© Pediatr Med Rodz 2019, 15 (1), p. 57–66
DOI: 10.15557/PiMR.2019.0010

Received: 31.07.2018
Accepted: 19.10.2018
Published: 31.05.2019

Beata Kaźmierczak-Pilch[1], Jadwiga Kaźmierczak[2], Anna Obuchowicz[1]

Atherosclerosis risk factors in prepubertal children in relation to their birth weight and gestational age

Czynniki ryzyka miażdżycy u dzieci w wieku przedpokwitaniowym w odniesieniu do ich masy urodzeniowej i wieku płodowego

[1] Clinical Department of Paediatrics, Paediatrics Clinic in Bytom, School of Health Sciences in Katowice, Medical University of Silesia in Katowice, Bytom, Poland.
Head of the Department and Clinic: Professor Anna Obuchowicz, MD, PhD
[2] Department of Nursing, Department of Health Promotion and Community Nursing, School of Health Sciences in Katowice, Medical University of Silesia in Katowice, Katowice, Poland.
Head of the Department: Professor Tomasz Irzyniec, MD, PhD
Correspondence: Beata Kaźmierczak-Pilch, MD, PhD, Clinical Department of Paediatrics, Paediatrics Clinic in Bytom, Specialist Hospital No. 2, Batorego 15, 41-902 Bytom, Poland, tel.: +48 32 786 14 98, e-mail: pedbyt@sum.edu.pl

Abstract

According to Barker's hypothesis, intrauterine malnutrition results in abnormal metabolism of a foetus and a tendency to develop atherosclerotic disease in the future life. **Aim of the research:** Assessment of atherosclerosis risk factors in prepubertal children, depending on their birth weight and duration of pregnancy. **Material and methods:** 113 children aged 7–9 were divided into groups: born prematurely, with low body weight (group I – 37 people), born on time, with low body weight (group II – 36 people) and born on time, with normal body weight (group K – 40 people) and groups of children born with body weight <10th or ≥10th percentile for gestational age, regardless of the length of pregnancy. Demographic and social data on health behaviours and health status of the children and their parents were collected. Anthropometric measurements and blood pressure was taken. Body composition was estimated with bioelectrical impedance method. Glucose, cholesterol and triglyceride levels in the blood were determined with the strip test method. **Results:** Compared to the other groups, in group K, significantly higher mean values and significantly higher occurrence of high centile values of body mass index and waist circumference as well as insignificantly higher rate of adipose tissue and abnormal glucose and cholesterol concentrations were found. In children born prematurely or on time, with birth weight <10th percentile, the centiles of waist circumference were significantly less frequent. A positive correlation was found in the body mass index of children born at the time with low body mass and body mass index of their mothers. Among the independent variables which influence the number of atherosclerosis risk factors, the importance of parental obesity was confirmed. **Conclusions:** 1) Premature birth or birth with low birth weight does not increase the risk of obesity or elevated cholesterol and glucose levels in the prepubertal age. 2) The occurrence of atherosclerosis risk factors in prepubertal children (regardless of duration of gestation and birth weight) is associated with obesity/overnutrition of parents.

Keywords: birth weight, duration of pregnancy, risk factors for atherosclerosis, prepubertal age

Streszczenie

Według hipotezy Barkera niedożywienie wewnątrzmaciczne skutkuje zaburzeniami metabolizmu płodu i skłonnością do rozwoju chorób na podłożu miażdżycy w przyszłych latach życia. **Cel pracy:** Ocena występowania czynników ryzyka miażdżycy u dzieci w wieku przedpokwitaniowym, w zależności od ich masy urodzeniowej i długości trwania ciąży. **Materiał i metody:** 113 dzieci w wieku 7–9 lat podzielono na grupy: urodzone przedwcześnie, z małą masą ciała (grupa I – 37 osób), urodzone o czasie, z małą masą ciała (grupa II – 36 osób) i urodzone o czasie, z prawidłową masą ciała (grupa K – 40 osób) oraz na grupy dzieci urodzonych z masą ciała <10. lub ≥10. centyla w stosunku do wieku ciążowego, niezależnie od długości trwania ciąży. Zgromadzono dane demograficzno-społeczne, dotyczące zachowań zdrowotnych, stanu zdrowia badanych oraz ich rodziców. Dokonano pomiarów antropometrycznych, wysokości ciśnienia tętniczego oraz składu masy ciała metodą impedancji bioelektrycznej. Metodą testów paskowych oznaczono we krwi stężenia glukozy, cholesterolu i triglicerydów. **Wyniki:** W porównaniu z pozostałymi grupami w grupie K stwierdzono istotnie wyższe średnie wartości i znamiennie częstsze występowanie wysokich wartości centylowych wskaźnika masy ciała i obwodu talii oraz nieznamiennie częstsze występowanie zwiększonego odsetka tkanki tłuszczowej i nieprawidłowych stężeń glukozy oraz cholesterolu. U dzieci

urodzonych przedwcześnie lub o czasie, z masą urodzeniową <10. centyla istotnie rzadziej występowały wysokie wartości centylowe obwodu talii. Stwierdzono dodatnią korelację wartości wskaźnika masy ciała dzieci urodzonych o czasie, z małą masą ciała i wskaźnika masy ciała ich matek. Wśród zespołu zmiennych niezależnych wpływających na liczbę czynników ryzyka miażdżycy potwierdzono istotne znaczenie otyłości rodziców. **Wnioski:** 1) Urodzenie przedwczesne lub o czasie, z małą masą urodzeniową nie zwiększa ryzyka wystąpienia otyłości ani podwyższonych stężeń cholesterolu i glukozy we krwi w wieku przedpokwitaniowym. 2) Występowanie czynników ryzyka miażdżycy u dzieci w wieku przedpokwitaniowym (niezależnie od długości trwania ciąży i urodzeniowej masy ciała) ma związek z otyłością/nadmiernym odżywieniem rodziców.

Słowa kluczowe: masa urodzeniowa, długość trwania ciąży, czynniki ryzyka miażdżycy, okres przedpokwitaniowy

INTRODUCTION

Since the last century, an increase in the incidence of civilisation diseases such as obesity, diabetes mellitus and cardiovascular diseases has been observed. Among many risk factors are the ones that are subject to modifications, those that are unmodifiable and the so-called new risk factors. The most important factor that determines health in 50–60%, is lifestyle. According to the hypothesis by David Barker, low birth weight is associated with an increased risk of developing cardiovascular diseases in the future[1]. This hypothesis assumes that malnutrition in the prenatal period, in "critical periods" for foetal development, determines irreversible changes in the structure, metabolism and function of its organs (disturbances concern mainly β cells of the pancreas, nephrons and cardiomyocytes) as part of adaptation to an unfavourable period. The term "small for gestational age" (SGA) refers to babies born with weight and/or body length which is too low in relation to their gestational age and gender (less than −2 *SD* or below 10th percentiles for gestational age)[2]. The occurrence of low birth weight may depend on maternal, foetal and placental factors. According to the catch-up growth hypothesis, the body weight of people born with intrauterine hypotrophy (not conditioned constitutionally) is increasing compensatory rapidly, usually in the first two years of life. It is believed that these people are more prone to excessive accumulation of adipose tissue and 3–4 times more likely to suffer from hypertension, hyperlipidaemia, cardiovascular disease or type 2 diabetes mellitus in later life[1]. The location of excess fat is particularly important. The development of the abovementioned diseases is largely influenced by its android placement. The progress of civilisation fosters a change in lifestyle with limitation of physical activity and excessive consumption, which – especially in those born with low body mass – increases the accumulation of adipose tissue (especially visceral one)[2]. Considering the suggested long-term health effects of birth with low body mass, children born as SGA should be monitored for the development of atherosclerotic disease[1].

The aim of the study is to assess the occurrence of atherosclerosis risk factors in prepubertal children born prematurely or on time with low body mass compared to peers born with normal body weight from full-term pregnancies.

MATERIAL AND METHODS

After obtaining the consent of the Bioethics Commission at the Medical University of Silesia in Katowice (Resolution No. KNW/0022/KB1/62/13 of 25.06.2013 and Resolution No. KNW/0022/KB1/62/I/13/16 of 5.04.2016 – prolonging the time of conducting research) in 2013–2016, 113 children aged 7–9 were tested, who were invited to participate in research during parent–teacher conferences in primary schools and during visits to the primary care clinics. The criteria for inclusion in the study were: age 7–9 years, birth on time or before the 37th week of pregnancy, with low or normal birth weight (qualification for a given group) and parents' written consent to participate in the study. Lack of parental consent for participation in the study, genetically conditioned diseases, disability as well as births from a multiple pregnancy, features of acute infectious disease on the day of the study and the presence of chronic diseases (except for dyslipidaemia, diabetes mellitus, hypertension, obesity) determined the exclusion from the study. The children came from families with comparable living conditions. The respondents were divided into three groups, taking into account their birth weight and duration of pregnancy:

- **group I** – 37 children born before the 37th week of gestation, with body weight <2,500 g;
- **group II** – 36 children born on time, with low body weight (<2,500 g);
- **control group, K** – 40 children born o time, with normal birth weight.

Considering Barker's hypothesis, which assumes that low birth weight in relation to gestational age (SGA) is associated with an increased risk of metabolic disorders and the development of atherosclerotic disease in the future, an additional division of the examined children was conducted into groups born with body weight <10 or ≥10th percentile for gestational age. These groups included 10 children from group I and all children from group II (46 children in total) and 27 children from group I and all children from group K (in total 67 children).

Authorial questionnaire was used to obtain demographic and social data describing the period of pregnancy and birth, concerning health behaviours (nutrition, physical activity) of the examined children as well as referring to the health condition of their parents (presence of risk factors for atherosclerosis). Some of the obtained data was used in

DOI: 10.15557/PiMR.2019.0010

this work. In addition, physical examination and anthropometric assessment of the nutritional status were carried out, taking into account the measurement of body weight (to the nearest 0.1 kg) and body height (to the nearest 0.1 cm) as well as the waist and hip circumferences (with an accuracy of 0.5 cm). The body mass index (BMI) was calculated, the value of which was related to centile grids for a given gender and age[3]. BMI values in the range from 85th to 94th percentile are considered overweight and BMI ≥95th percentile – obesity. The results of waist circumference measurements were also referred to the right percentile grids[4], qualifying values above the 95th percentile for sex and age as abdominal obesity. Using the Bioscan 920-II apparatus with the bioelectrical impedance method, the composition of the body weight of the respondents was assessed, and from the obtained data, the percentage of fat in total body weight (FAT) was used in this study. The results were referred to the norms for patients in developmental age, indicated by the apparatus's software based on the given parameters. Determinations of cholesterol, triglycerides and glucose were made in fasting, capillary blood, using test strips available in the general practitioner's office (devices by MultiCareIn and Accu-Chek Active). The results were referenced to standards taking into account the age of the respondents[5].

Statistical analysis was made on the basis of: chi^2 test (comparison of groups in terms of incidence of abnormal nutritional status parameters and environmental risk factors of atherosclerosis), multiple step retrograde regression analysis (assessment of the dependence of the number of atherosclerosis risk factors in the tested children from the independent variables group, i.e. to group I or II, age, duration of breastfeeding, physical activity, excessive nutritional status and health burden in parents of the subjects), Spearman's correlation of rank (assessment of the relationship between the BMI value of children and the BMI values of their parents).

RESULTS

In the mothers of the examined children, obesity was most frequently observed in all groups (group I – 24%, group II – 19%, group K – 23%) as well as arterial hypertension (group I – 19%, group II – 14%, group K – 3%), thyroid diseases (group I – 14%, group II – 3%, group K – 10%) and hypercholesterolaemia and hypertriglyceridaemia in individual cases. In the fathers of the examined children, obesity was most common in all groups (significantly more often in group K – 32% compared to fathers from group II – 3%, $p = 0.003$) and hypertension (group I – 13%, group II – 3%, group K – 6%), in addition, coronary disease, thyroid disease, hypercholesterolaemia in individual people.

Among the health burden in the families of children covered by the study, the occurrence of abnormalities in nutritional status was analysed. Both obesity and overweight in the highest percentage were diagnosed in mothers of children from group I (35% and 17%, respectively) and mothers of children from group K (33% and 14%, respectively), without significance of differences between groups (Tab. 1). Analysis of the BMI value of fathers, however, showed its significant variation between groups. In the fathers of children from groups I and K, the BMI exceeded normal values significantly more often than in group II. The most common presence of overweight (60%) was found in fathers from group I, whereas obesity was diagnosed in the largest percentage of fathers from group K (22%) (Tab. 1).

When analysing the dependence of the BMI values of the examined children from each group and the BMI values of their parents, only a positive correlation of the BMI values of the children from group II and the BMI values of their mothers was proved ($r = 0.60$, $p < 0.001$).

Based on the survey data on the method of feeding children during infancy, statistically significant differentiation of groups in the field of natural nutrition was found. 62%, 72% and 90% children were fed in such a way from birth, respectively from

Ranges of BMI values [kg/m^2]		Fathers of examined children									
		Group I $n = 37$		Group II $n = 36$		Group K $n = 40$		p*	p* (I/II)	p* (I/K)	p* (II/K)
		n	%	n	%	n	%				
<18.5	Underweight	0	0	4	11	0	0	**0.001**	**0.008**	0.442	**0.001**
18.5–24.9	Normal weight	9	24	20	56	10	25				
25–29.9	Overweight	22	60	9	25	21	53				
≥30	Obesity	6	16	3	8	9	22				
Ranges of BMI values [kg/m^2]		**Mothers of examined children**									
<18.5	Underweight	2	5	5	14	1	3	0.295	–	–	–
18.5–24.9	Normal weight	16	43	21	58	20	50				
25–29.9	Overweight	13	35	7	19	13	33				
≥30	Obesity	6	17	3	9	6	14				

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Pearson's chi-squared test.
BMI – body mass index.

Tab. 1. Nutritional status of fathers and mothers of children from the study and control groups based on the body mass index (BMI)

 DOI: 10.15557/PiMR.2019.0010

Feeding method of the respondents during infancy (months)	Examined children – *n* = 113						*p**	*p** (I/II)	*p** (I/K)	*p** (II/K)
	Group I		Group II		Group K					
	n	%	*n*	%	*n*	%				
Natural feeding	23	**62**	26	**72**	36	**90**	**0.016**	0,360	**0,003**	**0.045**
Including:										
Until the 1st month	1	4	3	12	4	11	0.13			
From the 1st to the 3rd month	6	26	14	**54**	9	25				
From the 4th to the 6th month	10	**44**	6	22	14	**39**				
From the 7th to the 12th month	6	26	3	12	9	25				
Inclusion of milk mixtures for breastfed feeding										
Until the 1st month	1	3	3	8	3	8	**0.047**	0.16	**0.03**	0.223
From the 1st to the 3rd month	21	57	16	44	14	34				
From the 4th to the 6th month	4	10	10	28	15	38				
From the 7th to the 12th month	10	27	5	14	8	20				
Not included at all	1	3	2	6	0	0				

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Pearson's chi-squared test.

Tab. 2. Natural feeding in nutrition of children from the study and control groups in infancy

groups I, II and K, with a statistically significant difference between groups I and K and II and K (Tab. 2). The duration of natural feeding was not significantly differentiated between groups. Statistical analysis, however, showed a significant diversity of groups I and K in terms of time of inclusion of dairy mixtures. The results are summarised in Tab. 2.

The current diet of the examined children did not differ significantly between the groups in terms of the frequency of meals and their type during the day. In a similar percentage, the examined children usually consumed five meals a day. The menus of the studied persons contained similar types of declared meals, and the frequency of their consumption was at a similar level. Noteworthy is the frequent occurrence of snacking in all groups (81% – I, 89% – II and 80% – K), including sweets (51% – I, 50% – II, 68% – K) and fruit (59% – I, 56% – II, 35% – K) (Tab. 3).

Survey data regarding physical activity of the respondents showed that all children participated in school physical activities. Participation of children in extracurricular physical activities was declared by 86% of mothers of children from group I, 86% from group II, 78% from group K, but it was mainly cycling (69%, 68%, 71%, respectively). The observed differences in frequency are not statistically significant (Tab. 4).

Based on the analysis of the occurrence of abnormal results of anthropometric measurements, a statistically significant

Frequency of meals	Examined children – *n* = 113						*p**
	Group I *n* = 37		Group II *n* = 36		Group K *n* = 40		
	n	%	*n*	%	*n*	%	
3 times daily	1	3	2	6	5	13	0.271
4 times daily	13	35	7	19	11	27	
5 times daily	23	**62**	27	**75**	24	**60**	
Type of meals consumed during the day:							
1st breakfast	36	97	35	97	38	95	0.824
2nd breakfast	36	97	32	89	34	85	0.180
Dinner	37	100	36	100	40	100	1.000
Dessert/Afternoon tea	27	73	27	75	27	67,5	0.751
Supper	36	97	35	97	40	100	0.572
Snacking, including:	30	81	32	89	32	80	0.536
Sweets	19	**51**	18	**50**	27	**68**	0.224
Fruit	22	**59**	20	**56**	14	**35**	0.685
Vegetables	0	0	0	0	1	3	0.398
Yoghurt	0	0	1	3	0	0	0.339
Sandwiches	0	0	2	6	0	0	0.113

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Pearson's chi-squared test.

Tab. 3. Frequency and type of meals consumed by children from the study and control groups

Characteristics of physical activity of examined children according to the survey data		Examined children – *n* = 113						*p**
		Group I *n* = 37		Group II *n* = 36		Group K *n* = 40		
		n	%	*n*	%	*n*	%	
Children participating in physical activities at school (PE)		37	**100**	36	**100**	40	**100**	1.000
Children participating in extracurricular activities		32	**86**	31	**86**	31	**77.5**	0.575
Type of extracurricular activities	Jogging	19	**51**	20	**56**	22	**55**	0.925
	Cycling	22	**59**	21	**58**	22	**55**	0.918
	Swimming	18	**49**	19	**53**	19	**47.5**	0.976

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Pearson's chi-squared test.

Tab. 4. Participation of children from the study and control groups in physical activities

DOI: 10.15557/PiMR.2019.0010

Compared parameters		Examined children – $n = 113$			
		Group I $n = 37$	Group II $n = 36$	Group K $n = 40$	p*
BMI (centile)	>95th percentile		>95th percentile	>95th percentile	**0.009**
	n	3	1	7	
	%	**8.11**	**2.78**	**17.50**	
BMI (z-score)	≥2		≥2	≥2	0.164
	n	1	1	4	
	%	2.70	2.78	10.00	
Waist circumference (centile)	≥95th percentile		≥95th percentile	≥95th percentile	**0.045**
	n	5	1	8	
	%	**13.51**	**2.78**	**20.00**	
FAT%	≥21		≥21	≥21	0.499
	n	12	9	15	
	%	32.43	25.00	37.50	
SBP	>95th percentile		>95th percentile	>95th percentile	0.867
	n	5	6	5	
	%	13.51	16.67	12.50	
DBP	n	3	2	3	0.903
	%	8.11	5.56	7.50	
BMI (centile)	<5th percentile		<5th percentile	<5th percentile	0.335
	n	0	2	1	
	%	0.00	5.56	2.50	
BMI (z-score)	<–1.0		<–1.0	<–1.0	**0.018**
	n	3	11	4	
	%	**8.11**	**30.56**	**10.00**	
Waist circumference (centile)	<5th percentile		<5th percentile	<5th percentile	**0.019**
	n	7	13	4	
	%	**18.92**	**36.11**	**10.00**	
FAT%	<14		<14	<14	0.812
	n	7	7	10	
	%	18.92	19.44	25.00	

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Chi² statistical test (NW).
BMI – body mass index; **BMI z-score** – normalised body mass index; **FAT%** – fat mass expressed as a percentage; **SBP** – systolic blood pressure; **DBP** – diastolic blood pressure.

Tab. 5. Comparison of the incidence of abnormal values of nutritional status and blood pressure in children from the study and control groups

differentiation was found in the incidence of high BMI centile values and waist circumference in the studied groups. They were observed in a few children from group I (8.11% and 13.51%, respectively) and group II (2.78% and 2.78%, respectively), and were significantly most common in group K (17.5% and 20% of children in this group, respectively) ($p = 0.009$). However, there was no statistically significant differentiation in the percentage of adipose tissue and the incidence of abnormal values of systolic and diastolic pressure between the examined groups. There was a statistically significant differentiation of the groups in terms of the incidence of low (<5th percentile) centile waist circumference values as well as BMI z-score. They occurred in several children from group I (8.11% and 18.92%, respectively) and group K (10% and 10%, respectively), whereas they were most frequent in group II (30.56% and 36.11% of children in this group, respectively) (for different waist circumference $p = 0.019$, and for BMI z-score $p = 0.018$) (Tab. 5).
When analysing abnormal results of biochemical tests, it was found that glucose and cholesterol concentrations exceeding the upper limit of the standard were sporadic, and their frequency and average values of concentrations did not differ significantly between the groups. In individuals, slightly exceeded norms of glucose and cholesterol concentrations were found (in seven children, the norm of glucose concentration was exceeded by 0.11 mmol/L, in one child the norm of cholesterol concentration was exceeded by 0.03 mmol/L). Triglyceride concentrations exceeding the upper limit of the norm were more frequent: in 16% of children from group I, 22% – II, 20% – K. Their prevalence and mean values of concentrations did not differ significantly between the examined groups (Tab. 6).
On the basis of a statistical analysis performed with the method of multiple-step retrograde regression, there was a significant positive dependence of atherosclerosis risk factors (elevated glucose, cholesterol, triglycerides, high BMI, waist circumference, adipose tissue) from the independent variables in the incidence of maternal obesity ($\beta = 0.223$, $p = 0.027$) and fathers ($\beta = 0.251$, $p = 0.013$) of the examined children. There was no such dependence on other

Examined biochemical parameters [mmol/L]	Examined children – $n = 113$									
	Group I $n = 37$		Group II $n = 36$		Group K $n = 40$		p*	Post hoc analysis		
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		p (I/II)	p (I/K)	p (II/K)
Glucose	**5.16**	0.30	**4.96**	0.40	**5.19**	0.23	**0.038****	NS	NS	NS
Cholesterol	3.44	0.78	3.27	0.72	3.67	0.87	0.097			
Triglycerides	86.38	18.53	89.69	29.10	89.75	19.04	0.082			
	n	%	n	%	n	%	p***			
Glucose ≥5.5	3	**8.11**	0	0	4	**10**	0.588			
Cholesterol ≥4.9	0	0	0	0	1	**2.50**	0.351			
Triglycerides ≥1.13	6	16	8	**22**	8	20	0.806			

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight; **group K** – children born on time with normal body weight.
* Variation analysis.
** Kruskal–Wallis test.
*** Chi² statistical test (NW).
Concentration range according to[6].

Tab. 6. Mean values of biochemical tests results and the frequency of abnormal biochemical results in children from the study and control groups

 DOI: 10.15557/PiMR.2019.0010

Dependent variables	Independent variables	BETA	*p**
Risk factors for atherosclerosis (elevated glucose, cholesterol, triglycerides, high values of BMI, waist circumference, adipose tissue percentage)	Adherence to group I	–0.080	0.535
	Adherence to group II	–0.161	0.217
	Age	0.023	0.838
	Length of breastfeeding	0.087	0.418
	Physical activity	–0.147	0.199
	Obesity of mothers	0.223	**0.027**
	Hypertension in mothers	–0.065	0.568
	Diseases of cardiovascular system in mothers	0.163	0.271
	Obesity of fathers	0.251	**0.013**
	Hypertension in fathers	–0.037	0.760
	Diseases of cardiovascular system in fathers	0.078	0.594

Group I – children born prematurely, with low body weight; **group II** – children born on time with low body weight.
* Multiple step retrograde regression analysis.

Tab. 7. Summary of the analysis of the dependence of the number of atherosclerosis risk factors in children on the independent variables (multiple regression analysis)

independent variables, including premature birth or birth with signs of intrauterine hypotrophy (Tab. 7).

When analysing the mean values of measurements of anthropometric features, BMI, blood pressure and biochemical tests in groups of children born as SGA or normal birth weight in relation to gestational age, it was found that children born with normal body weight showed significantly higher values of BMI and waist circumference as well as of glucose and cholesterol concentrations (Tab. 8). There was also a significantly more frequent occurrence of high waist percentile values in this group of children (≥95th percentile) (Tab. 9).

Compared parameters	Examined children – *n* = 113				*p**
	Born prematurely or on time, with body weight less than 10th percentile in relation to gestational age (SGA) – *n* = 46		Born prematurely or on time, with normal body weight in relation to gestational age – *n* = 67		
	$\bar{x}$	*SD*	$\bar{x}$	*SD*	
Body weight [kg]	25.7	6.1	28.6	8.1	0.064
Height [m]	1.3	0.1	1.3	0.1	0.364
BMI (z-score)	–0.3	1.3	0.4	1.1	**0.005**
BMI (centile)	42.2	30.9	59.9	27.7	**0.002**
Waist circumference (centile)	31.5	31.6	41.3	33.3	**0.012**
FFM%	81.9	6.3	80.4	7.1	0.434
FAT%	18.1	6.3	19.6	7.1	0.434
SBP [mm Hg]	100.1	12.7	102.3	12.8	0.235
DBP [mm Hg]	59.9	9.2	61.4	9.1	0.171
Glucose [mmol/L]	5.0	0.4	5.2	0.3	**0.016**
Cholesterol [mmol/L]	3.2	0.7	3.7	0.8	**0.006**
Triglycerides [mmol/L]	1.0	0.3	1.0	0.2	0.501

* Mann–Whitney *U* test.
SGA – small for gestational age; **BMI –** body mass index; **BMI z-score** – normalised body mass index; **FFM%** – non-fat mass expressed as a percentage; **FAT%** – fat mass expressed as a percentage; **SBP** – systolic blood pressure; **DBP** – diastolic blood pressure.

Tab. 8. Comparison of the average values of anthropometric features, body mass composition, blood pressure and biochemical parameters in children born with mass <10th percentile or ≥10th percentile in relation to gestational age

DISCUSSION

Apart from inborn and inflammatory causes, diseases of the cardiovascular system are most often atherosclerotic-based. Already in childhood, early changes in the arteries are observed, which for many years develop most often – asymptomatically[6]. Among the methods of primary prevention of the cardiovascular diseases, education of the patient aimed at convincing them into a proper way of life, is the most important one. Taking into account Barker's hypothesis that in the future in people born with low body weight, obesity and other metabolic disorders develop due to abnormal development of foetal cells and organs, the study included a group of children born prematurely or on time with low body weight and their peers born on time with normal birth weight. Conducting the study among children in the prepubertal age enabled the evaluation of hormonal and metabolic stability in the period, which facilitated the interpretation of the obtained results.

Many countries are currently struggling with the problem of obesity and obesity-related diseases, i.e. hypertension, diabetes mellitus and dyslipidaemia. While examining the amount and distribution of adipose tissue in infants born on time and the ones born prematurely, Uthaya et al. confirmed that the latter are characterised by a significantly smaller amount of subcutaneous adipose tissue, and at the same time, its increased amount in an intra-abdominal area[7]. Such disturbed distribution of fat increases the risk of cardiovascular diseases in the future, which confirms the Barker's hypothesis[1]. In studies carried out by the National Food and Nutrition Institute, it has been stated that since the 1970s, there has been an upward trend in the incidence of excessive body mass in adolescents in Poland[8]. When comparing the nutritional status of children born with low body mass and nutrition of children with normal birth parameters, Nordman et al. noticed that lower birth weight values often translate into lower BMI values in prepubertal age[9]. Slovakian studies by Blusková et al., which also included the population of prepubertal children, showed that the difference in the prevalence of high BMI values between the group of children born with low body weight and a control group was statistically insignificant[10]. Other results were presented by Gallo et al. who showed that in both boys and girls born with low body weight, obesity in prepubertal age is more common[11]. In the authors'

DOI: 10.15557/PiMR.2019.0010

Compared parameters		Examined children – $n = 113$		
		Born prematurely or on time, with body weight less than 10th percentile in relation to gestational age (SGA) – $n = 46$	Born prematurely or on time, with normal body weight in relation to gestational age – $n = 67$	p*
BMI (centile)		>95th percentile		
	n	2	9	0,089
	%	**4.35**	**13.43**	
BMI (z-score)		>2		
	n	1	5	0.262
	%	**2.17**	**7.46**	
Waist circumference (centile)		≥95th percentile		
	n	2	12	**0.022**
	%	**4.35**	**17.91**	
FAT%		≥21		
	n	12	24	0.272
	%	**26.09**	**35.82**	
SBP		>95th percentile		
	n	8	8	0.418
	%	**17.39**	**11.94**	
DBP	*n*	3	5	0.847
	%	**6.52**	**7.46**	
Glucose [mmol/l]		≥5,6		
	n	1	6	0.117
	%	**2.17**	**8.96**	
Cholesterol [mmol/L]		≥4,9		
	n	0	1	0.305
	%	**0**	**1.49**	
Triglycerides [mmol/L]		≥1,13		
	n	9	13	0.982
	%	**19.5**	**19.4**	

* Chi^2 statistical test (NW).
SGA – small for gestational age; **BMI** – body mass index; **BMI z-score** – normalised body mass index; **FAT%** – fat mass expressed as a percentage; **SBP** – systolic blood pressure; **DBP** – diastolic blood pressure.

Tab. 9. Comparison of the frequency of abnormal results of anthropometric measurements, percentage of adipose tissue, blood pressure and biochemical parameters in children born with mass <10th percentile or ≥10th percentile in relation to gestational age

own study, the occurrence of excessive BMI percentile values, waist circumference and percentage of adipose tissue in the highest percentage, was found in children from the control group, while the birth with intrauterine hypotrophy was associated with worse parameters of the nutritional state in prepubertal age. When comparing the incidence of abnormal anthropometric parameters in the groups of children born as SGA and born with normal body mass in relation to gestational age, significantly higher occurrence of high waist circumferences and unusually higher occurrence of high BMI values and body fat percentage in children born with normal body mass were found in relation to gestational age. On the basis of the analysis, it can therefore be considered – as some earlier authors have stated – that premature birth or intrauterine hypotrophy does not increase the risk of obesity or abdominal obesity in children aged 7–9. Assessment of the future development of the nutritional status of children included in the study will be possible on the basis of further observation.

Among chronic diseases, obesity in parents is considered the most important risk factor for obesity in their children[12]. While examining a group of 8-year-olds, Olszanecka-Glinianowicz et al. proved that obesity of both parents and maternal obesity had a significant relationship with the obesity of their children[12]. Moraeus et al. studied children aged 7–9 and stated that excessive body mass affecting parents had the greatest impact on the development of obesity in their children[13]. Furthermore, Białokoz-Kalinowska et al. found that an excessive nutritional status of children aged 7–10 was significantly determined by the parents' lifestyle[14]. When analysing the health burden in families of children included in the authorial study, the incidence of obesity was higher than of other chronic diseases. During the study, excessive body mass was found comparatively often in mothers of children born prematurely and in mothers of children from the control group, and less often in mothers of children born with intrauterine hypotrophy. The fathers of children born prematurely and also from the control group were characterised by overweight and obesity significantly more frequently than the fathers of children born with intrauterine hypotrophy. The analysis of the correlation of the percentile values of BMI for children and their parents confirmed a strong positive association of the examined trait in children born with intrauterine hypotrophy and their mothers. Multiple regression analysis indicated that among the considered independent variables, parental obesity was mostly associated with the occurrence of risk factors for atherosclerosis (including obesity) in children. This may prove the significant impact of environmental factors, including nutrition, on the nutritional status of all family members.

The method of feeding during infancy is a factor which not only has a fundamental health significance in the first period of a child's life, but also affects their health in the following years. According to the guidelines by the Polish Society of Gastroenterology, Hepatology and Child Nutrition, the ESPGHAN (European Society for Paediatric Gastroenterology, Hepatology and Nutrition) Committee on Nutrition and the recommendations of the World Health Organization (WHO), natural feeding should be maintained for at least first 6 months of the child's life, and then continued after extending the diet[15]. Partial breastfeeding or natural feeding lasting less than 6 months may also play an advantageous role in the development of a child – it is supposed to reduce the risk of overweight and obesity or diabetes mellitus in the future[16]. Some authors emphasize the time-limited protective effect of natural feeding – up to the first years of a child's life[17]. However, there are also opinions that the protective effect of natural feeding is noticeable

 DOI: 10.15557/PiMR.2019.0010

in school-aged children and even young adults[18]. Early initiation of artificial nutrition may be a factor influencing the development of hypertension and obesity[19]. According to Szajewska et al., 98% of children in the first days of their lives and only 68% of babies in the sixth month of life are naturally fed[15]. According to data published by the Central Statistical Office (Polish: Główny Urząd Statystyczny, GUS) published in 2016, 87% of children were breastfed for a different length of time, of which only 13% were fed in this way for the first 6 months[20]. In our own research, differences in the way of feeding groups of children during infancy were found. Immediately after birth, 62–90% of the subjects were fed naturally. Children from the control group were significantly more often breastfed. In the case of 38% of them, natural nutrition was maintained for up to 6 months. When referring the nutritional status of the respondents to the way they were fed during infancy, excessive body mass was found significantly more often in children from the control group. Obtained results do not, therefore, support the protective effect of natural feeding on the development of excessive body weight in children in this age group. This problem is very difficult to resolve, because the influence of the feeding method after the infancy period is also important. The etiopathogenesis of civilisation diseases emphasises the special role of easy access to processed foods, including fast food and sweets. According to Kołodziej et al., the main type of snacks eaten between meals in the group of examined children were sweets[21]. In our own research, such eating habits were present especially in the control group, which, among other factors, could cause a significantly higher prevalence of overweight in children from this group than in the other groups in which the most-declared snack was fruit. Therefore, considering the nutritional status of the examined children, it was found that a birth with intrauterine hypotrophy is associated with worse parameters in the prepubertal age.

Since 2016, the National Health Programme has been implemented in Poland, the main assumption of which is to prevent the occurrence of civilisation diseases by improving lifestyle[22]. According to data from the Ministry of Health, only 30% of all children devote their time to sport appropriate to the needs of the body, of which the highest percentage of physically active children are 6- and 7-year-old children (70%)[22]. According to the GUS report from 2016, 98% of children attending school participate in physical education (PE), and every second child (5 years ago only every third) engages in sports or extracurricular recreation regularly[20]. According to the authorial surveys, physical activity in the school classes was undertaken by all children and most of them took part in the extracurricular activities. It should be emphasised that the limitation of the presented study is the subjective assessment of parents regarding the lifestyle of their children, which may be incomplete or more optimistic than it is. Obtaining more reliable information about the lifestyle of the examined children requires in-depth research.

Lipid disorders are the most common and at the same time – the worst-controlled risk factor of cardiovascular diseases in Poland[23]. They are also an independent risk factor for cardiovascular events. The guidelines recommend maintaining total serum cholesterol below 5.2 mmol/L and triglycerides below 1.13 mmol/L in children[5]. Lipid metabolism should be evaluated in children over 2 years of age, if the family history is burdened with an early occurrence of cardiovascular disease or other risk factors[23]. The best period for screening lipid metabolism is the age of 9–11, and in the case of correct results, the study should be repeated at the end of the second decade of life[23].

Banaś and Kardas found that 7-year-old children with abdominal obesity had lipid disorders as well as a strong correlation of elevated triglycerides and abdominal obesity[24]. The results of the lipid profile parameters in children born with a diversified birth weight are not conclusive, though. Stawerska et al. did not find any statistical differences in lipid metabolism between prepubertal children born with intrauterine hypotrophy or normal body weight[25]. In turn, Huang et al., who investigated the concentration of lipids in prepubertal Chinese children born with low body weight, showed a significantly more frequent occurrence of hypercholesterolaemia in this group (by 33%) and hypertriglyceridaemia (by 23%) in comparison with children with normal parameters birth[26].

In this study, total cholesterol, triglyceride and glucose levels were determined based on a method that uses strip capillary blood test, which allows quick diagnostics of biochemical abnormalities and is available in the general practitioner's office. Data from the literature indicate the reliability and acceptable sensitivity and specificity of this method[27]. Presence of abnormalities in cholesterol test results was found in one child in the control group, and abnormalities in the results of triglyceride concentrations were recorded in children from all groups, with no statistical significance of differences in frequency and the level of these concentrations. The diversity between the groups might be visible in the later years of the respondents' lives, with longer exposure to abnormal health behaviours.

Based on the method of capillary blood strips, fasting glucose was also determined. Diagnosis of diabetes mellitus was recognised as the equivalent of the diagnosis of ischaemic heart disease; therefore, the procedure for the prevention of cardiovascular disease in a person with diabetes mellitus is similar to that of a person who has suffered from a heart attack[28]. In addition, birth body weight below the 10th percentile in relation to gestational age may be an additional risk factor for the development of diabetes mellitus in the future[1]. The problem is significant because the WHO predicts the number of over 500 million patients with diabetes mellitus in 2030[29].

According to the Polish Diabetes Association, an oral glucose tolerance test should be performed every 2 years for children older than 10 years of age in whom BMI exceeds 95th percentile[30]. Incorrect glycaemia is less common than

DOI: 10.15557/PiMR.2019.0010

impaired glucose tolerance in obese children[30]. In a study by Blusková et al., it was found that in the prepubertal age, children with low birth weight were characterised by significantly higher fasting glucose levels compared to the peer group[10]. In our study, there was no significant difference between the groups of children, neither in terms of mean values of fasting glucose concentrations (post-hoc analysis) nor in relation to the incidence of abnormal fasting glucose concentrations. The incidence in children born as SGA (1%) and those born with normal body mass in relation to gestational age (6%) also did not significantly differ statistically.

The incidence of civilisation diseases (chronic non-infectious diseases), which has been growing for several decades around the world, indicates the need to continue research to identify their risk factors. When analysing the presence of these factors in children born prematurely or with intrauterine hypotrophy, there was no relation between their time of birth and birth weight with the current state of nutrition and the results of biochemical tests found. Ambiguous results of research on the role of birth weight in the development of lifestyle diseases and their complications emphasise the need to consider the duration of pregnancy and birth weight among the above risk factors and observe their consequences in the subsequent years of patients' life, which should be an indication for the general practitioner.

It is worth mentioning that the team of authors of this study published the results of studies comparing the occurrence of atherosclerosis risk factors in young adults born prematurely or on time, with low body weight and those born on time with normal body weight[31].

CONCLUSIONS

1. Birth on premature or due time, with low birth weight (small for gestational age) does not increase the risk of obesity as well as of elevated cholesterol and glucose levels in the prepubertal age.
2. The occurrence of atherosclerosis risk factors in prepubertal children (regardless of duration of gestation and birth weight) is associated with obesity/overnutrition of parents.

Conflict of interest

Authors do not declare any financial or personal relations with other people or organisations which may negatively influence the content of this publication or claim the right to this publication.

Funding/Support and role of the sponsor

Study financed from contracts for the implementation of scientific and research work by a doctoral student (grant obtained from the Ministry of Science and Higher Education). Contract number: KNW-2-O32/D/4/N; KNW-2-O28/D/5/K; KNW-2-K06/D/6/K.

References

1. Barker DJ: Fetal origins of coronary heart disease. BMJ 1995; 311: 171–174.
2. Korpysz A, Szalecki M: Hipotrofia wewnątrzmaciczna w aspekcie zaburzeń hormonalnych. Stand Med Pediatr 2016; 13: 942–946.
3. Kułaga Z, Różdżyńska A, Palczewska I et al.: Siatki centylowe wysokości, masy ciała i wskaźnika masy ciała dzieci i młodzieży w Polsce – wyniki badania OLAF. Stand Med Pediatr 2010; 7: 690–700.
4. Kułaga Z, Litwin M, Zajączkowska MM et al.: Porównanie wartości obwodów talii i bioder dzieci i młodzieży polskiej w wieku 7–18 lat z wartościami referencyjnymi dla oceny ryzyka sercowo-naczyniowego – wyniki wstępne projektu badawczego OLAF (PL0080). Stand Med Pediatr 2008; 5: 473–485.
5. Krawiec P, Pac-Kożuchowska E: Diagnostyka i leczenie zaburzeń lipidowych u dzieci. Endokrynol Pediatr 2012; 41: 81–87.
6. Kawalec-Kajstura E, Malinowska-Lipień I, Brzostek T: Biochemiczne czynniki ryzyka miażdżycy w grupie młodzieży kończącej szkołę ponadgimnazjalną – ocena zmian w okresie rocznej obserwacji. Probl Hig Epidemiol 2015; 96: 205–210.
7. Uthaya S, Thomas EL, Hamilton G et al.: Altered adiposity after extremely preterm birth. Pediatr Res 2005; 57: 211–215.
8. Szponar L, Ciok J, Jarosz M et al.: Opcje polityki przeciwdziałania rosnącemu zagrożeniu otyłością. Przekrojowe badania porównawcze (Polska). Instytut Żywności i Żywienia, Warszawa 2006.
9. Nordman H, Voutilainen R, Laitinen T et al.: Growth and cardiovascular risk factors in prepubertal children born large or small for gestational age. Horm Res Paediatr 2016; 85: 11–17.
10. Blusková Z, Koštálová L, Celec P et al.: Evaluation of lipid and glucose metabolism and cortisol and thyroid hormone levels in obese appropriate for gestational age (AGA) born and non-obese small for gestational age (SGA) born prepubertal Slovak children. J Pediatr Endocrinol Metab 2014; 27: 693–699.
11. Gallo P, Cioffi L, Limauro R et al.: SGA children in pediatric primary care: what is the best choice, large or small? A 10-year prospective longitudinal study. Glob Pediatr Health 2016; 3: 2333794X16659993.
12. Olszanecka-Glinianowicz M, Małecka-Tendera E, Klimek K et al.: Czynniki ryzyka otyłości prostej u dzieci śląskich w wieku 7–9 lat. Endokrynol Pediatr 2006; 5: 31–38.
13. Moraeus L, Lissner L, Yngve A et al.: Multi-level influences on childhood obesity in Sweden: societal factors, parental determinants and child's lifestyle. Int J Obes (Lond) 2012; 36: 969–976.
14. Białokoz-Kalinowska I, Abramowicz P, Konstantynowicz J et al.: Ocena stanu odżywienia dzieci w wieku wczesnoszkolnym z regionu Podlasia. Pediatr Współcz Gastroenterol Hepatol Żywienie Dziecka 2007; 9: 127–129.
15. Szajewska H, Horvath A, Rybak A et al.: Karmienie piersią. Stanowisko Polskiego Towarzystwa Gastroenterologii, Hepatologii i Żywienia Dzieci. Stand Med Pediatr 2016; 13: 9–24.
16. Novaes JF, Lamounier JA, Colosimo EA et al.: Breastfeeding and obesity in Brazilian children. Eur J Public Health 2012; 22: 383–389.
17. Uwaezuoke SN, Eneh CI, Ndu IK: Relationship between exclusive breastfeeding and lower risk of childhood obesity: a narrative review of published evidence. Clin Med Insights Pediatr 2017; 11: 1179556517690196.
18. Oddy WH, Mori TA, Huang RC et al.: Early infant feeding and adiposity risk: from infancy to adulthood. Ann Nutr Metab 2014; 64: 262–270.
19. Elenberg Y, Shaoul R: The role of infant nutrition in the prevention of future disease. Front Pediatr 2014; 2: 73.
20. Piekarzewska M, Wieczorkowski R, Zajenkowska-Kozłowska A: Stan zdrowia ludności Polski w 2014 r. Główny Urząd Statystyczny, Warszawa 2016.
21. Kołodziej K, Piaseczna-Piotrowska A, Strzelczyk J: Uwarunkowania środowiskowe oraz rodzinne występowania otyłości u dzieci. Pol Merkur Lekarski 2010; 28: 195–198.

22. Uchwała Rady Ministrów w sprawie ustanowienia programu wieloletniego „Narodowy Program Zdrowia na lata 2016–2020". Warszawa 2015. Available from: http://www.legislacja.gov.pl/docs//2/12270850/12281779/12281780/dokument164277.pdf [cited: 23 May 2018].

23. Banach M, Jankowski P, Jóźwiak J et al.: Wytyczne PTL/KLRwP/PTK postępowania w zaburzeniach lipidowych dla lekarzy rodzinnych 2016. Lekarz POZ 2016; 2: 254–300.

24. Banaś I, Kardas P: Pomiar obwodu talii u dzieci i młodzieży narzędziem przesiewowym oceny czynników ryzyka chorób sercowo-naczyniowych. Forum Med Rodz 2011; 5: 229–238.

25. Stawerska R, Szałapska M, Borowiec M et al.: The influence of *INS* VNTR class III allele on auxological parameters, glucose, insulin, lipids, and adipocytokines secretion in prepubertal children born small for gestational age. Endokrynol Pol 2016; 67: 585–591.

26. Huang Y, Li Y, Chen Q et al.: Low serum adiponectin levels are associated with reduced insulin sensitivity and lipid disturbances in short children born small for gestational age. Clin Endocrinol (Oxf) 2015; 83: 78–84.

27. Plüddemann A, Thompson M, Price CP et al.: Point-of-care testing for the analysis of lipid panels: primary care diagnostic technology update. Br J Gen Pract 2012; 62: 224–226.

28. Hajar R: Diabetes as "coronary artery disease risk equivalent": a historical perspective. Heart Views 2017; 18: 34–37.

29. World Health Organization: Diabetes. Available from: http://www.who.int/mediacentre/factsheets/fs312/en [cited: 23 May 2018].

30. Zalecenia kliniczne dotyczące postępowania u chorych na cukrzycę 2016. Stanowisko Polskiego Towarzystwa Diabetologicznego. Diabetologia Kliniczna 2016; 5 (supl. A): A1–A76.

31. Kaźmierczak-Pilch B, Kaźmierczak J, Frąckiewicz J et al.: Stan odżywienia i wybrane czynniki ryzyka miażdżycy u młodych osób dorosłych a ich masa urodzeniowa. Pediatr Med Rodz 2018; 14: 293–300.

DOI: 10.15557/PiMR.2019.0010 PEDIATR MED RODZ Vol. 15 No. 1, p. 57–66