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The Interaction Between Prenatal Exposure to Home Renovation and Reactive Oxygen Species Genes in Cord Blood IgE Response is Modified by Maternal Atopy

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Purpose: Although home renovation exposure during childhood has been identified as a risk factor for the development of allergy, there is limited information on the association between prenatal exposure to home renovation and cord blood (CB) IgE response. The aims of this study were to identify the effect of prenatal exposure to home renovation on CB IgE levels, and to investigate whether this exposure interacts with neonatal genes and whether the effect can be modified by maternal atopy. **Methods:** This study included 1,002 mother-neonate pairs from the COhort for Childhood Origin of Asthma and allergic diseases (COCOA). Prenatal environmental factors were collected using a questionnaire. The levels of CB IgE were measured by the ImmunoCAP system, and DNA was extracted from CB. **Results:** Exposure to home renovation during the prenatal period was associated with significantly higher levels of CB IgE only in neonates from atopic mothers, and the effect of renovation exposure on CB IgE levels persisted from 31 months before birth. Furthermore, prenatal exposure to home renovation increased the risk of CB IgE response interacting with polymorphisms of *NRF2* and *GSTP1* genes only in neonates from atopic mothers. **Conclusions:** Maternal atopy modified the effect of prenatal exposure to home renovation on CB serum IgE response as well as the interaction between the exposure and neonatal genes involved in the oxidative stress pathway. These findings suggest that the genetically susceptible offspring of atopic mothers may be more vulnerable to the effect of prenatal exposure to home renovation on the development of allergy.

Key Words: Cord blood; gene-environment interaction; IgE; prenatal; reactive oxygen species; renovation; single nucleotide polymorphism

INTRODUCTION

Epidemiologic studies have reported that exposure to home renovation increases the risk of allergic diseases during child-

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hood.[1,2] However, there is limited information on the association between exposure to home renovation during the prenatal period and the development of childhood allergy. In a previous study, home redecoration during pregnancy was not associated with wheezing during early childhood, although redecoration during the first or second year of life increased the risk of wheezing during the same period.[1] By contrast, the Lifestyle-Immune System-Allergy (LISA) birth cohort study reported that exposure to indoor volatile organic compounds (VOCs) during pregnancy is associated with cord blood (CB) immune status.[3] Significantly elevated levels of VOCs in indoor air have been found in new and renovated buildings.[3-5]

Maternal exposure to environmental factors, including cigarette smoke and microbials, is known to alter fetal immune function and increase the risk of allergic disease in children.[6-8] Lower interferon γ (INF-γ) levels or a reduced number of T regulatory cells (Treg) in neonates was reported to induce T helper (Th) 2-skewed immune response, which is a main pathogenesis of development of allergic diseases during childhood.[9,10] These data suggest that prenatal environmental factors are important in programming neonatal immune response and in the subsequent development of allergic diseases. Recently, CB immune response was reported to be modifiable by maternal atopy.[11] Furthermore, the levels of maternal inflammatory cytokines during pregnancy are associated with corresponding cytokines in infants at the age of 1 year.[12] These data suggest that maternal immune status may provide an intrauterine environment that influences the development of the immune system, having effects beyond the fetus stage. However, to the best of our knowledge, no studies have evaluated the effect of prenatal environmental factors on CB immune response in relation to maternal immune status.

Although genome-wide association studies have identified several genes associated with allergic diseases, especially asthma, the results do not account for the significant trait variation observed.[13] Gene–environment interaction can explain some of this missing heritability. Exposure to environmental factors in early life increases the risk for allergic disease in individuals with a susceptible genotype.[14-17] However, there is limited information on the interaction between environmental factors in prenatal periods and genes that affect CB immune response.

The aims of this study were to investigate the association between maternal exposure to prenatal home renovation and CB IgE response in a prospective birth cohort and to assess whether this exposure interacts with genetic variants in neonates and whether this association can be modified by maternal atopy.

MATERIALS AND METHODS

Study design

The COhort for Childhood Origin of Asthma and allergic Diseases (COCOA) study is an ongoing prospective longitudinal birth cohort one.[18] A total of 1,369 pregnant women were recruited at 26 weeks of pregnancy from 4 tertiary hospitals (Asan Medical Center, Samsung Medical Center, Severance Hospital, and CHA Gangnam Medical Center) and 7 public health centers in Seoul, Republic of Korea. The study methods have been described in detail elsewhere.[18] A total of 1,200 neonates born to those mothers were enrolled after exclusion of neonates who were premature or who had a major congenital anomaly or birth asphyxia, and after withdrawals from participation. Neonates with no information available on prenatal home renovation exposure, maternal atopic status, or CB IgE levels were also excluded. Finally, 444 neonates were included in the analysis (Figure). The study protocol was approved by the institutional review boards of Asan Medical Center (IRB No. 2008-0616), Samsung Medical Center (IRB No. 2009-02-021), Yonsei University (IRB No. 4-2008-0588), and CHA Medical Center (IRB No. 2010-010). Informed consent was confirmed by each IRB and obtained from the parents of each infant.

Prenatal exposure and maternal atopy

Standardized questionnaires were administered during pregnancy (at week 26) and included information on demographic

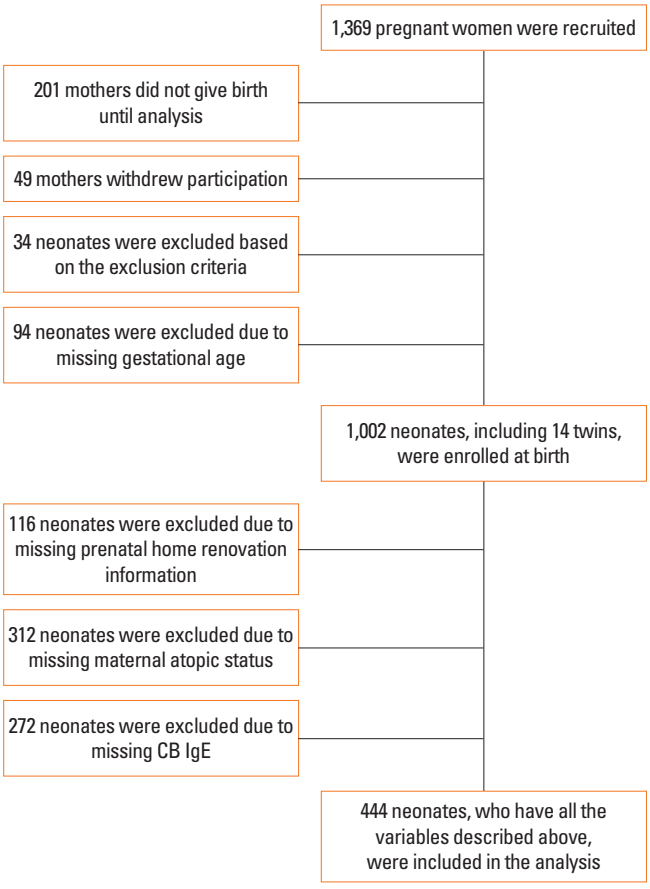

Figure. Enrollment and outcomes.

data, social economic status, family history of allergic disease, and history of home renovation. Questions about home renovation were as follows: "Have you ever renovated your home where you are resident?", "If you answer yes, when did you renovate it? (describe the renovation date as a year and a month.)"

Maternal atopy was assessed by a skin prick test (SPT) within 6 months after birth. SPT was performed on the backs of the mothers using standard methods. Commercial extracts of the following common allergens were used: mites (*D. pteronyssinus* and *D. farinae*), molds (*Alternaria* and *Aspergillus*), pollens (grasses, trees I and II, ragweed, mugwort, oak, and elder), animal dander (dog and cat), and cockroach. Histamine and isotonic saline were used as positive and negative controls, respectively. A positive SPT was defined by a mean wheal diameter of ≥3 mm and at least as large as that of the positive control. Atopy was defined as the presence of at least 1 positive SPT result.

Cord blood IgE

The methods for measuring CB IgE levels have been described in detail elsewhere.[19] Briefly, CB samples were collected from the umbilical cord vein, and the total IgE level (cutoff, 0.001 kU/L) was measured by the ImmunoCAP system (ThermoFisher, Uppsala, Sweden).

Genotyping analysis

DNA from CB mononuclear cells was isolated using the Gentra Puregene® Blood kit (Qiagen, Germantown, MD, USA) and screened for single nucleotide polymorphisms (SNPs) of IL-13 (rs20541), toll-like receptors 4 (TLR4) (rs1927911), CD14 (rs2569190), N-acetyltransferase 2 (NAT2) (rs4271002), nuclear factor erythroid 2-related factor 2 (NRF2) (rs6726395), and Glutathione-S-transferase P1 (GSTP1) (rs1695) by using the TaqMan assays. Assay ID numbers for SNPs are C_2259921_20, C_11722141_10, C_16043997_10, C_31028511_10, C_155538_10, and C_3237198_20, respectively (ABI, Foster City, CA, USA). The final polymerase chain reaction (PCR) volume was 5 μL, containing 10 ng of genomic DNA, 2.5 μL of TaqMan Universal PCR Master Mix, and 0.13 μL of 40× assay mix. All PCRs were performed on 384-well plates and using a 384-Well Veriti thermal cycler (ABI). The endpoint fluorescent readings were performed on an ABI PRISM 7900 HT Sequence Detection System (ABI). Duplicate samples and negative controls were included to ensure genotyping accuracy.

Statistical analysis

Associations between the levels of CB IgE and the general characteristics of the study subjects were assessed by the χ^2 test or *t* test, as appropriate. The effect of prenatal home renovation exposure on CB IgE response was assessed according to the time of prenatal renovation in each atopic or non-atopic mother using analysis of variance by the LSMEANS procedure, adjusted for maternal age at birth, maternal education level, gender of neonates, maternal total serum IgE levels, and birth weight. The interaction of prenatal home renovation exposure and genetic polymorphisms on CB IgE response was investigated in subjects from each atopic or non-atopic mother by the LSMEANS approach. Statistical analyses were conducted with SAS for Windows (version 9.3). A *P* value of <0.05 was considered statistically significant.

RESULTS

CB IgE levels according to maternal and neonatal general characteristics

The general characteristics of mothers and neonates included in this analysis were not different from those of subjects not included for analysis, except for maternal education, maternal diagnosis of allergic disease, maternal serum total IgE level, and birth weight (Table 1 and Table S1).

The levels of CB IgE according to maternal and neonatal general characteristics are summarized in Table 2. CB IgE levels were higher in mothers who were older than 40 years at birth than in other age groups (P=0.020). Atopic mothers had a higher CB IgE level than non-atopic mothers (P=0.0002). Male neonates had a higher CB IgE level than female neonates (P=0.036).

CB IgE levels, prenatal home renovation exposure, and maternal atopic status

Among all subjects, CB IgE levels were not significantly different between the groups with exposure and non-exposure to prenatal home renovation (geometric mean [range of 1SD], 0.31 kU/L [0.23-0.41] and 0.30 kU/L [0.23-0.39], respectively). When subjects were divided according to the period from birth to home renovation (tertiles), the levels of CB IgE were not significantly different among the 3 groups (Table 3).

When all subjects were classified into 2 groups according to maternal atopy, higher levels of CB IgE in the exposure group compared to the non-exposure group were only seen in neonates with atopic mothers (0.74 kU/L [0.50-1.09] and 0.46 kU/L [0.32-0.65], respectively, P=0.026). However, no such difference between the exposure and non-exposure groups was noted in neonates with non-atopic mothers. In terms of the renovation timing, the levels of CB IgE were significantly higher in atopic mothers in the exposure group in the first and second tertiles compared to the non-exposure group, while no difference was seen among subjects classified into the third tertile (first tertile 0.76 [0.49-1.19], P=0.038, second tertile 0.96 [0.62-1.49]), P=0.039, and third tertile 0.41 [0.24-0.68]). However, there was no significant difference in CB IgE levels between the exposure and non-exposure groups in any of the 3 tertiles when considering only non-atopic mothers.

When the levels of maternal IgE were compared between the non-exposure group and each tertile exposure group, no signif-

Table 1. General characteristics of mothers and neonates

Variables	Included (n=444)		Not included (n=558)		*P*
	mean±SD or n (%)		mean±SD or n (%)		
Maternal characteristics					
Age at birth (year)	32.1±3.4		32.5±3.3		0.0881
BMI (kg/m^2)	20.6±2.6		20.7±2.6		0.5396
Maternal education					
≤High school graduation	32/443	(7.2)	34/508	(6.7)	0.0157
College or university graduation	288/443	(65.0)	372/508	(73.2)	
≥Graduate school graduation	123/443	(27.8)	102/508	(20.1)	
Mode of delivery					
Vaginal	286/407	(70.3)	341/502	(67.9)	0.4478
Caesarean section	121/407	(29.7)	161/502	(32.1)	
Parity					
No	99/358	(27.7)	120/456	(26.3)	0.6692
Yes	259/358	(72.4)	336/456	(73.7)	
Renovation					
No	333/444	(75.0)	322/442	(72.9)	0.4662
Yes	111/444	(25.0)	120/442	(27.2)	
Maternal diagnosis of allergic diseases*					
No	328/443	(74.0)	299/450	(66.4)	0.0131
Yes	115/443	(26.0)	151/450	(33.6)	
Paternal diagnosis of allergic diseases*					
No	304/412	(73.8)	303/411	(73.7)	0.9834
Yes	108/412	(26.2)	108/411	(26.3)	
Atopy					
No	276/444	(62.2)	146/245	(59.6)	0.5074
Yes	168/444	(37.8)	99/245	(40.4)	
Serum total IgE (kIU/mL)**	428	41.2 (10.6-159.9)	427	49.6 (13.1-188.1)	0.0432
Infant characteristics					
Gender (male, %)	241/444	(54.3)	287/556	(51.6)	0.4024
Birth weight	444	3.3±0.3	556	3.2±0.4	0.0296
Season of birth					
Spring (March to May)	99/437	(22.7)	122/536	(22.8)	0.4378
Summer (June to August)	103/437	(19.7)	120/536	(22.4)	
Autumn (September to November)	133/437	(30.4)	146/536	(27.2)	
Winter (December to February)	102/437	(23.3)	148/536	(27.6)	
Cord blood IgE (kIU/mL)**	444	0.27 (0.07-0.94)	286	0.27 (0.08-0.88)	0.8090

*Allergic diseases include asthma, allergic rhinitis, and atopic dermatitis; **Data are expressed as geometric mean (range of 1SD).

icant differences were seen in atopic or non-atopic mothers (Table S2).

Interaction of prenatal home renovation exposure and neonatal genes on CB IgE response

We chose SNPs for *IL-13* rs20541, *TLR4* rs1927911, *CD14* rs2569190, *NAT2* rs4271002, *NRF2* rs6726395, and *GSTP1* rs1695 as candidate genes based on the results of our previous studies[16,20,21] to evaluate the interaction between prenatal exposure to home renovation and neonatal genes on CB IgE response. No SNP interacted with renovation exposure in any subjects. When the subjects were classified into 2 groups according to maternal atopy, SNPs for polymorphisms of *NRF2* and *GSTP1* interacted with renovation in subjects from atopic mothers, but did not have any interaction with renovation in subjects from non-atopic mothers (Table 4). There was no interaction between SNPs for *IL-13*, *TLR4*, or *CD14* and renovation exposure in subjects from either atopic or non-atopic

Table 2. Cord blood IgE according to maternal and neonatal general characteristics

Variables	Cord blood IgE (kIU/mL)		
	n (%)	Geometric mean (range of 1SD)	*P*
Maternal characteristics			
Age at birth (year)			
20-29	109/444 (24.5)	0.32 (0.10-0.98)	0.0196
30-39	324/444 (72.9)	0.25 (0.07-0.86)	
40+	11/444 (2.4)	0.59 (0.07-4.58)	
Maternal education			
≤High school graduation	32/443 (7.2)	0.28 (0.06-1.21)	0.8328
College or university graduation	288/443 (65.0)	0.27 (0.08-0.91)	
≥Graduate school graduation	123/443 (27.7)	0.25 (0.06-0.96)	
Parity (yes)			
No	99/358 (27.7)	0.27 (0.09-0.75)	0.6133
Yes	259/358 (72.3)	0.25 (0.07-0.86)	
History of home renovation			
No	333/444 (75.0)	0.26 (0.08-0.84)	0.4311
Yes	111/444 (25.0)	0.29 (0.06-1.28)	
Parental diagnosis of allergic diseases*			
No	221/419 (52.7)	0.25 (0.07-0.89)	0.1478
Yes	198/419 (47.3)	0.29 (0.08-1.00)	
Maternal diagnosis of allergic diseases*			
No	328/443 (74.0)	0.25 (0.07-0.91)	0.0981
Yes	115/443 (26.0)	0.32 (0.10-1.01)	
Paternal diagnosis of allergic diseases*			
No	304/412 (73.8)	0.27 (0.07-0.96)	0.7547
Yes	108/412 (26.2)	0.26 (0.07-0.89)	
Atopy			
No	276/444 (62.2)	0.23 (0.07-0.75)	0.0002
Yes	168/444 (37.8)	0.35 (0.09-1.30)	
Infant characteristics			
Gender			
Male	241/444 (54.3)	0.30 (0.08-1.08)	0.0359
Female	203/444 (45.7)	0.23 (0.07-0.78)	
Mode of delivery			
Vaginal	286/407 (70.3)	0.27 (0.08-0.86)	0.0956
Caesarean section	121/407 (29.7)	0.22 (0.06-0.71)	
Birth weight (≤2.5 kg)			
No	435/443 (98.2)	0.27 (0.07-0.95)	0.3358
Yes	8/443 (1.8)	0.17 (0.08-0.38)	
Season of birth (%)			
Spring (March to May)	99/437 (22.7)	0.25 (0.08-0.81)	0.5576
Summer (June to August)	103/437 (23.6)	0.26 (0.06-1.09)	
Autumn (September to November)	133/437 (30.4)	0.30 (0.10-0.92)	
Winter (December to February)	102/437 (23.3)	0.25 (0.06-0.93)	

*Allergic diseases include asthma, allergic rhinitis, and atopic dermatitis.

mothers (Table S3).

DISCUSSION

Prenatal exposure to home renovation increased the risk for CB IgE response only in subjects from atopic mothers. Exposure to renovation from 31 months before birth onward increased the risk of elevated CB IgE levels, while that before 31 months had no effect. Furthermore, prenatal home renovation exposure increased the risk of CB IgE response interacting with polymorphisms of reactive oxygen species genes only in subjects from atopic mothers.

Surprisingly, the effect of home renovation exposure on IgE response was prominent in the offspring from atopic mothers exposed to home renovation before fertilization, indicating that home renovation exposure can have an indirect effect on the fetus. Furthermore, these findings suggest that maternal exposure to home renovation may have important effects on CB immune response. Recently, maternal exposure to air pollution, including PM_{10} and benzene, 3 months before pregnancy as well as during pregnancy was reported to alter the percentage of CB Treg cells.[22]

Although IgE is not thought to cross the placenta, meaning that CB IgE is presumed to originate from fetal production, a recent study showed that increased CB IgE levels may be caused by maternofetal transfer, suggesting that measurement of IgA levels could be indicative of falsely elevated IgE levels in CB.[23] In this study, CB IgE levels may have been contaminated by maternal IgE because maternal IgE levels were significantly correlated with CB IgE levels ($r=0.328$, $P<0.0001$, Fig. S1). However, we analyzed the association between prenatal exposure to home renovation and CB IgE levels after adjusting for maternal IgE levels. In addition, the levels of maternal IgE at birth did not differ according to exposure or time to renovation irrespective of maternal atopic status (Table S1). Although CB IgE level has not shown good sensitivity for predicting the development of allergic diseases during childhood,[24] several studies found that elevated CB IgE levels are associated with aeroallergen sensitization and development of allergic diseases in children, particularly in those with a family history of atopy.[25,26]

Which environmental factors related to home renovation could increase the risk for CB IgE response? Because exposure and time of renovation were recorded based on questionnaires, our results may be confounded by recall bias and unmeasured causes. According to previous studies, VOCs are emitted after renovation.[4,5] Exposure to VOCs during pregnancy has been demonstrated to be associated with CB immune status and eosinophil/basophil progenitors in children diagnosed with cradle cap within the first year of life in LISA and Lifestyle and environmental factors and their Influence on Newborns Allergy risk (LINA) birth cohort studies.[3,27]

Our findings showed that maternal atopy modified the effect of prenatal exposure to home renovation on CB IgE response. Maternal atopy may provide the fetus with an intrauterine environment that affects fetal immune development, resulting in allergic predisposition in response to prenatal exposure to home renovation. A previous study reported that neonatal immune response to a TLR2 agonist was modified by maternal atopy.[11]

Table 3. Cord blood IgE according to the time of home renovation exposure and maternal atopic status

Variables		Cord blood IgE (kIU/mL) n, geometric mean (range of 1SD)					
		Total		Non-atopic mothers		Atopic mothers	
No renovation		333	0.30 (0.23-0.39)	212	0.27 (0.17-0.43)	121	0.46 (0.32-0.65)
Renovation	Total	111	0.31 (0.23-0.41)	64	0.20 (0.13-0.33)	47	0.74 (0.50-1.09)*
	1st tertile	34	0.35 (0.25-0.48)	17	0.23 (0.14-0.38)	17	0.76 (0.49-1.19)**
	2nd tertile	34	0.37 (0.26-0.50)	18	0.19 (0.11-0.32)	16	0.96 (0.62-1.49)†
	3rd tertile	32	0.25 (0.18-0.35)	22	0.22 (0.13-0.37)	10	0.41 (0.24-0.68)

First, second, and third tertiles indicated home renovation within 13 months before birth, between 14 months and 31 months before birth, and more than 31 months before birth, respectively.
*P=0.0262, compared to those not exposed to prenatal home renovation, and adjusted for maternal age at birth, maternal education level, gender of child, maternal total IgE level, and birth weight; **P=0.0375; †P=0.0393, compared to those not exposed to prenatal home renovation, and adjusted for multiple comparisons by Tukey-Kramer.

Table 4. Interaction of prenatal exposure to home renovation and neonate genes for reactive oxygen species on cord blood IgE response

Gene	Genotype	Renovation	Cord blood IgE (kIU/mL) n, geometric mean (range of 1SD)					
			Total		Non-atopic mothers		Atopic mothers	
NAT2	GG	No	177	0.33 (0.28-0.38)	109	0.26 (0.22-0.32)	68	0.45 (0.35-0.57)
rs4271002	GG	Yes	61	0.31 (0.26-0.38)	33	0.15 (0.12-0.20)	28	0.71 (0.53-0.96)
	GC+CC	No	141	0.35 (0.30-0.41)	95	0.27 (0.22-0.33)	46	0.49 (0.38-0.63)
	GC+CC	Yes	41	0.46 (0.37-0.58)	25	0.31 (0.23-0.41)	16	0.79 (0.56-1.13)
Nrf2	GG	No	125	0.32 (0.27-0.38)	74	0.28 (0.23-0.35)	51	0.37 (0.29-0.47)
rs6726395	GG	Yes	45	0.34 (0.27-0.43)	29	0.27 (0.20-0.35)	16	0.45 (0.31-0.64)
	GA+AA	No	200	0.34 (0.29-0.40)	134	0.26 (0.22-0.32)	66	0.52 (0.41-0.66)
	GA+AA	Yes	56	0.39 (0.32-0.48)	29	0.17 (0.13-0.22)	27	1.00 (0.76-1.31)*
GSTP1	AA	No	219	0.31 (0.27-0.36)	149	0.25 (0.20-0.30)	70	0.47 (0.37-0.60)
rs1695	AA	Yes	58	0.33 (0.27-0.40)	34	0.21 (0.16-0.27)	24	0.59 (0.44-0.80)
	AG+GG	No	106	0.39 (0.33-0.46)	59	0.32 (0.25-0.40)	47	0.49 (0.38-0.62)
	AG+GG	Yes	45	0.42 (0.34-0.53)	24	0.22 (0.16-0.29)	21	1.00 (0.72-1.39)**

*P=0.0023, compared to those not exposed to prenatal home renovation with the GG genotype; **P=0.0458, compared to those not exposed to prenatal home renovation with the AA genotype. All P values were adjusted for maternal age at birth, maternal education level, gender of child, maternal total IgE levels, and birth weight, and adjusted for multiple comparisons by Tukey-Kramer.

In addition, mothers with atopy have a genetic susceptibility to atopy, which can be inherited by the next generation, and may thus reflect a partly genetic susceptibility of neonates for allergy development.

When we evaluated whether renovation exposure, which affects CB IgE response, could interact with candidate genes in the offspring, we found an interaction between prenatal exposure to home renovation and polymorphisms of *NRF2* and *GSTP1* genes, which are involved in oxidative stress, on CB IgE response, only in offspring from atopic mothers, whereas no interaction was seen with genes for *IL-13*, *TLR4*, and *CD14*. To the best of our knowledge, this is the first study to prospectively show interactions between prenatal exposure to home renovation and neonate genes on CB IgE response. Previous epidemiologic study and *in vitro* and *in vivo* studies demonstrated that VOCs, which can be emitted following home renovation, induce T-cell differentiation toward a Th2 phenotype through oxidative stress.[3,28,29] Glutathione S-transferase (GST) is a well-known enzyme that acts as an antioxidant, and *GSTP1* Ile105 Val polymorphism (rs 1695) lowers GST enzyme activity.[30] High diesel exhaust particles increase the risk for wheezing only in children with the *GSTP1* rs 1695 G allele.[31] Our finding that prenatal exposure to home renovation elevated CB IgE levels in neonates with *GSTP1* G or *NRF2* A alleles from atopic mothers suggests that prenatal exposure to home renovation may induce T-cell differentiation to Th2 through oxidative stress. Interestingly, the finding that gene-environment interactions are only present in the offspring from atopic mothers suggests that the maternal atopic status may modify the interactions between genetic polymorphisms of reactive oxygen specifies and prenatal exposure to home renovation through another interaction with atopy-related genes of neonates inherited from atopic mothers or via the intrauterine environment provided by atopic mothers.

There are some limitations in this study. Only 444 neonates were included in the analysis among 1,002 neonates enrolled, with the remaining neonates lacking information on prenatal exposure to home renovation, maternal atopic status, and/or CB IgE levels. However, we adjusted for confounding variables, including maternal education, maternal serum total IgE levels, and birth weight of neonates between subjects included in the analysis and those who were not. For gene–environment interactions, we chose only 6 SNPs for IL-13, *TLR4*, CD14, *NAT2*, *NRF2*, and *GSTP1* as candidate genes. However, these candidate genes were chosen based on the results of our previous studies, which showed that these genes were associated with the development of allergy during childhood in Korea.[16,20,21] In addition, for the analysis of gene-environment interactions, we did not subclassify subjects into 3 tertile groups based on the period from renovation to birth due to the small sample size.

In conclusion, maternal atopy modified the effect of prenatal exposure to home renovation on CB IgE response and the interaction between home renovation exposure and genetic polymorphisms of oxidative stress genes in neonates. Our results indicate that the genetically susceptible offspring of atopic mothers may be more vulnerable to the effects of prenatal exposure to home renovation, even before pregnancy, on the development of allergy.

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