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Environmental Tobacco Smoke and Child Development: A Case-control Study on Hong Kong Chinese Toddlers

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Abstract

Objective: To investigate the relationship between environmental tobacco smoke (ETS) exposure during prenatal and early childhood period and developmental delay among Hong Kong Chinese toddlers. ***Methods:*** A case-control study was carried out on 392 children with newly diagnosed developmental delay and 393 controls with normal development. A self-administered questionnaire was used to collect household smoking history. The main outcome measures were the adjusted odds ratios for developmental delay in different ETS exposures during prenatal and postnatal period. ***Results:*** Before adjustment, household ETS appeared to be associated with elevated rates of developmental delay among toddlers, before and after birth (crude ORs = 1.53 [95%CI 1.13-2.07] & 1.44 [95%CI 1.06-1.96] respectively). The main contribution was from paternal smoking (crude ORs = 1.73 [95%CI 1.24-2.42] & 1.90 [95%CI 1.34-2.68] respectively). However, these associations became non-significant statistically when the child's gender and socioeconomic factors of the family were adjusted (adjusted ORs = 1.18 [95%CI 0.86-1.63] & 1.23 [95%CI 0.88-1.73] respectively). ***Conclusion:*** There is some evidence of an association between environmental tobacco smoke in both prenatal and early childhood period and developmental delay among Hong Kong Chinese toddlers. However, this association appears to be confounded by gender of the child and socioeconomic factors. However, since home is the most significant ETS exposure location for toddlers, educational efforts for family members about reducing their children's ETS exposure are essential.

Key words Developmental delay; Environmental tobacco smoke (ETS)

Introduction

Human brain develops rapidly during pregnancy and the first two and a half years of life. Exposure to toxicants during this period is believed to have the greatest impact on neurodevelopmental functioning.[1] The biological mechanism through which tobacco may exert adverse effects on neurodevelopment are potentially complex, given that tobacco smoke has over 2000 chemical constituents, most at trace levels. The two most well-examined constituents are carbon monoxide and nicotine, both of which are neurotoxic in a variety of species.[2,3]

The negative effects of maternal smoking during pregnancy on children's general intellectual ability, language tasks and academic achievement have been demonstrated by some overseas studies.[4-7] At least three studies have shown an effect on mental development, including an association with a reduced cognitive functioning by age three and a reduction in vigilance in the young child.[7-9] These studies often reported dose-related effects.[7-11] The commonly accepted mechanism for these effects is altered brain development resulting from fetal hypoxia due to either nicotine in cigarette smoke that acts to reduce blood flow to the fetus or possibly carbon monoxide, which produces higher levels of carboxhemoglobin.[11] Nicotine may also target specific neurotransmitter receptors in the fetal brain, causing abnormalities in cell proliferation and differentiation.[12] On

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the other hand; the effect and mechanism of environmental tobacco smoke on child's long-term growth and development is still relatively unclear.

Environmental tobacco smoke (ETS) is also known as "second-hand smoke", and ETS exposure is frequently used interchangeably with "passive smoking". The person who inhales it often has no choice in the matter. This is especially true for children. If parents smoke in the home, children have no alternative but to be a passive smoker. Very often, these children have also been exposed to ETS during fetal development. Therefore, it is difficult to separate the effects of those two periods of passive smoking.[13] Very few studies have examined the relationship between neuropsychological development and postnatal ETS exposure of the child, independent of prenatal exposure to maternal active smoking.[14-17] None of them is on Chinese children. No conclusions regarding causality can be made on the basis of these studies. In 1991, Bauman et al demonstrated that postnatally exposed children to ETS had substantially lower score in Raven's progressive matrices and Peabody Picture Vocabulary Test, when compared to children of nonsmokers.[6] Some other studies demonstrated similar effects.[8,12-14] But because smoking habit and lower social class are closely related, the adverse effects of ETS exposure virtually disappear when social class and the interaction of lifestyle factors have been taken into account.[15-17] Nevertheless, all these studies do provide suggestive evidence that ETS exposure may pose a neuropsychological developmental hazard.[15-18] The study of the relationship between ETS exposure and developmental delay in Chinese toddlers becomes an interesting and important public health issue.

In 2003, the overall smoking prevalence in Hong Kong was 14.4%, where 26.1% of men and 3.6% of women, aged 15 or above, were every day smokers.[19] According to a study by Lam et al 2001, 33.6% of fathers reported smoking during a visit to Maternal Child Health Centre, while 4.6% of mothers smoked.[20] Among nonsmoking mothers, 65% reported ETS exposure during pregnancy, composed of 50.5% with occasional exposure and 14.2% with daily exposure. After delivery, infant exposure to ETS at home, via smoking by fathers or others, was found in 41.2%.[20,21] Nearly half of the Hong Kong infants are exposed to various degrees of ETS at home. This could pose considerable health implications to our society. Compared with other developed countries where the maternal smoking rates are higher (e.g. 31.7% in the United States), our local maternal smoking rate is considered to be low (4.6%),[20] making Hong Kong a suitable place to examine the effects of ETS on child health or development.

The author reports here a case-control study on Hong Kong Chinese toddlers. The objective is to explore whether or not ETS exposure is associated with developmental delay in children. The environment being explored in this study included both the prenatal environment and the environment provided by children's parents in their first year of life. If the association between ETS exposure and delay in child development could be demonstrated, it would have an important implication for child health policy and another good reason to encourage parents to quit smoking in the future.

Methods

Subjects' Recruitment

A case-control study on Hong Kong Chinese toddlers was carried out from May 2003 to April 2004. Cases were clients from all seven Child Assessment Centers (CACs) of the Department of Health. The CACs serve all children aged below 12 in Hong Kong. They are secondary referral centers for children with suspected developmental problems. One of the main referrers is from the Maternal Child Health Centers (MCHCs). From the annual statistics of the CACs, there were around 6000 referrals in the year 2003 and MCHCs accounted for nearly 60% of the referrals.[22] From the unpublished statistics of MCHCs in 2001, more than half of the preschool children aged 18 months or older (range from 55% in urban area of Kwun Tong to 95% in the New Territories of Fanling) visited the MCHCs for free preventative care and immunisation.[23] Therefore, many of the Hong Kong preschool children with suspected developmental problems are referred to the CACs for further management. The comparison group was sampled from the local Chinese-speaking kindergartens and nurseries. A stratified cluster sampling method was used. The strata consisted of three main subdivisions of Hong Kong, namely Hong Kong Island, Kowloon and the New Territories, and the cluster units were nurseries and kindergartens within these strata. Invitation letters, with explicit explanation about the study, the participants' roles and the questionnaire, were sent to the principals or the centre-in-charges of the selected schools to invite their participation in the study. Altogether, 15 nurseries and kindergartens (three from Hong Kong Island, six from Kowloon and six from the New Territories) were invited. All of them agreed to participate in this study.

For case recruitment, children aged two to three years

old, newly diagnosed to have delay in development, with no obvious underlying reason, were included in the study. All of them had been assessed by a trained developmental paediatrician in the CACs, using the Griffiths Mental Development Scale. This assessment scale tests on five aspects of child development, including locomotion, personal-social skills, hearing and speech, eye-hand coordination and the overall performance.[24] After the assessment, a developmental quotient that reflects the age-specific developmental level of the child would be obtained. Those who got an overall developmental quotient less than 80 were considered to have delay in development.[24] Control children were recruited from the selected kindergartens and nurseries. They were matched to case children by age. All children in the control group should have normal development. To avoid mixing of potential cases with the controls, developmental level of individual child was screened. Mothers were asked to report two developmental milestones of their children. They were (1) time when the child first walked alone and (2) time when the child spoke first meaningful word. Children, who could walk alone and speak first meaningful word at less than 15-month-old, were considered to have age-appropriate development and were included as controls.[25] The exclusion criteria of the study included: (1) children who were non-Chinese; (2) whose mothers smoked during pregnancy; (3) children who have known or co-morbid causes of delay in development, including childhood autism, cerebral palsy, known genetic syndromes and chromosomal anomalies.

Main Outcome Measure

Odds Ratio (OR) was used to estimate "relative risk" of delay in development for those who were exposed to ETS as compared with those who were not.

Sample Size Calculation

Since there was no previous Chinese study on this topic, the estimated effect size of this study was based on overseas studies. As mentioned in the introductory section, the effects of ETS on child development are inconclusive; therefore, the actual magnitude of the adverse neurocognitive effects of tobacco exposure for children was not entirely clear. In 2001, Weitzman et al did a systematic review on this topic.[8] They suggested that an OR of approximate 1.5 would be a reasonably modest estimate of the effect of ETS on children's cognitive function. In this study, an OR of 1.5 was used as the estimated effect size in the sample size calculation. Locally, it was documented that around 40% of the infants were exposed to ETS at home, via smoking by fathers or others.[20,21] With the power of 80%, significant level of 0.05, the minimal sample size based on EPI-INFO will be 385 for each group.

Data Collection

Children, who met the inclusion criteria for cases, were recruited after their assessment by the paediatrician. The mother was given a standardised, self-administered questionnaire to fill in before they left the clinic. For those children attending the selected nurseries, the same standardised, self-administrated questionnaire was distributed to their parents and collected by class teachers after completion. The content of the questionnaire consisted of three main parts. The first part asked about information on the child, including his/her gender, birth order, gestation, mode of delivery, birth weight, breastfeeding history, and important developmental milestones. The second part ascertained household smoking habits including maternal and paternal smoking, as well as smoking by other household members during both pregnancy and infancy period. The last part concentrated on socioeconomic variables of the family that included parental education level and their occupation and housing type. Participation was voluntary and confidentiality was emphasised. The purpose of the study was explained in the questionnaire. Written consent from parents was obtained and the completed questionnaires were sealed in provided envelopes before handed in to the clinic paediatrician or the class teacher. They were returned directly to the investigator.

The study received ethics approval from the Institutional Review Board of the University of Hong Kong/Hospital Authority/Hong Kong West Cluster, as well as the Ethics Committee of Department of Health, HKSAR.

Finally, 401 questionnaires were distributed to the parents of the suitable cases in the CACs. Most of them completed the questionnaire (n=392) before leaving the clinic, so the response rate was 98%. On the other hand, 690 questionnaires were distributed to the kindergartens and nurseries. Five hundred and seventeen questionnaires were returned in the sealed envelopes. The response rate was 75%. Among the 517 respondents, 49 of them did not consent to complete the questionnaires. Seventy-six of them were ineligible due to the exclusion criteria. These 115 questionnaires were excluded from the final analysis. A final sample of 393 questionnaires from the controls was used.

In order to have a thorough understanding on the possible effects of ETS exposure on child development, the analysis included the following areas: (1) ETS exposure during pregnancy; (2) ETS exposure in infancy; and (3) possible

dose-response effects of ETS exposure, in terms of smoking habit of household members.

Statistical Analysis

To compare the general characteristics between cases and controls, χ^2 tests for independence was used. Bivariate and multivariate logistic regression analyses were employed to study the association between ETS patterns and child development. Odds ratio with 95% confidence interval was used to estimate "relative risk" of delay in development for those who were exposed to ETS as compared with those who were not. To study any dose-response relationship, χ^2 test for trend was used, using the amount of cigarettes smoked per day (none, ≤5 cigarettes per day, >5 cigarettes per day) as an ordinal variable. For multivariate analyses, potential predictors were included if they were associated with a P value <0.05 at bivariate analyses. The following independent variables were included in the multivariate models: gender of the child, birth weight (<2500 g, ≥2500 g), breastfeeding history (no vs. yes), paternal and maternal education level (matriculation or above, secondary school level, primary or below) and occupation of father and mother (non-manual, manual, non-working).

All analyses were conducted using *SPSS, Version 11.0*.

Results

Subject Characteristics

A total of 392 cases and 393 controls were investigated. The mean age in the cases and controls were 2.79 (SD 0.55) and 3.13 (SD 0.50) years respectively. Since the main interest of this study was the events during prenatal and infancy periods, the age at diagnosis of the child was not a factor to be studied. Other demographic characteristics of the cases and controls are shown in Table 1. The two groups were similar in the child's birth order, mode of delivery and gestation. However, there were statistically significant differences in the child's gender, birth weight, breastfeeding history, father's education level and occupation, mother's education level and occupation (all with P values <0.05). More boys were found to have developmental delay (75% vs. 52%). The cases were more likely to have low birth weight (9.9% vs. 3.8%) and less likely to be breastfed (46% vs. 53%). These children also appeared to come from lower socioeconomic classes as reflected from the results of their parental education level and occupation.

Exposure to Tobacco Smoke During Pregnancy

During the prenatal period, fetal exposure to ETS was through maternal environment. Table 2 summarises the ORs for developmental delay by the presence of different ETS exposures. Before adjustment for possible confounders, there was higher level of prenatal exposure to ETS at home for children with developmental delay than those in the control group (crude OR=1.53 [95%CI 1.13-2.07]). Since all mothers who smoked during pregnancy were excluded in the study, the prenatal ETS exposure at home was due to smoking by fathers and other household members. Paternal smoking appeared to give a statistically significant contribution in household ETS (crude OR=1.73 [95%CI 1.24-2.42]). However, this relationship became statistically non-significant after adjustment for child's gender, birth weight, breast-feeding history, housing type, parental educational level and occupation (adjusted OR=1.18 [95%CI 0.86-1.63]).

Exposure to Tobacco Smoke in Infancy

In most households, children are at home for the majority of their infancy, therefore ETS exposure before the first birthday is considered mainly at home. The unadjusted results in Table 2 shows a significantly higher proportion of children with developmental delay were exposed to household ETS in their early childhood (crude OR=1.44 [95%CI 1.06-1.96]). The contribution of paternal smoking in postnatal ETS was again statistically significant (crude OR=1.90 [95%CI 1.34-2.68]). Similar to the prenatal period, these effects did not persist when other confounding factors were taken into consideration (adjusted OR=1.23 [95%CI 0.88-1.73]). Although there was more maternal smoking in the cases (5.6% [n=22/392] vs. 3.1% [n=12/393]), the difference between the two groups was not statistically significant.

Dose-response Effects of ETS Exposure in Terms of Smoking Habits

Table 3 shows the estimated risks for a child to get developmental delay when exposed to different amount of ETS in utero and after birth. There was a clear dose-response gradient (P value for trend = 0.008) when considering the amount of paternal cigarette-smoking at home prenatally. A child whose father smoked more than five cigarettes at home per day during pregnancy would have more than twice the chance to get developmental delay than a child whose father did not smoke (crude OR=2.29 [95%CI 1.30-4.04]).

Table 1 Comparison between the characteristics of case and control subjects in the total sample

Variables	Controls (Total = 393) N (%)	Cases (Total = 392) N (%)	P value
Gender			**
Female	188 (47.8)	98 (25.0)	
Male	205 (52.2)	294 (75.0)	
Birth order			0.95
1st	245 (62.3)	240 (61.2)	
2nd	114 (29.0)	117 (29.8)	
3rd or above	34 (8.7)	35 (8.9)	
Delivery			0.36
Spontaneous vaginal delivery	247 (62.8)	232 (59.2)	
Caesarean section	116 (29.5)	134 (34.2)	
Assisted delivery	30 (7.6)	250 (6.6)	
Gestation			0.16
Preterm (<36 week)	23 (5.9)	33 (8.4)	
Term	370 (94.1)	359 (91.6)	
Birth Weight			**
≥2500 g	378 (96.2)	353 (90.1)	
<2500 g	15 (3.8)	39 (9.9)	
Breast feeding history			0.05*
Yes	208 (52.9)	180 (45.9)	
No	185 (47.1)	212 (54.1)	
Father's education level			**
Matriculation or above	117 (29.9)	83 (21.5)	
Secondary school level	250 (63.9)	249 (64.5)	
Primary or below	24 (6.1)	54 (14.0)	
Mother's education level			**
Matriculation or above	101 (25.8)	77 (19.7)	
Secondary school level	274 (69.9)	270 (69.1)	
Primary or below	17 (4.3)	44 (11.3)	
Father's occupation			**
Non-manual workers	257 (66.1)	191 (48.8)	
Manual workers	119 (30.3)	164 (41.9)	
Unemployed/non-working	13 (3.3)	36 (9.2)	
Mother's occupation			**
Non-manual workers	229 (58.3)	156 (39.9)	
Manual workers	6 (1.5)	15 (3.8)	
Unemployed/non-working	158 (40.2)	220 (56.3)	
Housing type			0.003*
Private housing	220 (56.0)	206 (52.6)	
Government subsidided sale flats	87 (22.1)	64 (15.8)	
Public rental housing	86 (21.9)	124 (31.6)	

*P <0.05; **P <0.001

Table 2 Crude and adjusted odds ratios (OR) for developmental delay according to the presence of different ETS exposures

Smoking category	Number (controls/cases)	Crude OR	(95%CI)	Adjusted OR[a]	(95%CI)
In utero					
Exposure to ETS at home					
No	289/253	1.00		1.00 [b]	
Yes	104/139	1.53	(1.13-2.07)*	1.15	(0.82-1.61)
Father's smoking habit					
No	320/281	1.00		1.00 [c]	
Yes	73/111	1.73	(1.24-2.42)*	1.18	(0.86-1.63)
Other household smokers					
No	342/336	1.00		1.00 [d]	
Yes	51/56	1.12	(0.74-1.68)	0.76	(0.48-1.20)
After birth					
ETS exposure at home					
No	288/257	1.00		1.00	
Yes	105/135	1.44	(1.06-1.96)*	1.07	(0.77-1.50)
Mother's smoking habit					
No	381/370	1.00		1.00 [e]	
Yes	12/22	1.89	(0.92-3.87)	0.99	(0.52-1.90)
Father's smoking habit					
No	328/285	1.00		1.00 [f]	
Yes	65/107	1.90	(1.34-2.68)*	1.23	(0.88-1.73)
Other household smokers					
No	337/347	1.00		1.00 [g]	
Yes	56/45	0.78	(0.51-1.19)	0.61	(0.38-0.98)

Note: CI= confidence interval; ETS= environmental tobacco smoke

[a] Model was adjusted for child's sex, birth weight, breast feeding history, housing type, parents' educational level and occupation. [b] Additional adjustment for any ETS at work during pregnancy. [c] Additional adjustment for ETS due to other household smoking other than paternal smoking; [d] Additional adjustment for ETS due to paternal smoking. [e] Additional adjustment for ETS due to other household smoking other than maternal smoking. [f] Additional adjustment for ETS due to other household smoking other than paternal smoking. [g] Additional adjustment for ETS due to other household smoking other than maternal and paternal smoking

*P<0.05

The risk dropped to 1.39 times and became statistically non-significant when other confounding factors were taken into consideration but the dose-response relationship was still present (P value for trend = 0.02). A statistically significant association also appeared between the paternal smoking habit during the infancy period and the chance of getting developmental delay in the child. The relationship was dose-related (P value for trend = 0.002). When comparing fathers who did not smoke with those who smoked five or less; and those who smoked more than five cigarettes per day at home, the unadjusted odds ratios increased steadily from 1.0 to 1.59 (95%CI: 1.05, 2.39) to 2.67 (95%CI: 1.48, 4.84). This relationship became statistically non-significant after the adjustment for possible confounders but the linear trend still persisted (P value for trend = 0.01). In both prenatal and postnatal periods, if the smoking father did not smoke at home, there appeared to be no increased risk for getting developmental delay in the child (prenatal $OR_{adjusted}$ = 1.04 [95%CI 0.68, 1.61]; postnatal $OR_{adjusted}$ = 1.03, [95%CI 0.65, 1.63]). On the

Table 3 Crude and adjusted odds ratios (OR) for developmental delay according to different amount of ETS exposures (dose – response relationship)

Smoking category	Number (controls/cases)	Crude OR	(95%CI)	Adjusted OR [a]	(95%CI)
In utero					
Paternal smoking habit at home					
Non-smoker	258/225	1.00		1.00	
Smoker, none at home	62/56	1.04	(0.69, 1.55)	1.04	(0.68, 1.61)
Smoker, ≤5 cigarettes/day	53/71	1.54	(1.03, 2.29)	1.15	(0.74, 1.77)
Smoker, >5 cigarettes/day	20/40	2.29	(1.30, 4.04)	1.39	(0.75, 2.58)
P value for linear trend		0.008**		0.02*	
After birth					
Maternal smoking habit at home					
Non-smoker	369/364	1.00		1.00 [b]	
Smoker, none at home	12/6	0.51	(0.19, 1.37)	0.66	(0.23, 1.93)
Smoker, at home	12/22	1.86	(0.91, 3.81)	1.01	(0.45, 2.29)
P value for linear trend		0.09		0.45	
Paternal smoking habit at home					
Non-smoker	268/236	1.00		1.00 [c]	
Smoker, none at home	60/49	0.93	(0.61, 1.41)	1.03	(0.65, 1.63)
Smoker, ≤5 cigarettes/day	48/67	1.59	(1.05, 2.39)	1.19	(0.75, 1.89)
Smoker, >5 cigarettes/day	17/40	2.67	(1.48, 4.84)	1.69	(0.87, 3.29)
P value for linear trend		0.002**		0.01**	

Note: CI= confidence interval; ETS= environmental tobacco smoke

[a] Model was adjusted for child's sex, birth weight, breast feeding history, housing type, parents' educational level and occupation. [b] Additional adjustment for any smoker at home other than maternal smoking after birth. [c] Additional adjustment for any smoker at home other than paternal smoking after birth.

*P<0.05; **P<0.01

other hand, maternal smoking habit after birth did not show a statistically significant dose-response effect on the delay in child development.

Discussion

This study questions whether prenatal and postnatal environmental tobacco smoke, due to household smoking, is associated with elevated rates of developmental delay among Hong Kong Chinese toddlers. The results reveal an association between household smoking and developmental delay in the child both prenatally and postnatally. The main contribution of household ETS is paternal smoking. A clear dose-response relationship can be demonstrated for the amount of prenatal or postnatal paternal smoking and the presence of developmental delay in their children. However, this association appears to be confounded by gender and birth weight of the child and socioeconomic factors of the family.

Consistent with some previous local studies, this study has shown that paternal smoking is the main contribution for ETS at home in Hong Kong.[20,21] Although not significant at the 0.05 level, our findings about dose-response relationship between paternal smoking habit and developmental delay agree with the findings by Bauman in 1991, who demonstrated a dose-related effect between parental smoking and cognitive performance in older children.[6] It is suggestive that paternal smoking at home was the main driver of the increased risk for delay in child

development. We also found in this study that as long as smoking fathers do not smoke at home, the risk for developmental delay in child will not increase. This is an important public health implication when considering promotions for smoking cessation or when enhancing proper smoking hygiene practices in household members.

Several strengths are seen in this study. It is the first Chinese study on this issue. The low maternal smoking rate in Hong Kong makes it easier to obtain sample with non-smoking mothers during pregnancy and to separate maternal smoking in pregnancy from other types of ETS. Since the majority of children with developmental delay in our society are referred to the Child Assessment Centers for further management, the representativeness of the cases for Chinese children in Hong Kong is quite high. The use of self-administered questionnaire to obtain information from parents was easy and inexpensive. The response rate, especially in the cases (>90%), was good. Moreover, confounding factors were controlled for in data analysis.

Although this study could not demonstrate a statistically significant relationship between ETS and developmental delay in child, such a relationship is still possibly present. Several limitations could be identified and suggest that further investigation of this issue should be pursued. Firstly, the sample size of the study was small. Despite there were nearly 400 subjects in each group, it would be considered to be inadequate when the strength of relationship under-investigation is not strong and accurate categorisation of ETS exposure is difficult. However, the odds ratios for prenatal or postnatal ETS exposure obtained in this study (i.e. crude ORs = 1.73 [95%CI 1.24-2.42] and 1.90 [95%CI 1.34-2.68] respectively) are quite consistent with the previous studies.[8] Weitzman et al in 2001 conducted a systemic review on this subject and obtained a similar result of pooled risk of around 1.5.[8] Even after adjustment for confounders, the odds ratios in this study shows an increased risk for prenatal and postnatal paternal smoking although they became statistically non-significant (adjusted ORs=1.25 [95%CI 0.87-1.81] and 1.36 [95%CI 0.91-2.04] respectively). Moreover, the dose-response relationships between the amount of paternal smoking and the chance of getting developmental delay in children during and after pregnancy, agree with the previous findings of Bauman et al.[6] These suggest that insufficient power could be an important reason for failure to detect a statistically significant association between ETS and child development after adjusting for confounders.

A second limitation is the possibility of misclassification about ETS exposure due to recall error in household smoking history. This recall error could be random or systemic (bias) and is one limitation in all case-control study designs. Recall bias in case-control study would usually lead to over-reporting of exposure in cases resulting in higher OR. However, a study from California Environmental Protection Agency in 1997 showed that assessment of current ETS exposure of children is somewhat less problematic.[14] Although concerns regarding misclassification remain, children, especially infants and young children, are likely to be exposed to tobacco smoke in fewer circumstances than adults. Greenberg et al in 1989 found that cotinine concentrations in children are well correlated with smoking by the mother; thus, information on cigarette consumption by the mother is likely to provide a reasonable proxy for a young child's ETS exposure.[25] Moreover, information on household smoking behaviors is likely to be relatively well reported because smoking is generally fairly well recalled especially on qualitative information, although quantitative information on the number of years of smoking, dates of smoking, or number of cigarettes smoked per day is sometimes less reliably provided.[14] The use of biomarker measurements (such as urinary nicotine level) may be useful in validating the questionnaire-based exposure status of ETS exposed subjects. But one problem with ETS markers and biomarkers is that most of them are only capable of estimating ETS exposure over a relatively short period of time; whereas, many health effects of ETS, including child development, are believed to be associated with long-term exposures that are measured in months if not years.[14] Moreover, biomarker measurement is a more expensive and inconvenient investigation when comparing with the use of questionnaire.

A third important limitation in this study concerned the use of children with the diagnosis of developmental delay. The definition of "developmental delay" is rather non-specific. It represents a wide spectrum of pre-requisite developmental difficulties. It is neither equivalent nor predictive for future intellectual impairment.[26-28] Most of the cases in this study belong to the category of borderline developmental delay (83%), where many of them are 'slow' to start with because of environmental deprivation, possibly due to socioeconomic disadvantage. If they are provided with suitable environmental stimulation, such as early developmental training, majority of them will 'grow out' of their problem at later age. Only a small percentage will turn out to have more serious intellectual impairment at latter life.[28] As the effects of tobacco smoke are more

obvious in children with severe intellectual impairment, it will be difficult to prove such a relationship in less severe cases of borderline developmental delay. Moreover, the effects of passive smoking on cognitive development is likely to be long term and cumulative.[15] The association is more likely to be demonstrated if the cognitive development of the child could be followed up to an older age.

The final explanation involves the potentially confounding variables. In a systematic review by Eskenazi and Castorina in 1999, they pointed out the difficulty in demonstrating the adverse effects of ETS exposure on neurodevelopment.[12] Apart from the complex web of genetic and socioenvironmental factors that could influence human cognitive development, there are a number of immeasurable differences between smokers and non-smokers that cannot be readily ascertained (e.g. personality, child-rearing practice). Not controlling for these factors is likely to bias the results away from null.[12] In this study, three confounding factors are found to be significantly related to development outcomes apart from ETS. They are gender and birth weight of child and socioeconomic factors such as parental occupation and education level. When these variables are controlled for, the relationships between household ETS and developmental delay are no longer significant.

Studies have showed that boys have more developmental problems of all sorts than girls.[29,30] Therefore, it is not unexpected to find more boys in the cases (75%) than the controls (52%). Since gender is an important factor in determining the developmental status in a child, it should be well controlled of in future studies.

Another possible confounder in this study is the birth weight of the child. Maternal ETS exposure during pregnancy may lower baby's birth weight in turn could potentially be related to lowered cognitive abilities. Because birth weight may be on the causal pathway between ETS exposure and adverse neurodevelopmental outcomes, Baghurst et al discussed the potential for over control if birth weight remained in the multivariate model.[31] Due to the possibility of overadjustment of the data, birth weight was not considered as a confounder in this study.

For the last confounder in this study, previous evidence showed that socioeconomic factors had a great impact on child's development. The presence of parental smoking either during pregnancy and/or during a child's development may serve as an indicator that other factors, such as low parental education, may place a child at risk for developmental delay. Parental background and behavior are more robust risk factors and are often associated with parental smoking.[13,31,32] For future studies, care must be taken to document parental education and home environment in order to develop a better understanding of the effects of parental smoking on child development.

Public Health Implications and Recommendations

Although the present study was restricted by inadequate sample size and strong influence of child's gender and socioeconomic factors, it reveals a possible association between ETS exposure at home and developmental delay in the child both prenatally and postnatally. This is rather consistent with the results of other studies.[8,13,15-17] The present data supports the setting up of public policy to the promotion of smoking cessation in all household members, during as well as after pregnancy; or at least proper smoking hygiene (e.g. not to smoke at home) could be practiced for those unable to quit, so as to reduce the chance of developmental delay in children. ETS exposure and child development is such an important topic that further investigations with better methodological methods are recommended. Suggested improvements in the study methodology include using (1) bigger sample size and random sampling method, if time, money and manpower allowed; (2) better measure of ETS exposure, e.g. matching with biomarker measurements and the use of cohort study design; (3) more specific definition for cases, e.g. using subjects with mild grade mental retardation instead of developmental delay; and (4) better control for the confounders, e.g. study in boys or girls only, stratification of subjects into different social classes. Further topics are also suggested for future studies. These include (1) identifying effective ways to encourage parents to quit smoking or practice appropriate harm reduction strategies; and (2) investigating whether reduction in ETS exposure can result in better child development. All these recommendations aim to decrease developmental delay in children living in households exposed to tobacco smoke and reduce the possible economic burden in providing additional preschool educational intervention by the society.

Conclusion

There is some evidence of an association between environmental tobacco smoke and developmental delay among Hong Kong Chinese toddlers, in both prenatal and early childhood periods. This association appears to be

confounded by gender of the child and socioeconomic factors of the family. Insufficient sample size in this study appeared to contribute largely to the statistically non-significant results after adjustment of the confounders. Nevertheless, with home as the most significant ETS exposure location for these age groups, educational efforts for women who are pregnant (or plan to become pregnant) and their family members about reducing their children's ETS exposure are warranted.

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