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Hydration status, frequency of consumption of water-rich foods, and anthropometric measurements in 10–12-year-old Polish schoolchildren

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Abstract

Introduction and Objective. Hydration status is mainly influenced by the amount of beverages and water-rich foods they consume, although it is interesting to look for relations with other factors. Therefore, the aim of the study was to search for associations between hydration status and frequency of consumption of selected products, anthropometric measurements, and body composition in schoolchildren.

Materials and Method. A cross-sectional study was conducted in Polish primary schools, during d 2,849 schoolchildren aged 10–12 years examine. Food frequency questionnaires were used to assess the consumption of selected beverages and foods (FFQ). Anthropometric measurements were taken: height (H), body weight (BW), and waist circumference (WC). Body composition parameters: fat mass (FM), fat-free mass (FFM), and total body water (TBW) were measured using a bioelectrical impedance analysis (BIA). Hydration status was assessed by TBW measurement. Odds Ratios (OR) and 95% Confidence Intervals (95%) were calculated.

Results. Variables that reduced the probability of dehydration were increased frequency of juice and vegetable consumption, and a high level of physical activity in study children. Additionally, a 1-unit increase in BMI was associated with increased odds of dehydration, and a 1-unit increase in FFM was associated with decreased odds.

Conclusions. Consumption of beverages, especially water and products rich in this ingredient, should be promoted to ensure adequate hydration in children at home, as well as at school where children spend a large part of the day. This situation can be influenced by guaranteeing constant access to water by providing appropriate school infrastructure, such as water dispensers and springs, as well as workshops and educational activities.

Key words

hydration status, anthropometric measurements, total body water, children aged 10–12, frequency consumption of selected products

INTRODUCTION

Water plays a vital role in the organism, e.g., as an internal cell environment, an excellent solvent, involved in thermoregulation, responsible for transporting substances in the body, and has a protective and hydrating function. Adequate intake recommendations for water for children aged 10–12 years are 1,900 mL/d for girls and 2,100 mL/d for boys, and should be provided to the body through beverages and food [1]. Studies most often indicate gender, physical activity and place of residence as factors that differentiate the amount and type of beverages chosen [2, 3]. These factors were therefore analysed for the frequency and type of beverages consumed among pupils who participated in the study.

Proper hydration is essential for children's physical health and cognitive development, supporting immune function and overall well-being [4]. Inadequate water intake can lead to dehydration which can affect kidney function (urinary infections and kidney stones), physical and mental performance (impaired memory and concentration), hyperactivity, and irritability [5].

The Polish Central Statistical Office has indicated that the average volume of water consumed per person/month increased by 1 liter in 2022 (5.90 l) compared to 2016 (4.90 l). The consumption of fruit and vegetable juices remained

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comparable throughout the aforementioned period, with an average of approximately one liter per person/month. However, a slight downward trend was observed in the consumption of sweetened beverages during the same period [6, 7]. According to observations by teachers, children bring bottled water with them and also use the water available at school [8]. Only approximately 60% of children aged 12 drink water regularly, with tea being the most common beverage consumed. Fruit juices are consumed by approximately 70% of children, while vegetable juices are consumed by only approximately 20%. However, half of the children consume sugar-sweetened beverages [9].

It should also be underlined that water is one of the most important components of the human body. Total body water (TBW) decreases with age, reaching approximately 75% of body weight in infants, 60% in children up to 12 years of age, 55% in adults, and 50% in older people [10]. A change in body water of less than 2% body mass loss is the normal daily variation, but a body mass deficit of more than 2% is defined as dehydration [5]. The hydration status in children is mainly influenced by the amount of beverages and water-rich foods, such as the vegetables and fruit they consume, and the amount of physical activity they engage in. The most commonly used methods to assess hydration status in children are changes in body weight, body composition using bioelectrical impedance analysis (BIA), and urine biochemical analysis [5, 11]. Based on the idea that dehydration results in concentrated urine, urine osmolality is a measure of the total solute content of urine and is one of the better methods for assessing hydration status [12]. BIA measurements provide data about total body water by measuring the resistance of body tissues to a small electrical current. The resistance varies with water concentration [12]. BIA is widely used to estimate body composition in a variety of clinical settings and in paediatrics [11], and is considered a precise, non-invasive, and inexpensive method [13].

The presented study was undertaken because there are no large-scale studies in Poland regarding the connection of the relationship between hydration status measured by BIA and socio-demographic factors, consumption of beverages and water-rich foods, and anthropometric measurements in schoolchildren, The aim of the study was to search for associations between hydration status measured by BIA and frequency of consumption of sweetened beverages, juices, dairy products, fruits and vegetables, anthropometric measurements, and body composition in Polish schoolchildren aged 10–12 years.

MATERIALS AND METHOD

Study design and participants. The study was conducted from April 2022 – November 2023 in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Institute of Human Nutrition, at the University of Life Sciences in Warsaw Poland (Resolution No. 18/2022). This research was a cross-sectional study of schoolchildren conducted as part of the Junior-Edu-Żywienie (JEŻ) Project. Detailed information on the recruitment of the sample and the methods and procedures used have been published previously [14].

This study included 2,849 primary school pupils, boys and girls, aged 10–12 years, specifically in the 4th – 6th grades. Inclusion criteria were pupils in grades 4th-6th of primary school, and age 10–12 years.

Parents' consent to participate in the study, no contraindications to body composition analysis, and use of the Polish language were among the inclusion criteria. Children who were absent from school on the day of measurement, or were afraid of the procedure, withdrew immediately before the anthropometric and body composition measurements were not measured.

A representative sample of pupils from schools in all 16 provinces of Poland was the main idea of the Project. They were selected based on their distribution in the regions, taking into account three sizes of place of residence: towns of up to 100,000 inhabitants and cities with more than 100,000 inhabitants. Five separate macro-regions were identified to take this into account: Central, North-Eastern, North-West, South-Western, and South-Eastern. The study included pupils with low, moderate, or high levels of physical activity based on their self-assessment of physical activity.

Frequency of food consumption. Assessment of the children's dietary habits and selected food consumption was based on validated questionnaires: KomPAN® and SF-FFQ4PolishChildren® [15]. The first question related to the pupils knowledge of beverages: 'How much fluid should you drink during the day?'. The question was closed with four possible answers: '1.0 m1–1.55 liters', 'about 2.0 liters', 'more than 3.0 liters', and 'I don't know'. Only one answer was correct, and for further analysis, two variants of the answer were accepted: 'proper' and 'improper'. The following questions asked about the frequency of consumption of selected products consumed in the 12 months before the study: sugar-sweetened beverages (e.g., cola, tea, water with added syrup), fruit or mixed fruit and vegetable juices, energy drinks, dairy products (e.g., milk, yogurt, cottage cheese, cheese), vegetables (e.g., fresh, cooked, baked, stewed) and fruits (fresh or frozen), using a food frequency questionnaire (FFQ). Vegetables and fruits were included in the questionnaire due to their relatively high water content, and the possibility of using them to prepare beverages, The frequency of consumption for each food group was according to the following categories: 1) never or rarely, 2) less than once a week, 3) once a week, 4) 2–4 times a week, 5) 5–6 times a week, 6) every day, and 7) several times a day.

Anthropometric measurements and body composition. Selected anthropometric measurements of the children were taken: height (H, cm), body weight (BW, kg), and waist circumference (WC, cm). The above measurements were carried out by all procedures. H was measured using a stadiometer and recorded to the nearest 0.1 cm (TANITA Corporation. Tokyo, Japan), BW was measured to the nearest 0.1 kg using an electronic digital scale (TANITA Corporation. Tokyo, Japan), while WC was measured with a non-stretchable and tensile-resistant tape that provided constant tension with a precision 0.1 cm (SECA 201, Hamburg, Germany). The body composition (BC) of the schoolchildren was analyzed according to bioelectrical impedance analysis (BIA) measurement procedures [16]. To perform this measurement, the professional TANITA MC-780 S MA multi-frequency, portable, segmented body composition analyser (TANITA Corporation, Tokyo, Japan) was used. The device automatically analysed and calculated

the parameters of body composition, including fat mass (FM), fat-free mass (FFM), muscle mass (MM), and total body water (TBW). For the purposes of this study, the following were taken into account: TBW (kg, %), FM (kg) and FFM (kg). Hydration status was measured by TBW (% of body weight). The reference value for TBW for children under 12 years of age was 49–75% [6]. Values below 49% indicated dehydration, while over 75% indicated over-hydration. Body mass index (BMI) (kg/m^2) was calculated, and the criteria given in Table 1 were used [17].

Table 1. BMI (kg/m^2) criteria for girls and boys according to age [17]

Parameters	Girls		Boys	
	10 years	11–12 years	10 years	11–12 years
underweight	<14.3	<15.1	<14.4	<15.2
normal	14.3-20.4	15.1-22.0	14.4-20.2	15.2-21.8
overweight	20.5-23.0	22.1- 25.0	20.3-22.8	21.9- 25.0
obesity	> 23.0	> 25.0	> 22.8	> 25.0

All measurements were taken by qualified researchers in all schools between 08.00 – and 12.00 with professional equipment and same type of measuring tape. Measurements were taken twice with the children dressed in light clothing and without shoes. The averages were calculated. All measurement details have been previously published [14].

Statistical analysis. All analyses were performed using the SAS 9.4 statistical package (SAS Institute, Cary, NC, USA) at a significance level of $\alpha = 0.05$. The normality of distribution was examined using the Kolmogorov-Smirnov test. Results are presented as mean and standard deviation (SD), median, minimum, and maximum for continuous or data sample proportion (%) for categorical data. Differences between groups, according to gender or hydration status, were tested using the chi-square test (categorical data) and the Mann-Whitney U test (continuous variables with a non-normal distribution for two independent groups). In addition, a multivariate logistic regression model was calculated and adjusted for gender, age, and place of resident, to evaluate the factors associated with dehydrated status in the study group. Odds Ratios (OR) and 95% Confidence Intervals (95%) were calculated. The level of significance of the OR was verified with Wald's test.

RESULTS

The highest percentage of children in the study were 10-years-old (42%), lived in towns of up to 100,000 inhabitants (52%), came from the North-Eastern region (37%), and self-assessed their physical activity as high (Tab. 2). Significantly, the highest percentage of boys (38%) and girls (45%) were aged 10 years, compared to other age groups. In addition, a significantly higher percentage of boys self-assessed their physical activity as high (51%), while girls as moderate (49%), compared to other activity levels.

The frequency of consumption of selected beverages and products, anthropometric measurements, body composition, and knowledge about the amount of beverages consumed during the day are shown in Table 3. Statistical analysis showed that boys consumed sugar-sweetened beverages and

Table 2. Socio-demographic characteristics of the study group according to the gender

Variables	Total n = 2,849	Boys n = 1,380	Girls n = 1,469	p-value*
	n (%)	n (%)	n (%)	
Age (years)				
10	1,189 (42)	529 (38)	660 (45)	0.006
11	948 (33)	479 (35)	469 (32)	
12	712 (25)	372 (27)	340 (23)	
Place of residence				
villages	805 (28)	397 (29)	408 (28)	0.113
towns	1,489 (52)	712 (52)	778 (53)	
cities	554 (20)	271 (19)	283 (19)	
Regions				
Central	661 (23)	305 (22)	356 (24)	0.631
North-Eastern	1,044 (37)	506 (37)	538 (37)	
South-Western	428 (15)	208 (15)	220 (15)	
North-West	378 (13)	190 (14)	188 (13)	
South-Eastern	338 (12)	171 (12)	167 (11)	
Physical activity				
low	333 (12)	184 (13)	149 (10)	< 0.001
moderate	1,209 (42)	494 (36)	715 (49)	
high	1,307 (46)	702 (51)	605 (41)	

* chi-square test

Table 3. Frequency of consumption, anthropometric measurements and body composition according to gender in the study group

Variables	Total n = 2,849	Boys n = 1,380	Girls n = 1,469	p-value*, **
Frequency of consumption of selected products				
sugar-sweetened beverages	3.1 ± 1.5[a]	3 (1 – 7)[b]	2 (1 – 7)	< 0.001*
juices	3.8 ± 1.5	4 (1 – 7)	4 (1 – 7)	0.660*
energy drinks	1.3 ±1.0	2 (1 – 7)	1 (1 – 5)	< 0.001*
dairy products	4.6 ± 1.4	4 (1 – 7)	4 (1 – 7)	0.122*
vegetables	4.0 ± 1.6	3 (1 – 7)	4 (1 – 7)	< 0.001*
fruits	4.0 ± 1.7	3 (1 – 7)	4 (1 – 7)	< 0.001*
"How much fluid should you drink during the day?"				
improper	1234 (43)[c]	589 (42)	645 (43)	0.515**
proper	1615 (57)	791 (58)	824 (57)	
Anthropometric parameters and body composition				
BMI (kg/m^2)	19.0 ± 3.8	18.2 (12.3 – 37.2)	18.0 (12.1 – 35.2)	0.023*
WC (cm)	66.4 ± 10.2	64.3 (32.2 – 109.3)	64.3 (48.3 – 104.6)	0.842*
TBW (%)	56.1 ± 4.7	58.2 (30.4 – 66.5)	56.2 (33.5 – 64.2)	< 0.001*
TBW (kg)	23.7± 4.9	23.8 (17.2 – 34.5)	22.8 (13.2 – 41.9)	< 0.001*
FM (kg)	23.2 ± 6.4	20.5 (9.2 – 58.4)	23.3 (12.2 – 54.2)	< 0.001*
FFM (kg)	32.4 ± 6.7	32.5 (19.0 – 64.4)	31.1 (18.1 – 57.3)	< 0.001*
BMI category – n (%)				
underweight	267 (8)	108 (8)	122 (8)	<0.001**
normal	1,948 (70)	916 (66)	1,073 (73)	
overweight	365 (13)	200 (14)	163 (11)	
obesity	269 (10)	156 (12)	111 (8)	

* Mann Whitney U test; ** chi-square test; [a] Mean ± standard deviation; [b] Median (minimum – maximum); [c] number of respondents (%); BMI body mass index; WC – waist circumference; TBW – total body water; FM – fat mass; FFM – free fat mass

energy drinks more frequently than girls. However, girls consumed vegetables and fruits significantly more often than boys. Based on anthropometric measurements and body composition analysis, a significantly higher FM content was found in girls (23.3 kg) compared to boys (20.5 kg). The remaining parameters BMI (kg/m^2), total body water (TBW), and fat-free mass (FFM) were significantly higher in boys than in girls. Moreover, the average TBW (%) indicates that the groups of boys and girls were adequately hydrated (56.1%). The results also showed that the most significant percentage of boys and girls had a normal BMI, with a significantly higher percentage of girls (73%) than boys (66%). However, significantly more boys (26%) than girls (18%) had excessive body weight.

Table 4 shows socio-demographic variables according to the hydration status in the schoolchildren, of whom approximately 10% were dehydrated. In both the dehydrated and adequately hydrated groups, the highest percentage of children lived in towns – 58% and 51%, respectively. However, there was a higher percentage of adequately hydrated pupils (21%) than dehydrated (13%) among those living in cities. In addition, it was statistically significant that the largest percentage of schoolchildren who reported moderate physical activity were dehydrated (50%). In comparison, the most important percentage of the adequately hydrated group was characterized by high physical activity (48%).

Table 4. The socio-demographic characteristics of the study group according to the hydration status

Variables	Dehydrated[a] n = 238	Properly hydrated[b] n = 2,611	p-value*
	n (%)	n (%)	
Age (years)			
10	101 (42)	1,088 (42)	
11	91 (38)	857 (32)	0.073
12	46 (20)	666 (26)	
Place of residence			
villages	71 (29)	734 (28)	
towns	139 (58)	1,351 (51)	0.046
cities	28 (13)	526 (21)	
Regions			
Central	68 (29)	593 (23)	
North-Eastern	91 (38)	953 (36)	0.412
South-Western	31 (13)	397(15)	
North-West	19 (8)	359 (14)	
South-Eastern	29 (12)	309 (12)	
Physical activity			
low	44 (18)	289 (11)	
moderate	121 (50)	1,088 (41)	< 0.001
high	73 (32)	1,234 (48)	

[a] Dehydrated TBW below 49%; [b] Properly hydrated; TBW – 49–75%; * chi-square test

The analyses compared the frequency of consumption of selected beverages and products, anthropometric measurements, body composition, and knowledge about the proper amount of beverages consumed during the day (Tab. 5). In the study group, pupils who were properly hydrated had a significantly higher frequency of consumption of sugar-sweetened beverages, juices, and vegetables, compared to dehydrated children. However, the group of dehydrated schoolchildren was characterized by a significantly higher BMI (kg/m^2) and FM (kg), compared to the adequately hydrated children. For BMI (%), a significantly higher percentage of normal body weight was observed in properly hydrated pupils (75%) compared to those who were dehydrated (3%). Knowledge about the amount of fluid consumed in schools during the day was not found to be a significant variable in children's hydration status. The results of the logistic regression analysis are presented in Table 6.

Table 5. Frequency of consumption, anthropometric measurements, and body composition according to hydration status in the study group

Variables	Dehydrated[a] n = 238	Adequately hydrated[b] n = 2,611	p-value*,**
Frequency of consumption of selected products			
sugar-sweetened beverages	2 (1–7)[c]	3 (1–7)	0.005*
juices	3 (1–7)	4 (1–7)	0.012*
energy drinks	1 (1–5)	1 (1–7)	0.704*
dairy products	4 (1–7)	4 (1–7)	0.117*
vegetables	3 (1–7)	4 (1–7)	0.008*
fruits	4 (1–7)	4 (1–7)	0.663*
"How much fluid should you drink during the day?"			
improper	109 (45)[d]	1,125 (43)	0.418**
proper	129 (55)	1,486 (57)	
Anthropometric parameters and body composition			
BMI (kg/m^2)	26.2 (18.9–37.2)	17.7 (12.1–28.9)	< 0.001*
WC (cm)	65.9 (49.7–109.3)	64.2 (32.2–105.6)	0.262*
FM (kg)	36.1 (33.0–58.4)	21.7 (9.2–33.2)	< 0.001*
FFM (kg)	31.2 (18.1–64.4)	39.0 (24.4–62.8)	< 0.001*
BMI category			
underweight	0 (0)	230 (9)	
normal	8 (3)	1,981 (75)	< 0.001**
overweight	48 (20)	315 (12)	
obesity	182 (77)	85 (4)	

* Mann Whitney U test; ** chi-square test; [a] Dehydrated TBW below 49%; [b] Properly hydrated TBW 49-75%; [c] Median (minimum – maximum); [d] number of respondents (%); BMI - body mass index; WC - waist circumference; FM - fat mass; FFM - free fat mass

High, compared to low physical activity, had a limiting effect on the dependent variable; the probability of dehydration decreased by 68% (OR: 0.32; 95% CI: 0.12–0.86). Increasing the frequency of juice consumption significantly reduced the dependent variable. Each increase in this variable reduced the probability of dehydration by 18% (OR: 0.83; 95% CI: 0.68–0.99), while a one-step increase in the frequency of vegetable consumption reduced the probability of dehydration by 11% (OR: 0.89; 95% CI: 0.78–0.95).

From the anthropometric and body composition data, BMI and FFM were found to be significant in the model. Each 1-unit increase in BMI was associated with a 4.5-fold increase in the odds of dehydration (OR: 4.49; 95% CI: 3.53–5.70), while each 1-unit increase in FFM was associated with a 30% decrease in the odds of dehydration (OR: 0.70; 95% CI: 0.65–0.76). The variables gender, age, and place of residence were used to adjust the model, none of which were significant in the model.

Table 6. Multivariate model for dehydration in children based on TBW measurement

Variables	Dehydrated[a]				
	β[b]	eβ[c]	95% CI[d]		p-value*
Physical activity					
low	1	1	1	1	1
moderate	-0.718	0.48	0.19	1.22	0.127
high	-1.136	0.32	0.12	0.86	0.024
Sugar-sweetened beverages[f]	-0.123	0.88	0.71	1.09	0.252
Juices[f]	-0.191	0.82	0.68	0.99	0.049
Energy drinks[f]	0.004	1.01	0.73	1.38	0.977
Dairy products[f]	0.137	1.14	0.93	1.41	0.193
Vegetables[f]	-0.113	0.89	0.78	0.95	0.041
Fruits[f]	0.036	1.03	0.83	1.27	0.756
BMI (kg/m^2)	1.502	4.49	3.53	5.70	<0.001
WC (cm)	-0.003	0.99	0.96	1.02	0.791
FFM (kg)	-0.345	0.32	0.12	0.86	0.024

* Wald test, model adjusted for gender, age and place of resident; [a] Dehydrated TBW below 49%; [b] estimate; [c] OR-point estimate (eβ); [d] 95% confidence intervals; [f] the data presented relate to frequency of consumption; BMI – body mass index; WC – waist circumference; FFM – free fat mass

DISCUSSION

In the study group, boys consumed sugar-sweetened beverages and energy drinks more frequently than girls; on the other hand, girls consumed vegetables and fruits significantly more frequently than boys. Based on anthropometric measurements and body composition analysis, a significantly higher FM content was found in girls compared to boys, but the remaining parameters, BMI, TBW, and FFM, were significantly higher in boys than in girls. Moreover, the average TBW (%) indicated that the group of boys and girls were adequately hydrated. However, variables that reduced the probability of dehydration in the study group were an increase in the frequency of juice and vegetable consumption and a high level of physical activity. At the same time, a 1-unit increase in BMI was associated with increased odds of dehydration, and a 1-unit increase in FFM was associated with decreased odds.

Other studies confirm the more frequent consumption of sugar-sweetened beverages by boys [18] and fruits and vegetables by girls [2]. In turn, dietary recommendations indicate that fruits and vegetables should be consumed with each meal, i.e., 5–6 portions per day [19]. It is supposed that girls are more likely than boys to choose these products because they are concerned about their appearance, and want to consume healthy and unprocessed products [20]. However, the consumption of sweet drinks among children has increased and has become a daily part of their diet [21]. As is widely known, a diet rich in sugar-sweetened beverages due to the free sugars they contain is one of the factors that may contribute to the development of overweight and obesity and/or tooth decay, but it can also contribute to the development of many cardiovascular diseases, and diabetes [22, 23]. Unfortunately, as shown by the current study, the frequency of consumption of sweetened beverages among Polish teenagers is high, especially among boys. However, it was also observed in the study that boys had higher BMI and FFM compared to girls. Other researchers have found similar results due to the physiological structure of the human body and the differences between the genders [3, 24].

The findings of the presented study indicate that more frequent consumption of juice and vegetables reduced schoolchildren's dehydration odds, and that high physical activity reduces the odds of dehydration. Juices are recommended as an alternative to consuming fruit and vegetables. According to the recommendations, it is possible to replace one portion of these products with juice [19]. The best solution would be to prepare a portion of such a drink from fresh vegetables and/or fruit without added sugar. Vegetables can be consumed on their own or can be used as an ingredient in prepared cocktails. As a result, they can also be a valuable source of water for the body. The educational project of a social nature, 'Five portions of fruit, vegetables or juice', also has as its main objective the promotion of a healthy lifestyle, which consists primarily of a correct and balanced diet rich in appropriate portions of fruit, vegetables, or juice. An important aspect of the campaign is to raise awareness among children and adults about the need to consume these products and their positive effects on the human body [25]. A properly nourished and hydrated body translates into high physical activity in schoolchildren [3]. It is notable that pupils who are aware of the importance of physical activity are more inclined to engage in it. Concurrently, they consume greater quantities of water and other beverages, which indicates that they are characterized by a superior hydration status compared to other children. A pro-health lifestyle is characterized by a combination of physical activity, adequate hydration, and a rational approach to dietary behaviours.

In the current study it was found that the average TBW (%) was within the reference values for this component. Other authors [3] obtained similar results in children, although there were children in the study group who were below the reference values. It is important to remember that children are more susceptible to dehydration than adults. They are more likely to lose water because they have a greater body surface area per unit of body weight, have a smaller water reserve, are partially dependent on their caregiver, and have a different thirst sensitivity [12].

The presented study also confirmed that an increase in BMI was associated with increased odds of dehydration, and an increase in FFM was associated with decreased odds. This can be explained by the fact that a higher BMI usually means more adipose tissue, which contains less water than muscle tissue. However, it should be remembered that a higher BMI does not always indicate overweight or obesity, especially in children [26]. On the other hand, attention should be paid to the beverages chosen by children, which may contribute to weight gain due to the added sugar. Promoting adequate eating habits is vital in maintaining proper hydration in children; hence, long-term, systematic, and effective nutritional education is so important.

Strengths and limitations of the study. The strength of our study is the relatively large group of schoolchildren from the whole of Poland, from both rural and urban environments, with a similar percentage of boys and girls. Secondly, for the analyses, socio-demographic data were used: age, place of residence, regions, physical activity, and the frequency of consumption of sugar-sweetened beverages, juices, energy drinks, dairy products, vegetables, and fruits. Thirdly, anthropometric measurements were performed of BW, H,

and body composition analysis – TBW, FM, and FFM. All measurements were taken with professional equipment and measuring tapes of the same type in all schools, used by well-trained people who took anthropometric measurements and collected dietary data. Of the above factors, those that had a significant impact on dehydration in schoolchildren were identified.

A limitation of the study was the timeline of the project which did not include a quantitative assessment of the participants' food intake; therefore, there is no information about what could be an additional source of water for the pupils. Secondly, the frequency of consumption of selected beverages, fruits, and vegetables was collected using the FFQ, which does not allow the true water intake from food to be assessed. Therefore, the study has typical errors for this method and should be supplemented in the future with other more accurate methods of food intake assessment. On the other hand, the FFQ is a well-established, validated, and widely used questionnaire. Thirdly, the study had cross-sectional observations, thus only an association between variables could be found, without any cause-and-effect being demonstrated. Fourthly, the body composition device that was used could only measure TBW, without the ability to measure intracellular and extracellular water; however, these measurements are planned for future studies. Moreover, future research should also consider precise methods of hydration status (e.g., urine osmolality and specific gravity) and other factors linked to the water intake, such as time of year and ambient temperature, as well as health status, i.e., fever, vomiting, and diarrhea in the days before the examination, as well as other diseases and medications taken that could affect the outcome of the study.

CONCLUSIONS

The study demonstrated that boys consumed sugar-sweetened beverages and energy drinks more frequently than girls, but girls consumed vegetables and fruits significantly more frequently than boys. The average TBW (%) indicated that the group of boys and girls were adequately hydrated. In study group, variables that reduced the probability of dehydration were an increase in the frequency of juice and vegetable consumption and a high level of physical activity. No other frequency of beverage consumption was found to be significant in the context of hydration status measured by BIA in children aged 10–12 years. Moreover, at the same time, a 1-unit increase in BMI was associated with increased odds of dehydration, and a 1-unit increase in FFM was associated with decreased odds. Factors such as the availability of fluids are essential predictors of hydration status, so it is important to know critical factors in the schoolchildren's diet. Consumption of beverages, especially juice and water, and products rich in this ingredient, such as vegetables and fruit, should be promoted to ensure adequate hydration in children at home and school, where children spend a large part of the day. This situation can be influenced by ensuring constant access to water through the provision of appropriate school infrastructure, such as water dispensers and springs, as well as workshops and educational activities. There is a need to increase public awareness of the common challenges related to children's hydration and limit their access to sources of sweetened beverages.

It should also be underlined that the hydration status of pupils was determined in the study not only by such demographic factors as gender, age and place of residence, but also by such chosen aspects of life style as physical activity, as shown in the results of this study. Therefore, the obtained results highlight the need for further research to clarify the relationship between diet, including the consumption of beverages, vegetables and fruits, anthropometric measurements and body composition, in the analysis of the hydration status of schoolchildren.

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