Original paper

Dietary habits, physical activity and nutritional status in children with Down's syndrome

Żywienie, aktywność fizyczna i stan odżywienia dzieci z zespołem Downa

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Słowa kluczowe: zespół Downa, dzieci, otyłość, żywienie, aktywność fizyczna.

Abstract

Introduction: To date, the risk factors for overweight and obesity in children with Down's syndrome (DS) have not been comprehensively described, as studies on the subject are rare and usually conducted among small groups.
Aim of the research: To assess the dietary habits and physical activity, and their associations with nutritional status, in children with DS compared to a group of their typically developing peers.
Material and methods: A sample of 102 children with DS and 107 children without SD aged 5–14 years. Eating habits were assessed using the patient's diary method over three days. Physical activity was measured using pedometers. Nutritional status was assessed based on body mass, height and fat percentage.
Results: Children with DS had an excessive body mass index ($p < 0.0001$) and fat percentage ($p < 0.0001$) more often than the controls. They showed lower physical activity ($p < 0.0001$) and a higher risk of an insufficient intake of dietary fibre ($p = 0.0113$). Other factors potentially affecting body mass and fat percentage in children with DS included age, female gender and fewer underage family members.
Conclusions: Physical activity in children with DS is insufficient to prevent chronic diseases. It is necessary to develop intervention programmes aimed at increasing participation in various forms of physical activity and changing their dietary habits.

Streszczenie

Wprowadzenie: Czynniki ryzyka wystąpienia nadwagi i otyłości u dzieci z zespołem Downa (ZD) nie zostały dotąd wyczerpująco opisane, a badania w tym zakresie były podejmowane sporadyczne i prowadzone zazwyczaj w grupach o małych liczebnościach.
Cel pracy: Ocena żywienia, poziomu aktywności fizycznej oraz ich powiązań ze stanem odżywienia u dzieci z ZD w porównaniu z grupą typowo rozwijających się rówieśników.
Materiał i metody: Analizie poddano dane 102 dzieci z ZD oraz 107 dzieci bez ZD w wieku 5–14 lat. Sposób żywienia oceniono metodą bieżącego notowania przez 3 dni. Aktywność fizyczną zbadano za pomocą krokomierzy. Stan odżywienia badano na podstawie pomiarów masy i wysokości ciała oraz procentowej zawartości tkanki tłuszczowej.
Wyniki: U dzieci z ZD częściej występowały nadmiary względnej masy ciała (BMI) ($p < 0{,}0001$), tkanki tłuszczowej ($p < 0{,}0001$), stwierdzono także niższy poziom aktywności fizycznej ($p < 0{,}0001$) i wyższe ryzyko niedostatecznego spożycia błonnika pokarmowego ($p = 0{,}0113$) w porównaniu z grupą kontrolną. Na wystąpienie większej masy ciała i większej ilości tkanki tłuszczowej u dzieci z ZD mogły mieć wpływ także takie czynniki, jak wiek, płeć żeńska i mniejsza liczba osób niepełnoletnich w gospodarstwie domowym.
Wnioski: Aktywność fizyczna dzieci z ZD jest niewystarczająca, aby skutecznie zapobiegać rozwojowi chorób przewlekłych. Konieczne jest opracowanie programów interwencyjnych umożliwiających zwiększenie udziału tych dzieci w różnych formach aktywności fizycznej oraz zmiana nawyków żywieniowych.

Introduction

Down's syndrome (DS) is a chromosomal mutation involving a tripling of the genetic material on the 21st chromosome. It is the most common genetic disorder. Between 2011 and 2015 in Europe, 8031 live births of children with DS were recorded each year. The prevalence of DS was 10.1 per 10,000 live births [1]. Individuals with DS display abnormalities in relation to their brain structure, function and development that lead to varying levels of intellectual disability [2–4]. Furthermore, individuals with DS are more likely than the general population to display congenital heart disorders, defects of the gastrointestinal tract, defects of the urogenital, muscular, osteoarticular and haematopoietic systems, impaired immune response, vision and hearing, epilepsy, type 1 diabetes, leukaemia and Alzheimer's disease [3, 5, 6], thyroid hormone disorders [7, 8], diseases of the oral cavity and teeth [9], food intolerances, malabsorption syndrome, metabolic disorders, and vitamin and mineral deficiencies [10, 11].

Many studies have indicated a higher prevalence of overweight and obesity in children with DS, compared to their peers without DS [7, 10–13]. Basil *et al.* observed a 47.8% prevalence of obesity in children with DS aged 2–18 years, compared to 12.1% in a control group of children [12]. A review of the literature conducted by Bertapelli *et al.* demonstrated that the prevalence of being overweight and obese in children and youth with DS aged 0–19 years ranged from 23% to 70% [7]. The causes of overweight and obesity in children with DS include metabolic disorders, compulsive eating caused by difficulties in chewing food, muscle hypotonia leading to decreased satiety after meals and abnormal blood leptin levels, as well as comorbidities such as hypothyroidism [7, 12, 14–16]. However, the studies do not provide clear results with respect to the genetic causes of obesity in children with intellectual disabilities. Researchers have also indicated the role of environmental factors, including bad dietary habits and insufficient physical activity in children with DS [7, 11].

Overweight in children with DS is associated with many disorders. It is thought to increase the risk of dyslipidaemia, hyperinsulinemia, stroke, heart failure, hypertension, type 2 diabetes, obstructive sleep apnoea and incorrect gait. However, the relationship between obesity and health is difficult to determine due to the high number of comorbidities associated with DS [7, 11, 17]. Obesity not only leads to severe health problems, but also impacts an individual's ability to self-manage [18], which is crucial in the case of individuals with special needs, including patients with DS.

Aim of the research

The aim of this study was to assess the dietary habits and physical activity, and their associations with nutritional status, in children with DS compared to a group of their typically developing peers.

Material and methods

Research organisation

The study participants comprised children with DS aged 5–14 years. The control group consisted of their peers without DS or other genetic disorders. The participants were selected using snowball sampling from among the members of associations and foundations for children with DS and their parents, as well as from preschools and primary schools attended by children both with and without DS. The participants lived in large cities and in their vicinity, in the areas of central-eastern and southern Poland (Kielce, Krakow, Lublin, Warsaw) with the aforementioned foundations. From a total of 108 children with DS and 115 children without DS recruited for the study, 6 of the children with DS and 8 children without DS were rejected due to incomplete or illegible data. The final sample size for the nutritional assessment was 102 children with DS and 107 children without DS. The assessment of the physical activity using pedometers was performed among 101 of the children with DS and 107 children without DS.

The study received Approval No. 47/2018 from the Bioethics Committee at the Collegium Medicum of the Jan Kochanowski University of Kielce. Prior to the study, the parents or guardians of each child provided written consent for their participation.

Research methods and tools

Methodology for the nutritional status assessment and results analysis

The participants' nutritional status was assessed based on the body mass (kg) and height (cm), which were used to calculate the BMI (kg/m^2). Body fat percentage (%BF) was determined based on bioelectric impedance using an Inbody 120 body composition analyser. The interpretation of the data concerning the nutritional status of the children with and without DS was based on the Polish developmental standards for children and youth [19]. Both of the groups were divided into children with a low (< 10 centile), normal (10–90 centile) and high (> 90 centile) BMI. The participants' %BF was compared to the Polish weight and height standards for children and youth [20]. Consequently, both groups were divided into children with a low (< 10 centile), normal (10–90 centile) and high (> 90 centile) %BF.

Methodology for the analysis of dietary habits

The participants' dietary habits were assessed using the patient's diary method over a period of 3 days. The diaries were filled in by the children's parents or guardians. The nutritional content of the children's diets was then estimated using the Dieta 6 software. The intake of nutrients, including proteins, fats, carbohydrates, dietary fibre and sucrose, was calculated. The mean intake of these nutrients was presented, according to age and gender, based on the Polish dietary norms [21]. Furthermore, the adequacy of the intake of protein and dietary fibre was assessed using the Estimated Average Requirement/Adequate Intake (EAR/AI) cut-off point, in order to estimate the percentage of children with a usual intake that was lower than the EAR/AI. This yielded data concerning the magni-

Table 1. Basic sociodemographic data of children with DS and the control group

Variable	Children with DS *N* (%*N*)	Control group *N* (%*N*)	Statistical test	
Age [years] (x ± SD)	10.2 ±2.9	10.1 ±2.8	Z = 0.37	p = 0.7126
Gender:				
Girls	43 (42.2)	62 (57.9)	**χ^2 = 5.21**	**p < 0.0001**
Boys	59 (57.8)	45 (42.1)		
Number of family members:				
Total (x ± SD)	4.3 ±1.2	4.6 ±1.2	**Z = –2.18**	**p = 0.0291**
Underage (x ± SD)	2.0 ±1.0	2.2 ±0.9	**Z = –2.30**	**p = 0.0217**
Family's financial situation:				
Below average	17 (16.7)	11 (10.3)	χ^2 = 2.24	p = 0.3256
Average	57 (55.9)	60 (56.1)		
Above average	28 (27.5)	36 (33.6)		

Z – Mann-Whitney U test, χ^2 – Pearson's chi-squared test, p – p-value; statistically significant results are marked in bold.

tude of the populational risk of an insufficient intake of a nutrient in the sample. The cut-off point method was not used in the case of energy, because the intake of energy increases with the demand. Instead, the distribution of the BMI in the sample was determined and used to analyse the nutritional state.

Assessment methodology for physical activity and the results analysis

The participants' level of physical activity was measured by counting the steps taken per day, over a period of three days, using Tanita AM-180E pedometers. Three categories of physical activity were distinguished as follows: sedentary lifestyle (< 7000 steps/day in girls and < 10000 steps/day in boys), low activity (7000–9499 steps/day in girls and 10,000–12,499 steps/day in boys), and moderate to high activity (≥ 9500 steps/day in girls and ≥ 12,500 steps/day in boys) [22].

Additional data concerning the participants' age, number of family members and the family's financial situation were collected using a survey questionnaire.

Statistical analysis

The statistical analysis was performed using the StatSoft Statistica PL v. 13.1 software package. The data were considered to be statistically significant at $p \leq 0.05$. The distribution of categorical variables was assessed using Pearson's χ^2 test. Quantitative and ordinal variables were compared between the groups using Student's *t*-test or the Mann-Whitney *U* test, depending on whether the requirements related to the normality of distribution and the uniformity of variables were met. Pearson's linear correlation coefficient was used to determine the relationship between a participant's intake of energy, intake of nutrients and physical activity, and their nutritional status. The effect of each factor on the indicators of the nutritional status (BMI and %BF) was estimated by creating separate multifactor models for the children with and without DS. Independent variables included the child's age, gender, family's financial situation, number of underage family members, intake of energy, total intake of fat, total carbohydrates and sucrose, and physical activity based on the number of steps taken per day.

Results

Participant characteristics

The participants with DS and without DS (the control group) did not differ significantly in terms of age (Table 1). Boys made up a higher percentage of the DS group than the control group. The number of family members, as well as the number of underage family members, was significantly lower in the DS group than in the control group. No significant difference in the family's financial situation between the groups was observed.

Assessment of nutritional status

The children with DS showed a significantly higher BMI than the control group (Table 2). The percentage of children classified as having overweight and obesity was also significantly higher in the participants with DS than in the control (56.9% and 15.0%, respectively). More children in the DS group also had a high %BF (> 90 centile) than in the non-DS group (86.3% and 52.3%, respectively).

Assessment of nutrient intake

The children with DS aged 4–6 years consumed significantly less sucrose and dietary fibre compared to the control group, while the children with DS

Table 2. Comparison of nutritional status indicators between children with DS and the control group

Nutritional status indicator	Children with DS		Control group		Statistical test	
	N	*%N*	*N*	*%N*		
BMI:						
BMI [kg/m²] (x ± SD)	22.4 ±4.0		18.1 ±3.5		***Z* = 7.52**	***p* < 0.0001**
Risk of malnutrition	0	0	14	13.1	χ^2 **= 46.74**	***p* < 0.0001**
Normal weight	44	43.1	77	72.0		
Overweight and obesity	58	56.9	16	15.0		
%BF:						
%BF (x ± SD)	25.8 ±5.8		19.7 ±6.7		***t* = 7.07**	***p* < 0.0001**
Low content	2	2.0	24	22.4	χ^2 **= 31.39**	***p* < 0.0001**
Normal content	12	11.8	27	25.2		
High content	88	86.3	56	52.3		

BMI – body mass index, %BF – body fat percentage, Z – Mann-Whitney U test, χ^2 – Pearson's chi-squared test, t – Student's t-test, p – p-value, statistically significant results are marked in bold.

aged 7–9 years consumed significantly less protein and sucrose compared to the control group (Table 3). Boys with DS aged 10–12 years consumed significantly less energy, protein, fat, sucrose and dietary fibre compared to their peers without DS. In the girls of the same age, a lower intake of sucrose in the girls with DS was the only significant difference observed between the two groups. The diet of the girls with DS aged 13–15 years contained less energy and total carbohydrates, sucrose and dietary fibre compared to the diet of the girls without DS. Conversely, the boys with DS of the same age consumed significantly less energy and protein compared to the control group.

The mean intake of protein was the same among the children with and without DS. In both groups, protein accounted for 16% of the overall energy. The populational risk of an insufficient intake of protein was higher in the children with DS than in the control group, being 15.7% in the former group and less than half this value in the latter (Table 4). However, the difference was not statistically significant. Fats accounted for 28% of the dietary energy in the children with DS and 30% in the controls, while carbohydrates accounted for 56% and 54%, respectively. Sucrose accounted for 9% and 12%, respectively, with the children without DS consuming significantly more sucrose than the recommended 10% of the daily energy intake. The children with DS also showed a significantly higher risk of an insufficient intake of dietary fibre compared to their peers in the control group.

Assessment of participants' physical activity

The assessment of the participants' physical activity showed that the children with DS took much fewer steps per day, on average, than the children without DS (3927.2 ±2348.1 vs. 6901.8 ±3314.1). A vast majority of the children with DS (almost 90% of the sample) had a sedentary lifestyle (Table 5), compared to 59.8% of the children without DS. One in 3 children without DS showed a low level of physical activity, while several showed moderate or high levels of physical activity.

Relationship between participants' dietary habits and physical activity and their nutritional status

An increased intake of energy and total carbohydrates was related to an increase in the %BF among the children, both with and without DS, as well as being related to an increased BMI, but only in the control group (Table 6). In turn, a high intake of sucrose was positively associated with an increased BMI and %BF among both groups. No significant relationships were found between the total intake of fat or dietary fibre and the nutritional status indicators. Increased BMI and %BF were observed among both groups in the children who showed low levels of physical activity (took fewer steps per day than their peers). The strongest correlation occurred between the level of physical activity and the BMI in children without DS (r = –0.69).

A multivariate regression analysis was performed in order to determine what factors were associated with the participants' nutritional status. A positive relationship was observed between the BMI in the children with DS and their age and intake of sucrose, while a negative relationship was observed between the BMI and physical activity, calculated as the number of steps taken per day (Table 7). With each year of age, the mean BMI increased by 0.23 kg/m² (with the other parameters remaining constant). Each ad-

Table 3. Comparison of the mean consumption of energy and nutrients between children with DS and the control group according to age categories and gender, $x \pm SD$

Nutrient	Group	Children aged 4–6 years *N* = 15(ZD)/13(c)	Children aged 7–9 years *N* = 27(ZD)/37(c)	Girls aged 10–12 years *N* = 11(ZD)/18(c)	Boys aged 10–12 years *N* = 20(ZD)/10(c)	Girls aged 13–15 years *N* = 11(ZD)/19(c)	Boys aged 13–15 years *N* = 18(ZD)/10(c)
Energy [kcal]	With DS	1140.3 ±240.1	1210.0 ±230.0	1298.9 ±320.5	1111.1 ±294.8	1185.6 ±238.9	1153.0 ±215.7
	Control	1414.5 ±470.5	1287.8 ±366.0	1448.3 ±362.0	1499.2 ±388.5	1423.3 ±330.2	1416.8 ±342.2
Statistical test and *p*-value	*t*	–1.90	–1.04	–0.73	**–2.87**	**–2.10**	**–2.46**
	p	0.0746	0.3021	0.4720	**0.0078**	**0.0447**	**0.0213**
Protein [g]	With DS	47.2 ±13.7	48.0 ±11.0	54.5 ±13.4	46.6 ±13.2	48.5 ±12.8	44.5 ±8.8
	Control	54.3 ±14.8	54.6 ±14.0	55.9 ±13.1	58.9 ±12.7	53.6 ±12.7	62.4 ±12.9
Statistical test and *p*-value	*t*	–1.34	**–2.02**	0.06	**–2.26**	–1.08	**–3.06**[Z]
	p	0.1925	**0.0473**	0.9503	**0.0319**	0.2909	**0.0022**[Z]
Fats [g]	With DS	38.5 ±14.8	38.3 ±14.0	45.0 ±13.4	37.5 ±18.2	41.8 ±14.3	35.1 ±9.9
	Control	46.8 ±20.3	43.4 ±18.3	52.2 ±18.9	55.0 ±16.0	48.7 ±16.1	48.7 ±17.9
Statistical test and *p*-value	*t*	–1.20[Z]	–1.23	–0.83	**–2.44**[Z]	–1.19	–2.13
	p	0.2310[Z]	0.2250	0.4139	**0.0146**[Z]	0.2455	0.0574
Carbohydrates [g]	With DS	156.4 ±34.2	173.9 ±27.7	174.8 ±48.7	152.3 ±31.4	158.5 ±37.2	170.7 ±38.0
	Control	201.2 ±70.8	176.0 ±49.7	195.6 ±52.2	200.5 ±60.7	200.0 ±55.0	189.6 ±56.6
Statistical test and *p*-value	*t*	–2.08	–0.21	–0.65[Z]	–2.11	**–2.17**[Z]	–1.03
	p	0.0529	0.8366	0.5146[Z]	0.0591	**0.0302**[Z]	0.3121
Sucrose [g]	With DS	17.8 ±10.3	25.6 ±12.7	24.0 ±14.3	24.3 ±13.1	32.1 ±12.6	37.6 ±13.8
	Control	45.6 ±26.3	39.8 ±23.4	45.8 ±25.1	49.1 ±27.4	46.8 ±20.4	47.8 ±33.4
Statistical test and *p*-value	*t*	**–3.77**	**–2.47**[Z]	**–2.31**[Z]	**–2.49**	**–2.15**	0.00[Z]
	p	**0.0008**	**0.0134**[Z]	**0.0206**[Z]	**0.0303**	**0.0400**	1.0000Z
Dietary fibre [g]	With DS	10.0 ±3.1	11.3 ±3.5	12.0 ±2.9	10.9 ±4.3	9.3 ±3.2	11.7 ±3.1
	Control	14.5 ±4.5	12.6 ±4.4	14.0 ±3.7	16.2 ±6.7	14.4 ±7.0	14.8 ±6.4
Statistical test and *p*-value	*t*	**–3.09**	–1.17[Z]	–1.19	**–2.18**[Z]	**–2.50**[Z]	–1.83[Z]
	p	**0.0047**	0.2424[Z]	0.2439	**0.0294**[Z]	**0.0125**[Z]	0.0679[Z]

[Z]Mann-Whitney U test, t – Student's t-test, p – p-value, [c] – Control group; statistically significant results are marked in bold.

Table 4. Populational risk of an insufficient intake of nutrients in children with DS and the control group

Nutrient	Children with DS		Control group		Mann-Whitney *U* test	
	N	*%N*	*N*	*%N*	*Z*	*p*
Protein*:						
< EAR/AI	16	15.7	8	7.5	–1.02	0.3059
Fats:						
< 20% energy	7	6.9	6	5.6	–0.01	0.9909
> 35% energy	21	20.6	21	19.6		
Carbohydrates:						
< 45% energy	8	7.8	10	9.4	0.54	0.5868
> 65% energy	10	9.8	6	5.6		
Sucrose:						
> 10% energy	39	38.2	64	59.8	**–2.69**	**0.0071**
Dietary fibre*:						
< EAR/AI	96	94.1	79	73.8	**–2.53**	**0.0113**

**The intake was assessed using the EAR/AI cut-off point, Z – Mann-Whitney U test, p – p-value, statistically significant results are marked in bold.*

Table 5. Level of physical activity in children with DS and the control group

Physical activity	Children with DS		Control group		Mann-Whitney *U* test	
	N	*%N*	*N*	*%N*	*Z*	*p*
Sedentary	90	89.1	64	59.8	**–6.82**	**< 0.0001**
Low	11	10.9	37	34.6		
Moderate or high	0	0	6	5.6		

Z – Mann-Whitney U test, p – p-value, statistically significant results are marked in bold.

ditional consumed gram of sucrose in the children with DS increased the BMI by 0.06 kg/m^2. However, each additional step taken by the children with DS decreased the mean BMI by 0.0007 kg/m^2. In the control group, the only observed relationships were a positive relationship between BMI and intake of sucrose, as well as a negative relationship between BMI and physical activity, as calculated based on the steps taken per day. The mean BMI increased by 0.05 kg/m^2 with each additional consumed gram of sucrose, while it decreased by 0.0006 kg/m^2 with each step taken. The constructed models explained the value of the BMI in the children with DS in 42% of the participants (R^2 = 0.4190), and in the children without DS in 58% (R^2 = 0.5829).

Furthermore, a negative relationship was observed between %BF in the children with DS and the number of underage family members, as well as physical activity calculated based on the number of steps taken, while there was a positive relationship between %BF and gender and the intake of carbohydrates (Table 8). The mean %BF (with the other parameters remaining constant) decreased by 1.24% with each additional underage family member and by 0.001% with each step that was taken. Moreover, the mean %BF was higher by 2.1% in the boys with DS than in the girls with DS. The intake of an additional gram of total carbohydrates increased the %BF by 0.04%. The control group showed a positive relationship between %BF and the intake of sucrose, as well as a negative relationship between %BF and physical activity. Specifically, the mean %BF increased by 0.05% with each additional consumed gram of sucrose and decreased by 0.001% with each step that was taken. The constructed models explained the %BF in 33% of cases (R^2 = 0.3267) among the children with DS and in 35% (R^2 = 0.3516) among the control group.

Discussion

An excessive body mass is not only the result of a positive energy balance, but is also a complex biochemical, physiological, sociological and psychological problem. However, the most important behavioural factors leading to the development of overweight and obesity are an incorrect diet and a low level of physical activity [23]. A correct diet and sufficient physical activity also play a major role

Table 6. Correlations between intake of energy, nutrients and physical activity and nutritional status in children with DS and the control group

Nutrient	Group	Nutritional status indicator			
		BMI		%BF	
		r	*p*	*r*	*p*
Energy	With DS	0.14	0.1712	**0.25**	**0.0136**
	Control	**0.28**	**0.0035**	**0.26**	**0.0062**
Total fats	With DS	0.04	0.6671	0.13	0.1930
	Control	0.09	0.3673	0.17	0.0831
Total carbohydrates	With DS	0.19	0.0582	**0.28**	**0.0049**
	Control	**0.43**	**< 0.0001**	**0.31**	**0.0010**
Sucrose	With DS	**0.46**	**< 0.0001**	**0.25**	**0.0113**
	Control	**0.53**	**< 0.0001**	**0.35**	**< 0.0001**
Dietary fibre	With DS	0.07	0.5054	0.05	0.6037
	Control	0.14	0.1483	0.15	0.1283
Number of steps	With DS	**–0.58**	**< 0.0001**	**–0.42**	**< 0.0001**
	Control	**–0.69**	**< 0.0001**	**–0.56**	**< 0.0001**

r – Pearson's linear correlation coefficient, p – p-value.

Table 7. Results of multivariate regression analysis for assessment of the effect of selected factors on BMI in children with DS and the control group

Variable	*B*	*B* standard error	95% confidence interval	*t*	*p*	β	β standard error
Children with DS:							
Constant term	21.1966	1.4216	18.3751 – 24.0180	14.9106	< 0.0001		
Number of steps	–0.0007	0.0001	–0.0010 –0.0005	–5.4893	< 0.0001	–0.4579	0.0834
Age	0.2287	0.1115	0.0074 –0.4501	2.0510	0.0430	0.1761	0.0859
Sucrose	0.0582	0.0237	0.0112 – 0.1053	2.4570	0.0158	0.2084	0.0848
Control group:							
Constant term	20.1545	0.7679	18.6318 – 21.6773	26.2467	< 0.0001		
Sucrose	0.0494	0.0095	0.0306 – 0.0682	5.2097	< 0.0001	0.3475	0.0667
Number of steps	–0.0006	0.0001	–0.0008 – –0.0005	–8.6837	< 0.0001	–0.5793	0.0667

B – regression model coefficient, t – Student's t test, p – p-value, β – B standardised regression coefficient.

in the lives of individuals with DS, and may benefit their health and development [7, 11, 24]. The results obtained in this study showed that children with DS had a significantly higher BMI and %BF compared to their peers from the control group. These results are consistent with those obtained by Basil *et al.*, who observed that almost half (47.8%) of a sample of children aged 2–18 years had obesity, compared to 12.1% in a control group [12]. Other authors have also confirmed that children and youth with DS display an overweight and obese condition [7, 10, 25] and an increased %BF more often than their peers without DS [26].

The diets of the children, both with and without DS, contained a correct mean share of protein, fats and carbohydrates in relation to the daily energy demand. However, one in five children exceeded the daily recommended share of fats in their diet (> 35% of the energy demand) among both groups. The populational risk of an insufficient intake of protein was almost 16% in the children with DS, which was twice as high as in the control group. Less than 10% of the children with DS and less than 6% of the children without DS exceeded the recommended percentage of carbohydrates in their diet; but on the other hand, many of the children consumed an excessive share of su-

Table 8. Results of multivariate regression analysis for assessment of the effect of selected factors on %BF in children with DS and the control group

Variable	*B*	*B* standard error	95% confidence interval	*t*	*p*	β	β standard error
Children with DS:							
Constant term	27.2762	2.8594	21.6004 – 32.9520	9.5392	< 0.0001		
Number of underage family members	–1.2415	0.4669	–2.1683 – –0.3147	–2.6591	0.0092	–0.2258	0.0849
Number of steps	–0.0010	0.0002	–0.0014 – –0.0005	–4.6495	< 0.0001	–0.3924	0.0844
Total carbohydrates	0.0345	0.0142	0.0062 –0.0627	2.4238	0.0172	0.2051	0.0846
Gender	–2.0741	0.9742	–4.0079 – –0.1403	–2.1290	0.0358	–0.1812	0.0851
Control group:							
Constant term	24.3673	1.8366	20.7254 – 28.0093	13.2680	< 0.0001		
Sucrose	0.0523	0.0227	0.0074 – 0.0973	2.3091	0.0229	0.1921	0.0832
Number of steps	–0.0010	0.0002	–0.0014 – –0.0007	–6.0571	<0 .0001	–0.5038	0.0832

B – regression model coefficient, t – Student's t test, p – p-value, β *– B standardised regression coefficient.*

crose. However, the children with DS adhered to the recommended intake of simple sugars, i.e. below 10% of the energy demand, significantly more often than their peers without DS [27]. The analysis of the results also indicated that the children with DS had a significantly higher risk of an insufficient intake of dietary fibre. Other authors who have conducted studies on individuals with DS also observed an incorrect intake of macronutrients. For example, children from Saudi Arabia with DS aged 6–18 years were found to consume much more carbohydrates and fats than a control group (children without DS) [11]. In turn, Roccatello *et al.* conducted a study among the Italian population, where they found that children with DS consumed too much protein and too little dietary fibre [28]. An insufficient intake of dietary fibre was also observed in the current study. Such an incorrect intake of nutrients in children with DS may be related to a frequent use of elimination diets [29] and to the consumption of highly processed foods with a low content of dietary fibre.

Most of the participants, in both groups, showed insufficient levels of physical activity. Even so, the children with DS had a significantly lower level of physical activity than the control. Other authors have also reported that the level of physical activity in children with DS was lower than in children without DS, with the daily duration of physical activity not exceeding 60 min in a vast majority of the former group [30]. Izquierdo-Gomez *et al.* conducted a study among youth aged 11–20 years, where they found that only 43% of teenagers with DS adhered to the recommended 60-min daily duration of physical activity [31]. However, the latest research has underlined a need to develop special criteria for the assessment of physical activity in individuals with DS, rather than measuring their physical activity using the same methods and intensity cut-off points that have been developed for their peers without DS [32]. The somatic traits characteristic for DS, including particular body proportions, muscle hypotony, joint hypermobility and bad posture, along with intellectual disability, can impede the motor functioning. Furthermore, the abnormal structure and function of the cardiovascular system reduces the ability of these individuals to perform sustained physical effort [33, 34]. To date, no specific criteria have been developed for children and youth with DS. On the other hand, the results of a different study showed that the cut-off points for sitting time that were designed for children with normal development can also be used for children with DS, because the children with disabilities did not show significantly different behaviours than the children without chronic diseases [35].

Nordstrøm *et al.* reported that overweight and obesity in children with DS appears as soon as the age of 4–5 years and added that this necessitates earlier prophylaxis, in order to prevent the development of chronic diseases at an older age [36]. In particular, obesity increases the risk of type 2 diabetes, insulin resistance, dyslipidaemia and hypertension. It may also make it difficult to provide care to the individuals with DS and can lead to a lower quality of life. Consequently, prophylactic measures to address obesity among children with DS are crucial. They should include introducing a healthy diet and increasing the amount of physical activity [37]. The results obtained in the current study indicated a relationship between an increased intake of energy, total carbohydrates and sucrose, and the nutritional state in children both with and without DS. Another study conducted among preschool children with DS showed that their nutritional state was affected by bad dietary habits, specifically, eating too much food. The children with DS who had overweight or obesity ate more meals at preschool – specifically, they ate two dinners (one at preschool and one at home) – considerably more often than their peers (80% vs. 55.6% of the sample). The same study also showed that as many as 25% of children with overweight or obesity children snacked every day [29]. An analysis of the studies conducted among children without DS shows that the children with overweight or obesity consumed an excessive amount of energy and showed an incorrect composition of their meals; in particular, there was an excessive share of simple sugars and saturated fats. A low content of fruits, vegetables and wholegrain products in the diet also caused an insufficient intake of dietary fibre [38–41].

The nutritional state of the children in the current study was also affected by their physical activity. Higher values of the nutritional state indicators were observed in the participants, both with and without DS, who were less physically active than their peers. These results are consistent with those obtained by Bertapelli *et al.*, who found that physical activity may significantly reduce the risk of obesity in children with DS [7]. Similar results were obtained by other authors, who also observed a positive relationship between a lack of physical activity and an excessive body mass [24, 33].

The results described above lead to the conclusion that the nutritional state of children with DS is affected not only by a genetic defect and its comorbidities, but also by environmental factors, such as physical activity and dietary habits. To date, the interventions aimed at preventing obesity among children and youth with DS have usually involved developing and implementing appropriate exercise programmes. However, the research indicates that such interventions are insufficient to reduce the body mass and %BF [7]. Furthermore, it should be taken into account that the dysfunctions characteristic of DS may make increasing the physical activity not as effective for reducing excessive fat tissue in children with DS, when compared to their peers without DS [33]. In this study, the nutritional state of the children with DS may also have been affected by sociodemographic factors, such as their gender, age and the number of underage family members. Boys had a lower mean %BF than the girls. These results are consistent with those obtained by Bertapelli *et al.* [7] and Osaili *et al.* [13], who observed a higher BMI and %BF in girls with DS than in boys. A higher mean %BF in girls than in boys results from the biological changes that are characteristic of puberty [42]. Other authors have confirmed that the sexual dimorphism related to the amount and distribution of fat tissue in youth with DS is similar to the sexual dimorphism in young people without DS [43]. The results of this study also showed that the %BF decreased with each additional underage family member. Other authors have also observed an effect of the number of children in a family on the prevalence of obesity, where obesity was demonstrated to be diagnosed more frequently in children with no siblings than in children who have siblings [44, 45]. In some studies, it was found that children with no siblings showed a much lower level of physical activity compared to those who had siblings, which led to an increased risk of obesity [46, 47], because having siblings created more opportunities for active play and sport. It can also be suggested that the families with more underage members paid more attention to healthy eating and developing correct dietary habits than the families with fewer underage members. In turn, Oulmane *et al.* found that none of the analysed factors (gender, age, family's socioeconomic status, parents' education, number of meals per day and physical activity) constituted a risk factor for obesity in a population of children with DS [48].

The limitations of this study are related to the assessment of the children's physical activity using pedometers. Since pedometers cannot measure certain forms of activity, including water sports and cycling, as well as activities that primarily involve the upper body, this may lead to an underestimation of a child's physical activity. Furthermore, the study assessed the physical activity of all the participants using the same cut-off points that were designed for children without DS. However, no special criteria for children and youth with DS have been developed to date, and some studies suggest that the cut-off points for sitting time that were designed for typically developing children can also be used in children with DS [35].

One of the strengths of this study is the inclusion of many different factors for the analysis that may potentially affect a child's nutritional status, i.e. diet, physical activity and sociodemographic factors. Another strength worth underlining is that the study used an objective method of assessment and a control group composed of the participants' peers from the same environment, i.e. children attending the same schools and preschools as the participants with DS.

Conclusions

Children with DS showed an excessive BMI and %BF much more frequently than children from the control group. The share of fat in their daily energy consumption was too high in one in five of the children from both groups. The children with DS also showed an increased risk of an insufficient intake of dietary fibre and a slightly increased risk of protein deficiency. Consequently, there is a need to develop special nutritional patterns for children and youth with DS, and to educate their parents and guardians on proper nutrition.

The primary factors causing the increased risk of developing overweight and obesity, along with an increased risk of developing metabolic disorders in the future, among the children both with and without DS, were a low level of physical activity and a high intake of sucrose. The increased BMI and %BF in the children with DS may have also been caused by sociodemographic factors, including the child's age, a female gender and fewer underage members of the family. Consequently, it is necessary to continue research on the risk factors of overweight and obesity in children with DS.

The physical activity of children with DS seems be considerably too low to effectively prevent the development of chronic diseases, due to a sedentary lifestyle. Consequently, it is necessary to develop multidirectional strategies for the prevention of overweight and obesity in children and youth with DS; in particular, it is necessary to create special intervention programmes aimed at increasing their participation in various forms of physical activity, adjusted to their capabilities.

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Conflict of interest

The authors declare no conflict of interest.

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