

# Smoking during pregnancy – hematological observations in pregnant women and their newborns after delivery

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## Abstract

Cigarette smoking is a global public health problem. According to the current estimations, more than one billion people worldwide smoke tobacco. The highest prevalence of smoking is observed in Europe and Central Asia. In Poland, nearly a half of males and 1/3 of females are smokers. Information concerning an increase in the prevalence of tobacco smoking among women is alarming. It is estimated that tobacco smoking is the cause of approximately 10% of deaths worldwide. If the present trend maintains itself, in the present 21<sup>st</sup> century nearly one billion people will prematurely lose their lives due to tobacco smoking. Tobacco smoking by pregnant women additionally exerts a negative effect on the developing foetus. The objective of the study was analysis of haematological parameters of the erythropoietic system in pregnant women and their newborn babies after delivery according to the number of cigarettes smoked daily by the mothers in pregnancy. The studies were based on the questionnaire forms. The studies were carried out in all hospitals in Poland where pregnant women were hospitalized with their newborns on one day in 2010 and 2011. The material for the study were replies to the questions concerning the results of blood tests of mothers and newborns. No significant changes concerning haematological parameters of the erythropoietic system were observed in women after delivery. With respect to newborns, an increase was noted in the level of haemoglobin in the babies of women who, in the third trimester of pregnancy, smoked more than 6 cigarettes daily. The hematocrit value and amount of erythrocytes did not change. The results of the studies showed that tobacco smoking in pregnancy exerts a negative effect on the environment in which the foetus develops, and consequently, on the health of newborn babies.

## Key words

tabacco smoking, pregnancy, newborns, haemoglobin

## INTRODUCTION

Smoking is the most prevalent form of tobacco consumption. It is estimated that more than 1.1 billion people worldwide smoke tobacco, which constitutes 1/3 of the world population aged over 15 [1]. Although in the countries with a high income the number of smokers decreases, this trend is opposite in the countries with low and mediocre income, where an increase is observed in the prevalence of smoking [2]. On a world scale, tobacco smoking among males considerably exceeds smoking by females. This difference is slightly smaller in highly developed countries, where 24% admit that they smoke, compared to 7% in the developing countries [3]. According to data by the WHO, globally, the problem of tobacco smoking concerns 47% of males and 12% of females [1]. The highest prevalence of smoking is noted in Europe and Central Asia [2]. Although in the countries of Europe nearly a half of males smoke tobacco, the discrepancies between individual countries are considerable. In the Russian Federation, as many as 63% of males are smokers, whereas in Sweden – 17% [4]. In Poland, the prevalence of smoking among males is 46%, while in females aged 20-44 – 31% [5].

In the population of Polish adolescents, 11.82% of 15-year-olds declare that they smoke tobacco, and this prevalence systematically increases to reach the level of 28.18% among 19-year-olds [6]. At present in Europe, a decrease is observed in the consumption of tobacco by males, with a simultaneous increase in its consumption by females [7].

Tobacco smoking kills one person every 6 minutes [8]. 10% of all deaths worldwide are caused by tobacco. Only this year, it will be the cause of death of nearly 5 million people [8], and by 2030 this number will increase to 8 million annually [8, 9]. Further calculations are even more alarming. If decisive actions are not undertaken, aimed at the reduction in the frequency of tobacco consumption, 500 million people living today will die due to this reason [10]. As a result, in the present 21<sup>st</sup> century, 1 billion people will prematurely die due to tobacco use [11]. This is a tremendous increase in mortality, compared with the 20<sup>th</sup> century, when tobacco was the cause of death of approximately 100 million people [2].

The presence of a high level of CO leads to a functional anaemia both in the mother and the foetus. A compensatory mechanism is the production of red blood cells in both in the mother and the foetus, and increase in the hematocrit level in both [12, 13, 14]. An increased level of hematocrit may lead to an increased blood viscosity in the mother. The consequence of such a situation may be an abnormal placental flow, which will additionally lead to the reduction in oxygen

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transport for the needs of the foetus and intensification of hypoxia [13, 15].

## STUDY OBJECTIVES

- 1) Analysis of haematological parameters of the erythropoietic system in women after delivery, according to the number of cigarettes smoked daily in pregnancy.
- 2) Analysis of haematological parameters of the erythropoietic system in newborns after birth, according to the number of cigarettes smoked daily by their mothers in pregnancy.

## METHODS

In the presented report, the results of population studies were conducted in Poland within the monitoring of mother and child health – Pregnancy-related Assessment Monitoring System (PrAMS-BabyMo). The study was conducted in all hospitals in Poland where mothers were hospitalized after giving birth with their newborn babies, on a single day in 2010 and 2011. The survey was carried out with the use of a questionnaire form consisting of two sections. Mothers, hospitalized after delivery with their newborn babies, completed the first section of the questionnaire themselves (self-questionnaire), whereas the second section was completed by specialized medical staff (physician or nurse) providing care of the mother and her baby.

The results are obtained from replies provided by the medical staff concerning the results of a blood test of the

mothers and their newborn babies. Not all questionnaires were completed with regard to the items concerning all the three blood parameters analyzed (levels of haemoglobin, hematocrit, red blood cells). Therefore, there are certain differences concerning groups (n) of the mothers and newborns who had individual blood parameters analysed. A detailed description of the research methodology was described by Wojtyła A, et al [6] in other work also based on the Pregnancy-related Assessment Monitoring System (PrAMS-BabyMo). Figure 1 [6], presents chronology and methodology of research.

## STATISTICAL ANALYSIS

Statistical analysis was performed using the Statistica 8.1 PL computer package. Variables were presented as frequency table and bar chart, descriptive statistics and contingency tables. In the latter, the relationships between categorical variables were analysed by the Pearson Chi<sup>2</sup> test and between continuous and categorical variables with analysis of variance.

## RESULTS

In the questionnaire forms, the replies to questions concerning tobacco smoking were obtained from 5,214 pregnant women. A part of this group had a blood test performed after delivery. The results of a blood test were also obtained in the group of newborns. Figure 2 presents the data concerning prevalence of smoking among women in the third

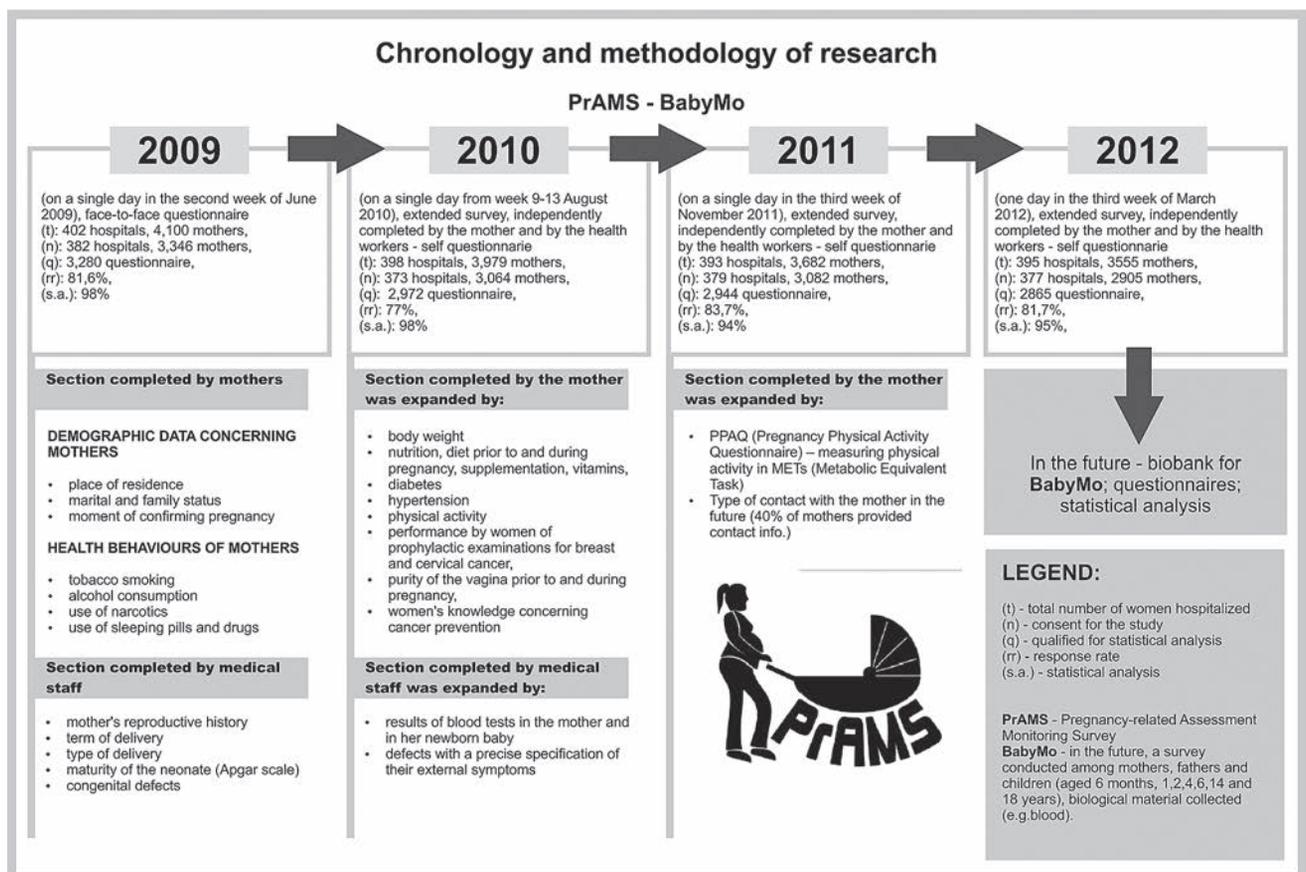
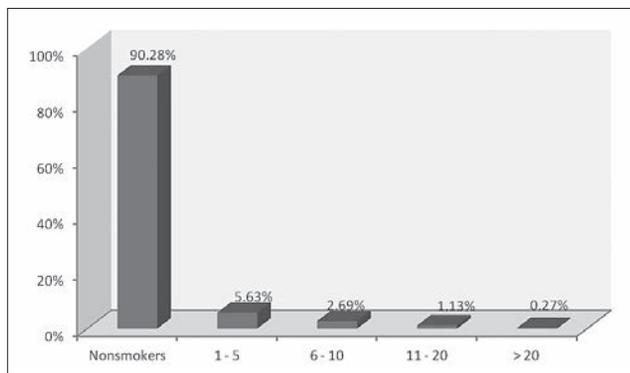


Figure 1. Chronology and methodology of research

trimester of pregnancy. Table 1 shows the characteristics of the group of women in the study.



**Figure 2.** Percentage distribution of the group of women examined according to the number of cigarettes smoked daily in the third trimester of pregnancy.

**Table 1.** Characteristics of the group of women examined.

Characteristics of women	Non-smokers	Smokers
<b>Age</b> (n=5014)	28.0 (n=4,530)	26.1 (n=484)
<b>Place of residence</b> (n=5,107)		
• Urban area >500,000 population	10.5%	1.0%
• Urban area 100–500,000 population.	11.7%	1.2%
• Urban area 50,000–100,000 population	9.9%	1.1%
• Urban area 10,000–50,000 population	14.4%	1.5%
• Urban area <10,000 population	5%	0.8%
• Rural area	38.9%	4.0%
<b>Education level</b> (n=5,161)		
• Elementary/no education	2%	1.3%
• Junior high school	1.9%	1.1%
• Vocational post-junior high school	11.8%	2.7%
• Secondary school	7.5%	1.0%
• Post-secondary school	21.5%	2.0%
• University vocational (licentiate, engineer)	12.5%	0.6%
• University master's degree	31.2%	0.7%
• Other	1.9%	0.3%
<b>Pregnancy</b> (n=5,111)		
• First	42.9%	4.5%
• Second	30.9%	2.7%
• Third	11.1%	1.5%
• Fourth	3.7%	0.7%
• Fifth	1.0%	0.2%
• Sixth	0.3%	0.1%
• Seventh and more	0.3%	0.1%

Over 90% (n = 4,707) of women declared that they did not smoke cigarettes in the third trimester of pregnancy. Among those who were smokers 5.63% (n = 294) smoked 1-5 cigarettes daily; 2.69% (n = 140) declared that they smoked 6-10 cigarettes daily, 1.13% (n = 59) of women smoked 11-20 cigarettes, while only 0.27% (n = 14) smoked more than one packet of cigarettes in the third trimester of pregnancy. Tables 2, 3, and 4 present the results of blood test after delivery.

Cigarette smoking in the third trimester of pregnancy had no effect on the haematological parameters of the erythropoietic

**Table 2.** Level of haemoglobin in women after childbirth according to the number of cigarettes smoked daily in the third trimester of pregnancy

	Mean (g/dl)	SD	No.	p ANOVA
<b>Non-smokers</b>	11.0	1.7	2,735	
<b>1-5</b>	10.9	1.8	189	
<b>6-10</b>	11.0	1.9	78	
<b>11-20</b>	11.3	1.7	38	
<b>&gt;20</b>	11.5	1.2	9	
<b>Total</b>	11.0	1.7	3,049	0.586

**Table 3.** Hematocrit level in women after childbirth according to the number of cigarettes smoked daily in the third trimester of pregnancy

	Mean (%)	SD	No.	p ANOVA
<b>Non-smokers</b>	33.5	4.5	2,707	
<b>1-5</b>	33.2	4.5	194	
<b>6-10</b>	34.2	5.3	73	
<b>11-20</b>	33.9	4.3	38	
<b>&gt;20</b>	33.6	3.6	10	
<b>Total</b>	33.5	4.5	3,022	0.547

**Table 4.** Red blood cell count in women after childbirth according to the number of cigarettes smoked daily in the third trimester of pregnancy

	Mean (mln/dm <sup>3</sup> )	SD	No.	p ANOVA
<b>Non-smokers</b>	3.8	0.7	2,712	
<b>1-5</b>	3.7	0.7	193	
<b>6-10</b>	3.8	1.0	77	
<b>11-20</b>	3.8	0.5	39	
<b>&gt;20</b>	3.8	0.3	10	
<b>Total</b>	3.8	0.7	3,031	0.613

system of women after childbirth. Haemoglobin in mothers did not change significantly (pANOVA=0.586). The replies to the survey questions concerning the level of haemoglobin were obtained from 3,049 mothers after delivery. Women who did not smoke cigarettes in the third trimester of pregnancy had haemoglobin level of 11.0 g/dl (n=2,735). Considering the number of cigarettes smoked daily: 1-5, 6-10, 11-20 and >20, the mean haemoglobin levels were: 10.9 g/dl (n=189), 11.0 g/dl (n=78), 11.3 g/dl (n=38) and 11.5 g/dl (n=9), respectively.

Also, no statistically significant differences were observed with respect to the hematocrit level (pANOVA=0.547). Replies to the survey questions concerning the level of hematocrit were obtained from 3,022 mothers after delivery. Among women who did not smoke cigarettes, its level was 33.5% (n=2,707), while considering the number of cigarettes smoked daily: 1-5, 6-10, 11-20 and >20, the mean levels of hematocrit were: 33.2% (n=194), 34.2% (n=73), 33.9% (n=38), and 33.6% (n=10), respectively.

The mean red cell count did not change and both among non-smokers and smokers who smoked various number of cigarettes daily was 3.8 mln/mm<sup>3</sup> (pANOVA=0.613). Only women who smoked 1-5 cigarettes daily obtained the mean red cell count of 3.7 mln/mm<sup>3</sup> (n=193). The reply to the question concerning red cell count after delivery was obtained from 3,031 mothers.

However, different relationships were observed with respect to newborns of mothers who smoked cigarettes in the third trimester of pregnancy. The replies to the survey

questions concerning the level of haemoglobin in newborns after birth were obtained from the questionnaires concerning 1,656 newborn babies. The mean haemoglobin level in the newborns of mothers who declared that they did not smoke in the third trimester of pregnancy was 16.9 g/dl (n=1,482). This value increased with the number of cigarettes smoked daily, starting from 6 cigarettes smoked by the mother, and obtained the value of 19.0 g/dl (n=22) among babies of mothers who smoked from a half to one packet of cigarettes daily. Among babies of mothers who smoked more than one packet of cigarettes daily, a slightly lower value of haemoglobin was obtained – 18.0 g/dl (n=5). The levels of haemoglobin in newborns of mothers who smoked 1-5 and 6-10 cigarettes daily were 16.8 g/dl (n=103) and 17.6 g/dl (n=44), respectively. Thus, the changes in haemoglobin levels in newborns were statistically significant (pANOVA=0.022).

Such a relationship was not noted in the case of mean hematocrit values in newborns. In babies of mothers who did not smoke cigarettes in the third trimester of pregnancy this value was 50.8% (n=1,475). However, a decrease in the hematocrit value was observed in the newborns of mothers who declared that they smoked from 1-5 cigarettes daily – 49.6% (n=104), on average, and reached increasingly higher values with the number of cigarettes smoked daily, beginning from 6 daily. With 6-10 cigarettes smoked daily by mothers in the third trimester of pregnancy, the mean hematocrit level in newborns was 50.9% (n=43). This value increased up to 54.2% (n=21) among newborns of mothers who declared that they smoked 11-20 cigarettes daily, and similar to haemoglobin, reached a lower value in the group of women who admitted smoking more than 20 cigarettes daily – the mean value being 52.6% (n=5). However, these changes were statistically insignificant (pANOVA=0.547). With respect to the level of hematocrit, the replies were obtained from questionnaires concerning 1,648 newborns.

No significant changes were also observed considering the mean red blood cell count in newborns of mothers who smoked cigarettes in the third trimester of pregnancy, compared to those who did not smoke cigarettes at all (pANOVA=0.613). The babies of mothers who did not smoke cigarettes had a mean red blood cell count of 5.0 mln/dm<sup>3</sup> (n=1,429), while for the number of cigarettes: 1-5, 6-10, 11-20 and > 20 these values were: 4.9 mln/dm<sup>3</sup> (n=99), 5.2 mln/dm<sup>3</sup> (n=44), 5.2 mln/dm<sup>3</sup> (n=22), and 5.2 mln/dm<sup>3</sup> (n=5), respectively. The replies to the survey questions concerning red blood cell count were obtained concerning 1,599 newborns.

Tables 5, 6, and 7 present the relationships between the number of cigarettes smoked daily in the third trimester of pregnancy, and the mean values of the selected parameters of the erythropoietic system in their newborn babies.

**Table 5.** Haemoglobin level in newborns after birth according to the number of cigarettes smoked by their mother daily in the third trimester of pregnancy

	Mean (g/dl)	SD	No.	p ANOVA
<b>Non-smokers</b>	16.9	3.3	1,482	
<b>1-5</b>	16.8	3.0	103	
<b>6-10</b>	17.6	3.4	44	
<b>11-20</b>	19.0	3.2	22	
<b>&gt; 20</b>	18.0	1.3	5	
<b>Total</b>	16.9	3.3	1,656	0.022

**Table 6.** Hematocrit level in newborns after birth according to the number of cigarettes smoked by their mother daily in the third trimester of pregnancy

	Mean (%)	SD	No.	p ANOVA
<b>Non-smokers</b>	50.8	7.9	1,475	
<b>1-5</b>	49.6	9.5	104	
<b>6-10</b>	50.9	8.8	43	
<b>11-20</b>	54.2	6.8	21	
<b>&gt; 20</b>	52.6	3.4	5	
<b>Total</b>	50.7	8.0	1,648	0.186

**Table 7.** Red blood cell count in newborns after birth according to the number of cigarettes smoked by their mother daily in the third trimester of pregnancy

	Mean (mln/dm <sup>3</sup> )	SD	No.	p ANOVA
<b>Non-smokers</b>	5.0	0.8	1,429	
<b>1-5</b>	4.9	0.6	99	
<b>6-10</b>	5.2	1.3	44	
<b>11-20</b>	5.2	0.7	22	
<b>&gt; 20</b>	5.2	0.3	5	
<b>Total</b>	5.0	0.8	1,599	0.210

## DISCUSSION

Tobacco smoking is an exceptionally dangerous habit for pregnant women, because apart from exerting a negative effect on the mother it also exerts a not smaller but rather a greater effect on the developing foetus. The studies show that tobacco smoking is a risk factor for infertility and women who smoke become pregnant less easily [16]. With respect to newborns, tobacco smoking by pregnant women causes, among other things, abortions, low birth weight of the newborn, inhibition of intrauterine growth of the foetus, increase in the risk of ectopic pregnancy, and the development of other complications; it also increases the risk of sudden infant death, has a negative effect on the intellectual development of the child [16], and increases the risk of becoming a smoker in the future [17].

Despite an increasingly greater awareness of pregnant women concerning the negative effects of tobacco smoking on the development of the foetus and the functioning of a child, still only ¼ of women discontinue smoking in association with pregnancy [16]. Within the last 10 years in the United States, the percentage of pregnant women who smoked tobacco decreased from 18% in 1990 [18] to 12% in 2001 [19]. Nevertheless, considering teenage mothers, the prevalence of smoking at the beginning of the present century was 17.5% of this population group, which is an increase from 16.7% in 1994 [19]. It should be mentioned that the discontinuation of tobacco smoking is the most effective action which allows the reduction of the risk of an unfavourable pregnancy outcome. Therefore, it is very important to make young women and future mothers aware of this way of reduction of potential complications.

While comparing women who smoked cigarettes and those who were non-smokers, no statistically significant effect of smoking on the values of the examined parameters was observed. Similar observations were made by Bureau et al. [13], Nilsen et al. [20] and Dennis et al. [21].

In the studies conducted by Habek et al. [22], a decrease was noted in the values of Hb, Ht and RBC, together with an increase in the number of cigarettes smoked by women during pregnancy. Women who did not smoke had haemoglobin on the level of 12.1 g/dl., this value decreased down to 11.8 g/dl in those who smoked <20 cigarettes daily, and to 10.6 g/dl in those who smoked >20 cigarettes daily. Similar relationships were observed for the level of hematocrit and red blood cell count. Similar to haemoglobin levels, the values of hematocrit were: 35%, 32% and 29%, respectively, while the red blood cell count was 3.5 mln/mm<sup>3</sup>, 3.4 mln/mm<sup>3</sup>, and 3.1 mln/mm<sup>3</sup>.

In the studies by Zafar et al. [23], tobacco smoking was also associated with a decrease in the erythrocytes count and level of haemoglobin, compared to non-smokers.

The result obtained in the presented studies is also inconsistent with the results of other studies with which we are familiar [24, 25], where an increase in haematological parameters in smokers was also found.

In women who smoked in pregnancy, an increase was noted in the vascular resistance of maternal-foetal circulation, compared to pregnant women who did not smoke tobacco [26]. This effect depends on the concentration of CO measured in the blood of mothers. Its growth causes a dose-dependent increase in vascular resistance in the umbilical and uterine arteries. This disturbs blood flow and impairs the normal development of the foetus. Due to the reduced oxygen supply, the foetus develops in hypoxic conditions [27, 28]. The compensatory mechanism leading to the satisfaction for the demand of the foetus for oxygen is the activation of erythropoiesis [12, 29, 30, 31], expressed by an increase in haematological parameters of the erythropoietic system of the foetus.

The results of the presented studies are similar to the results obtained by Al-Alawi et al. [32] and Habek et al. [22] who, in their studies, observed an increase in Hb in the newborns of mothers who smoked cigarettes during pregnancy. This increase depended on the number of cigarettes smoked to such a degree that among newborns of mothers who smoked more than 20 cigarettes daily, polycythemia was more often noted. In the presented studies, smoking of more than 20 cigarettes daily was associated in most cases with a slight decrease in the level of Hb; nevertheless, these values were still higher than in babies of mothers who did not smoke in pregnancy. Other studies available [12, 31, 33, 34] also confirm the results of the presented studies with respect to the level of Hb; however, they also indicate an increase in the value of Ht. Similar relationships were also found by Bureau et al. [13]. Nevertheless, in their studies, no cases of polycythemia were observed among newborns of smoking mothers. Other studies [12, 34] also indicate an increase in red blood cell count in newborns of mothers who smoked cigarettes during pregnancy. The presented studies did not confirm these findings; however, they are consistent with investigations carried out by Mercelina-Roumans et al. [35], in which no relationship was found between cigarette smoking by pregnant women and an increase in red blood cell count in their newborn babies.

The studies conducted by Gam et al. [31], Knottnerus et al. [15] and Mercelina-Roumans et al. [35] confirmed the results of the presented studies with respect to the level of Ht, the changes of which were insignificant. In the above-mentioned studies, no significant changes in Hb levels were observed, and according to these studies, smoking by pregnant women

was not related with an increase in the above-mentioned blood parameters among newborns.

Studies were also conducted [36] in a group of Polish women, where no statistically significant differences in Hb, Ht and RBC were observed between newborns of mothers who smoked and did not smoke during pregnancy. Among babies of mothers who did not smoke tobacco, the mean Hb value was on the level of 19.06 g/dl, the mean Ht level – 54.01% and RBC – 5.28 mln/dm<sup>3</sup>. The values obtained in the group of newborn babies whose mothers were active smokers were 19.64 g/dl, 57.21% and 5.41 mln/dm<sup>3</sup>, respectively. Thus, the values obtained partly confirm the results of the presented studies. No significant differences were noted with respect to Ht and RBC, which confirms the conclusions of the presented studies. Additionally, no significant differences concerning Hb were found which, however, was not confirmed by the presented studies.

The studies were based on questionnaire forms, the first part of which was completed by the pregnant women themselves. This might have resulted in underestimation of the group of women who are smokers. In the developed countries, there is a high social awareness concerning the hazardous effect of tobacco smoking on human health and, in most cases, tobacco smoking during pregnancy is evaluated in negative terms. This brings about the risk that this type of data collection is not completely reliable. Although the questionnaires were completed anonymously, the women in the survey could have underreported the number of cigarettes smoked, or omitted to mention this fact and, in consequence, were qualified to the group of non-smokers. A more valuable method of qualification into individual groups might be the examination of the cotinine level in the blood or saliva. West et al. [37] investigated the prevalence of tobacco smoking by comparing the replies to questionnaire items completed by the respondents themselves, and the level of cotinine in their blood or saliva. The researchers observed significant differences between the results obtained by using both methods. In Poland, the underestimation was 6.0%. This is a considerable difference, which could have exerted a significant effect on the results of the above-mentioned studies. Therefore, similar studies should be carried out and pregnant women should be classified into adequate groups based on the measurement of the level of cotinine in their blood or saliva.

## CONCLUSIONS

No significant differences concerning haematological parameters of the erythropoietic system were observed between pregnant women who smoked cigarettes in the third trimester of pregnancy and those who were non-smokers.

An increase was noted in the level of haemoglobin among newborns of mothers who smoked more than 5 cigarettes daily. This is a manifestation of chronic exposure to the effect of carbon monoxide and the development of the foetus in hypoxic conditions. This is an attempt by the foetus to adapt to the insufficient amount of oxygen supplied. Such changes were not found with respect to the red blood cell count and Ht value.

The results of the presented studies indicate that smoking by women during pregnancy has an effect on the environment in which the foetus develops, and also on the child's health

after birth. The degree to which tobacco smoking by pregnant women contributes to the development of polycythemia in their newborn babies, which may exert an additional negative effect on their health, should be additionally investigated [38].

Similar studies should be carried out and pregnant women should be classified into adequate groups based on the measurement of the level of cotinine in their blood or saliva.

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