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ORIGINAL ARTICLE

EFFECT OF DIETARY COMPONENTS AND NUTRITIONAL STATUS ON THE DEVELOPMENT OF PRE-SCHOOL CHILDREN

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ABSTRACT

Background. The preschool period is a time of intensive changes: physical, motoric, cognitive, emotional and social development of the child. The diet should provide optimal energy andnutrient levels. Due to their properties, some of the dietary components may be particularly important in child development processess. These include *omega*-3 fatty acids, B vitamins, vitamin D, antioxidants, iron, calcium, magnesium, zinc and copper.

Objective. The aim of the study was to determine the effect of selected dietary components, the nutritional status and sleep duration in children at pre-school ages (3-6-years old) on their emotional sphere, as well as the cognitive, physical and social development.

Material and methods. Anonymous research was carried out among 75 randomly selected children aged 3-6 years old in the Municipal Kindergarten in Ruciane-Nida. Research methods consited of a questionnaire, a 3-day food record, growth charts, and standardized development observation sheets. Software used for evaluation and analysis of obtained results was Diet 5.0. and Statistica 13.

Results. It was observed that the increase of the BMI percentile correlated with a lesser social development of children. Children who slept a recommended number of hours presented higher level of cognitive developmnent. High level of cognitive development was more common in children supplementing vitamin D. Higher intake of folates, vitamin D, vitamin E, magnesium, zinc and copper correlated positively with a higher level of cognitive development.

Conclusions. Application of the proper nutrition and healthy lifestyle principles supports a proper child development. All dietary components should be balanced, however some nutrients are of especial significance during the childhood development and therefore their optimal intake is essential for this developmental period.

Key words: *preschool children; child development; vitamins; minerals; nutritional status;*

STRESZCZENIE

Wprowadzenie. Okres przedszkolny to czas intensywnego rozwoju: fizycznego, motorycznego, poznawczego, emocjonalnego i społecznego dziecka. Dieta powinna mieć optymalną wartość energetyczną i odżywczą. Właściwości niektórych składników diety wskazują, że mogą być one szczególnie istotne w procesach rozwojowych dziecka. Należą do nich: kwasy tłuszczowe *omega*-3, witaminy z grupy B, witamina D, antyoksydanty, żelazo, wapń, magnez, cynk i miedź.

Cel badań. Celem badań było ustalenie wpływu wybranych składników diety, stanu odżywienia oraz długości snu dzieci w wieku przedszkolnym (3-6-letnich) na ich poziom rozwoju poznawczego, fizycznego, a także sferę emocjonalną i rozwój społeczny.

Materiał i metody. Anonimowe badania przeprowadzono wśród wybranych losowo 75 dzieci w wieku 3-6 lat w Przedszkolu Miejskim w Rucianem-Nidzie. Narzędziami badawczymi, zastosowanymi w pracy były: autorski kwestionariusz ankiety, 3-dniowy dzienniczek żywieniowy, siatki centylowe oraz standaryzowane arkusze obserwacji rozwoju dzieci. Do oceny i analizy uzyskanych wyników użyto programów komputerowych: Dieta 5.0. i Statistica 13.

Wyniki. Stwierdzono, że wzrost centyla wskaźnika BMI korelował z gorszym rozwojem społecznym dzieci. Zalecany czas snu dla dzieci w tym wieku był skorelowany z wyższym poziomem ich rozwoju poznawczego. Wysoki poziom rozwoju kognitywnego występował częściej u dzieci suplementujących witaminę D. Zaobserwowano dodatnie korelacje pomiędzy większym spożyciem folianów, witaminy D, witaminy E, magnezu, cynku i miedzi a wyższym poziomem rozwoju poznawczego.

Wnioski. Stosowanie zasad prawidłowego żywienia i zdrowego stylu życia wspomaga odpowiedni rozwój dziecka. Dieta powinna być odpowiednio zbilansowana pod względem wszystkich składników diety, ale niektóre z nich wykazują szczególny wpływ na prawidłowy przebieg procesów rozwojowych w dzieciństwie i ich optymalna podaż jest bardzo istotna w tym okresie rozwojowym.

Słowa kluczowe: *dzieci w wieku przedszkolnym; rozwój dziecka; witaminy; składniki mineralne; stan odżywienia;*

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INTRODUCTION

The pre-school period is characterized by intensive growth and development of a humanbody. Child development is healthy if it occurs correctly and is age-adequate in all spheres: physical, motor, emotional, cognitive and social. Any disfunctions in one of the spheres may adversely affect the others [34].

Diet and lifestyle affect the development processes. These factors also shape current behavior and future habits of a person and affect their health status not only in childhood, but also in adulthood. A child's diet should be based on healthy nutrition principles and adapted to their age-adequate energy and nutrient requirements. Home (25% of total daily requirement) and kindergarten (75% of total daily requirement) nutrition should complement each other and together, form a balanced daily food ration. The development process is also supported by non-nutritional factors, such as adequate physical activity, optimal sleep duration and avoidance of stress [6, 12, 37].

Due to their properties, some of the dietary components may be particularly important in child development procesess. *Omega*-3 fatty acids help ensure the proper functioning of neurons and neuronal membranes. Lipid mediators, which are *omega*-3 fatty acids derivatives, have anti-inflammatory and neuroprotective effects [1, 33]. B vitamins are involved in the metabolism of homocysteine, high concentrations of which may contribute to cognitive decline [1, 33]. Copper and antioxidant deficiencies may negatively affect brain function, while folic acid, vitamin B_{12} and iron deficiencies may affect the learning outcomes of children of all ages [1, 33]. One of the consequences of insuficcient serum iron concentration is a reduced activity of brain enzymes, of which iron is one of the components [1]. Zinc deficiency may cause impairment of both cognitive and motor processes in children and increase the risk of hyperactivity or depression [1]. Vitamin D is associated with various neurobiological pathways and protects against neurodegeneration [33]. The active form of vitamin D is also responsible for proper bone mineralization, while calcium is the most important ingredient in the process of building bones and teeth. Magnesium has an effect on nerves and muscles functioning, and its deficiency leads to a decrease in bone mineral density [7].

The aim of the study was to determine the effect of selected dietary components, the nutritional status and sleep duration in children at pre-school ages (3-6-years old) on their emotional sphere, as well as the cognitive, physical and social development. The selection of dietary components for analysis was based on their role in development processes, according to scientific literature and the research conducted so far.

MATERIAL AND METHODS

The research was carried out in the Municipal Kindergarten in Ruciane-Nida during October-December 2018. Out of 140 children, 75 (34 girls and 41 boys), aged 3-6 years old, were randomly selected. The study group consitsed of 29 three year olds, 12 four year olds, 20 five year olds and 14 six year olds.

Parents of the subjects were informed about the purpose and methodology of the study and gave written consent to carry it out. The research consisted of a questionnaire, a 3-day food record, anthropometric measurements, and child development assessement tools. The research was approved by the Bioethics Committee of the Medical University of Bialystok, approval No. R-I-002/240/2018.

A quantitative diet evaluation was carried out using a 24-hour food recall, which was collected from the entire study group (75 children) from 3 days – 2 week days and 1 weekend day. Parents recalled their children's meals eaten at home, which should typically constitute 25% of a child's total daily requirement, while the remaining 75% is covered by pre-school nutrition [6]. Information on this part of the food ration was obtained based on the menu implemented in the kindergarten, which was provided by the facility. The analysis of children's food ration was performed using the Diet 5.0 software, developed by the Food and Nutrition Institute in Warsaw. It takes into account losses of nutrients, vitamins and minerals arising from food processing and storage. The values of energy and selected dietary components were averaged and the level of norm implementation was assessed through comparison of nutrients supply with the values recommended in the "Nutrition standards for the Polish population" redacted by *Jarosz* [21]. Subjects were divided into two age groups (3-year-old children and 4-6-year-old children) according to the nutritional norms available. The group's energy requirement (EER) was established. It was assumed that protein should constitute 13% of total energy requirement fats - 35%, and digestible carbohydrates - 52%, and at the same time not less than 130g/day. The desired ratio of animal to plant protein is about 2:1. The calculated values of vitamins and minerals were compared with the Recommended Dietary Allowance (RDA) for calcium, magnesium, iron, zinc, copper, B vitamins, vitamin C, eicosapentaenoic and docosahexaenoic acids, and Adequate Intake (AI) for dietary fiber, vitamin E, vitamin D and iodine.

The proprietary questionnaire consisted ofquestions about vitamin and mineral supplementation among the subjects and their sleep duration.

Anthropometric measurements of subjects were taken, i.e. height and weight, using a scale with a stadiometer, and the Body Mass Index (BMI) was calculated. The values obtained were comparedwith the reference values using the growth charts for children aged 3-18 years old, created based on the data from the "Olaf and Ola" projects, which were coordinated by the Children's Memorial Health Institute [9, 23, 24, 31].

The following percentile ranges for height and weight were used:

- <c3 – well below norm - developmental disorders
- c3-c10 – below norm - control and observation required
- c25-c75 – narrow norm (correct development - the most optimal range)
- c10-c90 – broad norm (proper development)
- c90-97 – above norm - control and observation required
- >c97 – well above norm - developmental disorders

The nutritional status of children was assessed based on curves on growth charts, marked as underweight, overweight and obesity cut-offs. They meet the standards adopted for adults, i.e. <18.5 kg/m^2 (underweight), 25.0-29.9 kg/m^2 (overweight), > 30 kg/m^2 (obesity). The area between the underweight and overweight cut-offs indicated the correct body weight. No specific reference points proposed by the World Health Organization (WHO) were adopted because, according to the authors of the growth charts, they are inadequate for the population of Polish preschool children and lead to over diagnosis of obesity [9, 23, 24, 31].

The development of the subjects was assessed using observation sheets for 3-, 4- and 5-year-olds and a of school readiness assessment for 6-year-olds. These assessment tools were developed by *Biela* and School and Pedagogical Publishers (WSiP), based on the core curriculum and further developed by kindergarten teachers [2, 3, 4, 5]. They assessed the adequacy of the skills of observed children to their age during a two-month observation (September and October). The assessment of physical development consisted of the analysis of skills in self-service activities, large and small motor skills. Child's emotional maturity was also checked by assessing their ability to experience and understand emotions, their independence and emotional resilience. Social development was verified based on the child's attitude towards peers and adults, as well as their compliance with the norms and principles in the kindergarten. Cognitive development level was assessed based on the skills and abilities in general knowledge, speech, memory, perceptiveness, visual-auditory coordination, readiness to speak a foreign language as well as mathematical skills and preparation for learning to read and write - depending on the child's age. The results were referred to the point scale prepared by the author of the sheets used, and converted into percentages.The level of child development (low, medium, high) was determined in the four studied areas [2, 3, 4, 5].

The results were statistically analyzed, using the Statistica 13 software, by StatSoft. The results are presented as means, standard deviations, minimum and maximum values and percentages. A *Chi*-square statistical test was used amongst nominal variables to check the relationship between the sleep duration, supplementation used and development level of children (low, medium, high). Spearman's rank correlation coefficient was also used to examine the correlation between the intake of selected dietary components (based on 24-hour fodd recall), nutritional status and the level of child development (presented as percentage). The results whose significance level was $p < 0.05$ were considered statistically significant.

RESULTS

Table 1 presents the average age and basic anthropometric parameters of the study group by gender.

Height, weight and BMI values of all subjects (n = 75) were compared with reference values for boys and girls using growth charts. The height of 70.8% of the male subjects (n = 29) was normal in relation to age - 39% of them (n = 16) were within the narrow norm, and 31.8% (n = 13) – within the broad norm. On the other hand, 29.2% of boys (n = 12) exceeded the upper or lower limit of the norm, and growth disorders were noticed in 14.6% of male children (n = 6). The height of 61.7% of female subjects (n = 21) was normal - 38.2% (n = 13) in the narrow norm and 23.5% (n

Table 1. Characteristics of the studied group of 3-6-year-old children

	Gender	n=75	Mean ± SD	Range (min-max)
Age	Girls	34	4.3±1.2	3-6
Height [cm]			106.2±10.2	82-124
Body weight [kg]			17.9±3.7	11-28
BMI [kg/m^2]			15.80±1.76	12.85-21.17
Age	Boys	41	4.2±1.2	3-6
Height [cm]			109.1±10.7	93-131
Body weight [kg]			19.8±5.4	11-36
BMI [kg/m^2]			16.35±2.20	11.45-24.59

= 8) - in the broad norm. The remaining percentage of the female subjects - 38.3% (n = 13) was outside the norm. In 14.8% of them (n = 5) the values of this anthropometric parameter exceeded the cut-offs, which meant that the deviations from the norm were so siginificantas to indicate the occurrence of growth disorders.

The weight of 73.2% of boys (n = 30) was age-adequate - 39% of boys (n = 16) were in the narrown norm range, and 34,2% (n=14) - in the broad norm. Deviations from the norms occurred in 26.8% of boys (n = 11), and 12.2% of them (n = 5) presented with abnormal body weight. The weight of 76.4% of girls (n = 26) was within the age-adequate norm - 52.9% (n = 18) in the narrow norm and 23.5% (n = 8) - in the broad norm. Body weight of 23.6% of female children (n = 8) exceeded the lower or upper limit of norm, with 11.8% of them (n = 4) presenting abnormal body weight. Figure 1 presents the weight-for-age and height-for-age growth charts (percentile) for girls and boys aged 3-18 years (Olaf and Ola), which were marked with the subjects' values of these parameters.

Normal BMI was found in 68.3% of boys (n = 28) and 73.5% of girls (n = 25). Overweight was found in 19.5% of boys (n = 8) and in 11.8% of girls (n = 4), obesity - in 7.3% of boys (n = 3) and 2.9% of girls (n = 1), and underweight in 4.9% of boys (n = 2) and 11.8% of girls (n = 4). Figure 2 presents body mass index-for-age growth charts (percentile) for girls and boys aged 3-18 years old (Olaf and Ola), which were marked with the subjects' BMI values.

The accurateness of the subjects'development (n = 75) was also assessed based on the skills they should have possessat the age of 3, 4, 5 and 6 years old in terms of physical, emotional, social and cognitive development. Figure 3 shows the percentage of children from each age group with low, medium and high degree of development.

An assessment of the energy and nutritional value of the daily food ration was performed. Table

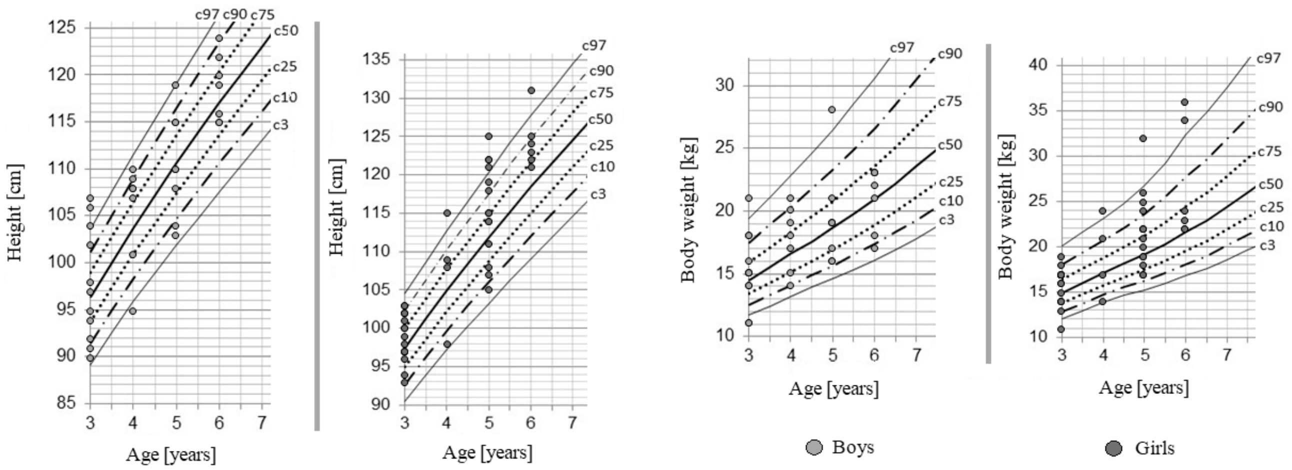

Figure 1. Percentiles of height and body weight of studied children

2 presents the daily food ration of the subjects divided into two age groups- including both home and kindergarten nutrition. Energy requirement was met in accordance with the recommendations in both 3-year-old and 4-6-year-old children. The norm for protein was exceeded in all subjects, but more so in younger children. The animal to plant protein ratio was correct. The analysis shows that the study group had a dietary fat deficiency. The intake of available carbohydrates however, was appropriate. Dietary fiber intake in younger children was slightly above the norm, and in older children - it was adequate. Significant deficiencies of EPA and DHA as well as vitamin D were noticed in diets of all children.Vitamin E, calcium and iron deficienies also occurred in the whole study group. Iodine and folate intake were in line with requirements. In contrast, the remaining B

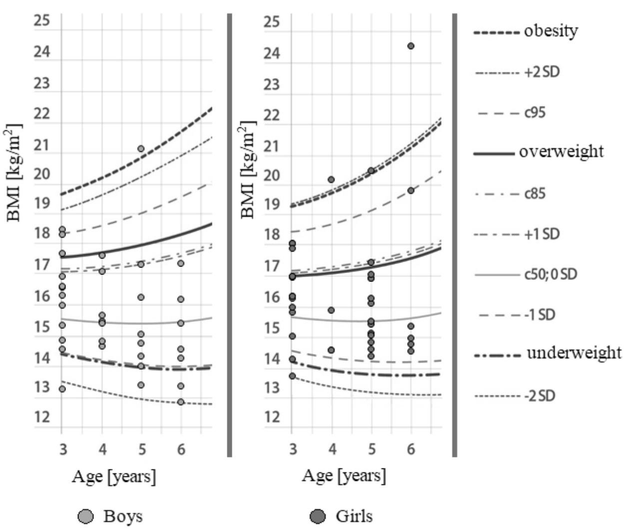

Figure 2. Nutritional status of studied children

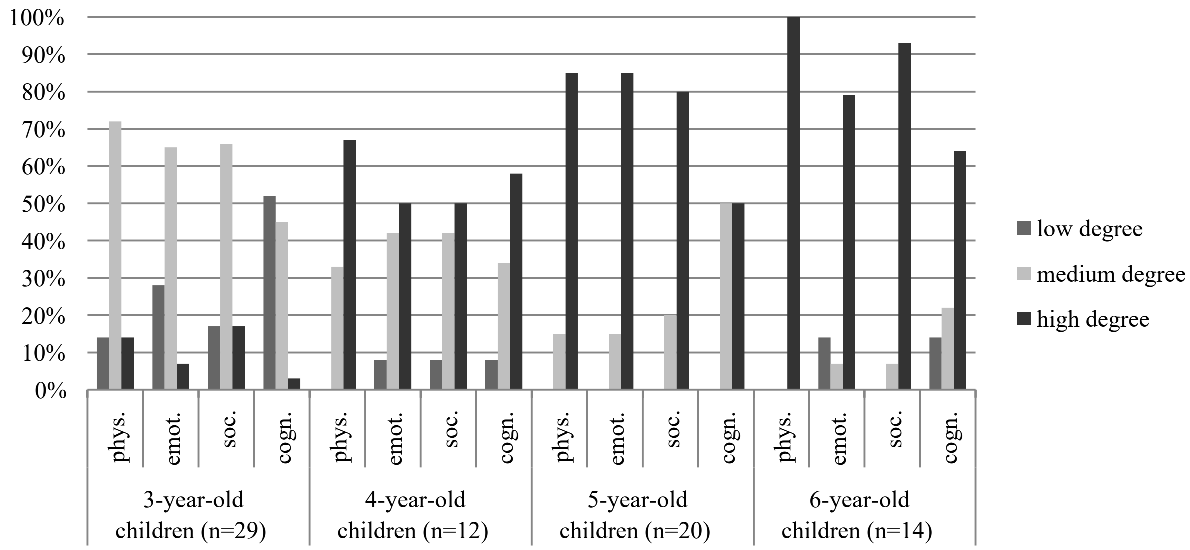

Figure 3. Degree of children development

Table 2. Daily food ration for 3-year-old and 4-6-year-old children

	3-year-old children (n=29)		4 - 6-year-old children (n=46)	
	Mean ± SD	% of standard*	Mean ± SD	% of standard*
Energy value of the diet [kcal]	1170.33±183.99	102	1239.70±227.84	93
Protein[g]	49.56±8.80	132	52.67±10.82	121
Animal protein [g]	33.86±7.53	156	34.92±8.78	115
Plant protein [g]	15.71±3.05	158	17.75±4.47	116
Fats [g]	35.05±7.00	80	37.70±9.83	73
EPA + DHA [mg]	112.24±180.49	43	107.31±168.30	41
Available carbohydrates [g]	162.56±29.37	108	171.01±34.48	98
Dietary fiber [g]	13.05±2.29	112	13.55±2.91	100
Vitamin E [mg]	3.87±0.98	76	4.79±2.60	77
Thiamine [mg]	0.69±0.16	130	0.74±0.16	126
Riboflavin [mg]	1.39±0.25	257	1.42±0.26	242
Niacin [mg]	8.87±2.26	132	9.90±4.25	126
Pyridoxine [mg]	1.30±0.24	238	1.34±0.33	227
Cobalamin [µg]	3.57±0.82	346	3.66±0.98	314
Vitamin C [mg]	70.99±28.15	158	71.98±40.19	143
Folate [µg]	170.74±34.27	102	184.56±42.83	94
Vitamin D [µg]	1.58±1.34	10,5	1.15±0.69	8
Calcium [mg]	675.42±145.96	82	693.09±137.26	72
Magnesium [mg]	208.70±42.48	213	224.43±46.69	183
Iron [mg]	6.94±1.31	84	7.09±1.48	74
Zinc [mg]	6.14±1.19	163	6.38±1.13	138
Copper [mg]	0.88±0.20	260	0.92±0.21	235
Iodine [µg]	87.57±18.06	98	93.09±25.83	103

SD - standard deviation EPA - eicosapentaenoic acid DHA - docosahexaenoic acid
*Nutrition standards for the Polish Population, amendment 2017. Food and Nutrition Institute., Warsaw, Poland

vitamins, vitamin C, magnesium, zinc and copper were supplied in excess compared to the norms.

The next stage of the study was to determine the effect of dietary components taken into account in the quantitative assessment of children's food ration (Table 2) on the level of their cognitive, emotional and physical development. *Spearman's* rank correlation coefficient has been applied. Statistically significant correlations ($p < 0.05$) were observed only in children in the older age group, namely in 4-6 year olds ($n = 46$) and only in the case of cognitive development.

A positive correlation (r=0.42, p=0.004) was observed between the level of cognitive development and the vitamin D intake. A positive correlation (r=0.34, p=0.020) was also found between the level of cognitive development and folate intake. In addition, a positive correlation (r=0.36, p=0,014) was observed between the cognitive development level and vitamin E intake. A positive correlation (r=0.35, p=0.017) was observed between the cognitive development level and magnesium intake. A positive correlation (r=0.40, p=0.005) was found between the cognitive development level and zinc intake. A positive correlation (r = 0.31, p=0.034) was also observed between the cognitive development level and copper intake. An increased intake of the above-mentioned dietary components positively correlated with an increase in cognitive development in children aged 4-6. Correlations depict the intake of vitamins and mineral components in the diet, supplementation is not taken into account. Figure 4 presents scatter graphs of the above-mentioned correlations.

The influence of the body mass index (the BMI values were allocated to their corresponding percentiles) on the social development of the subjected children has been assessed. *Spearman's* rank correlation coefficient has been applied. A statistically insignificant (r=-0.17, p=0,148) negative correlation between the level of the social development (n=75) and the BMI was found. The increase of the BMI percentile was correlated to a lesser social development. Figure 5 presents the correlations graph.

Dietary supplements used by subjects were also assessed (n=75). Vitamin D supplements were used by 41.3% of respondents (n=31), *omega*-3 or fish oil - by 36% of respondents (n = 27), vitamin C – by 34.7% of

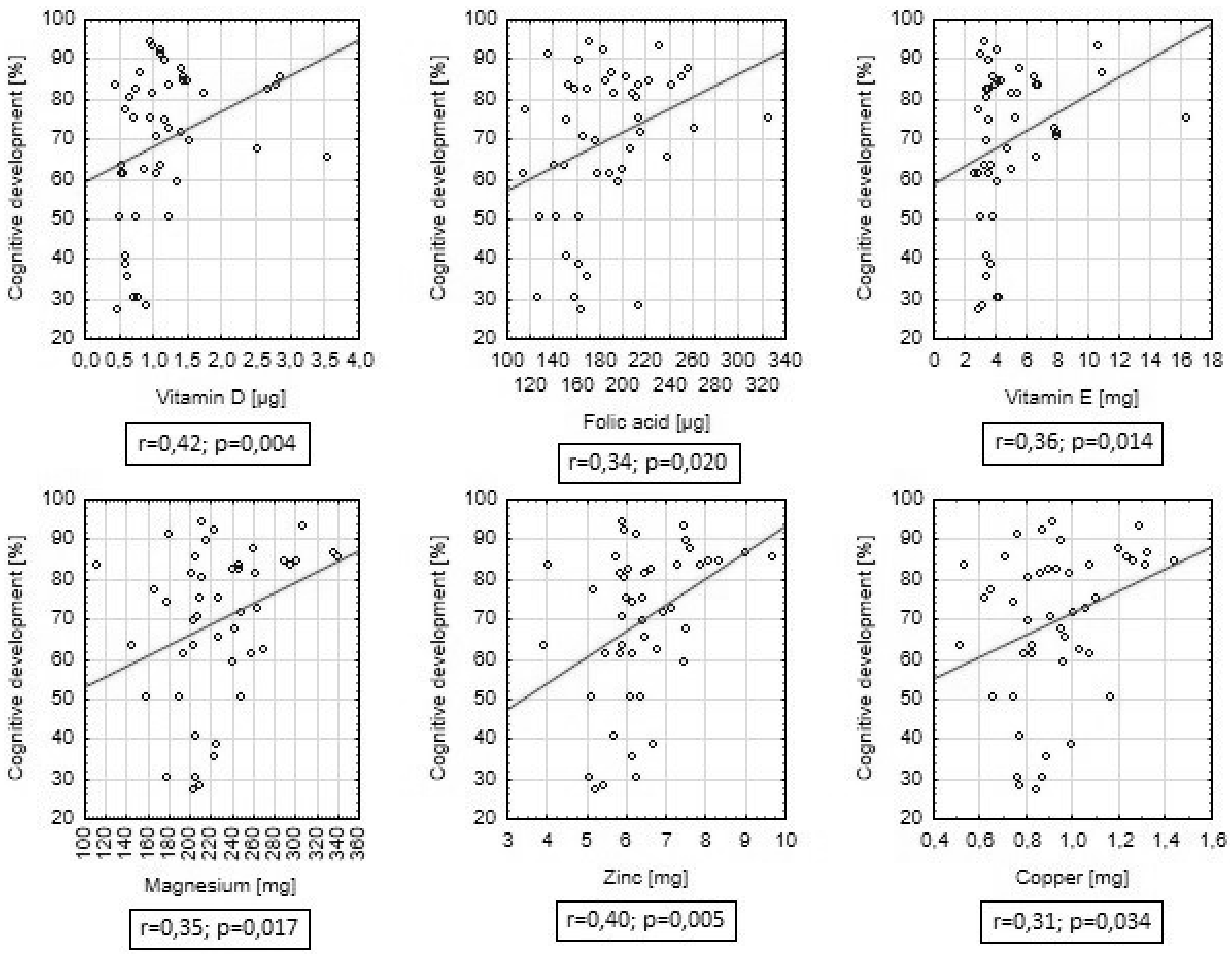

Figure 4. Correlations between the level of the cognitive development of children aged 4-6 and the intake of vitamins and minerals in the diet

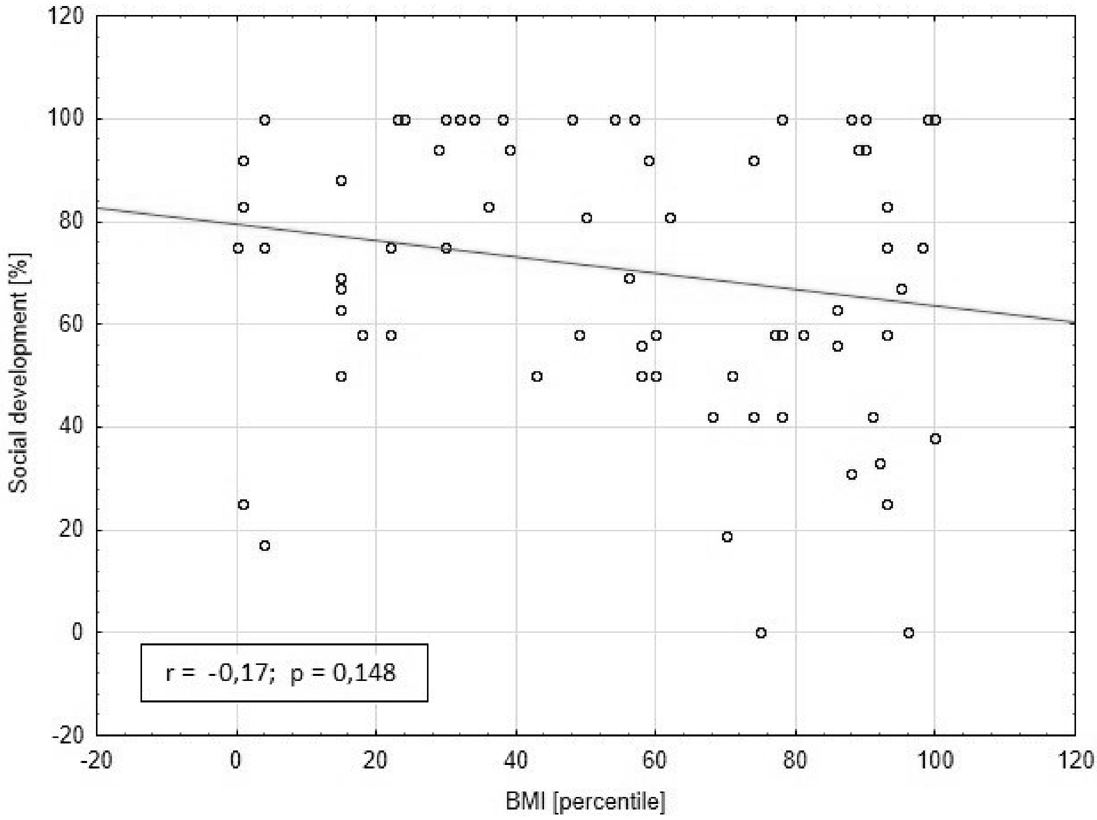

Figure 5. Correlation between children's social development and BMI percentile

respondents (n = 26). Whereas 16% of children (n=12) received vitamin and mineral supplements. Calcium, magnesium and B vitamins were supplemented by 5.3% of children (n=4) and iron preparations – by 4% (n=3) while 24% of respondents (n=18) did not use any supplements at all.

Among children who did not supplement vitamin D (n=44), the highest percentage was characterized by medium (47.7%, n=21) and low (27.3%, n = 12) cognitive development levels. In contrast, among children supplementing vitamin D (n=31), cognitive development level was high in 51.6% of them (n=16). These differences were close to statistical significance (p=0.05).

Parents also provided information regarding the sleep duration of their children (n=75). Sleep in 68% of them (n=51) lasted 9-10 hours. In contrast, 22.6% of children (n=17) slept 11-12 hours. The daily sleep duration of 6.7% of respondents (n=5) was 8 hours, and of 2.7% of children (n=2) - 6-7 hours.

Among children who slept 9-10 hours a day (n=51), the majority had a high (41.2%, n = 21) and medium (45.1%, n=23) level of cognitive development. However, among children whose sleep duration was too short (6-8 hours) or too long (11-12 hours) (total n=24), the 45.8% (n=11) had a low cognitive development level. These differences were statistical significance ($p<0.05$).

DISCUSSION

During the first 4 years of life, a child's brain already reaches a mass only 200 grams smaller than that of the shaped adult brain. Because of this, during childhood special attention should be paid to intakes of all nutrients, minerals and vitamins essential for the proper structural and functional development of the brain [1].

The nutritional status of most of the subjects was normal. Underweight was observed in 5% of boys and 12% girls, overweight - in 20% of boys and 12% of girls, and obesity - in 7% and 3%, respectively. Therefore, the abnormal nutritional status occurred in a much smaller percentage of children. However, given the fact that these data relate persons in a developmental period, which in turn affects all subsequent stages of life, these findings are disconcerting. A statistically significant negative correlation was found between the social development level and the body mass index, while increased body mass index correlated positively with the development of children. In their research, Pratt et al. explored the relationship between the quality of life of children and adolescents aged 8-18 years old and a normal BMI or excessive body weight. One of the components assessed with a questionnaire was social development, which was lower in those with abnormal body mass index [29].

The present study assessed the intake of dietary components that play a significant role in child development. Siginificant deficiencies of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) have been reported in children's diets. However, 36% of children surveyed supplemented *omega*-3 or fish oil. In our own research, no effects of EPA and DHA acid intake on cognitive development were found. The results of other authors' research are contradictory. *Oyen* et al. [28] observed a relationship between the consumption of oilyfish, which are a good source of *omega*-3, and the level of cognitive development of preschool children. However, *Gispert* et al. [16] did not find such relationship in school-age children, but noticed a positive effect of fish consumption on their emotional and social development.

The quantitative analysis of daily food rations of the subjects showed that their folate intake was sufficient. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and the intake of dietary folate. No other authors' studies, in which the subjects were children, were found. Therefore, further research in this area is necessary.

In own research, a substantial deficiency of vitamin D in daily food rations of the subjected children was observed. However, some of their parents declared supplementation. The insufficient intake of the vitamin in children of a similar age group was also observed by Marcinek et al. [27]. According to the latest recommendations from 2018, a supplementation of 600-1000 IU of vitamin D is reccomended for preschool children from September to May. The precise dose of supplemenation depends on weight and dietary intake of vitamin D, In the months from May to September, with sufficient sunlight, supplementation in this age group is not necessary, but is recommended [32]. However, only 41% of the subjects supplemented vitamin D. *Roszko-Kirpsza* et al. [30] assessed vitamin D supplementation among 2-3-year-old children. Supplemenents were usedby less than 35%. Our own research did not investigate the concentration of vitamin D metabolite in children's blood serum. However, taking into account the nutritional deficiencies in the study group and reduced skin synthesis during the time of research, i.e. in the autumn and winter, one can suppose that vitamin D levels would have been too low. In the research conducted by *Łupińska* et al., the level of dietary intake of this vitamin and the concentration of its metabolite in the blood serum of school-age children were analyzed. Subjects had both dietary and serum deficiencies. Only 8.5% of subjects had adequate vitamin D levels (≥ 30 ng / ml) [26, 32].

In this study, a statistically significant relationship was found between vitamin D supplementation in children and their cognitive development level. Among the subjects who did not supplement this vitamin, the highest percentages were characterized by medium and low levels of cognitive development, where as most children supplementing the vitamin had a high level of cognitive development. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and dietary intake of vitamin D. Its increased intake positively correlated with an increase in cognitive development in children aged 4-6 years old. *Zhu* et al. observed the relationship between vitamin D concentration in umbilical cord blood of newborns and their subsequent neurocognitive development [39]. Other researchers have also noticed the relationship between vitamin D concentration in umbilical cord blood of newborns and speech development in early childhood [17].

Dietary intake of antioxidant vitamins was analyzed. No vitamin C deficiencies were observed. The recommended daily intake for this vitamin was exceeded in both younger and older children. However, the insufficient intake of the vitamin C in children of a similar age group was also observed by *Marcinek* et al. [27]. My own research has not confirmed an influence of the vitamin C intake on the cognitive development level. Liu et al. did not observe such a relationship either [25]. In own research, insufficient intake of vitamin E was noted. The requirement was met in 76-77%. The results of *Marcinek* et al. research have also indicate the existence of diet insufficiencies vitamin E in children aged 1-4 [27]. In own research, a statistically significant correlation was observed between the vitamin E intake in the older group of children and their cognitive development level, which increased with increased intake of said vitamin. *Liu* et al. [25] observed the effect of prenatal vitamin E exposure on the intelligence quotient of pre-school children.

Magnesium intake in the subjects' food rations exceeded the recommended daily amounts. A statistically significant positive correlation was found between the cognitive development level of 4-6-year-old children and dietary magnesium intake. Increased intake of said mineral correlated with a higher level of cognitive development. Results of studies by other authors showed that children with attention deficit hyperactivity disorder (ADHD) had significantly lower serum magnesium levels compared to healthy children [10]. *El Baza* et al. [11] assessed the effect of magnesium supplementation in magnesium-defficient children with ADHD. An improvement in cognitive function was observed in the group of children who used supplementation. In contrast, no such improvement was observed in the control group. However, the size of the study group was small.

Randomized, blinded studies have not demonstrated the effectiveness of supplementation in treating such disorders in children with ADHD [14].

In own research, iron deficiencies were noted in both younger and older children. No relationship was found between dietary iron intake of children and their cognitive processes. Fuglestad et al. observed though, that iron deficiency in adopted children correlated with their worse cognitive development [13].

Dietary zinc intake in the studied group exceeded the recommended values. It has been observed that its increase positively correlates with the level of cognitive development of 4-6-year-old children. *Fuglestad* et al. [13] found that zinc deficiency affected the neurodevelopmental functions of adopted children. It was correlated with impairment of their memory. *De Moura* et al. [8] conducted a research on zinc supplementation among preschool and early school-age children without identified deficiencies. Their results showed the impact of supplementation on improvement of long-term memory and logical thinking.

In own research, copper requirement was exceeded more than two-fold, in both 3-year-olds and 4-6-year-olds. A statistically significant positive correlation was found between the level of cognitive development of 4-6-year-old children and dietary copper intake. An increased intake of said mineral positively correlated with an increase in cognitive development. Adequate copper intake has a positive effect on cognitive functions, as copper is essential for normal brain function [1]. However, an excessive intake of this micronutrient can negatively affect cognitive processes and cause cognitive disorders. *Zhou* et al. [38] observed that excessive levels of copper in the blood serum have a negative effect on memory in school-age children.

The systematic review of research of *Guzek* et al. has indicated a correlation between a proper intake of fruit and vegatables by children at a pre-school and school age and a lower risk of behavioural and emotional problems or depression. Fruit and vegatables are a source of numerous vitamins and minerals, including those previously analysed in own research (folic acid, vitamin E, calcium, magnesium or copper) [20].

In the present study, the average sleep duration of the subjects was assessed. Sleep in 68% of them lasted 9-10 hours. In contrast, 22.6% of children slept for 11-12 hours. The daily sleep duration of 9.4% of respondents was 6-8 hours. A statistically significant correlation was shown between children's sleep duration and their cognitive development. Among children who slept 9-10 hours a day, most were characterized by a high and medium degree of cognitive development. However, majority of children whose sleep was shorter (6-8 hours) or longer (11-12 hours) had a low level of cognitive development. Based on the conducted research, *Kocevska* et al. found that not only insufficient, but also excessive sleep duration adversely affects children's cognitive functions. The effect of sleep duration of 2-year-old children on their cognitive development at the age of 6 was studied [22]. According to the results of other authors' studies conducted among children up to the age of two, short sleep duration correlated with worse cognitive development. In addition, they observed that night sleep had a greater impact on child development than day time sleep [35]. *Velten-Schurian* et al. [36] also noted the effect of sleep duration on the cognitive processes in children. Insufficient sleep was associated with inappropriate behavior and problems with concentration. *Gruber* et al. [19] confirmed the occurrence of more frequent concentration disorders among children with insufficient sleep duration. The results of other studies by this author also indicate a relationship between sleep duration and emotional stability [18]. *Giganti* et al. observed the positive effect of naps on conscious memory functions in pre-school children [15].

To date, little research has been done on effects of dietary components, supplementation and various lifestyle components on child development. Own research, and research conducted by other authors so far, indicate the existence of such relationship. Therefore, further research in this topic is necessary.

CONCLUSIONS

1. The diet of the subjected children was not properly balanced. There was an insufficient intake of fats, EPA and DHA acids, vitamin D, vitamin E, calcium and iron. To meet the demand, the supply of the given ingredients should be higher.
2. It was found that an adequate intake of folates, vitamin D, vitamin E, magnesium, zinc and copper in the diet correlated with a higher level of cognitive development of 4-6-year-old children. The research emphasize how important it is to control the intake of the vitamins and minerals by children to ensure their proper development.
3. A positive influence of vitamin D supplementation on the cognitive development of the subject group was observed. Children who received supplements of the vitamin displayed a higher level of the cognitive development in comparison to those who did not. It is essential to promote the realization of the current recommendations for the supplementation of the vitamin D.
4. Excessive body weight correlated with a lower level of social development in pre-school children.
5. The influence of the daily sleep length on the cognitive development of the children subjected

to the study was observed. Both too short and too long sleep lengths were connected with a lower level of development.

6. Application of the proper nutrition and healthy lifestyle principles supports a proper child development. All dietary components should be balanced, however some nutrients are of especial significance during the childhood development and therefore their optimal intake is essential for this developmental period.

Conflict of interests

The authors declare no conflict of interest.

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