicionalne grčke mediteranske prehrane. Boduje se 11 namirnica, a svaka nosi bodove od 0 do 5, zajedno zbrojeni bodovi čine ukupan rezultat koji može iznositi između 0 do 55 (Morris i sur., 2015).

Bodovanje za DASH dijetu uključuje 7 skupina namirnica i 3 prehrambene komponente (ukupna masnoća, zasićene masne kiseline i natrij), svaki nosi 0, 0,5 ili 1 bod, ovisno o učestalosti konzumacije (Morris i sur., 2015).

Bodovanje MIND dijetu se sastoji od 15 prehrambenih namirnica, uključujući 10 „zdravih“ namirnica za mozak (zeleno lisnato povrće, drugo povrće, orašasti plodovi, bobičasto voće, mahunarke/grahorice, cjelovite žitarice, riba, pileтина, maslinovo ulje i vino) i 5 „nezdravih“ namirnica (crveno meso, maslac i margarin, sir, kolači i slatkiši te brza/pržena hrana). Za sve ostale komponente zbrojena je učestalost konzumiranja i porcija te im dodijeljen bod 0, 0,5 ili 1 (Morris i sur., 2015).

Statistička analiza

Programski sustav Statistica (inačica 14.0, StatSoft Inc., SAD) korišten je za statističku obradu rezultata, uz odabranu razinu slučajnosti od 0,05. Grafička obrada podataka je napravljena pomoću MS Office Excel tabličnog alata (inačica 2016., Microsoft Corp., SAD).

Rezultati prate normalnu razdiobu podataka (testirano Kolmogorov-Smirnov testom) no zbog malog broja ispitanika korišteni su neparametrijski statistički testovi.

Kategorički podaci predstavljeni su apsolutnim i relativnim frekvencijama, dok su numerički podaci opisani medijanom i interkvartilnim rasponom.

Za usporedbu kategoričkih podataka unutar i među skupinama korišten je Fischerov egzaktan test a za nezavisna mjerenja je korišten Mann-Whitney U test. Za izračun korelacija numeričkih podataka korišten je Spearmanov test.

Rezultati i rasprava

Upitnik je ispunilo 33 zdrave osobe i 16 oboljelih od PB-a, i nisu se značajno razlikovali po dobi i indeksu tjelesne mase (BMI) (Tablica 1). Srednje trajanje dijagnoze PB iznosi $4,6 \pm 4,2$ godina i kreće se od 0,25 godina do 15 godina.

Među oboljelima od PB više je muškaraca (69 %) u odnosu na žene (31 %), a što je u skladu s istraživanjima provedenima na povezanosti spola i incidencije PB, kojima je potvrđena veća incidencija među muškarcima (Kouli i sur., 2018; De Lau i Breteler, 2006).

Tablica 1. Usporedba odabranih karakteristika između osoba oboljelih od PB i zdravih osoba

Table 1. Comparison of age and Body Mass Index between people diagnosed with PD (n=16) and health counterparts (n=33)

Karakteristike	Ispitanici	n	Medijan (25 % - 75 %)	Min	Max	P*
Dob	Zdravi	33	60 (56 – 63)	45	82	0,773
	PB	16	60 (46 – 70)	46	70	
BMI (kg/ m ²)	Zdravi	32	30,1 (26,0 – 32,5)	19,6	42,5	0,498
	PB	16	28,0 (20,2 – 39,3)	20,2	39,3	

PB – ispitanici s dijagnozom Parkinsonove bolesti; Zdravi – ostali ispitanici; Min – minimalna vrijednost; Max – maksimalna vrijednost; SD – standardna devijacija

*statistička značajnost kod $p < 0,05$ (Mann-Whitney U test)

Kod zdravih ispitanika (55 %) i kod oboljelih od PB (63 %) većina je nepušača koji nikada nisu aktivno pušili. Iako se na inverznu vezu pušenja i razvoja PB ukazalo još 1999. godine, tek su nedavna istraživanja pokazala kako su inverzne promjene u razinama dopamina kod oboljelih od PB i ovisnosti o nikotinu vjerojatni razlog inverzne povezanosti pušenja i rizika za razvoj PB (Wang i sur., 2022).

Oboljeli od PB imaju značajno veći broj obroka od zdravih ispitanika, njih 87 % ima više od dva obroka dnevno, dok zdravih 63 % ima više od dva obroka dnevno ($p=0,031$) (Tablica 2). Također je utvrđeno

kako s porastom dobi oboljelih od PB opada i broj obroka ($r=-0,476$). Istraživanja pokazuju da kod većine oboljelih od PB dolazi do smanjenja apetita zbog nedostatka dopamina koji ima ulogu u regulaciji unosa hrane, što dovodi do gubitka tjelesne mase i pojave malnutricije, te je zbog toga od iznimne važnosti održavanje pravilnog načina prehrane (Aiello i sur., 2014). Malnutricija je povezana s lošijom kvalitetom života, kraćim životnim vijekom, slabijim odgovorom na terapiju, osteoporozom, osjetljivošću na infekcije i upale i pogoršanje motoričkih, mentalnih i autonomnih funkcija (Tomić i sur., 2015).

Tablica 2. Usporedba karakteristika prehrane prema tri principa DASH, MeDi i MIND prehrane između oboljelih od PB i zdravih osoba
Table 2. Comparison of dietary characteristics according to tree principles DASH, MeDi and MIND diet between people diagnosed with PD ($n=16$) and health counterparts ($n=33$)

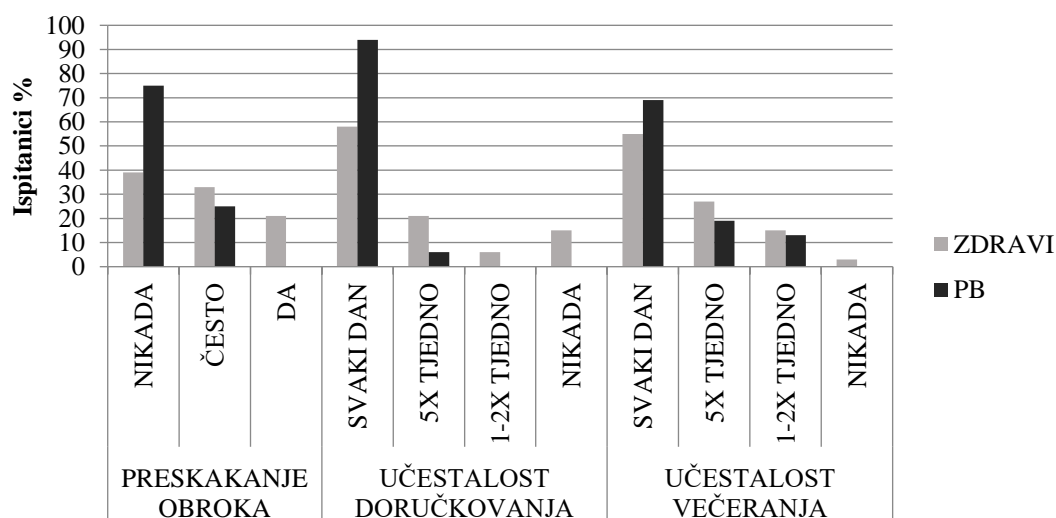
	Ispitanici	n	Medijan (25 % - 75 %)	P*
Broj obroka/dan	Zdravi	33	2,9 (2,5 – 3,0)	0,031*
	PB	16	3,0 (3,0 – 5,0)	
DASH	Zdravi	33	4,6 (3,8 – 5,2)	0,678
	PB	16	4,8 (4,1 – 5,4)	
MeDi	Zdravi	33	17,4 (15,8 – 19,5)	0,400
	PB	16	18,3 (16,4 – 20,9)	
MIND	Zdravi	33	5,9 (4,9 – 6,9)	0,400
	PB	16	6,2 (5,5 – 7,4)	

PB – oboljeli od Parkinsonove bolesti; Zdravi – ostali ispitanici; SD – standardna devijacija

*statistička značajnost kod $p<0,05$ (Mann-Whitney U test)

Zdravi ispitanici češće preskaču obroke; njih 54 % često ili u pravilu preskaču obroke dok oboljeli od PB-a imaju bolje prehrambene navike te se njih 75 % izjasnilo da nikada ne preskaču obroke (Slika 1). Slični su podaci i o

učestalosti doručkovanja i večeranja koji su bolje kod oboljelih od PB-a u odnosu na zdrave ispitanike (Slika 1). Pozitivno je pak da je 85 % zdravih i 94 % oboljelih od PB reklo kako češće jedu kuhani obrok nego suhi, brzi obrok.



Slika 1. Prehrambene navike oboljelih od PB ($n=16$) i zdravih ispitanika ($n=33$)
Figure 1. Dietary habits of people diagnosed with PD ($n=16$) and health counterparts ($n=33$)

Promatrajući ostvareni broj bodova za DASH, MeDi i MIND dijetu (Tablica 2) vidljivo je da nema značajne razlike između zdravih i oboljelih od PB-a. Za DASH dijetu kod oboljelih od PB bodovi su iznosili 4,8 od maksimalnih 10, dok je kod zdravih prosječan broj 4,6 (Tablica 2). Prosječan broj bodova za MeDi kod oboljelih od PB iznosi 18,3, a kod zdravih 17,4 od maksimalnih 55, dok su oboljeli od PB imali 6,2 bodova za MIND dijetu, a zdravi ispitanici 5,9 bodova (Tablica 4). Također, nije utvrđena razlika u karakteristikama prehrane s obzirom na duljinu dijagnoze PB.

Različiti nutrijenti koje se nalaze u namirnicama tipičnima za MeDi imaju snažan utjecaj na naše pamćenje, koncentraciju, procese razmišljanja i emocionalno stanje te se upravo ovaj način prehrane ističe kao najbolji za zdravlje mozga (Dominguez i sur., 2021; Banjari i sur., 2014). Iako se uobičajeno preporučuje za kontrolu hipertenzije, DASH dijeta zbog kombinacije namirnica osigurava visok udio vlakana, proteina, kalija, magnezija i kalcija, s niskim sadržajem zasićenih masti, natrija, ukupnih masti i kolesterola (Morris i sur., 2015; Banjari i sur., 2013), što sve pozitivno djeluje na krvožilni sustav pa tako i mozak. Kombinacija ova dva principa je tzv. MIND dijeta kojoj je glavni cilj prevencija demencije i neuroprotekcija (Morris i sur., 2015).

Osim za broj obroka dnevno nije utvrđena ni jedna statistički značajna razlika između prehrambenih karakteristika zdravih ispitanika i oboljelih od PB. Ovi podaci potvrđuju da oboljeli od PB nisu dovoljno educirani o važnosti prehrane prilagođene njihovoj bolesti.

Zaključak

Rezultati ovog istraživanja potvrđuju potrebu za edukacijom oboljelih od PB u pogledu potrebe prilagodbe prehrane njihovoj bolesti. Prilagodba prehrane nije neophodna samo u pogledu učinkovitijeg djelovanja terapije već i u pogledu progresije bolesti, a po potrebi prehranu je potrebno prilagoditi nemotoričkim simptomima koji su česti u oboljelih od PB. Usporedbom prehrambenih navika zdravih ispitanika i oboljelih od PB vidljiv je veći broj pozitivnih karakteristika; od većeg broja obroka tijekom dana, rjeđeg preskakivanja obroka i prehrani koja je u većoj mjeri usklađena prehrani koja povoljno djeluje na zdravlje mozga.

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COMPARISON OF DIETARY HABITS BETWEEN PARKINSON'S DISEASE PATIENTS AND HEALTH COUNTERPARTS

Barbara Kolarić¹, Svetlana Tomić^{2,3}, Ines Banjari¹

¹Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 18, 31000 Osijek, Croatia

²University Hospital Osijek, Josipa Huttlera 4, 31000 Osijek, Croatia

³Josip Juraj Strossmayer University of Osijek, Faculty of Medicine Osijek, Josipa Huttlera 4, 31000 Osijek, Croatia

original scientific paper

Summary

Parkinson's disease (PD) is one of the neurodegenerative diseases of multifactorial etiology that most often affects people aged 60 and over, predominantly men. Due to the large number of symptoms that precede the diagnosis of PD, which are manifested as various gastrointestinal symptoms, nutrition is considered to play an important role in the development and progression of the disease. A comparison was made between the dietary habits of PD patients and healthy counterparts of the same age, with a special emphasis on the compliance to the Mediterranean diet (MeDi), the diet for the control of hypertension (DASH) and the diet for neuroprotection (MIND). The answers of 33 healthy people and 16 PD patients aged 60 were analyzed. Patients with PD had more positive dietary characteristics as compared to healthy counterparts; they have more meals per day ($p=0.031$), skip meals less often (75% never skip a meal) and their diet is more in line with MeDi, DASH and MIND principles, but the compliance is still extremely poor. The need to educate PD patients about dietary adjustments is necessary to ensure better treatment outcomes and disease progression.

Keywords: Parkinson's Disease, dietary habits, Mediterranean Diet, DASH Diet, MIND Diet

SIMULATION OF GLUCOSE AND INSULIN KINETICS MODEL USING THE GLYCEMIC LOAD OF MIXED MEALS

Sara Maraš, Davor Valinger, Tea Sokač Cvetnić, Tamara Jurina, Maja Benković,
Jasenka Gajdoš Kljusurić, Ana Jurinjak Tušek*

University of Zagreb Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000 Zagreb, Croatia

original scientific paper

Summary

This study aimed to assess how the glycemic load in various mixed meals affects glucose and insulin levels using a mathematical model of glucose and insulin dynamics. Three distinct dietary menus were formulated (high-carbohydrate, diabetic, and low-carbohydrate) each with calculated glycemic loads. The model was then simulated using the WR Mathematica 10.0 software using the data form developed menus. Findings revealed that meals with a high glycemic load significantly influenced blood glucose and insulin levels. Additionally, a negative correlation was observed between carbohydrate proportions and protein ($r = -0.9500$) as well as fat ($r = -0.9855$) proportions in the meals. The glycemic load of a single meal can serve as an initial value for simulating the glucose-insulin metabolism model, enabling a personalized approach to meal development through the application of the primary nutrient metabolism model.

Keywords: mathematical model of glucose and insulin kinetics, glycemic load, glucose concentration, model simulation

Introduction

In the human body, the blood glucose concentration depends primarily on the diet. Carbohydrates are the exclusive class of macronutrients that undergo direct conversion into glucose within the body, and their catabolism is initiated prior to that of other macronutrient groups (Chandel, 2021). The digestibility of the carbohydrates themselves depends on their structure; therefore, indigestible carbohydrates such as cellulose reach the colon intact and serve as a food source for beneficial bacteria (Kiely and Hickey, 2022). Moreover, indigestible carbohydrates, known as dietary fibers, exert a comprehensive influence on the digestive tract by slowing the absorption of nutrients, reducing serum cholesterol levels, and enhancing feelings of satiety. This, in turn, may lead to decreased caloric intake in subsequent meals, which has been demonstrated to confer protective benefits against diseases associated with obesity (Dayib et al., 2020). Carbohydrate metabolism provides the cell with constant and necessary energy supply. Blood glucose levels are tightly regulated (3.89-4.44 mmol/L during fasting and 7.78-8.89 mmol/L postprandially) by the hormone insulin. Any disruption in insulin synthesis or its interaction with cellular receptors impairs the homeostasis of glucose concentration in both the bloodstream and cells (Dimitriadis et al., 2021). This leads to an increased concentration of glucose in the blood, which can consequently cause numerous health problems such as insulin resistance, cardiovascular diseases, diabetes and similar (Roden and Shulman, 2019).

People suffering from diabetes need to monitor the amount of carbohydrates consumed daily in order

to maintain normal blood glucose concentration to prevent further complications of this disease. The American Diabetes Association (ADA) emphasizes the significance of medical nutritional therapy in both the prevention of diabetes and the management of the disease, highlighting its role in mitigating the risk of associated complications (ADA, 2024). For this reason, in 1950, in cooperation with the American Dietetic Association, they developed a system of foods that is divided into six groups according to caloric and nutritional value: bread and substitutes, fruits, vegetables, meat and substitutes, milk and substitutes and fats and substitutes. Foods from these groups is divided into units that have the same energy value, but different mass and quantity (e.g. if the meal contains one unit of bread or substitute, this means 25 g of white bread or 60 g of cooked pasta). One unit from the group of bread and fruit contains 15 g of carbohydrates, from the group of milk 12 g of carbohydrates, and from the group of vegetables 5 g of carbohydrates (Prašek and Jakir, 2009). To facilitate the analysis of the influence of macronutrients on blood glucose concentration, numerous mathematical models have been developed. Mathematical models of metabolism typically offer a simplified representation of the intricate biochemical processes occurring at the cellular level, within specific organs, or throughout the entire organism (Mc Auley, 2020). Despite being founded on specific assumptions, existing mathematical models of metabolism substantially enhance and streamline the analysis of cellular processes and the impact of environmental factors on macronutrient metabolism. These models aim to personalize nutrition based on individual needs,

*Corresponding author: ana.tusek.jurinjak@pbf.unizg.hr

utilizing molecular markers derived from food and disease prevention (Mitchelson et al., 2023; Vyas, 2023). Based on the aforementioned, the aim of this work was to analyse the influence of the proportion of carbohydrates expressed as glycemic load in individual meals on the concentration of glucose and insulin in the blood, using a mathematical model of glucose and insulin kinetics.

Materials and methods

Menus planning

To achieve the goal of the study, which focuses on the glycemic load of the meal, three menus with different glycemic loads were created: (i) high-carbohydrate (high GL), (ii) diabetic and (iii) low-carbohydrate (low GL) menus. The diabetic menu was designed according to the ADA system of foods and substitutes, establishing a daily energy intake of 1900 kcal. This menu, which includes three main meals and an additional night-time meal before

bedtime, follows a meal schedule proven optimal for individuals with type 1 diabetes. They must receive insulin doses at precise times, facilitating glycemic control, making it a common recommendation among experts (Pavić et al., 2023). To ensure better data comparison, the other menus were aligned with this same meal schedule. The energy distribution in each meal adheres to the guidelines, allocating 20-25% of daily energy intake for breakfast, 30-35% for lunch, 25-30% for dinner and 10-15% for snack (night-time meal), with minor deviations. All menus followed different recommendations regarding the proportion of carbohydrates: 45-65% (high-carbohydrate menu), 40-55% (diabetic menu), and 60 to 130 g/day (low-carbohydrate menu). Included are also the daily recommended fiber intake of 25-38 g/day (Pavić et al., 2023; USDA, 2020). The menus were developed using the USDA food composition database (FCDB) allowing calculation of energy and nutrients of daily offers. Glycemic index (GI) values were sourced from Foster-Powell et al. (2002). For each meal, the glycemic load (GL) was calculated (Eq. 1):

$$GL = \frac{\text{amount of carbohydrates (g)} - \text{amount of fiber (g)}}{100} \cdot GI \quad (1)$$

Simulation of the mathematical model of glucose and insulin metabolism

This work is based on the mathematical model of glucose and insulin metabolism in people with type 1 diabetes, created by Noguchi et al. (2014). The model is divided into three main subsystems shown in Figure 1. The first subsystem (carbohydrate metabolism) describes the influence of carbohydrates on blood glucose concentration, considering not only the amount of carbohydrates but also absorption parameters. The next subsystem (subcutaneous insulin) describes the kinetics of insulin from subcutaneous administration, denoted as $u_s(t)$ (in units of insulin per minute) to plasma insulin concentration, denoted as $I(t)$ (in micro-units per milliliter). Here, $u_s(t)$ represents the rate at which insulin is administered subcutaneously over time, while $I(t)$ indicates the concentration of insulin in the plasma at any

given time. Furthermore, these two subsystems serve as inputs to the glucose and insulin metabolism subsystem, which is based on Bergman's minimal model (Bergman et al., 1979); however, Noguchi et al. (2014) adjusted certain parameters to apply their model to individuals with type 1 diabetes, with blood glucose concentration as an output variable. The model includes 10 differential equations and 20 kinetic parameters.

Simulations of the model were performed using the software WR Mathematica 10.0 (Wolfram Research, Inc., Champaign, IL, USA) based on the different glycemic load of each meal of the developed menus. The influence of GL on blood glucose concentration and the concentration of subcutaneous insulin was monitored over 300 minutes, a period chosen to capture the complete physiological response and insulin activity cycle.

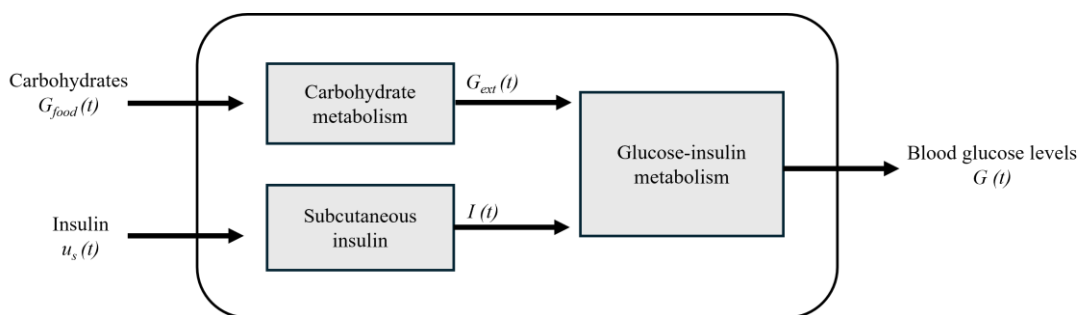


Figure 1. Diagram of proposed mathematical model (adapted from Noguchi et al., 2014)

Results and discussion

Menu analysis

The high-carbohydrate menu exhibits the highest carbohydrate content - 294.5 g (61.8%) and predominantly comprises simple carbohydrates, contributing to a high glycemic index. This menu archetype mirrors contemporary dietary trends characterized by widespread consumption of convenience foods, often deep-fried, necessitating minimal preparation. Concurrently, there is a surge in processed food consumption laden with high levels of fats and sugars, culminating in adverse health effects and heightened susceptibility to chronic non-communicable ailments such as insulin resistance, cardiovascular diseases and diabetes (Christ et al., 2019). The diabetic menu adheres to dietary guidelines tailored for individuals with diabetes, emphasizing meal planning based on the carbohydrate counting principle. This dietary approach prescribes a carbohydrate unit equivalent to 15 g, facilitating the dispersion of carbohydrate intake throughout the day (60 to 75 g per meal). This facilitates insulin therapy application and blood glucose regulation efficacy (Pavić et al., 2023; Franz 2016). Notably, the menu registers a total carbohydrate content of 202.3 g (42.6%), incorporating whole grains and fiber-rich foods like fruits, vegetables and seeds. Despite their limited nutritional value, these constituents contribute to gradual glucose release in the intestines, mitigating abrupt spikes in blood glucose levels. Widely recommended for diabetics, the traditional Mediterranean diet stands out for its holistic health benefits in managing obesity, cardiovascular diseases and diabetes, attributed to its inclusion of fruits, vegetables, whole grains, seeds, nuts, fish and olive oil (Dominguez et al., 2023; Martín-Peláez et al., 2022). However, recent American Diabetes Association guidelines advocate for a

personalized dietary approach, promoting reduced overall carbohydrate intake to mitigate blood glucose elevation (Evert et al., 2019).

Table 1 depicts the menu embodying a low-carbohydrate dietary regimen, aiming for an intake between 60 to 130 g, alongside increased protein and fat consumption. With a carbohydrate content of 114 g (24%), this plan boasts the lowest glycemic load. Conceived for experimental purposes, this menu facilitates comparative analysis of varying carbohydrate and blood glucose levels, delineating disparities between high and low glycemic loads. Furthermore, several studies affirm the efficacy of low-carbohydrate and ketogenic diets (carbohydrate intake up to 50 g/day) in reducing glycated hemoglobin and maintaining glycemic levels in diabetic individuals, while elevated protein and fat proportions enhance satiety, potentially aiding weight loss in obese individuals (Turton et al., 2023; Hancock et al., 2023). Despite the favourable outcomes of such dietary interventions on blood glucose variability, long-term benefits remain unverified, accompanied by inherent apprehensions. Clerc (2023) underscores that meals rich in fat (>40 g) and/or protein (>40-75 g) lack balance and are therefore unsuitable for inclusion in the daily diet of type 1 diabetes patients. For instance, Leow et al (2018) study unveiled the ketogenic diet's efficacy in regulating blood glucose levels among type 1 diabetes patients, although with potential complications like dyslipidemia and increased hypoglycemic episodes.

Menu compositions were formulated based on an energy intake target of 1900 kcal, with energy allocation distributed across meals as detailed in Table 2. Most meals met the recommended energy distribution guidelines with exceptions such as the breakfast of the high glycemic (29%) and diabetic menu (32%).

Table 1. Proposed menus

	Meal	Energy (kcal)	CHO (g)	Fibres (g)	GL
High GL menu	Breakfast: fruit and hazelnuts muesli (90 g), milk (1.9% m.f., 220 g), black coffee (100 g), brown sugar (5 g), medium banana (130 g)	551.7	115.2	10	65
	Lunch: baked chicken (150 g), French fries (150 g), tomato (100 g), fresh cucumber (90 g), apple juice (200 g)	695.3	72.6	6.6	38
	Dinner: Hazelnut spread (45 g), white bread (90 g)	486.5	72.5	6.2	37
	Night meal: fruit yogurt (180 g)	171.0	34.2	0	11
Diabetic menu	Breakfast: Low-fat yogurt (240 g), raspberries (100 g), flax seeds (5 g), boiled eggs (100 g), rye bread (70 g), butter (5 g)	611.4	67.1	13.0	19
	Lunch: chicken soup (250 g), stewed dark chicken meat (90 g), cooked brown rice (150 g), broccoli (100 g), olive oil (15 g), green salad (100 g), vinegar (5 g), plums (100 g)	661.7	64.7	8.7	20
	Dinner: drained canned sardines (60 g), cooked quinoa (100 g), cooked green beans (100 g), salad iceberg (100 g), olive oil (5 g), cashew nuts (15 g), pear (140 g), vinegar (5 g)	507.4	59.0	13.0	17
	Night meal: low fat milk (240 g)	120.0	11.5	0	4

Table 1. Continued...

Low GL menu	Breakfast: olive oil (5 g), iceberg salad (100 g), scrambled eggs (120 g), hard goat cheese (25 g), cooked turkey ham (30 g), orange (160 g)	476.8	24.7	5	6
	Lunch: cooked salmon (160 g), cooked whole grain macaroni (100 g), olive oil (15 g), feta cheese (25 g), tomato (100 g)	611	31.4	4	11
	Dinner: roasted turkey (170 g), white sauce (100 g), mushrooms (100 g), onions (50 g), rye bread (35 g)	574.3	36	5.3	6
	Night meal: cashew nuts (15 g), low-fat yogurt (240 g)	237.3	21.8	0.5	7

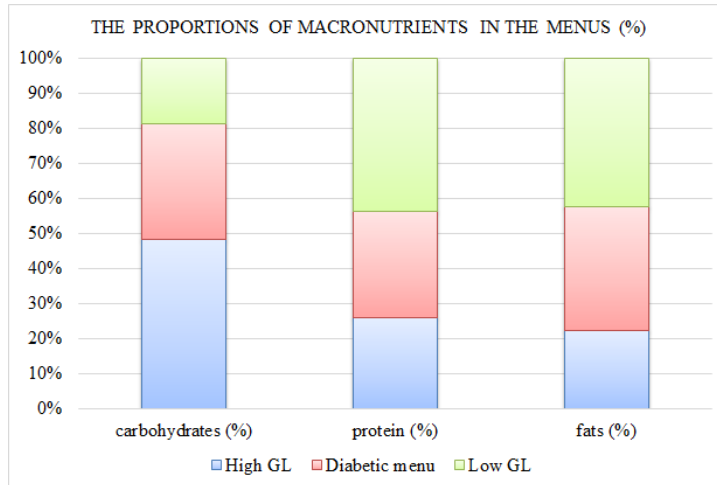
CHO - carbohydrates; GL - Glycemic load; m.f. - milk fat

Table 2. Energy allocation per meal according to guidelines

Meals	High GL menu (%)	Diabetic menu (%)	Low GL menu (%)	Guidelines (%)
breakfast	29	32	25	20-25
lunch	37	35	32	30-35
dinner	26	27	30	25-30
night meal	9	6	12	10-15

Furthermore, the proportions of macronutrients in each menu were analysed (Figure 2). In the high glycemic load menu (High GL), macronutrient proportions adhered to general population dietary guidelines, with carbohydrate intake comprising 62% (recommended range: 45-65%), protein at 19% (recommended range: 10-35%) and fat at 23% (recommended < 35%). Conversely, the diabetic menu

exhibited a slight excess of fat intake beyond recommendations, possibly influenced by database food choices. The low glycemic load menu (Low GL) displayed elevated proportions of fats (44%) and proteins (32%), with carbohydrates making up only 24%, yet remaining within the confines of a low-carbohydrate dietary regimen characterized by a daily carbohydrate intake of 60-130 g.

**Figure 2.** The proportions of macronutrients in the menus

The diabetic menu registered the highest fiber content (34.7 g), meeting or exceeding daily recommended intake levels (25-38 g/day), attributable to the inclusion of various fibrous fruits, vegetables, whole grains, and seeds. Despite comprising grains and carbohydrates, the high glycemic load menu contained 22.8 g of fiber, approaching recommended levels, reflecting the substantial quantity of these fibrous foods within the menu. Conversely, the low glycemic

load menu, characterized by elevated protein and fat proportions but devoid of fiber (14.8 g), demonstrated diminished overall fiber intake.

Macronutrient distribution in the menus

Figure 3A illustrates substantial variability in carbohydrate quantities, particularly noticeable during breakfast, across the various menus. Carbohydrate

quantities are relatively uniform across other meals. Meals characterized by high glycemic load exhibit the greatest carbohydrate variability, a pattern mirrored in protein and fat distributions across menus. Notably, meals with elevated carbohydrate content coincide with diminished protein and fat quantities, exemplified by the evening meal. Conversely, the diabetic menu displays consistent macronutrient distribution without notable daily fluctuations. In the context of low glycemic load menus, higher protein content inversely correlates with lower fat content and vice versa, while carbohydrate quantities remain relatively uniform.

These macronutrient distributions, particularly evident in menus with high glycemic load, significantly influence blood glucose variability, as corroborated by Dimova et al. (2023). Their investigation assessed the relationship between glycemic variability and dietary patterns among individuals with normal and impaired

glucose tolerance. Findings revealed heightened glucose variability parameters among those with impaired glucose tolerance, exacerbated by increased consumption of refined grain carbohydrates. Conversely, augmented consumption of whole grains was associated with improved glycemic parameters. Furthermore, a combination of protein intake with whole grains mitigated glucose variability. Graphical representation (Figure 3) underscores the marked disparity between protein intake and carbohydrate quantity, particularly noticeable in menus featuring high glycemic load, barring lunch. Notably, protein intake in high glycemic load menu remains substantially lower compared to carbohydrate intake, a contrast observed across other meal menus as well. The diabetic menu, characterized by consistent distribution of carbohydrates primarily from whole grains and high protein content, lends credence to the findings mentioned above (Dimova et al., 2023).

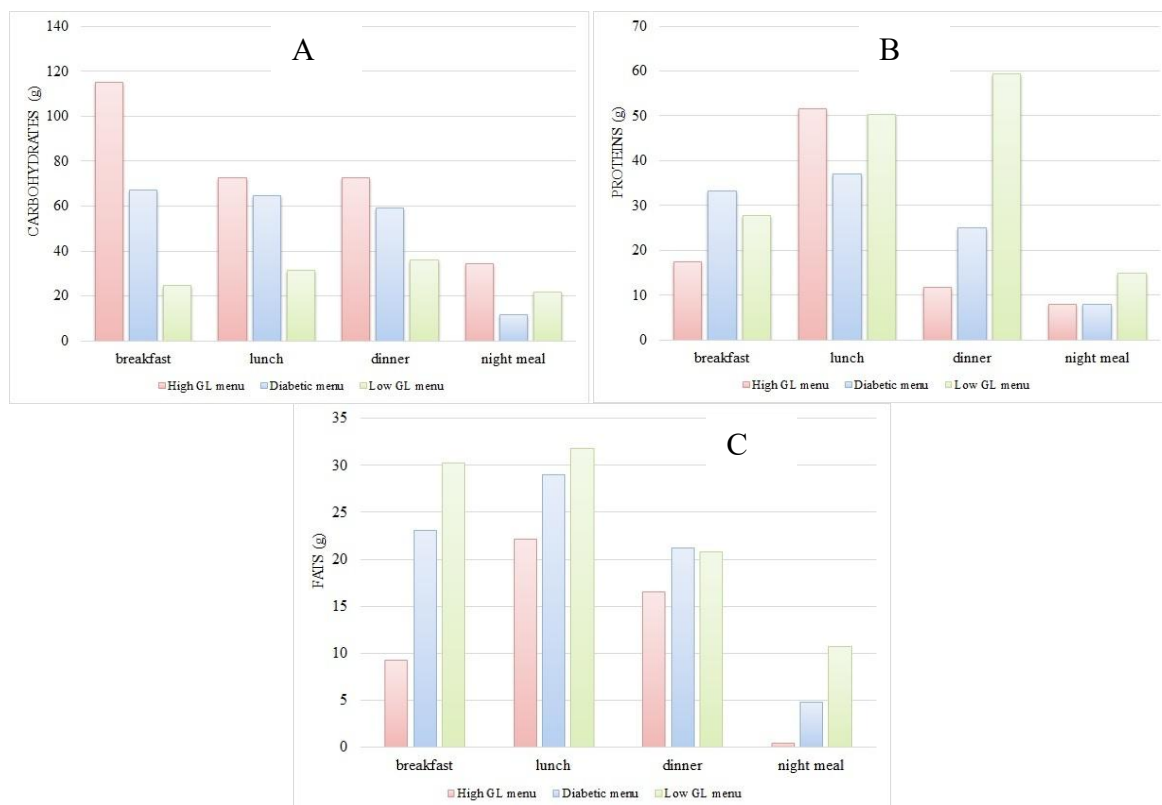


Figure 3. Macronutrient distribution in the menus

The correlation matrix

To gain insight into the interrelationships among macronutrient quantities (carbohydrates, proteins, fats and fibers) within the developed menus, Spearman correlation analysis was conducted. The results

presented in Table 3 reveal significant negative correlations between carbohydrate proportions and both protein ($r = -0.9500$) and fat proportions ($r = -0.9855$), indicating an inverse relationship. Consequently, as the proportion of carbohydrates increases, the proportions of proteins and fats decrease

within the menus. Additionally, a positive correlation was observed between protein and fat proportions ($r = 0.8834$), while negative correlations were found between protein proportions and fiber ($r = -0.6564$), as well as between fat proportions and fiber ($r = -0.2262$). Notably, Amankwaah et al. (2017) demonstrated in their study that proteins and fibers independently influence glucose metabolism regulation, a finding consistent with the correlation analysis results of the menus in this study. Their randomized controlled crossover trial investigated the independent and combined effects of normal versus higher protein and fiber intake, focusing on breakfast due

to typically lower protein and fiber consumption during this meal compared to lunch and dinner. Results indicated that a breakfast with elevated protein and fiber content did not significantly alter postprandial glucose response, or 24-hour glucose patterns compared to control breakfasts. However, increased fiber intake mitigated postprandial insulin response. Thus, while doubling protein and quadrupling fiber intake for breakfast may not notably enhance insulin and glucose responses, higher fiber intake could effectively reduce postprandial insulin response in healthy overweight young adults.

Table 3. Correlation matrix among macronutrient quantities (carbohydrates, proteins, fats and fibers) within the developed menus. Significant correlations ($p < 0.05$) are highlighted in bold (negative correlations – shades of red, positive correlations – shades of green).

	carbohydrates	protein	fats	dietary fiber
carbohydrates	1.0000			
protein	-0.9500	1.0000		
fats	-0.9855	0.8834	1.0000	
dietary fiber	0.3880	-0.6564	-0.2262	1.0000

Glycemic load

Figure 4 illustrates the spectrum of glycemic loads across meals. In menus characterized by high glycemic loads, breakfast emerges with the highest load, gradually declining towards later meals, while still exceeding counterparts in other menus by roughly double. This disparity is attributable to elevated carbohydrate quantities in the meals, compounded by their composition, primarily comprising foods rich in simple carbohydrates with a high

glycemic index. Conversely, the diabetic menu exhibits uniform glycemic loads across main meals, facilitated by evenly distributed carbohydrate quantities tailored to insulin doses, ensuring consistent glucose release into the bloodstream throughout the day. Furthermore, the carbohydrate quality is enhanced, featuring whole grains and increased dietary fiber content. A similar trend is observable in the low glycemic load menu, with lunch registering the highest value, while remaining meal values are relatively uniform.

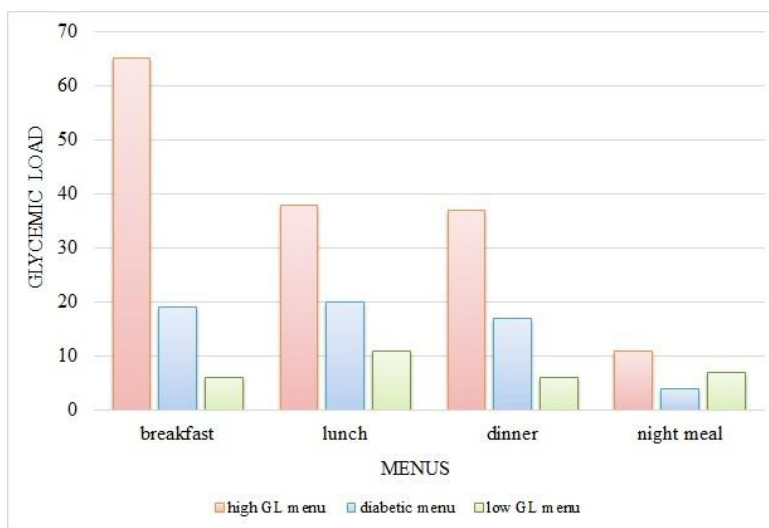


Figure 4. Glycemic load across meals

Simulation of glucose and insulin kinetics model

Initial simulation conditions were set to represent fasting conditions without insulin therapy to assess the influence of meal carbohydrate content on blood insulin concentration profiles across various meals. As depicted in Figure 5, changes in blood glucose concentration exhibit a consistent pattern across all daily meals. Following meal consumption, blood glucose concentration rises, peaking at approximately 80 minutes before gradually declining to around 5 mmol/L. Meals with high glycemic load notably yield the highest blood glucose values, particularly breakfast and lunch, elevating blood glucose concentration to approximately 13 mmol/L. Moreover, lunch with a high glycemic load demonstrates a sinusoidal glucose concentration profile with damping, attributed to the meal's high carbohydrate content. Notably, simulation results for diabetic meals indicate blood glucose concentration stabilizes after approximately 240 minutes, underscoring the multifactorial influence on blood glucose levels,

including pre-meal glucose levels, insulin therapy timing and administration method, insulin sensitivity, exercise, stress, other medications and illnesses (Bevier et al., 2007).

Simulation outcomes reveal that meals with low glycemic load consistently yield the lowest blood glucose values. Papakonstantinou et al. (2019) highlighted in their study that the addition of a small amount of fat affected glucose response primarily following the consumption of high-energy foods, suggesting a potential energy threshold beyond which fat exerts a heightened impact on glucose response, potentially inducing persistent or delayed hyperglycemia.

Simulation results from the insulin model mirror glucose concentration trends across all meals (Figure 6). Meals eliciting the highest blood glucose values correspondingly produce the highest insulin concentration values, although with varying timeframes to reach peak concentrations. While glucose peaks around 80 minutes post-meal, insulin peaks around 200 minutes post-meal.

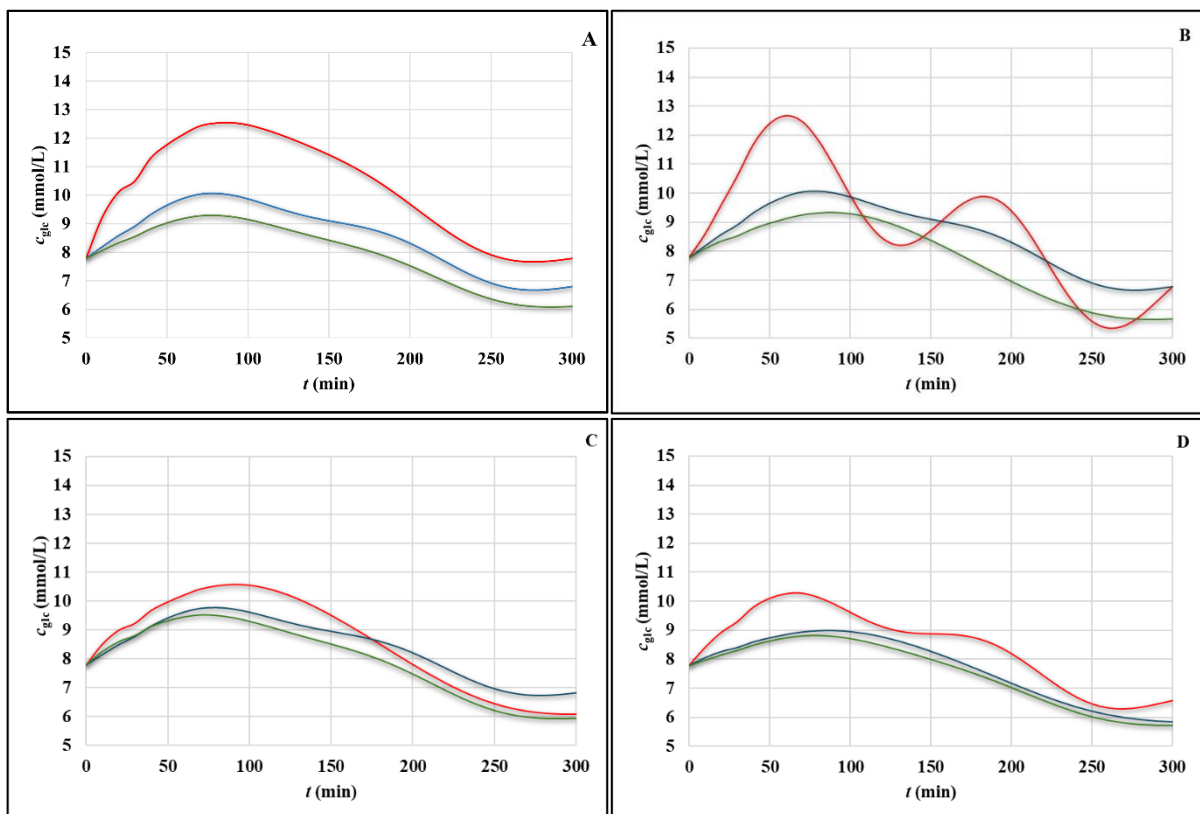


Figure 5. Graphical representation of the change in concentration of glucose (c_{glc}) over a period of 300 minutes after (A) breakfast, (B) lunch, (C) dinner, (D) night meal consumption (red - high glycemic load menu, blue - diabetic menu, green - low glycemic load menu)

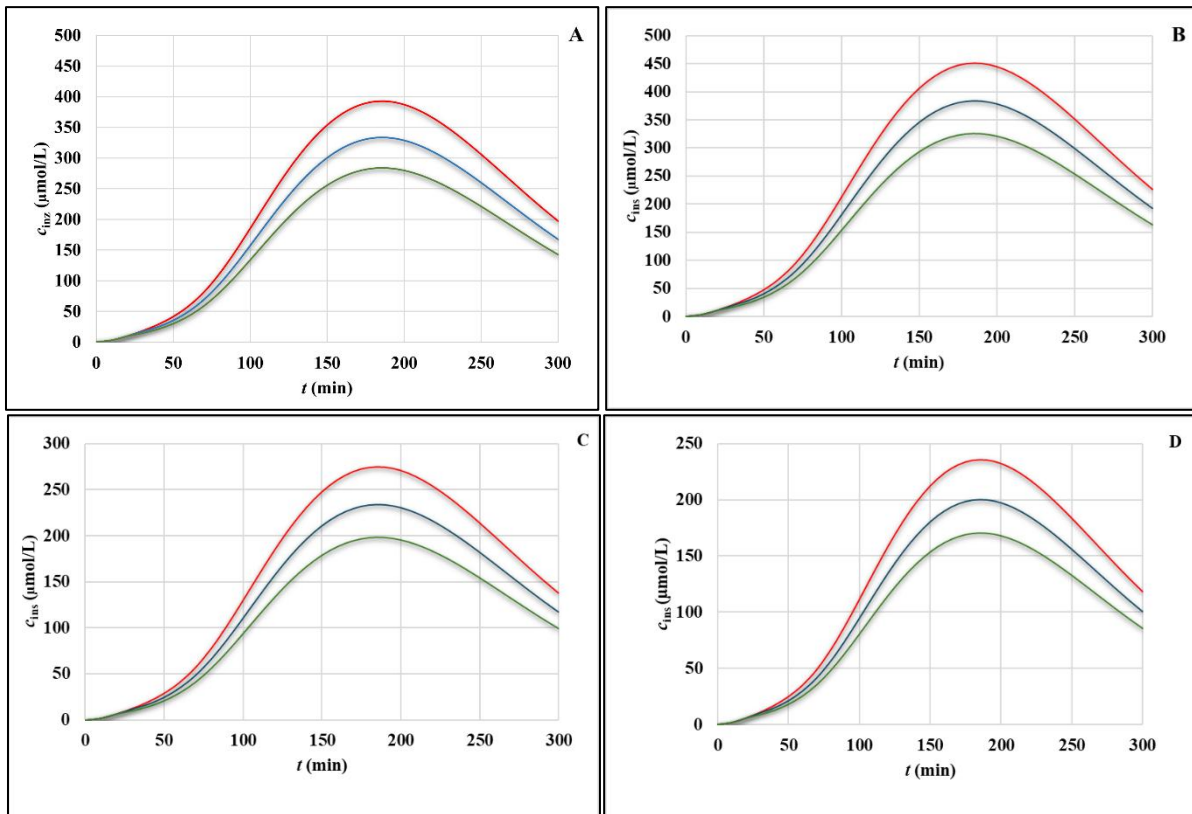


Figure 6. Graphical representation of the change in concentration of insulin (c_{ins}) over a period of 300 minutes after (A) breakfast, (B) lunch, (C) dinner, (D) night meal consumption (red - high glycemic load menu, blue - diabetic menu, green - low glycemic load menu)

Conclusion

The analysis of the menus and the simulation of the glucose-insulin metabolism model lead to several key conclusions. The developed menus show a very strong negative correlation between the proportion of carbohydrates and proteins ($r = -0.9500$), as well as between the proportions of carbohydrates and fats ($r = -0.9855$). The glycemic load of a single meal proves useful as an initial parameter for simulating glucose and insulin metabolism models. Furthermore, the glucose and insulin kinetics model simulation accurately describes the blood glucose and insulin concentration profiles, consistent with the available experimental data. Applying the metabolism model of the primary nutrients facilitates a personalized approach to menu development. Additionally, a diet with a low glycemic load demonstrates a reduced response in blood glucose concentration, making it a beneficial choice for individuals with diabetes.

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PROCJENA UČESTALOSTI I OPRAVDANOSTI OSLOBOĐENJA OD NASTAVE TJELESNE I ZDRAVSTVENE KULTURE

Vanessa Ivana Peričić^{1,2*}, Ines Jakšić³, Vesna Bilić-Kirin^{3,4}

¹Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno tehnološki fakultet Osijek, Franje Kuhača 18, 31000 Osijek, Hrvatska

²Nutrifil, obrt za nutricionističko savjetovanje, Put svetog Lovre 4, 21000 Split, Hrvatska

³Sveučilište Josipa Jurja Strossmayera u Osijeku, Medicinski fakultet Osijek, Josipa Huttlera 4, 31000 Osijek, Hrvatska

⁴Nastavni zavod za javno zdravstvo Osječko-baranjske županije, Drinska 8, 31000 Osijek, Hrvatska

izvorni znanstveni rad

Sažetak

Adekvatna fizička aktivnost važna je za prevenciju pretilosti čija se zastupljenost u djece povećava. Tjelesna i zdravstvena kultura (TZK) kao dio kurikuluma doprinosi ukupnoj fizičkoj aktivnosti djece i adolescenata kroz dan te ima potencijalnu ulogu u prevenciji pretilosti. Cilj je ovoga istraživanja bio utvrditi postojanje znanstveno neopravdanog oslobođenja od nastave TZK, ispitati povezanost sociodemografskih faktora s prilagodbom nastave, definirati zastupljenost vrste i trajanja oslobođenja te utvrditi najčešće skupine bolesti na temelju kojih učenici dobivaju potvrde o oslobođenju. Istraživanje je regrutiralo 655 učenika i studenata iz Osječko-baranjske županije koji su bili oslobođeni od nastave TZK tijekom školske godine 2021./2022. Svi su podaci prikupljeni iz njihovih zdravstvenih kartona te iz aplikacije za školsku medicinu *Complete.Prevention*. Rezultati su pokazali da je spol povezan s trajanjem oslobođenja ($p=0,006$), pri čemu je 2/3 ispitanika bilo ženskog spola. Mjesto stanovanja nije povezano s vrstom i trajanjem oslobođenja ($p=0,07$). Najviše ispitanika ima mišićno-koštane bolesti (32,06 %), pri čemu je 10,99 % od svih ispitanika imalo povratnu dislokaciju patele. Udio ispitanika koji su imali trajno oslobođenje je 74,20 %, a udio ispitanika koji su imali potpuno oslobođenje je 52,68 %. Dobiveni rezultati ukazuju na postojanje znanstveno neopravdanih oslobođenja od nastave TZK. Također, naglašavaju važnost edukacije liječnika koji izdaju potvrde o oslobođenju te potrebu za povećanom kontrolom procesa izdavanja istih.

Ključne riječi: tjelesna i zdravstvena kultura, tjelesni odgoj, školska medicina, učenici, studenti

Popis kratica

ALA – Američka asocijacija za pluća (eng. *American Lung Association*)

GAN – Globalni izvještaj o astmi (eng. *Global Asthma Network*)

HLZ – Hrvatski liječnički zbor

MZO – Ministarstvo znanosti i obrazovanja

NCD-RisC – (eng. *Noncommunicable diseases Risk Factor Collaboration*)

NZJZ SDŽ – Nastavni zavod za javno zdravstvo Splitsko-dalmatinske županije

OBŽ – Osječko-baranjska županija

PE – Tjelesna i zdravstvena kultura (eng. *Physical education*)

RH – Republika Hrvatska

TZK – Tjelesna i zdravstvena kultura

WHO – Svjetska zdravstvena organizacija (eng. *World Health Organization*)

MKB-10 – Međunarodna klasifikacija bolesti, 10. revizija

Uvod

Tjelesna i zdravstvena kultura (TZK) kao dio tjelesno i zdravstvenog odgojno-obrazovnog područja omogućava razvitak morfoloških obilježja, motoričkih i funkcionalnih sposobnosti, ali i stvaranje afiniteta prema redovitoj tjelesnoj aktivnosti, jednoj od komponenti zdravog stila života (MZO, 2019).

Nedovoljna fizička aktivnost jedan je od faktora koji doprinosi nastanku pretilosti, čija se zastupljenost u djece i adolescenata povećala zadnjih godina (Jebeile i sur., 2022; Lee i Yoon, 2018). Ove podatke potvrđuju i rezultati istraživanja iz 2024. godine kojim se utvrdilo da se broj pretilih osoba od 1990. godine do 2022. godine

povećao za otprilike 690 milijuna (NCD-RisC, 2024). Globalna epidemija pretilosti zahvatila je i Republiku Hrvatsku (RH) u kojoj je prema istraživanju iz 2021. godine svako treće dijete pretilo (Musić-Milanović i sur., 2021). Pretilost u djetinjstvu povećava rizik od nastanka kroničnih nezaraznih bolesti u kasnijim fazama života te posljedično i rizik od preuranjene smrti zbog čega se naglašava važnost prevencije pretilosti od najranije dobi (Jebeile i sur., 2022; Kumari i sur., 2022). Zbog toga je iznimno važno poticati fizičku aktivnost, posebice kod adolescenata jer se upravo tijekom razdoblja adolescencije najviše stvaraju pravilne navike koje mogu prevenirati dugoročne negativne posljedice pretilosti (van Sluijs i sur., 2022). Uzevši u obzir da se djeca

školske dobi u svoje slobodno vrijeme najčešće bave sedentarnim aktivnostima, poput igranja video igrice i sjedenja za računalom, TZK kao dio kurikuluma ima potencijalnu ulogu u prevenciji pretilosti (Kumari i sur., 2022). Naime, istraživanje iz 2015. godine utvrdilo je da učenici koji su fizički aktivni na nastavi TZK imaju veću energetske potrošnje od onih koji dobivaju samo usmene upute o primjeni fizičke aktivnosti (Kahan i Mckenzie, 2015). Prema smjernicama Svjetske zdravstvene organizacije (eng. *World Health Organization*) djeca od pet do 17 godina trebala bi se baviti aktivnostima umjerenog ili visokog intenziteta barem 60 minuta dnevno, pri čemu bi tri dana tjedno fokus trebao biti na aktivnostima visokog intenziteta. S druge strane, za osobe starije od 18 godina, u svrhu poboljšanja zdravlja, preporuča se minimalno 150 minuta aerobne aktivnosti umjerenog intenziteta, odnosno barem 75 minuta aerobne aktivnosti visokog intenziteta (WHO, 2020). Prema kurikulumu za nastavni predmet TZK djeca od prvog do trećeg razreda osnovne škole u RH imaju nastavu TZK oko 105 sati godišnje, odnosno tri sata tjedno, a djeca od trećeg do osmog razreda osnovne škole oko 70 sati godišnje, tj. dva sata tjedno. Dva sata nastave tjedno imaju i učenici prvog, drugog i trećeg razreda srednje škole u gimnazijama, dok učenici završne godine srednje škole u gimnazijama imaju 64 sata nastave TZK godišnje (MZO, 2019). Na temelju ovog, nastava TZK kao sama nije dovoljna kako bi se ispunila međunarodna preporuka za fizičku aktivnost.

Temeljem odredbi članka 80 Zakona o odgoju i obrazovanju u osnovnoj i srednjoj školi, ako učenik zbog zdravstvenog stanja nije u mogućnosti sudjelovati u određenoj školskoj aktivnosti ili ako bi sudjelovanje štetilo učenikovu zdravlju, učenik se može privremeno ili trajno osloboditi od pohađanja nastavnog predmeta ili sudjelovanja u određenim nastavnim sadržajima, ako ti nastavni sadržaji nisu iz osnovnih predmeta struke (Narodne novine 126/2012, Zakon o odgoju i obrazovanju u osnovnoj i srednjoj školi). Potvrdu o oslobođenju učenika od nastave TZK učeniku ili studentu daje nadležni liječnik uz navođenje specifične šifre prema Međunarodnoj klasifikaciji bolesti MKB-10 (HLZ, 2009). Ciljevi su ovoga istraživanja bili definirati učestalost znanstveno opravdanog oslobođenja od nastave TZK, učestalost vrste i trajanja oslobođenja od nastave TZK te ispitati povezanost spola i mjesta stanovanja s prilagodbom nastave, kao i najčešće skupine bolesti koje su uzrok oslobođenja od nastave TZK.

Materijali i metode

Ispitanici

Istraživanje je obuhvatilo sve osnovne i srednje škole i fakultete na području Osječko-baranjske županije, od

čega je regrutirano ukupno 655 ispitanika, tj. učenika osnovnih i srednjih škola te prve i druge godine studija na fakultetima. Kriterij uključivanja podrazumijevao je da su ispitanici bili oslobođeni nastave TZK uz odobrenje liječnika školske medicine tijekom školske godine 2021/2022. pri Službi za školsku medicinu nastavnog zavoda za javno zdravstvo Osječko-baranjske županije. Provedbu istraživanja odobrilo je etičko povjerenstvo Nastavnog zavoda za javno zdravstvo Osječko-baranjske županije.

Metode

Podatci su prikupljeni iz zdravstvenih kartona djece i mladeži te iz aplikacije za školsku medicinu *Complete.Prevention*. Uvidom u medicinsku dokumentaciju prikupili su se osnovni demografski podaci koju obuhvaćaju: spol ispitanika, mjesto stanovanja (grad ili selo), razred, vrstu škole (osnova, srednja ili fakultet) i podatke o bolestima ispitanika. Za dijagnozu bolesti korištena je Lista bolesti za oslobađanje u slučaju težih akutnih, kroničnih bolesti i oštećenja u kojoj su bolesti raspoređene u 15 kategorija prema MKB-10 (NZJZ SDŽ, 2023). Uz to, istraživanje je obuhvatilo podatke o učestalosti oslobođenja od nastave TZK, kao i podatke o vrsti oslobođenja nastave od TZK prema vremenskom (privremeno/trajno) i sadržajnom ograničenju (djelomično/potpuno).

Statističke metode

Za statističku analizu podataka korišten je program *MedCalc® Statistical Software* (inačica 20.014). Kategorijski podatci prikazani su kao apsolutne i relativne frekvencije, a za ispitivanje razlike varijabli koristio se χ^2 test i Fisherov egzaktni test. Numerički podatci prikazani su kao aritmetička sredina i standardna devijacija kod varijabli s normalnom razdiobom, odnosno kao medijan i granica interkvartilnog raspona ako varijable nisu imale normalnu raspodjelu. Shapiro-Wilkovim testom ispitana je normalnost numeričkih varijabli. Sve p vrijednosti su obostrane, pri čemu su rezultati bili značajni ako je p vrijednost bila manja od 0,05.

Rezultati i rasprava

Od ukupno 40 200 učenika i studenata na području Osječko-baranjske županije tijekom školske godine 2021/2022. od nastave TZK oslobođeno je 655 učenika, što čini 1,62 % od ukupnog broja učenika i studenata. Rezultati o oslobođenju prema vrsti škole pokazali su da je školske godine 2021/2022. od nastave TZK bilo oslobođeno 241 učenika osnovnih škola, 354 učenika srednjih škola i 60 studenata na fakultetima (Tablica 1).

Prema podacima školske godine 2020/2021. evidentiran je veći broj učenika koji su pratili prilagođeni program nastave TZK naspram školske godine 2021/2022. Naime, školske godine 2020/2021 od nastave TZK bilo je oslobođeno 375 učenika osnovnih škola, 530 učenika srednjih škola i 65 studenata (HZJZ, 2022). Pad oslobođenja od nastave TZK u školskoj godini 2021/2022. može se objasniti pandemijom COVID-19. Naime, tek je u ožujku 2020. godine, odnosno za vrijeme drugog polugodišta, Vlada RH odlučila da će se nastava odvijati udaljeno, tj. *online* putem (Vlada RH, 2024). Sukladno tome, mjere za suzbijanje COVID-19 krenule su se primjenjivati u potpunosti tek za vrijeme školske godine 2021/2022. S obzirom da se nastava nije odvijala fizički, vježbe nisu bile fizički zahtjeve kao u školi pa učenici i studenti nisu imali potrebe za podnošenjem zahtjeva za oslobođenjem od nastave TZK.

Ipak, uspješnost udaljenog pohađanja nastave TZK je upitna s obzirom da se tijekom pandemije COVID-19 fizička aktivnost kod učenika smanjila, a sedentarno ponašanje povećalo (Dunton i sur., 2020).

Uzevši u obzir vrstu škole, uočava se da je 54,0 % ispitanika koji su oslobođeni od nastave TZK u srednjoj školi, a 36,79 % u osnovnoj školi. Manja zastupljenost učenika koji prate prilagođeni oblik nastave u osnovnoj školi vjerojatno je rezultat veće zainteresiranosti osnovnoškolaca za nastavu TZK zbog čega oni manje predaju zahtjeve za oslobađanje od nastave TZK. Naime, djeca u osnovnim školama TZK promatraju kao jednostavan predmet koji je lako izvediv te im je jedan od omiljenih predmeta za razliku od srednjoškolaca (Tomac i sur., 2012).

Tablica 1. Raspodjele ispitanika po školama u Osječko-baranjskoj županiji i broj oslobođenja od TZK ovisno o vrsti škole
Table 1. Distribution of respondents among schools in Osijek-Baranja County and the number of exemptions from PE according to the type of school

Vrsta škole	Ukupan broj učenika	Broj oslobođenja	Udio (%)
Osnovna	19 885	241	1,21
Srednja	10 032	354	3,53
Fakultet	10 283	60	0,58
Ukupno	40 200	655	1,62

Iz Tablice 2 vidljivo je da je veći broj ispitanika ženskog spola (66,11 %), a malo više od polovice ispitanika je iz grada (53,74 %). Što se tiče raspodjele

ispitanika po mjestu prebivališta, može se zaključiti da je jednaka raspodjela ispitanika po spolu u selu i u gradu (Tablica 3).

Tablica 2. Raspodjela ispitanika po spolu i mjestu stanovanja
Table 2. Distribution of respondents based on sex and place of residence

	Spol		Mjesto stanovanja	
	Muški	Ženski	Selo	Grad
n (%)	222 (33,89)	433 (66,11)	303 (46,26)	352 (53,74)

Tablica 3. Raspodjela ispitanika po spolu ovisno o mjestu stanovanja
Table 3. Distribution of respondents by sex in relation to their place of residence

Mjesto stanovanja	Spol	n (%)
Grad	Muški	117 (33,24)
	Ženski	235 (66,76)
Selo	Muški	105 (34,65)
	Ženski	198 (65,35)

Rezultati ovog istraživanja su primjenom Fisherovog egzaktnog testa pokazali da mjesto stanovanja nije povezano s trajanjem oslobođenja ($p=0,07$), dok je spol povezan s istim ($p=0,006$). Više je oslobođenja neovisno o vremenu trajanja uočeno kod ženski ispitanika, pri čemu je 77,6 % ispitanica trajno oslobođeno od nastave TZK, a 22,4 % privremeno oslobođeno (Tablica 4). Veći broj oslobođenja kod ženskih ispitanika vjerojatno je rezultat veće

zastupljenosti psihičkih ograničenja među ženama, poput straha od ozljeđivanja. Naime, istraživanje iz 2020. godine utvrdilo je da djevojke imaju više percipiranih mentalnih ograničenja od dječaka, među kojima je manjak volje i energije za obavljanje fizičke aktivnosti (Roselli i sur., 2020). Osim toga, rezultati istraživanja Markuš i Vukmir (2015) navode da učenice imaju negativniji stav prema nastavi TZK te da manje vole vježbati tijekom iste u usporedbi s učenicima.

Tablica 4. Utjecaj spola i mjesta stanovanja na trajanje i vrstu oslobođenja**Table 4.** The influence of sex and place on residence on the duration and types of exemption

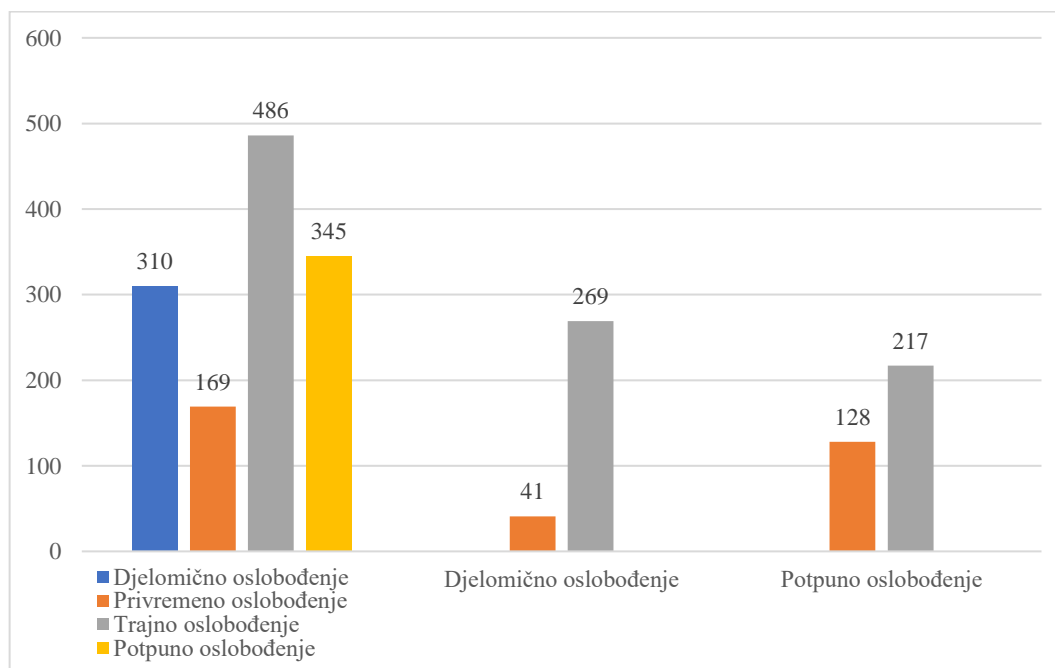
Trajanje oslobođenja	Spol		Mjesto stanovanja	
	Muški	Ženski	Selo	Grad
	n (%)	n (%)	n (%)	n (%)
Privremeno	72 (32,43)	97 (22,40)	68 (22,44)	101 (28,69)
Trajno	150 (67,57)	336 (77,60)	235 (77,56)	251 (71,31)
Djelomično	115 (51,80)	195 (45,03)	146 (48,18)	164 (46,59)
Potpuno	107 (48,19)	238 (54,97)	157 (51,82)	188 (53,41)

Iz Tablice 4 vidljivo je i da ne postoji statistički značajna povezanost između oslobođenja od nastave TZK po sadržajnom ograničenju sa spolom ispitanika kao ni s mjestom stanovanja ispitanika. Rezultati ranijeg istraživanja provedenog među 1136 učenika srednjih škola u Splitu također nisu ukazali na statistički značajnu povezanost između spola ispitanika i oslobođenja od nastave TZK po sadržajnom ograničenju (Kosinac i Banović, 2008).

Prema sadržajnom ograničenju učenici mogu biti oslobođeni od dijela aktivnosti nastave TZK (djelomično) ili od svih aktivnosti nastave TZK (potpuno). S druge strane, prema vremenskom ograničenju mogu biti oslobođeni tijekom cijele školske godine (trajno) ili u trajanju od jednog polugodišta ili semestra (privremeno) (NZJZ SDŽ, 2023). Iz slike 1 primjećuje se da je najveći broj učenika oslobođen trajno od nastave TZK prema vremenskom ograničenju, odnosno 486 učenika od 655 ispitanika. Promatrajući

sadržajno ograničenje veći broj učenika je oslobođen u potpunosti od aktivnosti TZK, tj. njih 310 od 655 ispitanika. Također, može se uočiti da je djelomično-trajno najčešća kombinacija oslobođenja od nastave TZK i to kod čak 41,07 % ispitanika.

U ranijem istraživanju iz 2012. godine privremeni oblik oslobođenja imalo je 12 % ispitanika, a trajni 2 % ispitanika. Svi ispitanici koji su bili trajno oslobođeni od nastave TZK imali su potpuni oblik oslobođenja, dok je 49 % bilo privremeno oslobođeno bez odrađivanja bilo kakve vrste fizičke aktivnosti tijekom tog perioda. Nadalje, 51 % ispitanika imalo je privremeni oblik oslobođenja od izvođenja nastave TZK, ali uz djelomično izvođenje vježbi (Topoljak, 2012). Ovi se rezultati ne podudaraju s rezultatima ovog istraživanja, kod kojeg su učenici najčešće trajno oslobođeni od nastave TZK uz djelomično izvođenje vježbi. Nadalje, najrjeđa kombinacija oslobođenja kod učenika i studenata OBŽ je djelomično-privremeno.

**Slika 1.** Broj oslobođenja od nastave TZK prema vrsti i trajanju oslobođenja i broj različitih kombinacija oslobođenja ovisno o trajanju i vrsti oslobođenja**Figure 1.** The number of exemptions from PE classes based on the duration and types of exemptions, as well as the number of different combinations of exemptions depending on the duration and types of exemptions

Prema Tablici 5 najzastupljenija skupina bolesti na temelju koje su ispitanici dobili oslobođenje je M kategorija, tj. bolesti mišićno-koštanog sustava i vezivnog tkiva, koje ima 32,06 % ispitanika. Potom slijedi J kategorija, odnosno bolesti respiratornog sustava, koja je uočena kod 17,71 % ispitanika. U istraživanju je 1,83 % učenika imalo oslobođenje nastave TZK u navedenim kategorijama. Prema istraživanju iz 2014. provedenom na djeci i adolescentima 4,9 % bolesti čine mišićno-koštane bolesti (Henschke i sur., 2014). Uzevši taj podatak u obzir, nije opravdano da se u ovom istraživanju kod 32,06 % ispitanika potvrda o oslobođenju od nastave TZK dobiva na temelju bolesti M kategorije.

Ispitanici su u ovom istraživanju oslobođeni od nastave TZK prema 19 kategorija bolesti, iako Lista za oslobađanje u slučaju težih akutnih bolesti, kroničnih bolesti oštećenja Hrvatskog društva za školsku i sveučilišnu medicinu izdvaja samo 15 kategorija na temelju kojih ispitanici mogu dobiti potvrdu o oslobođenju (NZJZ SDŽ, 2024). Kategorije odnosno dijagnoze pod T (trovanja i određene druge posljedice s vanjskim uzrokom) i Z (čimbenici s utjecajem na zdravstveni status i kontakt sa zdravstvenim ustanovama) nisu predviđene prema grupama bolesti Hrvatskog društva za školsku medicinu. Navedene kategorije bi trebale biti uključene u druge skupine.

Tablica 5. Klasifikacija bolesti prema MKB-10, njihova zastupljenost među ispitanicima te zastupljenost vrste ograničenja prema MKB-10

Table 5. The classification of diseases according to ICD-10, their prevalence among respondents, and the distribution of types of limitations based on ICD-10

Dijagnoza prema MKB-10	Naziv kategorije	n (%)	Djelomično	Potpuno
B (A00 – B99)	Zarazne i parazitarne bolesti	13 (1,98)	0	13
C (C00 – D48)	Neoplazme	3 (0,46)	1	2
D (D50 – D89)	Bolesti krvi i krvotvornih organa; poremećaji imunološkog sustava	15 (2,29)	6	9
E (E00 – E90)	Endokrine i metaboličke bolesti	14 (2,14)	6	8
F (F00 – F99)	Mentalni poremećaji i poremećaji ponašanja	17 (2,60)	2	15
G (G00 – G99)	Bolesti živčanog sustava	50 (7,63)	25	25
H (H00 – H59)	Bolesti oka i adneksa	13 (1,98)	8	5
I (I00 – I99)	Bolesti kardiovaskularnog sustava	17 (2,60)	9	8
J (J00 – J99)	Bolesti respiratornog sustava	116 (17,71)	93	23
K (K00 – K93)	Bolesti probavnog sustava	10 (1,53)	5	5
L (L00 – L99)	Bolesti kože i potkožnog tkiva	5 (0,76)	2	3
M (M00 – M99)	Bolesti mišićno – koštanog sustava i vezivnog tkiva	210 (32,06)	93	117
N (N00 – N99)	Bolesti genitourinarnog sustava	13 (1,98)	4	9
O (O00 – O99)	Trudnoća, porođaj i babinje	2 (0,31)	0	2
Q (Q00 – Q99)	Prirodne anomalije, malformacije i kromosomske abnormalnosti	35 (5,34)	14	21
R (R00 – R99)	Abnormalni klinički i laboratorijski nalazi, simptom i znakovi; neklasificirani drugdje	32 (4,89)	18	14
S (S00 – S99)	Ozljede specifičnih dijelova tijela	78 (11,91)	19	59
T (T00 – T98)	Trovanja i određene druge posljedice s vanjskim uzrokom	1 (0,15)	0	1
Z (Z00 – Z99)	Čimbenici s utjecajem na zdravstveni status i kontakt s zdravstvenim ustanovama	11 (1,68)	5	6

Iz Tablice 5 primjećuje se da su M i J kategorije bolesti najučestalije kod ispitanika s djelomičnim oslobođenjem, dok je od ukupnog broja ispitanika s potpunim oslobođenjem najviše njih imalo dijagnozu

M (33,91 %) prema MKB-10. Promatrajući pojedinačne dijagnoze iz navedenih skupina bolesti, 12,98 % ispitanika je dijagnosticirana astma, a 10,99 % ima bolesti patele/hondromalaciju patele (Tablica 6).

Tablica 6. Najzastupljenije pojedinačne dijagnoze među ispitanicima

Table 6. The most prevalent individual diagnoses among respondents

MKB-10	n (%)
J45 astma	85 (12,98)
M22 bolesti patele, hondromalacija patele	72 (10,99)

Astma je najučestalija bolest koju su imali ispitanici s trajnim oslobođenjem, njih 17,08 %, a bolesti patele bile su najučestalija pojedinačna dijagnoza koju su imali ispitanici s privremenim oslobođenjem, odnosno 13,02 % ispitanika. Što se tiče sadržajnih ograničenja, astma je bila najzastupljenija bolest kod djelomičnih oslobođenja te se uočava u 21,61 % ispitanika koji su djelomično oslobođeni od nastave. S druge strane, bolesti patele prisutne su najviše kod potpunih oslobođenja i to kod 9,86 % ispitanika s potpunim oslobođenjem (Tablica 7).

Rezultati istraživanja GAN pokazali su da astmu ima 11 % djece od šest do sedam godina, odnosno 9,1 % djece od 13 do 14 godina (García-Marcos i sur., 2022). Na temelju globalne zastupljenosti astme kod djece i ranih adolescenata može se zaključiti da je udio ispitanika koji su bili oslobođeni zbog astme opravdan. Fizička aktivnost vrlo vjerojatno može smanjiti simptome astme i poboljšati kvalitetu života

(Lang, 2019). Prema Američkoj asocijaciji za pluća učenici s dijagnozom astme mogu u sudjelovati u nastavi TZK uz prilagodbu nastave te preventivno korištenje brzodjelujućih inhalatora prije fizičke aktivnosti. Također, naglašava se i važnost edukacije nastavnika kako bi mogli prepoznati simptome, pravovremeno reagirati u slučaju pogoršanja istih te osigurati učenicima pristup lijekovima tijekom aktivnosti (ALA, 2020). U skladu s tim, ako je bolest dobro kontrolirana učenici/studenti s astmom ne bi trebali biti trajno oslobođeni od nastave TZK.

Dislokacija patele pojavljuje se u 29 od 100 000 adolescenata te je najčešća kod osoba mlađih od 20 godina (Krebs i sur., 2018). Iako je opravdano da učenici i studenti na temelju dislokacije patele najčešće dobiju potpuno-privremeno oslobođenje od nastave TZK, nije opravdano da je ista dijagnosticirana kod 10,99 % ispitanika kad se uzme u obzir incidencija kod opće adolescentne populacije.

Tablica 7. Povezanost najčešćih pojedinačnih dijagnoza s trajanjem i vrstom oslobođenja

Table 7. The connection between the most common individual diagnoses and the duration and types of exemption

Oslobođenje	Pojedinačna dijagnoza	n (%)
Privremeno	M22 bolesti patele, hondromalacija patele	22 (13,02)
Trajno	J45 astma	83 (17,08)
Potpuno	M22 bolesti patele, hondromalacija patele	34 (9,86)
Djelomično	J45 astma	67 (21,61)

Zaključak

Ovo je istraživanje pokazalo da su spol i oslobođenje od nastave TZK po vremenskom ograničenju povezani, pri čemu je više ispitanika ženskog spola trajno oslobođeno od nastave TZK. S druge strane, ne postoji statistički značajna povezanost između mjesta stanovanja te vrste i trajanja oslobođenja. Najčešće su ispitanici prema vremenskom ograničenju bili trajno oslobođeni od nastave TZK, a prema sadržajnom ograničenju najveći je broj učenika i studenata bio u potpunosti oslobođen. Astma i bolesti patele/hondromalacija patele najzastupljenije su dijagnoze na temelju kojih su ispitanici bili oslobođeni od nastave TZK. Najviše učenika je imalo djelomično-trajnu kombinaciju oslobođenja, pri čemu je ta kombinacija bila najzastupljenija kod astmatičara, no ne i opravdana s obzirom da se kod dijagnoze astme ne preporučuje trajno oslobođenje od nastave TZK. S druge strane, udio ispitanika koji su dobivali oslobođenje na temelju bolesti mišićno-koštanog sustava i vezivnog tkiva bio je neproporcionalan zastupljenosti istih u općoj pedijatrijskoj populaciji što može ukazati na neopravdana oslobođenja od nastave TZK. Dobiveni rezultati ukazuju da bi obiteljski

liječnici i pedijatri koji izdaju potvrde o privremenom oslobođenju od nastave TZK te specijalisti školske medicine koji su nadležni za izdavanje potvrda o trajnom oslobođenju od nastave trebali biti više educirani o dijagnozama na temelju kojih učenici smiju dobiti potvrdu o oslobođenju. Također, ovi rezultati naglašavaju i potrebu za povećanim nadzorom u slučaju namjernog nepropisnog izdavanja potvrda za oslobođenje od nastave TZK uzevši u obzir da je pravilna fizička aktivnost jedan od glavnih faktora u prevenciji pretilosti.

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EVALUATION OF PREVALENCE AND JUSTIFICATION OF EXEMPTIONS FROM PHYSICAL EDUCATION CLASSES

Vanessa Ivana Peričić^{1,2}, Ines Jakšić³, Vesna Bilić-Kirin^{3,4}

¹Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 18, 31000 Osijek, Croatia

²Nutrifil, Put svetog Lovre 4, 21000 Split, Croatia

³Josip Juraj Strossmayer University of Osijek, Faculty of Medicine Osijek, Josipa Huttlera 4, 31000 Osijek, Croatia

⁴Teaching Institute of Public Health for the Osijek-Baranya County, Drinska 8, 31000 Osijek, Croatia

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Summary

Proper physical activity is important for the prevention of obesity, the prevalence of which is increasing in children. Physical education (PE), as part of the curriculum, contributes to the overall physical activity of children and adolescents throughout the day and has a potential role in obesity prevention. The aim of this research was to determine the existence of scientifically unjustified exemptions from PE classes, examine the relationship between sociodemographic factors and the adjustment of classes, define the incidence of the types and duration of exemptions, and identify the most common groups of the diseases on the basis of which students receive PE medical exemption approvals. This research recruited 655 pupils and students from Osijek-Baranja County who were exempted from PE classes during the 2021-2022 school year. All data were obtained from their medical records and the school medicine application Complete.Prevention. The results showed that gender was associated with the duration of exemption ($p=0.006$), with 2/3 of the respondents being female. Place of residence was not associated with the type and the duration of exemption ($p=0.07$). The majority of respondents had musculoskeletal diseases (32.06%), with 10.99% of all respondents having recurrent dislocation of the patella. The proportion of respondents who had permanent exemption was 74.20%, while the proportion of respondents with complete exemption was 52.68%. The obtained results indicate the existence of scientifically unjustified exemptions from PE classes. They also highlight the importance of educating doctors who issue PE medical exemption approvals and the need for increased control over the process of issuing such approvals.

Keywords: physical education, physical activity, physical education, school medicine, pupils, students

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