[Turkish Journal of Medical Sciences](https://journals.tubitak.gov.tr/medical)

Volume 30 | Number 1 Article 9

1-1-2000

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Turk J Med Sci
30 (2000) 47–53

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Received: May 27, 1998

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Abstract: To investigate the influence of air pollution on birth weight, information on maternal and infant characteristics was collected from 458 mothers of infants less than one year of age born in 1995 and under observation at a mother and child health center in Ankara. In addition, the obstetrical histories of 520 infants born in 1990 were collected from the delivery room records of a maternity hospital. Daily air pollution data were obtained and mean monthly values were used for statistical analysis. Among the possible risk factors, sex, maternal age, maternal employment, paternal employment and parity were found to be influential factors on low birth weight. In addition, first trimester sulphur dioxide (SO_2) and particulate matter (PM) levels were also found to be factors affecting birth weight. However, these effects were shown not to be statistically significant by logistic regression analysis. A comprasion of mean birth weights according to maternal smoking and exposure to passive smoking on the basis of the third trimester SO_2 and PM levels revealed no significant difference; however, the difference in birthweight of non-smoking mothers was higher than that of smoking mothers when the third trimester SO_2 levels were above the minimum effect level (100 g and 220 g, respectively). These findings led us to propose a synergistic effect of smoking and air pollution. It was concluded that, air pollution in Ankara is not on its own a major risk factor for low birth weight.

Key Words: Birth weight, air pollution, smoking, maternal education level.

Introduction

Birth weight is the main index determining the potential development and life quality of the newborn; furthermore, it serves as the main criterion used in clinical appraisal and in epidemiological studies related to the newborn. Low birth weight (LBW) contributes to approximately 9 million infant deaths per year worldwide (1). Prevention of LBW is a public health priority in many developing countries, where the condition is largely attributable to intrauterine growth retardation. Although the uterus supplies a reasonably secure environment, it cannot be claimed that a developing fetus is fully protected there. Genetic characteristics greatly influence growth; however, numerous environmental factors result in differences in birth weight, the most important ones being pollution, cigarette smoking, low caloric intake or weight gain during pregnancy, the sex of the fetus and the height of the mother, and as well as ethnicity and socio-economic status (2).

Increasing concern has been expressed over pollution of the biosphere by overpopulation and industrialisation in recent years. Outdoor air pollution is caused by a mixture of pollutants from a variety of sources, such as traffic and heating. Industrial air pollution is comprised largely of smoke (particulate matter) and sulphur dioxide (SO_2) from the burning of coal and fuel. Vehicle exhaust emits oxides of nitrogen, carbon monoxide, hydrocarbons and lead. The health effects of this mixture are complex and the overall health risk of pollution is not known yet (3). The adverse effects of air pollution on the respiratory system have been clearly shown in various studies; however, in recent years much more concern has been focused on the reproductive health hazards of pollution(4). Therefore, the present study was undertaken to determine the relative importance of known risk factors affecting intrauterine growth, and to examine the relationship between air pollution and birth weight in Ankara, a city with heavy air pollution during the winter months.

Material and Methods

The data on which this study was based were collected from mothers who had children aged 0 to 1 years under observation at the Mother and Child Health Center No.3, Çankaya for periodic check-ups of their infants. Between September 1995 and October 1996 we interwieved 458 mothers and compiled sociodemographic data, obstetric and perinatal histories, and data related to maternal smoking practice and average exposure to tobacco smoking during pregnancy in terms of the approximate number of cigarettes smoked per day. Mothers' heights were measured by standard stadiometer, while birth weights and gestational ages were recorded from infants' birth certificates. Infants of birth weight (2500 grams or less) were defined as term newborns. The characteristics of the sample were as follows:

* 48 % of the infants were male
* 6.7% of infants had low birth weight (≤ 2500 g)
* 42.4 % were from primiparous mothers
* Mean birth weight was 3.23 ± 0.52 kg and birth length was 49.9 ± 2.6 cm
* Mean gestational age was 40 ± 1.6 week.

Ankara is the capital of Turkey. Air pollution in the winter has been the major environmental problem in this province for the last 30 years. Great efforts have been made to solve this problem in the last decade, and emissions beginning to decrease in 1989 (accepted as the year of heaviest air pollution) and reaching a minimum value in 1993 and 1994 (5). Therefore, in order to investigate the effects of air pollution on delivery outcome, the birth weights of infants born in 1989-1990 and in 1994-1995 were compared. Data for the year 1989-1990 were collected from one of the three main maternity hospitals (Ministry of Health, Zübeyde Hanım Maternity Hospital) in Ankara. Information on maternal age, gestational age, parity and sexuality was collected from delivery room records. Forty newborns were randomly selected for each month, for a total of 520 infants. Patients not living in Ankara and pretem infants were excluded from the study.

The analyses of air pollutants (sulphur dioxide and particulate matter) were performed by the Ministry of Health's Refik Saydam Institute of Hıfzısıhha and was monitored at World Health Organization Global Environmental Monitoring System (GEMS) sites in Ankara. Daily measurements are taken from all residences, and a mean monthly value for the city of Ankara is recorded. In this study mean monthly values for the years 1989-1990 and 1994-1995 were used for statistical analysis.

The EPI-Info program package was used for statistical analysis. The descriptive statistics of each parameter were calculated, and intergroup differences were tested with the Chi-square test. To study the association between intrauterine growth retardation and possible risk factors, logistic regression analyses were used and relative risk and 95% confidence intervals (CI) were calculated. Statistical significance level was accepted as $p < 0.05$.

Results

Low birth weight (LBW) infants comprises 6.7% of the study population, while 3.1% were preterms. The relationships between a number of risk factors were analysed, and the results are given in table 1. Among those factors, sex, maternal age, maternal employment, parental employment, parity and smoke exposure were found to increase the risk for LBW, with relative risks of 1.41, 1.87, 1.53, 1.46, 1.26 and 1.51. respectively.

Table 1. Distribution of risk factors for infants, with intrauterine growth retardation.

Risk Factors	Birth weight <2500g (%)	Relative risks (95% CI)
Sex		
Male	4.59	
Female	7.17	1.41 (0.78, 2.54)
Maternal Age (years)		
<20	4.95	
21 - 35	5.97	1.05 (0.45, 2.46)
36 and over	10.8	1.87 (0.49, 7.13)
Maternal education		
over 5 years	11.4	
under 5 years	12.25	0.50 (0.15, 1.68)
Maternal employment		
employed	8.3	
unemployed	12.18	1.53 (0.69, 3.36)
Paternal employment		
skilled	8.94	
unskilled	12.31	1.46 (0.73, 2.94)
Maternal height		
< 145 cm	11.11	
> 145 cm	11.41	0.98 (0.12, 8.05)
Parity		
1-2	5.43	
3 and over	6.83	1.26 (0.68, 1.43)
Maternal smoking		
none	6.29	
smoking	9.86	0.93 (0.46, 1.87)
Smoke exposure		
none	7.36	
< 10 c/day	8.42	1.17 (0.58, 2.35)
> 10 c/day	10.43	1.51 (0.72, 3.16)

Table 2 gives the effect of air pollution on birth weight. Our results indicated that in the first trimester, high SO_2 amd PM levels (over 150 µg/mm^3 for SO_2 and 120 µg/mm^3 for PM) increase the risk for LBW among the group born in 1989 - 1990 and exposed to heavy air pollution (RR= 2.18 p= 0.054 and RR= 1.91 p>0.05 respectively). These effects were not observed in the group born in 1994 - 1995, when the air pollution was not as high as in 1989 - 1990).

Table 3 gives the mean birth weights of infants born in 1990 and 1995, and the mean SO_2 and PM levels for the third trimester of pregnancy. The mean birth weight of the group born in 1990 was 3.32 ± 0.49 kg, while that for the group born in 1995 was 3.19 ± 0.55 kg. The mean birth weight in 1995 was lower than that in 1990 (a difference of 196 g); when the group was stratified according to birth month, a similar disparity was apparent except in the second month (February), which had the highest SO_2 and PM levels. As the intrauterine growth rate differs by trimester, we calculated the mean birth weight for each trimester on the basis of SO_2 and PM levels above vs. those below the average in order to determine whether the effect of air pollution depends on the stage of pregnancy {The minimum levels for effects on children are given as 150 mg/m^3 for SO_2 and 120 mg/m^3 for PM (6)}. Our results indicated that the mean birth weights of the groups with high SO_2 and PM levels in each trimester were slightly lower than in the groups with low SO_2 and PM levels, with no statistically significant difference (Table 4).

The rate of smoking (among those pregnant women from whom information was collected) was 24%. In this group, the mean cigarette consumption was 5 cigarettes per day, and 86% smoked fewer than 10 cigarettes per day. A comparison of mean birth weights according to maternal smoking and exposure to passive smoking on the basis of 3rd trimester SO_2 levels is given in Table 5. The difference in birth weight between smoking and non-smoking mothers was higher when 3rd trimester SO_2 levels were above the minimum effect level (100 g and 220 g, respectively). When passive smoking was taken into account, this difference was 110 gr between non- and maximum-exposed groups with high 3rd trimester SO_2 levels. The differences in low birth weight incidence were not statistically significant between smoking and non-smoking mothers (x^2 = 0.99, p>0.05; x^2 = 3.47, p>0.05). These results indicate that smoking does not seem to be a major influencing factor on birth weight, but may have a synergistic effect with air pollution.

Discussion

The short term health hazzards of chemicals and air pollution in general are well known; however, long-term effects (20 - 30 years' exposure) and effects during pregnancy have not yet been well defined. Reproductive hazzards of environmental pollution came into consideration at the end of the 19th century, and after reports on the effects of lead on growing fetus (such as neonatal deaths, malformations, abortions, etc.) were

Table 2. Effects of Air Pollution on birth weight on the basis of each trimester SO_2 and PM levels according to birth year

Years	1989-1990		1994-1995	
	RR (95% CI)	P	RR (95% CI)	P
1 st trimester SO_2 *	2.181 (0.99, 4.82)	p=0.054	1.00 (0.99, 2.75)	ns***
2 nd trimester SO_2	0.91 (0.62, 1.34)	ns	1.005 (0.99, 1.009)	ns
3 rd trimester SO_2	0.63 (0.27, 1.45)	ns	0.99 (0.98, 1.003)	ns
1 st trimester PM **	1.91 (0.88, 4.10)	ns	1.00 (0.99, 1.02)	ns
2 nd trimester	1.06 (0.69, 1.62)	ns	0.99 (0.98, 1.009)	ns
3 rd trimester	0.60 (0.24, 1.52)	ns	0.99 (0.98, 1.001)	ns

* Risk was calculated for the levels of SO_2 below and over 150 mg/mm^3

** Risk was calculated for the levels of PM below and over 120 mg/mm^3

*** ns= not statistically significant

published, it was forbidden for women to work in the lead industry (7). It is a well established fact that there is an inverse relation between cigarette smoking and birth weight (8). Taking into account the effect of smoking on birth weight, it has been hypothesed that air pollution could have a similar effect; however, there not enough studies have been done to support this hypothesis. A study from Czech-Republic comparing the pregnancy outcomes in a mining district having high air pollution with those of another district having lower air pollution indicated that the incidences of low birth weight and prematurity were significantly higher in the mining area (9). In contrast, the results of a Swedish study investigating the influence of environmental pollution on delivery outcome indicated no causal effect on low birth weight, malformations, stillbirths or fetal/infant deaths (10). Similarly, a report from California did not reveal any increased risk of low birth weight among infants born to women exposed to environmental contamination (11).

In our group, the incidence of LBW was 6.7 % and the mean birth weight was 3.321 ± 0.48 kg. Though Ankara has heavy air pollution in the winter, these results were not much different than from those of Neyzi et al. in 1986 for six regions in Turkey with no pollution problems (LBW was 7% and mean birth weight was 3252 ± 504 g) (12). It has been reported that emissions began to decrease in the year 1989 (accepted as the year of heaviest air pollution) and reached their minimum value in 1993 and 1994 (5). We may conclude that the group was not exposed to heavy air pollution, so we added a control group born in 1989 - 1990. The mean birth weight for this group was 3.31 ± 0.49 kg and the incidence of LBW was 7.3%, similar to the results of Neyzi's study (12). Slight differences in birth weights between the present and the previous studies might be the result of a variety of cultural, social and economic differences between the communities and other factors that can result in different birth weights.

When we stratified the group according to exposure to air pollution for each trimester, our results showed that infants exposed to air pollution (mean SO_2 level grater than 150 m/dl) during any trimester had lower birth weights than did nonexposed infants. It is known that fetal weight increases five fold between the 20th

Table 3. Mean birth weight of infants born in 1990 in 1995 and the mean sulphur dioxide (SO2) and particulate matter (PM) levels for each trimester related to birth month.

Years	1989-1990			1994-1995			
Months		Air Pollution			Air Pollution		
	Birth Weight (kg) (mean±SD)	3^{rd} Tr.SO_2 (µg/m^3)	3 rd Tr.PM** (µg/m^3)	Birth Weight (kg) (mean±SD)	3 rd Tr.SO_2 (µg/m^3)	3 rd Tr.PM (µg/m^3)	Probibility
January	3.36 ± 0.52	265	135	3.28 ± 0.66	89	85	ns**
February	3.36 ± 0.47	330	188	3.54 ± 0.51	111	87	ns
March	3.33 ± 0.46	304	165	3.16 ± 0.46	94	74	ns
April	3.34 ± 0.47	218	109	3.17 ± 0.49	74	62	ns
May	3.35 ± 0.38	146	88	3.17 ± 0.56	39	43	ns
June	3.24 ± 0.49	76	62	3.15 ± 0.57	28	35	ns
July	3.15 ± 0.50	46	53	3.19 ± 0.49	21	30	ns
August	3.25 ± 0.48	34	48	3.26 ± 0.45	21	27	ns
September	3.39 ± 0.51	39	53	3.18 ± 0.55	25	33	ns
October	3.26 ± 0.49	65	68	3.13 ± 0.59	30	44	ns
November	3.41 ± 0.46	133	98	3.00 ± 0.71	43	62	<0.05
December	3.34 ± 0.53	202	114	3.03 ± 0.41	67	79	<0.05

* Tr. = Trimester** PM= particulate matter *** ns= Not statistically significant

Table 4. Comparison of mean birth weight for each trimester according to air pollution level (1989-1990 Data)

	Birth Weight (kg) (Mean ± SD)					
	SO2<150 (µg/m^3)	P*	SO2>150 (µg/m^3)	PM<120 (µg/m^3)	PM>120 (µg/m^3)	P
1st Trimester	3.36 ± 0.54	ns**	3.29 ± 0.49	3.36 ± 0.48	3.29 ± 0.49	ns
2nd Trimester	3.36 ± 0.50	ns	3.29 ± 0.47	3.34 ± 0.50	3.30 ± 0.47	ns
3rd Trimester	3.39 ± 0.50	ns	3.27 ± 0.48	3.38 ± 0.49	3.25 ± 0.48	ns

* $p < 0.05$, statistically significance level ** ns = Not statistically significant

Table 5. Comparison of Mean Birth Weight according to maternal smoking and exposure to passive smoking on the basis of 3rd Trimester SO_2 levels

	SO_2 < 150 (mg/m^3)	SO_2 > 150 (mg/m^3)
	Birth weight (kg±SD)	
Smoking		
No (n=324)	3.29 ± 0.55	3.28 ± 0.57
Yes (n=102)	3.19 ± 0.60	3.06 ± 0.52
Smoke exposure		
None (n=162)	3.20 ± 0.56	3.19 ± 0.45
<10c/day (n=173)	3.18 ± 0.55	3.17 ± 0.59
>10c/day (n=114)	3.19 ± 0.52	3.08 ± 0.64

week of gestation and term, while the rate of weight gain is decreased but the gain in absolute weight (grams) is actually greatest during the third trimester (13). As shown in Table 3, the difference between birth weights was greater if the fetus was exposed to air pollution during the third trimester. A very recent study of Wang et al. also emphasizes the importance of the third trimester on fetal growth, and gives the mean levels of maternal exposure to PM and SO_2 during the third trimester of pregnancy as the best predictor of reduced birth weight (14). Fetuses and infants require high oxygen consumption because of increased cell division and metabolic rate during the periods of rapid growth, such as the third trimester (13). In addition, chemicals such as carbonmonoxide diminish the oxygen-carrying capacity of haemoglobin; thus if exposure to air pollution is prolonged, the biological and chemical content of the perfusion area changes, potentially affecting placental growth in cases of maternal hypoperfusion. This would jeopardize the fetal growth and well-being (15). The results of this study do not highly support this hypothesis, as we found that exposure to high SO_2 and PM levels during the first trimester leads to a sharper increase in the incidence of LBW than the second and third trimesters. It has been shown that cigarette smoking leads to reduced fetal growth with a gradient that is dependent not only on the amounth but also on the duration of smoking (15). It remains unknown whether this is true for exposure to air pollutants as well. Further investigations on animal models would provide much more information on the causal relationship between air pollution and birth weight. Here, we may conclude that, although air pollution seems to have no significant effect on birth weight, it could have hazardous effects if the fetus is exposed over a long period, especially during the third trimester.

Various risk factors affect birth weight. Our study group was not socially, economically and culturally homogenous. Therefore we stratified the group on those basis and calculated the relative risks by logistic regression for each risk factor, as shown in Table I. Sex was an important determinant of birth weight, as the risk of LBW increases by a factor of 1.41 if the infant is female (the incidences of LBW were 4.59% and 7.17% respectively in males and females). This may create a disadvantage starting at birth for women in Turkey. In addition, our results indicated that infants whose mothers are not working outside the home and whose fathers were unskilled workers had an increased risk of LBW. A study in Karachi revealed similar findings for socioeconomic variables, including a low level of maternal education as an important determinant for intrauterine growth retardation (16). In our study maternal education level did not seem to be a risk factor, as the education level of our mothers was high, while only 5.9% of mothers had less than 5 years of education.

Sufficient evidence is available in recent literature to show the relationship between maternal smoking and retarded fetal growth (15,17), it has been shown that tobacco smoking by pregnant women reduces the weight of the newborn by an average of 200gr (18). In our study group, the mean birth weight of newborns did not differ significantly between mothers who smoked during pregnancy with those did not smoked (3180 ± 0.54 g and 3220 ± 0.60 g, respectively). The rate of smoking during pregnancy in our study population was very low (24%), and most of the mothers in this group were light smokers (86% smoked fewer than 10 cigarettes per day). This might explain why cigarette smoking seemed not to be an important determinant of birth weight. However, our results interestingly indicated that birth weight was influenced by smoking when the air pollutants were above the minimum risk levels. Though no statistically significant difference exists, the mean birth weight of infants born to smoking mothers was 220 g less than that of infants of non-smoking mothers exposed to heavy air pollution (Table 5). This finding led us to propose a synergystic effect of smoking and air pollution.

In conclusion, due to the study's limitations, we cannot claim that air pollution has an important effect on fetal growth. However, our results support the evidence on the cumulative effect of air pollution on birth weight. Moreover, it should be kept in mind that Ankara is a large city with heterogenous residents; therefore there may still be some risks that we should take into consideration for individuals in local communities. In recent years a great effort has been made to improve the air quality, but there is still much to do in this area of public health. Primarily, a collaborative study is needed in areas with and without air pollution to investigate the long- and short-term effects of air pollution on the growing fetus. Such an epidemiologic survey with a larger sample size would provide clear answers. Secondly, the air quality guidelines, e.g, the minimum acceptable levels of the air pollutants, should be defined, so that national regulations may be created and anti-air pollution policies can be developed to avoide the possible adverse effects on the growing fetus.

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