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Maternal smoking and risk of obesity in school children: Investigating early life theory from the GRECO study

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ABSTRACT

Based on the Early Life Theory, maternal smoking may be a factor affecting child weight status, adiposity level and blood pressure later in life. The purpose of this study was primarily to examine the risk of maternal smoking during pregnancy with overweight and obesity, central and total adiposity in school children. Secondarily, to assess the effect of maternal smoking, with children's blood pressure (BP).

Data from the Greek Childhood Obesity cross sectional study (GRECO), conducted from October 2008 to May 2009, were used. A total of 2400 questionnaires gathered from children and their parents were analysed. Maternal and gestational data were gathered by a self-administered questionnaire. Women were categorized as non-smokers or smokers if they smoked ≥ 1 cigarettes/day during pregnancy. Children's body weight, height, waist circumference and BP were measured. Multiple logistic and linear regression analysis was conducted, adjusting for covariates. Four models were used in the process.

The study found that children of maternal-smokers were more likely to be overweight or obese (OR: 1.6 to 1.82) and to have a larger waist circumference (OR: 1.73 to 1.85), compared to children of non-smokers in all models used. Total fat percentage was not significantly associated with maternal smoking when adjusted. Systolic and diastolic BP was not associated with maternal smoking. Results of this study strengthen the need for smoking cessation during pregnancy in order to possibly reduce the childhood obesity epidemic. Creating public health awareness of the potential risk of maternal-smoking on children's weight status later in life is warranted.

Abbreviations.

SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
cd-FI	child derived Food Index
wc	waist circumference
GRECO	Greek Childhood Obesity study

1. Introduction

According to the Early Life Theory, a great number of chronic diseases that occur later in life start during utero development (Barker 1994) due to fetal adaptation in structure, physiology and metabolism (Bakker and Jaddoe 2011). There is increasing evidence that children's health and weight-status may also be programmed during this period (Bakker and Jaddoe 2011; Law and Shiell 1996; Li et al. 2015; Riedel et al. 2014a) by various factors, one of which is maternal smoking.

Maternal smoking during pregnancy has been described as a highly modifiable risk factor linked to children's weight status, blood pressure (BP) and cardiovascular disease (Barker 1994; Florath et al. 2014; Law and Shiell 1996; Li et al. 2015; Riedel et al. 2014a; Salsberry and B., 2005). Researchers have attributed the increased weight in children to specific effects of cigarette smoke on fetal development leading to later onset of overweight, obesity and central adiposity (Simmons 2008). Although ethical constraints makes the underlying mechanism difficult to investigate, longitudinal studies, sustain a potentially age related mechanism (Durmus et al. 2011; Li et al. 2015; Riedel et al. 2014b), reporting that children born to women who smoked during pregnancy have a higher risk of developing obesity over time (Riedel et al. 2014a; Widerøe et al. 2003). Findings, however, remain controversial, underlying mechanisms remain obscure, and researchers debate the strength of the association, due to possible genetic and environmental factors,

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such as children's dietary (Kleiser et al. 2009; Magriplis et al. 2015) and behavioral (Birch and Fisher 1998; Cappuccio et al. 2008; Grontved et al. 2014) habits.

In relation to blood pressure, researchers have reported a higher mean systolic blood pressure (SBP) in young children whose mother smoked during pregnancy, compared to non-smokers (Law and Shiell 1996; Lawlor et al. 2004), but these findings have not been confirmed (Bergel et al. 1999). Limited studies have assessed the effect of maternal smoking on children's weight status and BP while adjusting for potential obesogenic behavioral variables (Ino et al. 2012; Riedel et al. 2014a) and dietary patterns (Al Mamun et al. 2006), in order to enlighten these debates.

The primary aim of this study, therefore, was to examine the effect of maternal smoking on (i) school children's weight status, as defined by Body Mass Index (BMI) International Obesity Task Force (IOTF) cut offs, (ii) total body fat percentage (%), and (iii) waist circumference, while adjusting for the potential residual confounding effect of behavioral factors and dietary patterns. Secondarily, to examine the potential association of maternal smoking with children's BP in relation to children's weight status and diet quality.

2. Methods

Data from the Greek Childhood Obesity (GRECO) study, a nationwide cross sectional study, were used in the present study. The GRECO study was carried out from October 2008 to May 2009, using a stratified sampling scheme weighted by age, sex, and region, according to the population distribution (National Statistical Services, 2001 census) in 10 regions of the country. Precise sampling details have been previously published (Farajian et al. 2013). The study was conducted in accordance with ethical principles and guidelines laid down in the Declaration of Helsinki. Research tools and procedures used in the study were approved by the Hellenic Ministry of Education (Department of Education) and the Agricultural University of Athens Research Committee, as the law in Greece specifies for any studies conducted at school during formal working hours. All children, teachers and primary caregiver were informed of the aims and study procedures, and consent was obtained for participation.

2.1. Participants

The study included information collected from children (10–12 years old) and their parents upon signing an informed consent form. The study included a working sample of 2400 children (44.9% males, 55.1% females) for whom parental questionnaires were completed. The sample was representative of the overall study population ($n = 4439$). No significant differences were found in children's mean BMI (20.2 ± 3.8 and 20.2 ± 3.7 kg/m^2, respectively; $p = 0.861$) and the percentage of children categorized as overweight & obese (42.1% and 41.2%, respectively), between parental responders and non-responders. Mother's were the primary respondents (91.8%) of the parental questionnaire, solely (61.8%) or with the father (30.2%). Complete maternal and childhood data for 2017 (84%) of the primary sample were included in the final analysis.

2.2. Data selection

2.2.1. Anthropometric data

Anthropometrics gathered, included measurements by trained personnel, on body weight (kg) to the nearest 100 g (Tanita TBF 300), body-standing height without shoes using a portable stadiometer (Leicester height measure) to the nearest 0.1 cm. Body mass index (BMI) was calculated by dividing weight (kg) by standing weight squared (m^2). The prevalence of overweight and obesity among children was calculated using the IOTF age and gender specific body mass index cut-off criteria (Cole and Lobstein 2012). Waist circumference was measured to the nearest 0.1 cm (Seca, non elastic tape, Germany) upon a gentle expiration after placing the measuring tape in a horizontal plane around the trunk, midway between the lower rib and the iliac crest. Body fat (%) was estimated by foot-to-foot biompedence analysis while standing (Tanita TBF 300) to the nearest 0.1%. All measurements were performed during morning hours and with children wearing light clothing.

2.2.1.1. Dietary and behavior assessment. Dietary assessment was based on a 48 item, previously validated, picture aided Food Frequency Questionnaire (FFQ) (Farajian et al. 2009). The FFQ was self-reported and included 48 food items commonly consumed in the Greek population. All participants reported their consumption of these food items with the following response categories: (i) everyday, (ii) 3–6 times/week, (iii) 2 times/week, (iv) 1 time/week, (v) 1–2 times per month, and (vi) seldom/never. Specifics on the type of food consumed were also asked (such as whole wheat vs white bread/pasta/rice). Data obtained from the FFQ were used to construct a validated child derived FI (cd-FI), designed to predict overweight and obesity in children (Magriplis et al. 2015). The index was purely food based and included 8 protective and 6 potentially obesogenic foods as per a-priory knowledge. A score of 1–4 (for protective) or 4–1 (for obesogenic) was given to each food included in the index according to frequency of consumption. Details on the cd-FI derivation and validation have been published elsewhere (Magriplis et al. 2015). The cd-FI was used to adjust for the effect of children's dietary patterns that have been shown to increase children's risk for overweight and obesity.

Behavioral data were obtained on total screen time (watching TV, DVD, playing video games/consoles, using computer), and total sleep and study hours, per day. Additional questions included information on eating occasions (number of meals and snacks throughout the day), frequency of having meals in front of a screen (watching TV/DVD/videos and or using game consoles/computer), frequency of having meals with family members, and frequency of eating/ordering out. Response categories included: (i) everyday, (ii) 5–6 times/week, (iii) 3–4 times/week, (iv) 1–2 times/week, and (v) seldom/never. Physical activity was self-reported and was assessed via the International Physical activity Questionnaire (IPAQ) score (Kowalski et al. 1997). The score was examined by children's weight status and by maternal smoking status. In both cases it did not differ and was therefore excluded from the model.

2.2.1.2. Parental or primary health questionnaires. Parents were invited to complete a questionnaire on family and behavioral characteristics, personal anthropometric, neonatal data, and socio-economic characteristics. Information was self-reported and included current age, weight and height, mother's age and weight at pregnancy, weight gain during pregnancy, and education level. Parental weight status was classified by calculating BMI values for each individual. Education was divided into, (i) primary, (ii) secondary, and (iii) higher education. Information on alcohol intake and coffee intake during gestational period was also gathered. Women were asked to respond whether they consumed (i) none, (ii) 1 unit/day, (iii) ≥ 2 units/day of alcohol or coffee. Children's characteristics considered included birth weight (grams) and length (cm), age, gender, and gestational weeks at birth.

2.2.1.3. Maternal smoking status. Information on maternal smoking habits during pregnancy as well as prior to conception was acquired from the parental questionnaire (details on responders in 2.1.) The number of cigarettes smoked per day, were defined as: (i) none, (ii) 1–9 cigarettes per day, (iii) 10–20 cigarettes per day, and (iv) ≥ 20 cigarettes per day. Women were then categorized in two groups: (i) non-smokers if none, and (ii) smokers if > 1 cigarette per day was reported, since only 36 women reported smoking 10–20 cigarettes per day and 4 women reported ≥ 20 (16%). Also, the selection to maternal smokers or non-smokers during gestation was selected as the preferred

categorization, to examine the effect of any amount of cigarette smoking and to decrease recall bias due to the nature of the study (10–12 years recall).

2.2.2. Blood pressure

Blood pressure was measured in a single occasion within the school's settings using validated oscillometric devices (UA-787 oscillometric blood pressure monitor, A & D Company), equipped with the right type of cuff for children of this age. Prior to BP measurements children were calm, in a sitting position with their back supported, and their right arm resting on a solid surface at heart level. Two subsequent measurements were taken within a 5 min interval. The first was used to familiarize children with the procedure. The second measurements of SBP and diastolic BP (DBP) were recorded in mmHg. Blood pressure readings were used as a continuous variable.

2.3. Statistical analysis

Variable distribution was assessed via Kernel density plots. These were compared for maternal smokers and non-smokers using box plots. Descriptive statistics, including frequencies (%), means (± SD), and medians were calculated for normally distributed and skewed variables, respectively. Chi-square tests were used to examine differences between smokers and non-smokers. Student *t*-test was used for mean differences between normally distributed variables, and the non-parametric *U* test suggested by Mann and Whitney, for skewed.

Responding bias was examined via dummy variables created to screen the sample for potential differences. Non-significant differences were detected, suggesting that missing data were random and therefore no exclusions were made.

The association of maternal smoking and children's weight status, total and central adiposity was tested using multiple logistic regression models. Linear multiple regression models were used to assess the relationship between maternal smoking and children's BP. The median individual value was taken for waist circumference and total body fat, since there are no specific obesity cut-offs for the Greek childhood population. Bonferroni correction was not used for the models since in it has been shown that this correction leads to an increase of type II error (increase of false positives).

Due to the large number of variables used in the model, and in order to avoid collinearity, Variance Inflation Factor (VIF) test was performed after regression. The mean VIF for the model was 1.98 and all variables had a VIF value of < 2.5. To increase the power of the analysis and validate the model, bootstrap was conducted with 10 random replications; data remained significant. All reported *P*-values were based on two-sided hypothesis tests, with significance level at 5%. The statistical models were computed using STATA 12.0 (STATA corp. Texas).

3. Results

3.1. Descriptive statistics

Demographic characteristics are given in Table 1. Among 2017 parental questionnaires gathered, 1767 (87.6%) were non-smokers during pregnancy and 250 (12.4%) were smokers. Mothers who smoked during pregnancy had higher mean age ($p = 0.001$). Mother's who smoked during pregnancy had a significant higher rank, as per Man Whitney test, in the distribution of maternal BMI and in mean weight gain during pregnancy. No other significant differences were found among maternal smokers and non-smokers.

Among child characteristics (Table 1), no age or gender differences were found between maternal smokers and non-smokers. The mean children's weight and BMI, of mothers who smoked during pregnancy, was significantly higher compared to children whose mother did not smoke ($p = 0.021$ and $p = 0.002$, respectively), whereas the mean birth weight of these children was significantly lower ($p = 0.004$). A total of 41.9% of the children enrolled in this study were categorized as overweight or obese (30.3% overweight and 11.6% obese). A larger percentage of overweight & obese categorized children were born to mothers who smoked during gestation (51% compared to 40.7%, respectively, $p = 0.002$). The children's total body fat percentage ($p = 0.002$) and their waist circumference ($p = 0.013$) also differed significantly by maternal smoking status, with children of maternal smokers having higher mean levels in both cases.

3.2. Logistic regression results

3.2.1. Maternal-smoking and children's BMI status

The odds of children being overweight or obese were higher among women who smoked over 1 cigarette per day compared to non-smokers, in all 4 different models (Table 2). The models used were adjusted in an additive way, as shown in Table 2, starting from a-priori known confounding factors (model 1), adding for maternal alcohol and coffee intake (model 2), children's behavior (model 3) and dietary patterns (model 4). In the first model, children were 1.6 times more likely to be overweight or obese [95% CI: 1.03, 2.47] compared to their healthy weight peers if their mother smoked during pregnancy. Coffee and alcohol intakes, led to a significant increase in the odds of overweight or obesity in children among smokers. When behavioral variables were accounted for (Model 3), the odds of overweight or obese in childhood further increased (OR: 1.82; 95%CI: 1.09, 3.04). In model 4 adjustment was made for total cd-FI score also, the odds for overweight and obesity in children among maternal smokers slightly dropped, but maternal smoking remained a significant risk factor [OR: 1.81; 95% CI: 1.09, 3.03].

3.2.2. Maternal-smoking, body fat and central adiposity

Children's waist circumference was positively associated with maternal smoking, in a univariate analysis seen in Table 3. The odds of having a higher than the median population waist circumference was higher in children whose mothers smoked during pregnancy [OR: 1.73; 95% CI: 1.17, 2.69]. The effect slightly decreased when behavioral [OR: 1.84; 95% CI: 1.11, 3.05], and dietary variables [OR: 1.82; 95% CI: 1.09, 3.01] were added however, the relationship remained significant in all models. No significant effect was found between maternal smoking status and total body fat in any of the models.

3.3. Linear regression

In Fig. 1, mean SBP and DBP measures are depicted in a bar graph by maternal smoking status. No differences were found between children's BP and maternal smoking habits following a univariate or multivariate analysis.

4. Discussion

The present study showed that maternal smoking during pregnancy, one of the most important modifiable factors, was significantly associated with children's weight status and central adiposity. The association remained when factors, known to increase the risk for overweight and obesity in children, were accounted for. No association was found between maternal smoking and total body adiposity (%).

A total of 4 models were used to examine variables previously reported to be associated with childhood obesity. These included (i) maternal and child-neonatal characteristics, (ii) coffee and alcohol intake during pregnancy, (iii) child behavioral factors, and (iv) dietary patterns. These were used in order to investigate the effect that each of these group of variables may have on the maternal smoking childhood obesity association. Physical activity was not included in the third model since the mean value of the score did not differ between children's weight, or between maternal smoking status.

The present study and in accordance to others upon multi-level

Table 1
Demographic characteristics with mean (SD) and frequency (%) for maternal and child characteristics among maternal smokers and non smokers (N = 2017) from the GRECO study[1].

Characteristics	N[a]	Mean ± SD/ Median[b] / Frequency (%)	Non smokers (1767)	Smokers (250)	P-value* for difference
Maternal current BMI (kg m^{-2})	1861	23.5 (21.5, 26.2)	23.6 (21.5, 26.4)	23.2 (22.0, 24.0)	**0.044**
Maternal age at pregnancy (years)	1704	28.2 ± 4.7	28.1 ± 4.7	29.2 ± 5	**0.001**
Pregnancy weight gain (kg)	1747	13 (10, 18)	13 (10, 18)	15 (10, 20)	**0.039**
Maternal BMI at pregnancy (kg m^{-2})	1734	21.5 (19.8, 23.4)	21.5 (19.8, 23.4)	21.5 (19.7, 23.4)	0.633
Gestational weeks	1325				0.973
• < 32 weeks		28 (2.1)	25 (2.2)	3 ± 1.	
• 32–36 weeks		193 (14.6)	167 (14.5)	26 ± 14.9	
• 36–38		383 (28.9)	331 (28.8)	52 ± 29.7	
• ≥ 38 weeks		721 (54.4)	627 (54.5)	94 ± 53.7	
Maternal education	1802				0.107
• primary		123 (6.8)	108 (6.9)	14 (6.1)	
• secondary		761 (42.2)	642 (41.)3	111 (48.7)	
• university		918 (50.9)	805 (51.8)	103 (45.2)	
Drinking of alcohol	2001				0.07
• none		1916 (95.7)	1688 (96.1)	228 (93.1)	
• 1 unit/day		85 (4.3)	67 (3.8)	17 (6.9)	
• > 1 unit/day		1 (0.1)	1 (0.1)	0 (0)	
Child Characteristics					
Age (years)	2017	10.9 (0.7)	10.9 (0.7)	10.8 (0.8)	0.415
BMI (kg/m^2)	1950	20.2 (3.7)	20.1 (3.6)	20.9 (4.0)	**0.002**
Weight (kg)		45.5 (10.7)	45.3 (10.6)	47.0 (11.5)	**0.021**
Height (cm)		149.3 (7.8)	149.4 (7.8)	149.0 (7.5)	0.342
Gender	2017				0.486
• boys		891 (44.9)	776 (44.6)	115 (46.9)	
• girls		1095 (55.1)	965 (55.4)	130 (53.1)	
Birth weight (gr)	1400	3268.3 ± 542.2	3283.1 ± 549	3156.8 ± 483.5	**0.004**
Birth length (cm)	1245	51.3 ± 3.7	51.4 ± 3.7	51.1 ± 4.2	0.507
Body fat (%)	1938	21.3 ± 8.8	21.1 ± 8.7	22.9 ± 9.2	**0.002**
Waist circumference (cm)	1937	68.9 ± 9.7	68.7 ± 9.7	70.4 ± 10.2	**0.013**
Weight status	1950				
• normal weight		1132 (58.1)	1014 (59.3)	118 (49.0)	**0.002**
• overweight & obese		818 (41.9)	695 (40.7)	123 (51.0)	

significant in the model: *p < 0.1; **p < 0.01; ***p < 0.001; P < 0.05 for difference in main characteristics among smokers and non smokers during pregnancy; [a] N: Total of data per characteristic; [b] Mean(SD) or median values (25th, 75th, %iles) depicted for continuous variables and frequencies(%) for categorical variables; t-test or Mann Whitney tests for continuous normal and skewed variables, respectively. Chi-square test used for categorical variables.

[1] Greek Childhood Obesity cross sectional study (GRECO), from October 2008 to May 2009.

Table 2
Multiple logistic regression of children's weight status between maternal smokers versus non smokers using 4 models using data from the GRECO study[1] (N = 2017).

Maternal smoking status: Non smokers versus Smokers			
	Odds Ratio ± SE*	95% CI	P value[a]
Model 1	1.60 ± 0.36	1.03, 2.47	**0.036***
Model 2	1.80 ± 0.45	1.10, 2.94	**0.019***
Model 3	1.82 ± 0.48	1.09, 3.04	**0.021***
Model 4	1.81 ± 0.47	1.09, 3.03	**0.023***

significant: *p < 0.05; **p < 0.01; ***p < 0.001.

*overweight (ow) and obese (ob) children compared to healthy weight peers; [a] significance level at p < 0.05; OR, Odds Ratio; SE, Standard Error; 95%CI, 95% Confidence Interval.

Model 1: model adjusted for children's age & gender, children's birth weight & length, gestational weeks, maternal education, maternal BMI, weight increase during pregnancy and maternal age.

Model 2: model adjusted for the above and maternal alcohol & coffee intake during pregnancy.

Model 3: model adjusted for the above and children's sleep, screen and study time.

Model 4: model adjusted for all of the above and total FI score.

[1] Greek Childhood Obesity cross sectional study (GRECO), from October 2008 to May 2009.

adjustments (Al Mamun et al. 2006; Ino et al. 2012; Oken et al. 2005; Power and Jefferis 2002; Wang et al. 2013; Widerøe et al. 2003) contradict the argument that the effect of maternal smoking on children's weight status may be due to residual confounding (Florath et al. 2014; Harris et al. 2013; Yang et al. 2013). Also, a recent meta-analysis reported higher effect estimates on childhood obesity for maternal smoking when compared to paternal smoking (Riedel et al. 2014b). In the present study, maternal smoking remained a significant risk factor for child overweight and obesity upon accounting for birth influences, behavioral factors and dietary pattern, in agreement with other authors (Al Mamun et al. 2006; Ino et al. 2012; Power and Jefferis 2002). Results are further strengthened since compared to previous investigations study hours were used with total screen time, as an additional proxy to sedentary behavior. Study hours are a mandatory requirement for school-aged children, further adding to children's sedentary time. Also, although researchers to date have adjusted for various food items, including frequency of salad, fast food and red meat intake (Al Mamun et al. 2006), fried food, chips, fruits & vegetables and sweets (Riedel et al. 2014b), to our knowledge no studies have accounted for diet via a child derived food index (cd-FI) as was performed in this study. The cd-FI used in the analysis of the present study, includes the aforementioned foods along with a more elaborate food intake on healthy and potentially obesogenic food items, therefore strengthening the detected association of maternal smoking on children's risk for overweight and obesity. Although cd-FI slightly attenuated the odds of the effect, the association remained significant, possibly underlying the importance of the specific dietary pattern.

4.1. Body fat & Waist circumference used to strengthen results

Waist circumference and total estimated body fat, were used to examine the effect of maternal smoking on children's fat distribution and body fat (%), respectively. Waist circumference was used as a superior measure of central adiposity (Maffeis et al. 2001) and in order to decrease the random error that BMI calculations may incorporate in the results. BMI is influenced by body composition and is not a sensitive

Table 3
Multiple logistic regression of children's percent adiposity and waist circumference with maternal smoking status using data from the GRECO study[1] (N = 2017).

	Children's Adiposity % [a]			Children's waist circumference [b]		
	Odds Ratio ± SE*	95% CI	P value[C]	Odds Ratio (SE)*	95% CI	P value[C]
Model 1	1.28 ± 0.3	0.82, 1.20	0.280	1.73 (0.4)	1.17, 2.69	**0.014**
Model 2	1.34 ± 0.3	0.82, 2.19	0.244	1.85 (0.5)	1.13, 3.02	**0.015**
Model 3	1.29 ± 0.3	0.78, 2.13	0.326	1.84 (0.5)	1.11, 3.05	**0.017**
Model 4	1.28 ± 0.3	0.77, 2.11	0.338	1.82 (0.5)	1.09, 3.01	**0.021**

significant in the model: *p < 0.1; **p < 0.01; ***p < 0.001.
*overweight (ow) and obese (ob) children compared to healthy weight peers.
Model 1: model adjusted for children's age & gender, children's birth weight & length, gestational weeks, maternal education, maternal BMI, weight increase during pregnancy and maternal age.
Model 2: model adjusted for the above and maternal alcohol & coffee intake during pregnancy.
Model 3: model adjusted for the above and children's sleep, screen and study time.
Model 4: model adjusted for all of the above and total FI score.
[1] Greek Childhood Obesity cross sectional study (GRECO), from October 2008 to May 2009.
[C] Significant at the P < 0.05 level; [a] Comparing children above and below the median value of the sample. Measured with bioimpedence analysis; [b] Comparing children above and below the median value of the sample. Measured by trained personnel, using a with a non elastic standardized tape (Seca).

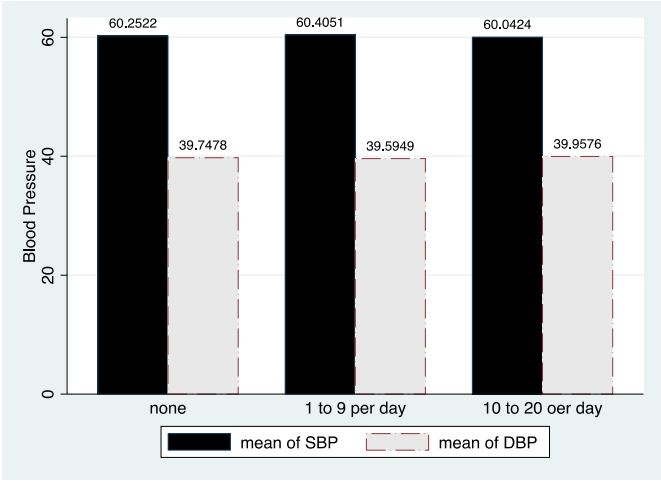

Fig. 1. Mean Systolic and Diastolic blood pressure of children by maternal smoking status as measured during the GRECO study[1]
[1] Greek Childhood Obesity cross sectional study (GRECO), from October 2008 to May 2009.

measure for overweight status.

In agreement with other studies (Oken et al. 2005; Widerøe et al. 2003), the association between maternal smoking status with children's risk for higher BMI and central adiposity remained significant upon adjusting for low birth weight and length. This strengthens the effect found since low birth weight and length have been independently linked with maternal smoking (Bakker and Jaddoe 2011; Bergel et al. 1999; Riedel et al. 2014a; Suzuki et al. 2011; Timmermans et al. 2014), increased weight status (Suzuki et al. 2011), and central adiposity development (Simmons 2008) later in childhood.

The present findings, therefore, are in agreement with others, and suggest direct effect of maternal smoking during pregnancy on children's risk of overweight and obesity, and central adiposity later in life (Al Mamun et al. 2006; Wang et al. 2013).

4.2. Maternal smoking and blood pressure

Maternal smoking was not associated with SBP and DBP in this study, in accordance to others findings (Bergel et al. 1999; Law and Shiell 1996). Lawlor et al., (2004) however, found that maternal smoking was related with a 1 mmHg increase in mean SBP, among 5 to 6 year old children (Lawlor et al. 2004). Other studies on childhood BP have shown that parental prenatal smoking have the same effect as maternal smoking during pregnancy. This suggests that BP may be due to other than intra-uterine programming, and that associations found by other studies may have been due to minimally adjusted models used, hence confounding (Brion et al. 2007).

4.3. Potential limitations

As in all observational studies, unmeasured systematic differences between smokers and non-smokers that are possibly associated with the outcome, may partially explain the findings. For this reason variables a-priori associated with children's weight status and adiposity, were included in the analysis. Social desirability concerns may have caused under-reporting of smoking behavior. To limit maternal underreporting of smoking, coffee found to significantly differ among maternal smokers and non-smokers and highly correlated with smokers, was therefore included in the analysis as a proxy for smoking habits. Paternal smoking was not assessed and could have added residual confounding. Many parents did not respond all questions. Lastly, the nature of the parental questionnaire, which was self-administered could have added some error. The study's, however, large sample size decreases the risk of potential reporting bias.

4.4. Strengths

Analyses conducted accounted for factors that have been related to child overweight and obesity such as age, gender and gestational weeks at birth, birth weight and length. The effect of dietary intake was also accounted for by adjusting for the child-derived cd-FI the children had achieved (Magriplis et al. 2015). Waist circumference was included in the analysis to account for body composition, since BMI may be prone to errors and does not account for variability in muscle mass, as has been criticized. Also, the results were validated further via random sampling (bootstrap, 10 replications).

5. Conclusion

The findings of the present study suggest that intrauterine exposure to maternal smoking increases the likelihood for an increased body weight and central adiposity in school aged children. Tobacco use has been implicated in many health issues and although it is a well known «negative behavior» during pregnancy, some women continue to smoke even «lightly», potentially due to lack of education on the potential risk outcomes to their offspring. Health care providers need to be made aware of the possible maternal-smoking-childhood obesity association, irrespective of the amount (> 1 cigarette/day), and of lifestyle factors (diet & behavior) as this study reports, contradicting residual

confounding. Results underline the need to derive policies and create appropriate population based campaigns that focus on maternal smoking and childhood overweight and obesity. Prospective cohort studies assessing amount of maternal smoking with childhood overweight & obesity, are warranted, to strengthen the evidence of association.

Authorship

A.Z., D.B.P., G.R. and P.F. were responsible for the study design and the supervision of the field study. E.M., and D.B.P., were responsible for the statistical analysis. E.M., and A.Z. were responsible for the interpretation of the data. All authors carried out data management, contributed to database preparation and participated in writing the final version of the submitted manuscript.

Compliance with ethical standards

Ethical Standards The Agricultural University of Athens research committee approved procedures as well as the Hellenic Ministry of Education (Department of Primary Education) as the law provides in Greece for any studies conducted at school during formal working hours. Data protection regulations were observed in the survey. Signed informed consent was obtained from main caregiver prior to enrolling the children in the study.

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Conflict of interest

None.

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