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Exploring Dietary Patterns and Their Associations with Obesity in School-Aged Children in Croatia: A Cross-Sectional CroCOSI Study

Jasmina Hasanović [1,*], Helena Križan [2], Zvonimir Šatalić [1] and Sanja Musić Milanović [2,3]

[1] Faculty of Food Technology and Biotechnology, University of Zagreb, Pierottijeva 6, 10000 Zagreb, Croatia; zvonimir.satalic@pbf.unizg.hr
[2] Croatian Institute of Public Health, Rockefeller St. 7, 10000 Zagreb, Croatia; helena.krizan@hzjz.hr (H.K.); sanja.music@hzjz.hr (S.M.M.)
[3] School of Medicine, University of Zagreb, Šalata 3, 10000 Zagreb, Croatia
* Correspondence: j_hasanovic@yahoo.com

Abstract

Background: While previous research on children's diets has primarily focused on individual nutrients or foods, recent years have seen increasing attention to the analysis of dietary patterns. In school-aged children enrolled in the CroCOSI study, this research focused on identifying the dietary patterns and examining their potential links with childhood obesity. Methods: Data were collected from a nationally representative sample comprising 5608 children aged 7–10 years and their parents in this cross-sectional study. To evaluate the nutritional status of the children, BMI-for-age was assessed using z-score values. Results: A factor analysis using data from the FFQ revealed three dietary patterns: Western, Healthy, and Breakfast. Children who scored high for consumption of fruits, vegetables, fish, cheese, dairy products, and 100% fruit juice were categorized into the Healthy dietary pattern, whereas those with high scores for cereals and milk were assigned to the Breakfast dietary pattern. Conclusions: The Western dietary pattern did not show a significant relationship with obesity among school-aged children (OR = 1.00, 95% CI: 0.98–1.00; $p = 0.11$). The risk of obesity was lower among children following the Healthy (OR = 0.98, 95% CI: 0.98–0.99; $p = 0.045$) and Breakfast (OR = 0.96, 95% CI: 0.95–0.99; $p = 0.001$) dietary patterns.The results can help in creating food policies with the aim of reducing childhood obesity in Croatia.

Keywords: childhood obesity; dietary patterns; COSI; dietary habits; children

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1. Introduction

Dietary patterns are characterized by the combinations and consumption frequencies of foods and beverages among population groups [1]. Earlier studies on children's diets have primarily examined the consumption of specific nutrients or foods [2]. However, dietary pattern analysis has become popular in recent years to describe overall dietary intake. The most common number of dietary patterns identified in research ranges from two to five [3].

Dietary patterns such as 'healthy' and 'traditional' are associated with higher intakes of nutritionally superior foods regardless of energy intake, whereas the 'processed' pattern is nutrient-poor and energy-dense [4,5]. Interestingly, children from all northern European countries exhibit high consumption of foods characteristic of the Mediterranean diet, such

as fruits, vegetables, and fish [6]. However, a Mediterranean-like dietary pattern is not strictly more prevalent among children in southern Mediterranean countries [7].

A global review found a higher risk of overweight among individuals following a Western/unhealthy dietary pattern. The Healthy dietary pattern is associated with a lower risk of overweight and obesity [7]. Childhood obesity is one of the greatest public health challenges, especially in Mediterranean countries, where there has been an increase in the prevalence of children with overweight and obesity [8]. The prevalence of childhood obesity has significantly increased in recent years in Croatia. According to the latest data from the last round of the CroCOSI study, the prevalence of obesity among children in Croatia is 15.4%, while every third child has overweight or obesity [9]. Children with excessive body weight or obesity in early or middle childhood have a higher probability of developing obesity as adolescents [10], while adolescents with obesity at ages 15–17 years have an even greater likelihood of developing obesity as adults [11]. The development of obesity in later life may, in part, be attributed to dietary patterns in youth that are high in calories and fat but low in fiber, as these have been shown to predispose individuals to overweight and obesity [12]. Investigating diet–disease relationships may be more informative when examining dietary patterns rather than the intake of individual nutrients or foods, as patterns capture the totality of dietary intake and potential synergistic effects [13]. Although obtaining high-quality data on children's diets and obesity is challenging, many European children who do not adhere to the Healthy dietary pattern show a higher percentage of body fat [6].

Reports on the associations between childhood obesity and dietary patterns are lacking in the literature. This study focused on identifying dietary patterns and examining their potential links with childhood obesity among school-aged children in Croatia.

2. Materials and Methods

This cross-sectional study was performed on a nationally representative, regionally stratified sample of 5608 school-aged children (49% girls, 51% boys) and their parents selected through random cluster sampling using data from the second round of the CroCOSI study from the 2018/2019 school year. The protocol and methodology of the COSI study have been detailed elsewhere [14]. Data collection and measurements were carried out over an eight-week period and included children aged 7 to 10 years, as well as their parents or caregivers. Ethical approval for the study was granted by the Ethics Committee of the University of Zagreb School of Medicine (641-01/23-02/01) and the Ethics Committee of the Croatian Institute of Public Health (030-02/18-07/2).

Information on educational attainment, employment status, region, income, and household size was collected from both parents and was taken into account as covariates in the analysis. Of the 7259 family record forms distributed, 5814 were completed by parents or caregivers, resulting in a response rate of 80.1%. The study included children aged 7–10 years with parental informed consent, child verbal consent, physiologically plausible BMI-for-age values (−5 to +5 SD), and completed parental questionnaires. From the initial sample (N = 5734), exclusions comprised children with implausible BMI values, exceeding the age limit, and 126 with incomplete dietary data, resulting in a final sample of 5608 participants.

Measurement of Body Weight and Height

Anthropometric data for the participating children were collected at school. According to the COSI protocol, height was measured twice, and the mean value was used for analysis.

Determination of Nutritional Status

During the analysis, z-score values of the body mass index (BMI)-for-age were used to determine the nutritional status of children [15]. The children were divided into two categories: those without obesity (including children who were underweight, normal weight, or overweight) and those with obesity (children with a BMI-for-age z-score > 2).

Assessment of Dietary Patterns

Dietary intake was measured through a food frequency questionnaire (FFQ) consisting of 19 items, which assessed the children's usual dietary intake on a weekly basis. The FFQ included the following foods and beverages: fruit, vegetables (including vegetable soups, excluding potatoes), soft drinks (such as juices, flavored water, iced tea), cereals, meat, fish, eggs, potatoes, milk, flavored milk, cheese, dairy products (yogurt, milk pudding, cream cheese, cottage cheese, and others), 100% fruit juice, diet or "light" soft drinks, salty snacks (e.g., potato chips, corn chips, popcorn, peanuts), sweet snacks (e.g., cakes, cookies, sweets), bread, other bakery products (e.g., pretzels, rolls, croissants, puff pastry, burek, etc.), fast food (e.g., pizza, French fries, hamburgers or sausages). Parents provided information on their children's weekly food and beverage consumption by selecting from five frequency categories: (1) never; (2) less than once a week; (3) 1–3 times a week; (4) 4–6 times a week; and (5) every day. The reported consumption frequencies were converted into weekly portions as follows: 'never' into 0, 'less than once a week' into 0.5, '1–3 times a week' into 2, '4–6 times a week' into 5, 'every day' into 7. Missing data were imputed using the hot deck method [16].

Using FFQ data, the dietary patterns were determined by a factor analysis, employing principal component analysis (PCA) and Promax rotation to extract factor loadings. The food frequency questionnaire (FFQ) is among the most frequently used methods for evaluating long-term dietary intake in studies exploring the relationship between dietary patterns and obesity in children [3]. PCA is a dimensionality reduction technique that identifies nonlinear combinations of dietary variables in several principal components, which explain the majority of variance within the data [17]. Promax rotation is appropriate when it is expected that the factors are correlated [18]. Before the factor analysis, the correlation matrix of all items in the FFQ was examined. The number of factors retained were determined by evaluating eigenvalues (cutoff ≥ 1), analyzing scree plots, and assessing the substantive interpretability of each factor [19]. This analysis indicated that a three-factor solution was optimal. A food item was included in a factor if its absolute correlation with that factor was 0.25 or higher. We computed factor loadings for each food and beverage group across the three identified dietary patterns (factors).

Association of dietary patterns with childhood obesity

Logistic regression was used to assess the impact of specific dietary patterns on childhood obesity (as the predictor variable), with adjustment for potential confounders. Multivariate adjusted OR were calculated by adjusting for the potential risk factors of obesity, including parents' educational attainment, employment status, region, income, household size, and children's sex.

All statistical analyses were performed using R (R Core Team, 2023), with p-values ≤ 0.05 considered statistically significant.

3. Results

The mean and SD for age, weight, height, and BMI-for-age are presented in Table 1. Of the total number of children, 15.6% were children with obesity.

Table 1. Sample characteristics, CroCOSI 2019.

Parameters	M	SD	MDN	MIN	MAX
Total					
Body weight (kg)	33.94	8.32	32.10	17.81	92.81
Body height (cm)	137.57	7.01	137.45	115.25	173.45
BMI-for-age	0.56	1.32	0.46	−4.79	4.99
Children without obesity					
Body weight (kg)	31.41	5.46	30.80	17.81	52.31
Body height (cm)	136.75	6.79	136.75	115.25	166.65
BMI-for-age	0.17	1.01	0.21	−4.79	2.00
Children with obesity					
Body weight (kg)	47.61	7.80	46.50	31.71	92.81
Body height (cm)	141.31	7.02	140.97	122.75	173.45
BMI-for-age	2.70	0.57	2.56	2.01	4.99

Table 2 shows the factor loadings of each pattern after Promax rotation. A factor analysis revealed three dietary patterns: a Western pattern, a Healthy pattern, and a Breakfast pattern. The three patterns accounted for 10.7%, 7.1%, and 5.1% of the variance in food intake, respectively, together explaining a total of 22.9% of the overall variance.

Table 2. Factor-loading matrix of the three dietary patterns and their associated foods and beverages among the children, CroCOSI, 2019.

	Missing (%)	Western Dietary Pattern	Healthy Dietary Pattern	Breakfast Dietary Pattern
Fruits	0.64	−0.220	**0.556**	−0.034
Vegetables	0.71	−0.196	**0.536**	−0.039
Soft drinks	0.57	**0.532**	−0.122	0.020
Cereals	1.36	−0.039	0.113	**0.292**
Meat	0.98	0.118	0.160	0.049
Fish	1.14	−0.105	**0.436**	−0.102
Eggs	1.03	0.119	**0.265**	−0.009
Potato	1.25	**0.335**	0.113	−0.023
Milk	1.41	−0.099	−0.058	**0.902**
Flavored milk	2.69	**0.309**	−0.079	0.152
Cheese	2.64	0.010	**0.379**	0.027
Dairy	1.28	0.082	**0.369**	0.121
100% fruit juice	4.62	0.232	**0.309**	−0.045
Diet or "light" drinks	1.96	**0.253**	0.050	−0.051
Savory snacks	1.39	**0.667**	−0.151	−0.058
Sweet snacks	1.03	**0.460**	−0.051	0.006
Bread	1.93	**0.277**	0.064	0.063
Bakery products	1.25	**0.521**	−0.066	−0.018
Fast food	1.02	**0.525**	−0.040	−0.087
Variance explained by each factor (%)		10.7	7.10	5.10
Cumulative variance (%)		10.7	17.80	22.90

The names of the dietary patterns were derived based on their characteristics (Figure 1). In the present study, the Western pattern (Factor 1) was characterized by high factor loadings for soft drinks, flavored milk, potatoes, savory snacks, sweet snacks, bakery products, and fast food. The Healthy pattern (Factor 2) was strongly associated with higher consumption of fruits, vegetables, fish, dairy products, cheese, and 100% fruit juice. The

third factor, referred to as the Breakfast pattern, was characterized by higher intakes of milk and cereals.

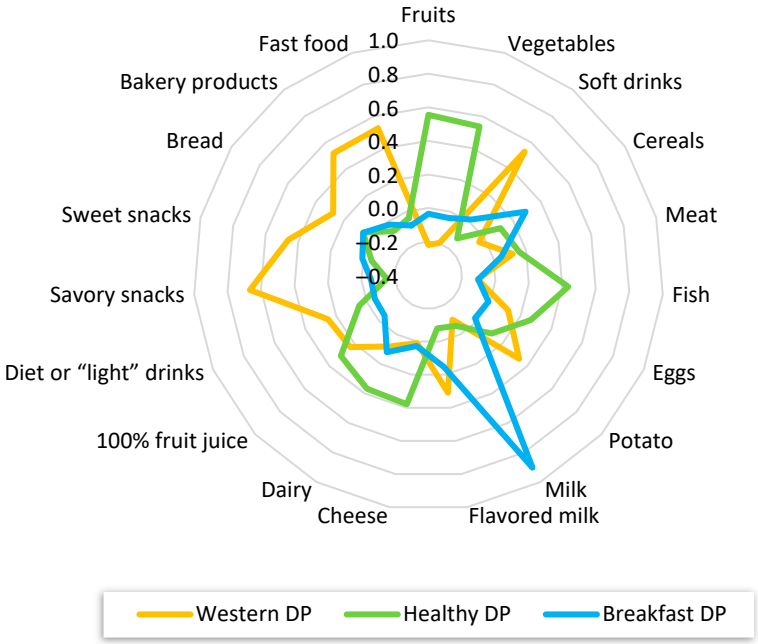

Figure 1. Radar chart for the three dietary patterns and related food or beverages in children.

As shown in Table 3, the most dominant dietary pattern was identified for each child, and the children were grouped according to their nutritional status, specifically whether they had obesity or not. Among the total number of children, the largest proportion belonged to the Breakfast dietary pattern, while the smallest proportion belonged to the Western dietary pattern.

Table 3. Number and percentage of children with and without obesity according to dietary patterns.

	Children Without Obesity N (%)	Children with Obesity N (%)	Total N (%)
Western DP	1344 (28.40)	291 (33.22)	1635 (29.15)
Healthy DP	1514 (32.00)	243 (27.74)	1757 (31.33)
Breakfast DP	1874 (39.60)	342 (39.04)	2216 (39.52)

After adjusting for potential confounders, the Western dietary pattern demonstrated no significant association with childhood obesity (OR = 1.00, 95% CI: 0.98–1.00; $p = 0.11$). In contrast, both the Healthy (OR = 0.98, 95% CI: 0.98–0.99; $p = 0.045$) and Breakfast patterns (OR = 0.96, 95% CI: 0.95–0.99; $p = 0.001$) showed protective effects against childhood obesity, with statistically significant results despite the modest effect sizes (Table 4).

Table 4. Multivariate logistic regression analysis of the association between dietary pattern scores and childhood obesity *.

	Coefficient	OR	CI (95%)	*p*
Western DP	−0.008	1.00	(0.98–1.00)	0.11
Healthy DP	−0.012	0.988	(0.98–0.99)	0.045
Breakfast DP	−0.035	0.966	(0.95–0.99)	0.001

* Adjusted for region, sex, parents' education, occupation, household income, and household size.

4. Discussion

The present study reports the results of the first national investigation of dietary patterns among Croatian primary-school-aged children and their association with obesity. In this cross-sectional study, we identified significant differences in the dietary patterns between children without obesity and those with obesity, independent of parental demographics. We derived three dietary patterns among the Croatian primary-school-aged children: "Healthy," "Western," and "Breakfast." The Healthy dietary pattern resembles the traditional Mediterranean diet, which is characterized by a high intake of fruits, vegetables, and cereals. Of the three dietary patterns identified, both the "Healthy" and "Breakfast" patterns showed an inverse relationship with obesity in children after adjusting for confounding factors.

Although different studies may use the same caption for a dietary pattern, the foods included in specific patterns can vary due to cultural and economic differences within populations, differing statistical methods, the number and types of food groups, and variations in dietary assessment methods. This makes comparisons between studies on dietary patterns troublesome [3,20,21]. Nevertheless, certain similarities exist. For example, research in China among children aged 3 to 6 years identified two dietary patterns: "Traditional Chinese," which includes foods such as fruits, vegetables, grains, eggs, and fish, and "Modern," which comprises processed foods [22]. Similar patterns ("Traditional Chinese" and "Modern") were also identified in another Chinese study. In Iran, three dietary patterns were identified: "Healthy Diet," "Western," and "Sweet" [23]. In Norway, among children aged 9 and 10 years, four dietary patterns were found: "western," "junk/convenience," "varied Norwegian," and "dieting" [24]. Most studies identify three dietary patterns: one typically includes processed foods, another emphasizes nutrient-dense foods such as fruits, vegetables, and grains, and the third is characterized by traditional national foods, as is the case in our study, where "Western" and "Healthy" dietary patterns were identified.

Croatia is a Mediterranean country, and the Mediterranean diet is part of its traditional cuisine. Therefore, the "Healthy" dietary pattern is also representative of the traditional dietary habits. In this study, the traditional dietary pattern is also classified as the "Healthy" dietary pattern. Additionally, a study in another Mediterranean country, Spain, identified four patterns, one of which featured foods characteristic of the traditional Mediterranean diet [10].

Research on the dietary patterns and obesity among children in Europe is limited. Similar results to those found in our study were obtained in research examining dietary patterns in five countries (Spain, France, the UK, Greece, Lithuania, and Norway), where five dietary patterns were identified. In this context, children who adhered less to the Healthy dietary pattern exhibited a higher percentage of body fat [6]. A similar finding was observed in our study, where children adhering to the Healthy dietary pattern, characterized by higher intakes of foods such as fruits, vegetables, fish, dairy products, cheese, and 100% fruit juice, had a reduced risk of obesity (OR = 0.98, 95% CI: 0.98–0.99; $p = 0.045$).

A study of children in Lebanon identified two dietary patterns: "Fast Food and Sweets" and "Traditional Lebanese." The "Traditional Lebanese" pattern, characterized by higher intakes of cereals, dairy products, fruits, and vegetables, was associated with a lower risk of overweight and obesity in children [19], consistent with our findings.

Surprisingly, the Western dietary pattern, characterized by high consumption of soft drinks, flavored milk, potatoes, savory snacks, sweet snacks, bakery products, and fast food, had no significant association with obesity in Croatian school-aged children, which is consistent with findings from a study among children in five European countries [6]. Similarly, a study in Iran found that the Western dietary pattern was not associated with a higher risk of abdominal obesity, which may be explained, among other factors, by

different factor loadings for each food group in forming a dietary pattern [23]. Also, due to limitations related to the fixed design of the COSI study, we were not able to include in the analyses absolute energy intake.

The importance of daily dairy product intake for reducing obesity was confirmed in a study from Greece in a large, nationally representative sample of schoolchildren aged 8 to 17 years. The children and adolescents who met the dietary recommendations for daily dairy intake (e.g., consuming two yogurts and/or 40 g of cheese, and a cup of milk daily) were less likely to be children with obesity. The Breakfast dietary pattern, characterized by the high consumption of cereals, fruit, milk, and dairy products, has been identified in studies among adolescents, where those adhering to this dietary pattern exhibited a lower risk of overweight and obesity [25]. The reason for these findings is that the Breakfast dietary pattern refers to foods typically consumed at breakfast, and children who regularly eat breakfast have a lower risk of overweight and obesity [26,27].

Some studies have not found an association between dietary patterns and overweight/obesity in children. For example, in the study by Chan et al., 2014, three dietary patterns were identified (vegetables–fruits, Western–beverages, and animal foods, fats and condiments), none of which were associated with overweight or obesity in children aged 10 to 12 years [28]. One reason for the differing results may be that most of the previous studies examined overweight and obesity together, whereas this study specifically investigated the relationship between various dietary patterns and childhood obesity.

Differences in the study results may be partially explained by differences in the dietary patterns between boys and girls, as some studies have revealed different associations between dietary patterns and overweight/obesity in girls and boys. Girls with overweight were more likely to belong to the Western and Sweet-Dairy patterns; this association was not observed for boys. For boys, higher adherence to the Healthy pattern was linked with a lower body mass index (BMI) [20]. Additionally, social and genetic differences between countries may explain the varying results in dietary pattern research [6,23].

Three dietary patterns were identified in this study, accounting for a cumulative explained variance of 22.9%, which is consistent with the ranges found in previous studies examining dietary patterns among children [19,24,29].

Since foods are consumed in combination rather than individually, this study's significant strength is considering the association between obesity in children and different dietary patterns [13]. An important limitation inherent to the factor analysis is the subjectivity involved in selecting the number of factors and the rotation method, which can significantly affect the interpretation and comparability of the results [30]. The use of a strict protocol on a nationally representative sample of second- and third-grade children in Croatia, combined with a high response rate, ensures that the findings can be generalized to the broader population of children in this age group.

The limitation of this study is its cross-sectional design, where data on children's dietary intake and weight status were collected at the same point in time, leading to difficulties in establishing temporality relationships. An additional limitation of this study is that children were not measured at the same time of day, potentially introducing variability in anthropometric data; however, 71.4% of children were measured before lunch, which may have minimized this effect. Although the FFQ is widely used in dietary research, there may be some reporting bias due to the surrogate source (parents/caregivers), especially for foods perceived as healthy, such as fruits and vegetables. Additionally, parents do not have complete insight into their children's dietary intake at school [31]. The FFQ was based on the frequency of consumption of specific foods and beverages on a weekly basis, without portion size quantification. However, the FFQ can derive dietary patterns due to its adequate relative validity and high reproducibility [32,33].

5. Conclusions

The data obtained in this study indicate that dietary patterns are linked to childhood obesity in Croatia. Namely, the Healthy pattern, characterized by a high intake of fruits, vegetables, fish, dairy products, cheese, and 100% fruit juice, and the Breakfast pattern (milk and cereals) were associated with a lower risk of obesity among school-aged children in Croatia. Promoting these dietary patterns could help prevent obesity in Croatian children.

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Informed Consent Statement: Written informed consent was obtained from the parents of all participating children, and each child gave verbal assent prior to the start of measurements.

Data Availability Statement: Dataset available on request from the authors.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body mass index
FFQ	Food frequency questionnaire
PCA	Principal component analysis
DP	Dietary pattern
M	Mean
SD	Standard deviation
MDN	Median
MIN	Minimum
MAX	Maximum

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