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Article

Municipal residence level of long-term PM_{10} exposure associated with obesity among young adults in Seoul, Korea

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Abstract: Background: The associations between long-term exposure to particulate matters (PM) in residential ambiance and obesity are comparatively less elucidated among young adults. Methods: Using 2017 Community Health Survey data with aged 19−29 participants in 25 communities, Seoul, the relationship between obesity and long−term PM_{10} levels of living district was examined. We defined obesity as overweight (25≤BMI<30) or obese (30≤BMI) using Body Mass Index (BMI) from self-reported anthropometric information. Analysis was conducted sampling weighted logistic regression models by fitting municipal PM_{10} levels according to individual residence periods with 10 years and more residing in a current municipality. Socio-demographic factors were adjusted over all models and age−specific effect was explored among aged 19–24 and 25–29. Results: Total study population are 3,655 [men 1,680 (46.0%) and aged 19–24 1,933 (52.9%)] individuals. Among the communities with greater level of PM_{10}; 2001–2005, associations with obesity were increased for overall with residence period; 10 years ≤ [Odds ratio, OR 1.071, 95% Confidence interval (CI) 0.969–1.185], 15 years ≤ [OR 1.118, 95% CI 1.004–1.245], and 20 years ≤ [OR 1.156, 95% CI 1.032–1.294]. However, decreased associations were detected for PM_{10}; 2006–2010, and age−specific effects were modified according to the residence period. Conclusions: Although currently PM_{10} levels are decreasing, higher levels of PM_{10} exposure at the residential area during the earlier life-time may contribute in increasing obesity among young adults.

Keywords: Community Health Survey; CHS; PM_{10} long-term effect, young adults, BMI

1. Introduction

Worldwide obesity has nearly tripled since 1975 and overweight or obese populations were 39% and 13% respectively out of aged 18 years and over in 2016 [1]. In International Classification of Diseases 11th Revision (ICD-11), obesity is classified as '05 Endocrine, nutritional or metabolic diseases' code 5B81 [2]. Obesity is a chronic, relapsing, multi-factorial, and neurobehavioral disease [3]. Therefore, it is necessary to consider a wide spectrum of risk factors including demographic factors and environmental conditions such as ambient air pollution in order to understand the obesity epidemic.

As one of environmental factor related with obesity, particulate matters (PM) were investigated for various comorbidity conditions [4-6] , age-groups [7-10] , gender [4] , regions [11] , and socio-economic status such as education level [12, 13], household income [13-18], or occupational characteristics [12]. They are mostly based on cohort study to figure out long-term effect of PM. In those examining, some studies suggest increased associations but the impact of PM on obesity remains mixed [19, 20].

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Obesity prevalence is increasing among younger generations worldwide and similar trend is detected in Korea over the past two decades. Obesity among young adults is an emerging health issue because of the early onset of comorbidity with various chronic conditions and the potential rise of their health expenditure. However, the relationships between obesity and PM among young adults were not clearly defined because young adults are likely to be set aside from lower priority compared to children or the elderly about concerning vulnerability.

Mostly, long-term effect of ambient pollutants was analyzed in using cohort data. Ascertainment of the results from cohort studies focused on individual exposures using their biomarkers. However, viewed in public health, in order to make an initiative for community intervention or action in community, we would find more efficient and economical approach to enhance study feasibility. So we adopted ecological approach to examine the association between community based long-term exposure of PM_{10} and obesity among young adults using data from municipality level of PM_{10}. We used data from municipality level of PM_{10} and individual health survey outcome. In this trial, we tested a hypothesis whether long-term exposure of higher PM_{10} in the living municipality is related to the more probability of obesity among young adults. In order to examine the relation between the level and exposure period of PM_{10} and obesity, we tested different exposure periods and time based on the municipality residing period for individuals and set the separate time-window such as 5 or 10 years in aggregating PM_{10} levels.

2. Materials and Methods

2.1 Study population

We used 2017 Community Health Survey (CHS) data in Korea and this survey has been conducted annually among the adults (19 years ≤) since 2008 by the Center for Disease Control and Prevention (CDC) in Korea and approximately 250 municipal community health centers. Those participants to CHS are randomly sampled under the regional sampling stratification and individual are accounted for combined individual and household sampling weights provided with the data.

This study's populations were young adults aged between 19 and 29 residing in 25 municipalities in Seoul metropolis. And their demographics, socio-economic status (SES), and health behaviors including the information of residence period in the current municipality were selected for analysis.

2.2 Environmental variables

We used air pollutant data collected among 25 municipalities from their own individual monitoring stations from year of 2001 to 2017 by the Korea Environment Corporation (Air Korea).

PM_{10} ($\mu g/m^3$) level was analyzed as the forms of annually average concentrations. Using the hourly measured PM_{10} levels in each municipality sites, we calculated daily mean and averaged out daily values into annual level according to each municipality between 2001 and 2017 (Figure 1). In addition, we aggregated annual PM_{10} levels into different terms of periods such as 5–years, 10–years, and 15–years. Municipalities were grouped into two levels; 'high' and 'low' levels of long-term PM_{10} using the median value as a cut-off onto each periodic average of PM_{10}.

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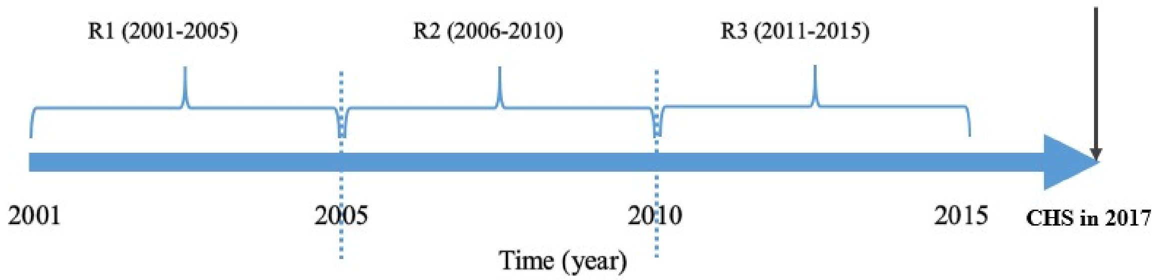

Figure 1. Study design applying periodic window for exposure of Particulate matters and residence period using Community Health Survey data in 2017, Korea

2.3 Statistical analysis

The CHS data is collected by survey sampled populations upon regional strata and the data is supplied with individual weight for each subject. We used BMI calculated by using personal weight and height and defined BMI into four categories; underweight (<18.5), normal weight (18.5≤ and <25), overweight (25≤ and <30), and obese (30≤) [21]. Obesity in this study was defined category of overweight and obese.

Initially, we investigated the distribution of demographic, SES, health behavior variables according to the residence period in the current municipality. Secondly, we assessed the association of population using logistic regression analysis for survey data with complex sampling design between obesity and individual's characteristics including demographics, SES, and health behaviors. Finally, under survey logistic regression analysis, we estimated the long-term effect of municipal PM_{10} by fitting the aggregated PM_{10} levels. In addition, age–specific effect was explored among aged 19–24 and 25–29 in estimating associations between obesity and municipal PM_{10} level under the fitting model adjusted demographic factors listed ahead.

All results related with association are presented as odds ratios (OR) with 95% confidence intervals (CIs). All procedures were conducted using SAS version 9.4 (SAS Institute, Inc., Cary, North Carolina) and all figures were modeled using R 4.0.2 (The Comprehensive R Archive Network: http://cran.r-project.org). All statistical tests were 2-sided and a *p*-value <0.05 was considered statistically significant.

2.4 Ethics

This study was approved for exempt by the Institutional Review Board of Seoul National University (IRB No. E1611/001-003). Informed consent was obtained when survey interviewers were collecting CHS data from the individual participants. The data were subsequently anonymized and de-identified prior to analysis.

3. Results

3.1 Descriptive statistics among study subjects

Total participants are 3,655 [men 1,680 (46.0%) and aged 19–24 1,933 (52.9%)](Table 1). Approximately 85% of the participants have education background with University or higher levels and nearly 60% take part in labor market. The averaged sleep hours per day during a recent week were distributed with <6 [540 (14.8%)], $6-7$ [1,140 (312%)], and $7\leq$ [1,975 (54.0%)]. Current smokers are to [665 (18.2%)]. Majority of the study populations did not get moderate or higher physical activity [2,723 (74.5%)] and their obesity prevalence is 23.1% (845 subjects) and it's national and Seoul regional trends have increased between 2008 and 2017 while annual aggregated PM_{10} levels of Seoul have decreased between 2001 and 2017 (Figure 2).

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Table 1. Descriptive characteristics of survey populations

Variable	Category	Residence period in a current community, n (%)						X^2(p-value)
		Overall	Less than 5years	5–10 years	10–15 years	15–20 years	Greater than 20years	
Total		3655 (100.0)	1120 (100.0)	377 (100.0)	402 (100.0)	434 (100.0)	1322 (100.0)	
Sex	Men	1680 (46.0)	483 (43.1)	171 (45.4)	181 (45.0)	198 (45.6)	647 (48.9)	8.57 (0.073)
	Women	1975 (54.0)	637 (56.9)	206 (54.6)	221 (55.0)	236 (54.4)	675 (51.1)	
Age group	19–24	1933 (52.9)	529 (47.2)	189 (50.1)	249 (61.9)	304 (70.0)	662 (50.1)	84.22 (<.0001)
	25–29	1722 (47.1)	591 (52.8)	188 (49.9)	153 (38.1)	130 (30.0)	660 (49.9)	
Education	Master's course	192 (5.3)	81 (7.2)	27 (7.2)	14 (3.5)	18 (4.1)	52 (3.9)	49.46 (<.0001)
	University	2929 (80.1)	921 (82.2)	307 (81.4)	315 (78.4)	340 (78.3)	1046 (79.1)	
	High school or less	532 (14.6)	118 (10.5)	43 (11.4)	72 (17.9)	76 (17.5)	223 (16.9)	
	Missing	2 (0.1)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	1 (0.1)	
Labor market participation	Active	2199 (60.2)	709 (63.3)	219 (58.1)	250 (62.2)	206 (47.5)	815 (61.6)	44.60 (<.0001)
	Inactive	1455 (39.8)	411 (36.7)	158 (41.9)	151 (37.6)	228 (52.5)	507 (38.4)	
	Unknown	1 (0.0)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	0 (0.0)	
Average Sleep hours (hours per day)	6-	540 (14.8)	169 (15.1)	50 (13.3)	69 (17.2)	53 (12.2)	199 (15.1)	7.08 (0.528)
	6–7	1140 (31.2)	346 (30.9)	121 (32.1)	115 (28.6)	132 (30.4)	426 (32.2)	
	7+	1975 (54.0)	605 (54.0)	206 (54.6)	218 (54.2)	249 (57.4)	697 (52.7)	
Moderate or vigorous physical activity rate	Yes	927 (25.4)	319 (28.5)	91 (24.1)	97 (24.1)	97 (22.4)	323 (24.4)	9.03 (0.0603)
	No	2723 (74.5)	800 (71.4)	285 (75.6)	304 (75.6)	337 (77.6)	997 (75.4)	
Smoking	Never	2802 (76.7)	857 (76.5)	307 (81.4)	320 (79.6)	338 (77.9)	980 (74.1)	13.03 (0.111)
	Former	188 (5.1)	64 (5.7)	15 (4.0)	17 (4.2)	20 (4.6)	72 (5.4)	
	Current	665 (18.2)	199 (17.8)	55 (14.6)	65 (16.2)	76 (17.5)	270 (20.4)	
Drinking	Never	237 (6.5)	54 (4.8)	29 (7.7)	24 (6.0)	26 (6.0)	104 (7.9)	22.56 (0.004)
	Former	158 (4.3)	62 (5.5)	11 (2.9)	17 (4.2)	8 (1.8)	60 (4.5)	
	Current	3260 (89.2)	1004 (89.6)	337 (89.4)	361 (89.8)	400 (92.2)	1158 (87.6)	
BMI (NIH)	Underweight (BMI<18.5)	279 (7.6)	94 (8.4)	25 (6.6)	30 (7.5)	33 (7.6)	97 (7.3)	
	Normal weight (18.5≤BMI<25)	2531 (69.2)	789 (70.4)	265 (70.3)	275 (68.4)	295 (68.0)	907 (68.6)	7.22 (0.843)
	Overweight (25≤BMI<30)	732 (20.0)	209 (18.7)	78 (20.7)	81 (20.1)	92 (21.2)	272 (20.6)	
	Obesity (30≤BMI)	113 (3.1)	28 (2.5)	9 (2.4)	16 (4.0)	14 (3.2)	46 (3.5)	

BMI, Body Mass Index; NIH, National Institute of Health, USA

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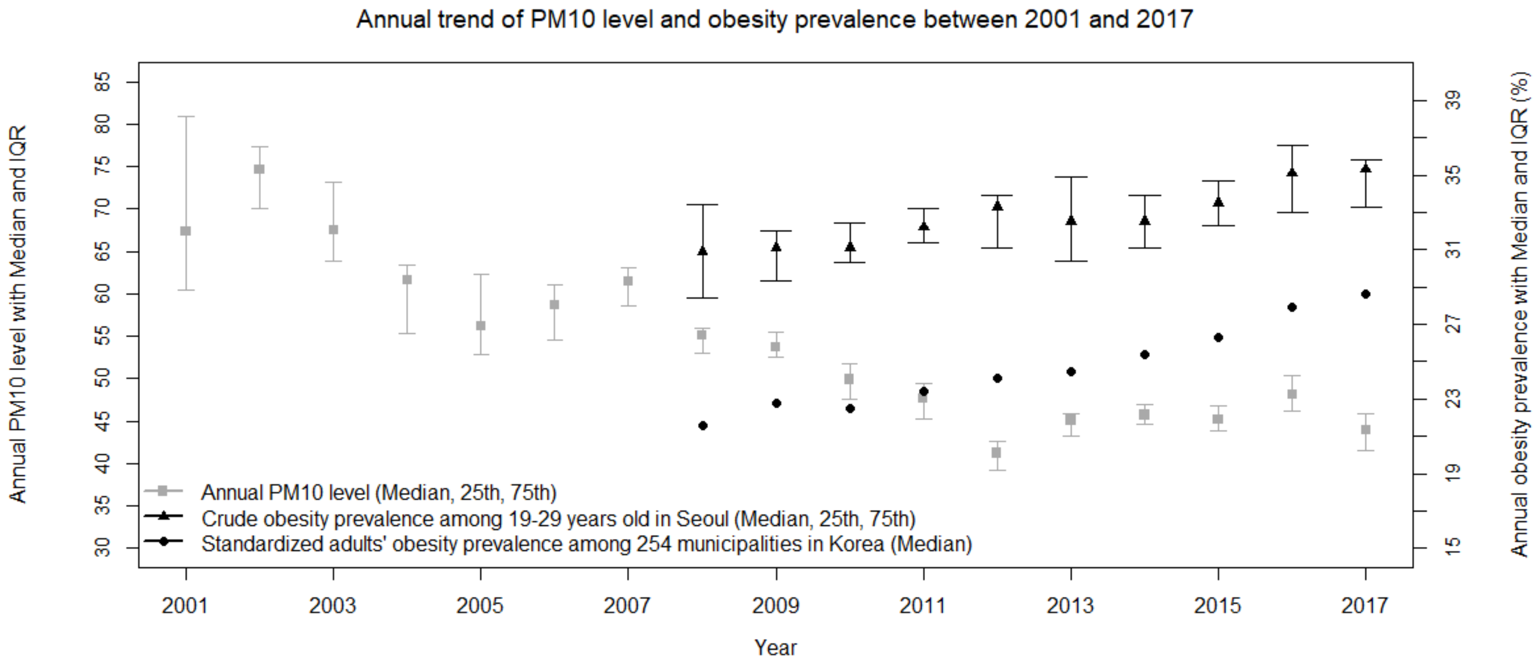

Figure 2. Annual trend of PM_{10} ($\mu g/m^3$)level and obesity prevalence, Annual level of PM_{10} was calibrated using hourly measured level of PM_{10} among 25 municipalities in Seoul between 2001 and 2017 and presented as median value with 25th and 75th. Crude obesity prevalence among study populations aged between 19 and 29 years old in Seoul was presented as form of median wit 25th and 75th. Standardized obesity prevalence among adults aged equal or greater than 19 years old was presented as form of median and this information was derived from Statistics of Community Health Survey, 2008–2017 published by the Center for Disease Control and Prevention.

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3.2 Associations between obesity and individual factors

The association between obesity and demographic characteristics were explored and the results were presented in Table 2. Women were less associated with obesity compared [Odds ratio, OR 0.493, 95% Confidence interval, CI 0.450–0.541] to men with sleeping hours of seven or greater per day showed less obesity [OR 0.880, 95% CI 0.787–0.983] than shorter-sleepers. Former smoking gives increased association [OR 1.245, 95% CI 0.997–1.555] compared to never smoking for obesity outcome. Residence period in a current municipality was shown varied but not statistically significant associations according to the length of residing.

Table 2. Associations between obesity and demographic characteristics in Community Health Survey, Seoul, Korea, 2017

Variable	Category	Odds ratio (95% Confidence interval)[1]
Sex	Men	1.00
	Women	**0.493 (0.450-0.541)**
Age	19–24	1.00
	25–29	1.076 (0.987-1.172)
Education level	Master's course	1.00
	University	0.937 (0.806-1.090)
	High school or less	1.073 (0.899-1.281)
Labor market participation	Active	1.00
	Inactive	0.998 (0.914-1.089)
Average Sleep hours (hours per day)	6-	1.00
	6–7	0.948 (0.837-1.073)
	7+	0.880 (0.787-0.983)
Moderate or vigorous physical activity rate	Yes	1.00
	No	0.960 (0.880-1.047)
Drinking	Never	1.00
	Former	1.187 (0.888-1.588)
	Current	1.000 (0.825-1.211)
Smoking	Never	1.00
	Former	1.245 (0.997-1.555)
	Current	0.926 (0.793-1.081)
Residence period in a current community	Less than 5 years	1.00
	5–10 years	1.096 (0.850-1.414)
	10–15 years	0.961 (0.769-1.201)
	15–20 years	1.127 (0.902-1.408)
	Greater than 20 years	0.982 (0.848-1.136)

BMI, Body Mass Index

[1] Odds ratio was calculated with those who have obesity (overweight or obese BMI) against those with under or normal weight in survey logistic regression.

3.3 Associations between obesity and municipal long-term PM_{10} level

We fitted, by turns, municipal PM_{10} levels with aggregated period according to the length of residing and age-group (Table 3).

Among the municipalities with high PM_{10} level during 2001–2005, the various but increased associations with obesity were observed total study subjects according to the residence period; 10 years ≤ [OR 1.071, 95% CI 0.969–1.185], 15 years ≤ [OR 1.118, 95% CI 1.004–1.245], and 20 years ≤ [OR 1.156, 95% CI 1.032–1.294]. In addition, decreased associations between obesity and levels of PM_{10} during 2006 - 2010 were observed regardless of the residence period.

Effect Modification by age was detected in assessing effect of PM_{10} levels during 2001–2005 by the residence period; 20 years ≤ [OR 1.225, 95% CI 1.078–1.394] among the 19–24 aged, and 10 years ≤ [OR 1.210, 95% CI 1.057–1.386] and 15 years ≤ [OR 1.211, 95% CI 1.060–1.383] among the other age group rest. In the meanwhile the association with obesity consistently decreased for the high PM_{10} municipalities. Between 2006 and 2010 among the 25–29 aged with statistical significance regardless of residence period; 10 years ≤ [OR 0.823, 95% CI 0.721–0.939] and 15 years ≤ [OR 0.827, 95% CI 0.729–0.938], and 20 years ≤ [OR 0.827, 95% CI 0.726–0.942].

In order to figure out the modification effect according to the residence of period, associations for the specified residence periods were calculated and the results were presented separately (Table S1). Relations were jagged according to the varied long-term community based PM_{10} levels within same residence period and age-specific groups.

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Table 3. Associations between obesity and particulate matters according to residence period among young adults in Community Health Survey, Seoul, Korea, 2017

Period of PM_{10} level [1]	Annual PM_{10} level median cut-off	Study population residence period (year)	Odds ratio (95% Confidence interval)[2]		
			Age 19–29	Aged 19–24	Aged 25–29
10 years (2008-2017)	47.2	10years ≤	1.002 (0.905–1.110)	0.948 (0.846–1.063)	1.065 (0.933–1.215)
		15years ≤	1.014 (0.909–1.132)	0.944 (0.830–1.075)	1.102 (0.965–1.259)
		20years ≤	0.964 (0.858–1.083)	0.875 (0.768–0.998)	1.040 (0.908–1.192)
15 years (2003-2017)	51.5	10years ≤	1.048 (0.948–1.158)	1.040 (0.929–1.163)	1.039 (0.907–1.190)
		15years ≤	1.067 (0.958–1.188)	1.080 (0.950–1.228)	1.039 (0.907–1.189)
		20years ≤	1.081 (0.965–1.212)	1.115 (0.981–1.268)	1.043 (0.907–1.199)
5 years (2001-2005)	68.7	10years ≤	1.071 (0.969–1.185)	0.984 (0.879–1.102)	1.210 (1.057–1.386)
		15years ≤	1.118 (1.004–1.245)	1.057 (0.930–1.202)	1.211 (1.060–1.383)
		20years ≤	1.156 (1.032–1.294)	1.225 (1.078–1.394)	1.106 (0.965–1.268)
5 years (2006-2010)	56.6	10years ≤	0.895 (0.808–0.991)	0.943 (0.839–1.060)	0.823 (0.721–0.939)
		15years ≤	0.936 (0.839–1.043)	1.037 (0.905–1.188)	0.827 (0.729–0.938)
		20years ≤	0.891 (0.794–1.000)	0.951 (0.826–1.094)	0.827 (0.726–0.942)
5 years (2011-2015)	46.2	10years ≤	1.038 (0.938–1.149)	0.987 (0.880–1.106)	1.102 (0.966–1.256)
		15years ≤	1.034 (0.927–1.153)	0.957 (0.840–1.090)	1.136 (0.997–1.294)
		20years ≤	1.023 (0.913–1.147)	0.967 (0.846–1.106)	1.082 (0.946–1.238)

[1] Annual level of PM_{10} ($\mu g/m^3$) was calibrated using hourly measured level of PM_{10} among 25 municipalities in Seoul between 2001 and 2017.

[2] Odds ratio was calculated with those who have obesity (overweight or obese BMI) against those with under or normal weight in survey logistic regression.

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4. Discussion

4.1 Principal findings

The association between obesity and long-term PM_{10} level among young adults was rarely studied and defined ambiguously. Since the level of PM_{10} is decreasing during the past two decades, short-term effect of PM_{10} have not been clearly distinct in obesity and other factors such as diet and physical exercise could work with population obesity more closely. On the other hand long-term approach of PM_{10} exposure from early life is possibly different with exposed PM_{10} level. This study supported that long-term exposure of high PM_{10} in community could increase the risk of obesity. The study results showed that participants living longer in municipalities with higher PM_{10} level were more likely to be overweight or obese than the lower level of PM_{10} in residence area. Therefore, in the application of community based approach for interventions or building strategies to reduce obesity prevalence, both health behaviors and environmental factors should be considered and discussed at the same time.

4.2 Associations between obesity and individual factors

At the individual level, World Health Organization (WHO) suggested engagement in regular physical activity to reduce overweight and obesity [1]. In our study, the study participants who have not engaged in moderate or vigorous physical activity have shown that they are less likely to be in an obesity group. As long as the current study data was collected based on cross-sectional study design, it could be interpreted that obesity subjects are more frequently participated with regular exercise to reduce weight.

Shorter sleep and poor sleep quality might contribute to the development of obesity in epidemiological studies using self-reported cross-sectional studies including young adult's populations [22-24]. Similar to the previous results, our study indicated that greater than 7 hours sleep per day have decreased association with obesity compared to the participants with less than 6 hours sleep per day.

In smoking behavior, the former smokers are more likely to be obesity while less association was detected in current smokers compared to never smokers. The positive relations between obesity and smoking were reported with higher smoking rates in obesity participants among young adults [25] and middle-aged adults [26]. However, considering general perception that smoking may reduce weight gain, especially among young women, smoking cessation intervention may need to consider weight management support.

In the middle aged, effect modifications of obesity, such as adverse associations between particulate matters and cardiovascular health effects were suggested in several cohort study [22, 27, 28]. . This study subjects were restricted to the twenties, these participants would be healthier and few have chronic conditions. Therefore, modification under comorbidity conditions was not considered in this study.

4.3 Associations between obesity and environmental factors

Over several decades, worldwide trend of obesity increases among young adults [1]. Although decreasing trends of PM_{10} are observed in some areas, PM_{10} exposure is still preserved as one of candidates of obesity risk factors. In our study, we examined PM_{10} as a representative of urban area's outdoor pollutants and detected that the relation increased when exposed to higher PM_{10} level in earlier life-time among young adults. Ambient PM_{10} or $PM_{2.5}$ level are highly related with traffics. Urbanized cities like Seoul are more likely to have greater traffic-related air pollutions. To figure out the consistency of this finding, several studies were referred and these studies were conducted to investigate the relationship between traffic-related air pollution and obesity especially for children [20, 29] or young adults [10]. In addition, among primary school-aged children, the exposure to ambient air pollution was associated with overweight and obesity at home and school [30]. From those studies, increased association between PM level and obesity were detected.

In our study, we set a hypothesis that the populations exposed with higher level of PM_{10} are more likely to be obese compared to those dwelling in area with lower level of PM_{10}. It was examined using municipal PM_{10} levels. Although the association between obesity and community PM_{10} level was increased for some exposure period 2001–2005, the association was inversed during exposure period 2006–2010 among high PM_{10} level's municipalities. The decreased association was more pronounced among aged 25–29 than 19–24 regardless of residence period.

Calculating participants' age retrospectively for each period, for instance, 29 years old participants were 18 and 22 years old in 2006 and 2010 respectively. Using the same backward calculation, median aged group; 24 years old and least aged group, 19 years old in the year 2017 were (13,17) and (8,12) in 2006 and 2010 respectively. Applying that calculation, this study subjects' age are ranged from 2 to 12 years old. These age difference may pull the effect variability and may accompany with the importance of early life exposures because of expectation of more hazardous health outcome. Due to the importance of early life exposure, Human Early Life Exposome (HELIX) study a prospective cohort to measure multiple environmental exposures during early life (pregnancy and childhood) to figure out child health outcomes [31]. In addition, similar approach was proceeded to describe the key principles from the literature regarding the relevance of these principles to early-life neurotoxicant exposures [32].

As long as CHS data was conducted based on cross-sectional study design, it was not measurable the time of obesity incidence among the participants. Therefore, it has limited information to conclude that earlier environmental exposure of higher PM_{10} is linked to obesity with causal association among young adults. However, this study results using residence period could support previous long-term effect of PM_{10} on obesity even among young adults.

Apart from air pollutants, the availability of neighborhood greenness [33, 34] or physical activity facilities [35-37] for physical activity were considered as beneficial environmental factors related with obesity. We reviewed the annual statistics of greenness area and local autonomous sports facilities. Through this approach, it was concluded that annual change was negligible in both variables and decided not to include them as another environmental factor. Instead, among the demographic variables, information on the frequency of physical activity during the week was used as a correction variable. For those who exercise regularly for weight management, it is common to use private institutions around their homes, workplaces, or schools. However, this study did not consider the frequency of subjects' use of private institutions because they could not be determined.

4.4 Study limitations

Our study has some limitations pertaining to air pollutant data and health outcome. This study aimed to access long-term effect of PM_{10} to obesity among young adults dwelling in community. First of all, the health data is only providing current status of obesity and no additional information for the incidence time point. Accordingly, long-term association is limited to assure to extend to causal association. Secondly, in accessing the relationship between obesity and PM_{10}, our study is limited in accuracy of PM_{10} exposure amount and period for individual study participants due to study design in data collection protocol. However, it strengthens the previous study results that earlier exposure in lifetime to higher levels of PM_{10} has driven those to become obese with higher chance. Finally, several studies compared the fraction size of PM and defined the association including coarse particle ($PM_{10\text{-}2.5}$) and fine particulate matters ($PM_{2.5}$), it was not suitable for comparing it in the current research. Only recent years of $PM_{2.5}$ measurement were available.

5. Conclusions

As part of the participation and efforts of various organizational or individual forms, levels of particulate matters are decreasing in some part of the world. However, still there are signals that the level of particulate matters exceeds WHO standards. Although currently PM_{10} levels are decreasing in Seoul, Korea, this study suggested that higher levels of ecological PM_{10} exposure during earlier lifetime may contribute in increasing individual obesity among young adults. In order to understand increasing obesity epidemic, wide spectrum of risk factors including environmental exposures and exposure time and period should be considered. Applying timely intervention for the overall population in order to make tailoring policies to improve physical health from the obesity, it is necessary to approach in community based environmental improvement.

Author Contributions: J.Kim formulated the objectives, designed the method and K.Yoon supervised in developing the study objective. J.Kim conducted statistical analysis. J.Kim and K.Yoon contributed to writing and finalizing the manuscript. All authors contributed on the completion of results and discussion.

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Conflicts of Interest: The authors declare no conflict of interest

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Table S1. Associations between obesity and particulate matters according to specific residence period among young adults in Community Health Survey, Seoul, Korea, 2017

Period of PM_{10} level [1]	Annual PM_{10} level median cut-off	Study population residence period (year)	Odds ratio (95% Confidence interval)[2]		
			Age 19–29	Aged 19–24	Aged 25–29
10 years (2008-2017)	47.2	10 years ≤	1.002 (0.905–1.110)	0.948 (0.846–1.063)	1.065 (0.933–1.215)
		10≤R.P<15	0.985 (0.858–1.130)	1.008 (0.876–1.160)	-
		15≤R.P<20	1.218 (1.019–1.455)	1.135 (0.931–1.383)	-
		20years≤	0.964 (0.858–1.083)	0.875 (0.768–0.998)	1.040 (0.908–1.192)
15 years (2003-2017)	51.5	10 years ≤	1.048 (0.948–1.158)	1.040 (0.929–1.163)	1.039 (0.907–1.190)
		10≤R.P<15	0.966 (0.835–1.117)	0.901 (0.788–1.029)	-
		15≤R.P<20	1.033 (0.875–1.218)	1.027 (0.844–1.249)	-
		20years≤	1.081 (0.965–1.212)	1.115 (0.981–1.268)	1.043 (0.907–1.199)
5 years (2001-2005)	68.7	10 years ≤	1.071 (0.969–1.185)	0.984 (0.879–1.102)	1.210 (1.057–1.386)
		10≤R.P<15	0.875 (0.759–1.009)	0.789 (0.682–0.914)	-
		15≤R.P<20	0.986 (0.826–1.177)	0.769 (0.630–0.939)	-
		20years≤	1.156 (1.032–1.294)	1.225 (1.078–1.394)	1.106 (0.965–1.268)
5 years (2006-2010)	56.6	10 years ≤	0.895 (0.808–0.991)	0.943 (0.839–1.060)	0.823 (0.721–0.939)
		10≤R.P<15	0.706 (0.605–0.823)	0.597 (0.518–0.687)	-
		15≤R.P<20	1.079 (0.910–1.279)	1.211 (1.007–1.455)	-
		20years≤	0.891 (0.794–1.000)	0.951 (0.826–1.094)	0.827 (0.726–0.942)
5 years (2011-2015)	46.2	10 years ≤	1.038 (0.938–1.149)	0.987 (0.880–1.106)	1.102 (0.966–1.256)
		10≤R.P<15	1.058 (0.922–1.214)	1.165 (1.013–1.338)	-
		15≤R.P<20	1.075 (0.904–1.279)	0.957 (0.796–1.149)	-
		20years≤	1.023 (0.913–1.147)	0.967 (0.846–1.106)	1.082 (0.946–1.238)

R.P, Residence period

[1] Annual level of PM_{10} ($\mu g/m^3$) was calibrated using hourly measured level of PM_{10} among 25 municipalities in Seoul between 2001 and 2017.

[2] Odds ratio was calculated with those who have obesity (overweight or obese BMI) against those with under or normal weight in survey logistic regression.