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The Influence of Mother's Active Smoking during Pregnancy on Body Mass Index of Newborns

Ivan Pavić[1], Slavica Dodig[1], Marija Jurković[2], Tereza Krmek[2] and Đurđa Španović[3]

[1] Srebrnjak Children's Hospital, Zagreb, Croatia
[2] General Hospital Vinkovci, Pediatric Unit, Vinkovci, Croatia
[3] Pediatrition Office Dubrava, Zagreb, Croatia

A B S T R A C T

Many investigations have noted bad influence of smoking during pregnancy. In the present article, the influence of mothers smoking during pregnancy on the body mass index (BMI), birth weight and birth length are examined. This retrospective research included 219 children: Group I: 109 children from rural area of east Slavonia (born in General Hospital-Vinkovci) and group II: 110 children from industrial area (born in Zagreb). The questioned subjects were divided into two groups depending on mothers smoking during pregnancy: newborns of mothers who didn't smoke during pregnancy (subgroup A) and newborns of mother who did smoke 10 or more cigarettes per day during pregnancy (subgroup B). Anthropometric parameters (BMI, birth length and birth weight) in newborns of non-smoking mothers were statistically higher ($p<0.05$) than in newborns of smoking mothers. Moderate correlation between birth length and birth weight in newborns of non-smoking and smoking mothers from rural area and from non-smoking mothers in urban area was statistically significant, but correlation in the group in newborns of smoking mothers from Zagreb was not statistically significant. Results of this research show that smoking during pregnancy significantly influences the birth weight and birth length. Further investigation is needed, to investigate the lack of correlation between the birth length and birth weight in newborns of smoking mothers from industrial city.

Key words: *mothers smoking during pregnancy, body mass index, birth weight, birth length*

Introduction

Smoking is the activity of breathing in tobacco smoke from a cigarette, cigar and pipe. There are about 1,3 billion smokers worldwide[1]. According to some statistics more then 17 million women in reproductive age are smokers, and only 20% of them stop smoking during pregnancy[2], while Hakansson et al. showed that 76% of smoking women continue to smoke during pregnancy[3].

Cigarette smoke contains an amazing array of gaseous and particulate compounds. The smoke from cigarette contains more then 4000 compounds, including more then 50 human carcinogens and many irritant and toxic agents[4], with emphasis on nicotine, benzopyrene and carbon-monoxide (CO).

Toxic ingredients in cigarette smoke cause damage not only to smokers but also to non-smokers by passive smoking. Bad influence of active and passive smoking is especially during pregnancy, because it influences the health of both woman and her unborn baby[5–7]. So, child could be exposed to tobacco smoke intrauterine, if mother smokes or if she is passively exposed to environmental tobacco smoke during pregnancy. Many investigations have noted bad influence of smoking on reproduction, such as conceiving problem[8,9], more risk for spontaneous abortion[8], increased risk of preterm baby[5,8,10–12], risk of having a low-birth weight baby[8,10,13–18], risk of having low-birth length baby[14,15,17,19,20], risk of premature rupture of the membranes, placenta previa, placental abruption and high risk of perinatal mortality[5,21,22].

The aim of this retrospective study was to find the incidence of smoking during pregnancy, the influence of smoking during pregnancy on birth weight, birth length and body mass index (BMI). The hypothesis was that there are differences between newborns of smoking and non-smoking mothers.

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Children from Ivankovo (rural area of east Slavonia, about 5500 citizens) and from Zagreb (industrial area, about 800 000 citizens) were compared, because of their different agricultural environment.

Subjects and Methods

This retrospective study included 219 children, 132 boys and 87 girls (Table 1). Subjects were divided into two groups depending on their birth place:

- Group I: newborns born in the General hospital Vinkovci from February 2001. to June 2003., N=109; after dismissed from hospital they were examined at doctor's office Ivankovo,
- Group II: newborns born in the Clinical hospital Zagreb at the same period as the newborns from Vinkovci, N=110; children were examined from June to October 2009. by paediatrician at doctor's office in Dubrava-Zagreb.

In this study we included newborns of healthy mothers, who didn't take any medications during pregnancy and with remarkable family and personal history. Children were conceived in natural way, with no problems during pregnancy and delivery, and all children were born on time. Anthropometric measurements were taken in the delivery room, just after the birth. Information about exposition to tobacco smoke, course of pregnancy and health status of newborns was collected from self-created questionnaire.

Subjects were divided into two groups depending on mothers smoking habits during pregnancy:

- Subgroup A – newborns of mothers who didn't smoke during pregnancy, N=156,
- Subgroup B – newborns of mothers who did smoke 10 or more cigarettes *per* day during pregnancy, N=63.

Birth weight is expressed in grams, birth length is expressed in centimetres and BMI is expressed in kgm^{-2}. Continuous variables were described as mean ($\overline{X}$) and standard deviation (SD) if they had normal distribution, or median (M) and interquartile (IQR) range if not. Comparisons between variables were made using χ^2-test, Student t-test or Mann-Whitney test. Correlation of the birth weight and birth length was expressed by coefficient of rank correlation (r). Values of $p<0.05$ were considered statistically significant. Receiver operating characteristics (ROC) curve analyses was undertaken for expression of diagnostic values of chosen anthropometric measurements. Data processing was performed using MedCalc software (Medisoftware, Mariakerke, Belgium).

Results

In both groups there were more boys than girls (Table 1) and there was no statistically significant difference in boys to girls ratio in the group (χ^2=0.780; p=0.377). In group I there were 26.6% (29/109) smokers, and in group II 30.9% (34/110). There was no statistically significant difference in smokers to non-smokers ratio between these two groups (χ^2=0.307; p=0.580). There was no statistically significant difference in birth length (p=0.2619), birth weight (p=0.4708) and in BMI (p=0.7955) in children born both in Vinkovci and Zagreb.

When anthropometric parameters were compared between boys and girls in both groups (Table 2) there was statistically significant difference in birth length (Group I – p=0.0004; Group II – p=0.0126), but there was no statistically significant difference in birth weight (Group I – p=0.0741; Group II – p=0.0516) and in BMI (Group I – p=0.871; Group II – p=0.5578).

In both groups newborns of non-smoking mothers (Table 3, subgroup A) had statistically significant larger birth length then newborns of smoking mothers (subgroup B). Newborns of non-smoking mothers from Vin-

TABLE 1
CHARACTERISTICS OF STUDIED GROUPS: GROUP I – NEWBORNS FROM VINKOVCI; GROUP II – NEWBORNS FROM ZAGREB

	Group I	Group II	Total
N	109	110	219
Male	62	70	132
Female	47	40	87
Male/Female ratio	1.3	1.8	1.5
A – Non-smoking mothers (N)	80	76	156
B – Smoking mothers (N)	29	34	63
A/B ratio	2.8	2.2	2.5
Length, $\overline{X}$±SD (cm)	50.8±1.8	51.0±1.8	50.9±1.8
Mass, $\overline{X}$±SD (g)	3460±434	3563±429	3541±431
BMI (kgm^{-2})			
$\overline{X}$±SD		13.6±1.2	
M (IQR)	13.5 (12.9–14.4)		13.6 (12.8–14.4)

N – number of subjects, BMI – Body Mass Index, SD – standard deviation, M – median, IQR – Inter Quartile Range

TABLE 2
BODY LENGTH, MASS AND BMI OF MALE AND FEMALE NEWBORNS FROM VINKOVCI (GROUP I) AND ZAGREB (GROUP II)

	Group I		Group II	
	Male	Female	Male	Female
Length (cm)				
$\overline{X}$±SD	51.3±1.8	50.1±1.7[a]	51.2±1.9	50.3±1.6[b]
Mass (g)				
$\overline{X}$±SD	3585±441	3436±413	3578±433	3422±428
BMI (kgm^{-2})				
$\overline{X}$±SD	13.6±1.1		13.6±1.1	13.5±1.3
M (IQR)		13.7 (12.7–14.2)		

BMI – Body Mass Index, SD – standard deviation, M – median, IQR – Inter Quartile Range, [a] p=.0004: Male : female, [b] p=.0126: Male : female

kovci (51.3±1.7 cm) were 1.9 cm (3.8%) longer then newborns of smoking mothers (49.4±1.4 cm), $p<0.0001$. Newborns of non-smoking mothers from Zagreb (51.8±1.5 cm) were 2.5 cm (5.1%) longer then newborns of smoking mothers (49.3±12 cm), $p<0.0001$.

In Group I median birth weight in newborns of non-smoking mothers (Table 3, subgroup A) was 3640 g, while median birth weight in newborns of smoking mothers (Subgroup B) was 3180 g. Newborns of non-smoking mothers had 447 g (14%) more than newborns of smoking mothers. In Group II median birth weight in newborns of non-smoking mothers was 3743 g, while median birth weight in newborns of smoking mothers (subgroup B) was 3159 g. Newborns of non-smoking mothers had 584 g (18%) more then newborns of smoking mothers. There was statistically significant difference in both groups ($p<0.0001$).

BMI in both groups was higher in newborns of non-smoking mothers (Table 3). Mean BMI in newborns of non-smoking mothers was 13.9 kgm^{-2}, both in Group I and in Group II, while mean BMI in newborns of smoking mothers was 13.2 kgm^{-2} (Group I) and 13.0 kgm^{-2} (Group II). BMI was 0.7 kgm^{-2} (5.3%) higher in new, while it was 0borns of non-smoking mothers from Vinkovci (p=0.0023).9 kgm^{-2} (6.9%) higher in newborns of non-smoking mothers from Zagreb (p=0.0001).

There was statistically significant difference in birth length in newborns of non-smoking mothers from Vinkovci and Zagreb (Table 3, subgroup A). Newborns of non-smoking mothers from Zagreb (birth length 51.3±1.7) were 0.5 cm longer then newborns of non-smoking mothers from Vinkovci (51.8±1.5). There was statistically significant difference, p=0.0328. There was no statistically significant difference in birth weight and BMI between group I and II ($p>0.05$).

Correlation between length and mass (Figure 1) in newborns from Vinkovci, both of mothers non-smokers (Figure 1a) (r=0.706; $p<0.0001$), and smokers (Figure 1b) (r=0.673; p=0.0004), and in newborns from Zagreb of non-smoking mothers was partial (Figure 1c) (r=0.563; $p<0.0001$). There was no significant correlation between length and mass (r=0.338) in newborns from Zagreb of smoking mothers (Figure 1d) (p=0.050).

ROC analysis of anthropometric data between newborns of smoking and non-smoking mothers (Table 4, Figure 2) has shown very good diagnostic efficiency for cut-off value of birth length (AUC=0.853; cut-off ≤50 cm) and birth weight (AUC=0.852; cut-off ≤3370 g) and good diagnostic efficiency for BMI (AUC=0.697; cut-off ≤13.5 kgm^{-2}). Statistical significance was p=0.0001 for all parameters, except for BMI (p=0.0014). Diagnostic sensitivity and specifity for birth length and birth weight were almost equal (Table 4), but for BMI diagnostic sensitivity (76%) was better than diagnostic specificity (62%). Negative predictive value (NPV) was greater than positive predictive values (PPV) for all selected parameters.

TABLE 3
BODY LENGTH, MASS AND BMI OF MALE AND FEMALE NEWBORNS OF NON-SMOKING MOTHERS (SUBGROUP A) AND SMOKIN MOTHERS (SUBGROUP B) FROM VINKOVCI (GROUP I) AND ZAGREB (GROUP II)

	Group I		Group II	
	Subgroup A	Subgroup B	Subgroup A	Subgroup B
Length (cm)				
$\overline{X}$±SD	51.3±1.7	49.4±1.4 [a]	51.8±1.5	49.3±1.2 [a]
Mass (g)				
$\overline{X}$±SD	3640±412		3743±349	3159±299 [a]
M (IQR)		3180 (2930–3343) [a]		
BMI (kgm^{-2})				
$\overline{X}$±SD		13.2±0.9	13.9±1.1	13.0±1.2 [c]
M (IQR)	13.9 (13.0–14.5) [b]			

BMI – Body Mass Index, SD – standard deviation, M – median, IQR – Inter Quartile Range, [a] p<.0001: Subgroup A : Subgroup B, [b] p=.0023: Subgroup A : Subgroup B, [c] p=.0001: Subgroup A : Subgroup B

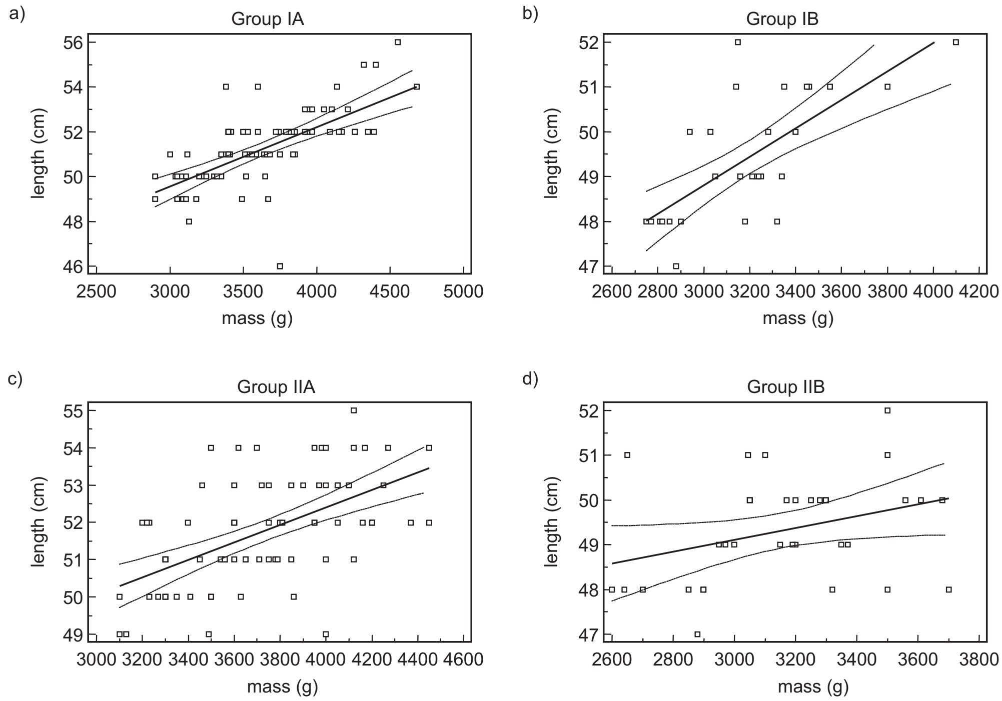

Fig. 1. Correlation (presented as scatter diagram and regression line) between length and mass in newborns from Vinkovci, from non-smoking mothers (A) (R=.706; p<.0001), and smoking mothers (B) (R=.673; p=.0004), and in newborns from Zagreb, from non--smoking mothers (C) (p=.563; p<.0001), and smoking mothers (D) (R=.338; p=.050), respectively 95% confidence interval is also presented.

TABLE 4
ROC CURVE ANALYSIS OF BIRTH LENGTH, BIRTH WEIGHT AND BMI OF NEWBORNS – COMPARISON BETWEEN NEWBORNS OF SMOKING MOTHERS AND NON-SMOKING MOTHERS

	Length	Mass	BMI
AUC	.853	.853	.712
p	.0001	.0001	.0001
Cut off value	≤50 cm	≤3370 g	≤13.5 kgm^{-2}
Sensitivity	79%	79%	76%
Specificity	75%	78%	62%
PPV	56%	59%	45%
NPV	90%	90%	87%

AUC – area under the curve, PPV – positive predictive value, NPV – negative predictive value

Discussion

Our hypothesis that there are differences in BMI, birth weight and birth length between newborns of smoking and non-smoking mothers is confirmed. Smoking during pregnancy has statistically significant influence on BMI, birth length and birth weight. Newborns of smoking mothers had lower birth weight, shorter birth length and lower BMI then newborns of non-smoking mothers, both in Vinkovci and Zagreb.

We found that one third of all women were smoking during pregnancy (26.6% in rural area, 30.9% in urban area), which is similar to the results of others authors. Latin et al. reported 25.3% women were smoking during pregnancy[23], Frković et al. found that 25.8% women were smoking during pregnancy[11], while Owen et al. found

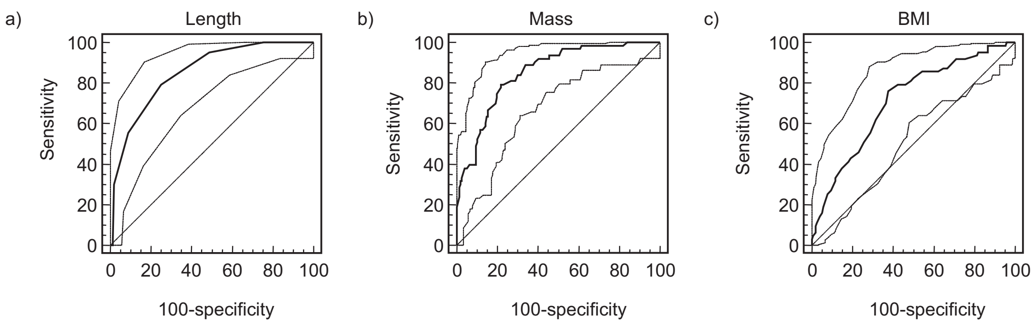

Fig. 2. ROC curve analysis of birth length (A), birth weight (B) and BMI (C) of newborns – comparison between newborns of smoking mothers (N=63) and newborns of non-smoking mothers (N=156).

that incidence of smoking during pregnancy in England was 28%[24]. Passive exposure to tobacco smoke could be different in different area. Meyer et al. found that 40% of children were exposed to passive smoking during pregnancy[25], while Kleinman and Madans found that 50% of children were exposed to passive smoking during pregnancy[16]. The results from Ventura et al. showed that 12.2% of women who gave birth during 2000. in the USA, were smoking during pregnancy[26]. Paul et al. found that tobacco-using mothers were more likely to be unmarried, adolescent, not college educate, and have late onset of prenatal care[27].

Newborns of smoking mothers have lower birth weight, even if mothers were passively exposed to tobacco smoke[5]. In this study anthropometric parameters (BMI, birth length and birth weight) in newborns of non-smoking mothers were statistically higher ($p<0.05$) than in newborns of smoking mothers, both in rural and urban area. The risk of having baby with 150–200 g lower birth weight is 2–3 times higher within the smoking mothers[16,25]. Klainman and Madans found that newborns of smoking mothers had 250 g lower birth weight than newborns of non-smoking mothers[16]. Obradović reported that newborns from smoking mothers who did smoke more than 10 cigarettes *per* day during pregnancy had 400 g lower birth weight and were 1.58 cm shorter than newborns of non-smoking mothers[17]. Meyer et al. showed that newborns of smoking mothers had 180 g lower birth weight than newborns of non-smoking mothers.[25] Voigt et al. found that smoking during pregnancy was strongly associated with lower birth weight and higher rate of small-for-gestational-age neonates[28]. They showed that especially women who smoke more than 10 cigarettes *per* day are at increased risk of experiencing foetal growth restriction. Ageliki et al. found that newborns whose mothers smoked >10 cigarettes/day during pregnancy have significant retardation in weight and length[29].

In our study birth weight of newborns of non-smoking mothers was from 447 g (14%) (in rural area) to 584 g (18%) (in urban area) higher then in newborns of smoking mothers. Newborns of non-smoking mothers in rural area were 1.9 cm (3.8%) and in urban area 2.5 cm (5.1%) longer then newborns of smoking mothers. Gomółka et al. found that the newborns of mothers who smoked and were exposed to environmental tobacco smoke had birth weight respectively 348.5 g and 281.1 g smaller than newborns of unexposed mothers[30]. They also found that the length of newborns of smoking and environmental tobacco smoke exposed mothers were respectively 2.8 cm and 0.7 cm shorter then newborns of unexposed mothers. Ingvarsson et al. found that newborns of smoking mothers had a significantly lower birth weight (3418 ± 533 *vs.* 3863 ± 503 g; $p<0.001$) and birth length (50.5 ± 2.6 *vs.* 52.3 ± 1.9 cm; $p<0.001$) than newborns of non-smoking mothers[14].

Resorption of toxic substances such as nicotine and CO could be the factor in the lower birth weight. Nicotine constricts placental blood vessels producing a state of placental and foetal hypo perfusion which lead to the lower birth weight. CO crosses the placenta into foetal circulation and combines with foetal haemoglobin, which has a higher affinity for CO than adult haemoglobin, leading to foetal tissue hypoxia. Chronic decrease in oxygen tension is a factor in the lower birth weight, length and intrauterine growth retardation[31]. Reduced production of the vasodilator nitric oxide (NO) in foetal vessels in pregnant smokers may lower the blood flow to the foetus and result in lower birth weight and length. Andersen et al. found that maternal smoking reduces endothelial NO synthase activity in the foetal vascular bed, contributing to retard foetal growth caused by the reduction of vasodilatory capacity[19]. Higher results in birth weight in our research could be explained by the fact that the other members of smoking mother's family also smoked which raised concentration of nicotine, CO and other chemicals in tobacco smoke and their harmful influence on intrauterine growth.

Moderate correlations between birth weight and birth length of newborns of smoking and non-smoking mothers from rural area and newborns of non-smoking mothers from urban area are statistically significant. Correlation in the group of newborns of smoking mothers from urban area is not statistically significant. The missing correlation in this group should be examined additionally.

On the basis of analysis of ROC curve, it could be presumed that newborns of smoking mothers would have birth length ≤50 cm, birth weight ≤3370 g, and BMI ≤13.5 kgm^{-2}.

The harmful effect of smoking during pregnancy, which is visible immediately at birth, is approved in many articles and by this investigation, too. Despite that, many smoking mothers keep on smoking even during pregnancy. Because the smoking during pregnancy has significant influence on birth length and birth weight of newborns, every woman must be informed about the fact that she endangers not only her own health but also exposes her own child to great and unnecessary risk. The final goal is to achieve motivation for ceasing smoking during pregnancy and, generally, to prevent starting of smoking and smoking at all.

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I. Pavić

Children's Hospital-Srebrnjak, Srebrnjak 100, 10 000 Zagreb, Croatia
e-mail: ivanpavic@net.hr

UTJECAJ AKTIVNOG PUŠENJA MAJKI U TRUDNOĆI NA INDEKS TJELESNE MASE NOVOROĐENČADI

SAŽETAK

Mnogim istraživanjima je dokazan štetni utjecaj pušenja u trudnoći. U radu je ispitan utjecaj pušenja u trudnoći na indeks tjelesne mase, BMI, odnosno na rodnu masu i rodnu duljinu novorođenčadi. Retrospektivnim ispitivanjem je obuhvaćeno 219 djece: skupina I. 109-ero djece iz ruralne sredine istočne Slavonije (rođene u OB Vinkovci), te skupina II: 110 djece iz industrijske sredine (rođene u Zagrebu). Ovisno o pušenju majke za vrijeme trudnoće ispitanici su svrstani u dvije podskupine: novorođenčad majki koje nisu pušile tijekom trudnoće (podskupina A) i novorođenčad majki koje su pušile 10 i više cigareta dnevno tijekom trudnoće (podskupina B). Antropometrijski pokazatelji (rodni BMI, masa i duljina) novorođenčadi majki nepušačica bili su statistički značajno veći ($p<0,05$) nego u novorođenčadi majki pušačica. Umjerena korelacija između duljine i mase u novorođenčadi nepušačica i pušačica iz ruralne sredine, te novorođenčadi nepušačica iz gradske sredine bila je statistički značajna, a korelacija u skupini novorođenčadi pušačica iz Zagreba nije bila statistički značajna. Rezultati ovog istraživanja pokazuju da pušenje majki tijekom trudnoće značajno utječe na BMI, odnosno na rodnu masu i duljinu novorođenčadi. Uzroke nepostojanja korelacije između rodne duljine i mase u novorođenčadi pušačica industrijskoga grada potrebno je dodatno ispitati.