Childhood Exposure to Ambient Air Pollution and Obesity

Subjects: Public, Environmental & Occupational Health
Contributor: Chao Huang , Shaokang Wang , , Jing Zhu , Guiju Sun

Obesity has become a worldwide epidemic; 340 million of children and adolescents were overweight or obese in 2016, and this number continues to grow at a rapid rate. Epidemiological research has suggested that air pollution affects childhood obesity and weight status, but the evidence remains inconsistent.

childhood air pollution obesity BMI

1. Introduction

Obesity has become a worldwide epidemic and urgent health issue [1]. The prevalence of overweight and obesity has increased considerably in the last few decades and nearly tripled since 1975. With regard to children and adolescents, 340 million of them were overweight or obese in 2016, and this number continues to grow at a rapid rate [2][3]. Childhood obesity has been associated with obesity and increased risks for chronic disease in adulthood [4][5], and these adverse effects may last the whole lifetime [6]. Research has identified multiple factors that can lead to childhood obesity and it has been shown that childhood obesity can be attributed to genetic, dietary, and behavioral factors [7]. Despite genetic and metabolic predispositions, the rising epidemic of obesity indicates environmental factors may play a role in accelerating the progression of childhood obesity [8].

The Global Burden of Disease study revealed that air pollution can be the most adverse environmental health hazard for disease and mortality worldwide [9][10]. Well over 80% of urban dwellers suffer from air pollution, and the most seriously affected individuals were low-income residents [11]. In recent years, mounting evidence suggests that air pollution can be an obesogenic factor [12]. It is mainly through the biochemical and behavioral pathways that air pollution affects body weight. Metabolic disorders [13], inflammatory reactions [14], reduced sleep duration and quality [15] that are caused by air pollution all contribute to the accumulation of adipose tissue and weight gain, as has been demonstrated in animal trials. Additionally, the decline in air quality reduces a person's willingness to engage in outdoor activities [16], which in turn increases indoor time, in order to reduce the impact of pollution on the human body [17].

Although there are numerous focus on air pollution and obesity, the effects remained inconsistent and differed among the populations, pollutant types, and pollutant concentrations [12]. It was found that previous ones were more concentrated on exposure during pregnancy [18][19], whereas recent one have increasingly examined the direct effects of children's exposure to air pollution on obesity [20][21]. However, the findings seem to be inconsistent even in children and adolescents only [22][23][24]. For instance, Fioravanti et al. suggested that the evidence that air pollution causes obesity was limited [23]. In contrast, some indicated that long-term exposure to air pollutants might be correlated with weight gain and the development of obesity [20][21][25][26]. Among the available information, the existing ones have been mostly concentrated on adults or whole populations, and quantitative synthesis of the contribution of air pollution to children and adolescents remains scarce [12][27][28]. A meta-analysis by Parasin et al. examined the relationship between air pollution and childhood obesity, but did not distinguish between exposure during pregnancy and individual exposure, and also did not standardize when combining the effects of pollutants across these [29]. Therefore, it was believe that the topic still has potential for further research. As such, it was to systematically and quantitatively analyze the scientific evidence on the influence of exposure to air pollution on weight gain and obesity in childhood.

2. The Association between Childhood Exposure to Ambient Air Pollution and Obesity

It was showed that long-term exposure to particulate matter and NO2 was significantly correlated with the risk of childhood obesity, while BMI also showed similar elevated results. Although O3 and NOx also had a positive effect on the increase in weight status, none reached significant levels. Notably, as the aerodynamic diameter of particulate matter decreases, the fattening effect on children increases, and researchers have begun to concentrate on the smaller particle size pollutants (PM1).

Of the 15 that were included in, around 73% were published in the last three years, and most were conducted in developing countries. It was compared a meta-analysis of the association between air pollutants and obesity in adults [28], where half of the included were published after 2019, with the difference that the areas were predominantly developed countries. An identifiable trend is that concerns about air pollution and childhood obesity are rising rapidly in developing countries. One plausible explanation is that although developed countries still maintain high rates of childhood obesity [30][31], the effect of air pollutants on body weight has been limited because air pollution levels have declined significantly in these countries [28]. Developing countries, in contrast, appear confronted with a double crisis, with increasing prevalence and growth rates of childhood obesity on the one hand [32], and deteriorating air quality resulting from urbanization and industrialization on the other [33][34]. Thus, numerous original ones were conducted in developing countries in recent years, and the effects tend to be more significant, further providing as the foundations.

As the main air pollutants of concern, particulate matter significantly influenced childhood obesity and BMI growth. The findings were consistent with the previous hypothesis that with smaller aerodynamic diameters of respirable particulate matter, the more toxic compounds would be adsorbed and also more easily inhaled deep into the lungs, therefore are more harmful to health [35][36]. In contrast to children, long-term exposure to PM10 and PM2.5 showed insignificant effects on adult obesity according to a meta-analysis that was conducted on adults [28]. Similar results were found for NO2 and O3, both pollutants were positively associated with the development of obesity. As can be seen, the effects of different pollutants on people can be diverse and complex, even for the same pollutant, the impact can vary depending on the characteristics of the population (for example, age, gender, region). These specific mechanisms require further investigation and validation.

While the mechanisms linking exposure to air pollution and obesity are not completely understood, biochemical mechanisms have been commonly mentioned and accepted as the main obesity-causing mechanisms in relation to air pollutants [12][25][37]. Firstly, from the perspective of human metabolism, air pollutants entering the body from the respiratory tract may increase oxidative stress in tissues and systems [38]. Take PM2.5, as an example, it can affect gene expression in mitochondria in brown adipose tissue, resulting in increased production of reactive oxygen species in brown fat stores, which lead to metabolic dysfunction [13], and susceptibility to lipid metabolism and glucose metabolism [39]. Secondly, the inflammatory response that is triggered by air pollutants can lead to vascular damage as well as insulin resistance, can also have an impact on body weight [14]. It was also found that the occurrence of sleep-disordered breathing (SDB) was related to exposure to air pollutants [40]. Those who lived in regions with high NO2 and PM2.5 levels were much more likely to suffer from SDB, which in turn caused mental and physical health disparities [41]. Sleep deprivation correlated with decreased levels of leptin secretion, lower thyroid stimulating hormone secretion, and lower glucose tolerance, all of which may increase BMI status[15]. Finally, behavioral mechanisms can be explained in another direction [12]. For example, air pollution can reduce people's willingness to participate in outdoor activities [16]. In addition, it can also improve the consumption of trans fats and fast food [42], which may contribute to obesity. However, attention should be drawn to the fact that while the obesogenic mechanisms of air pollution have been validated in animal models, uncertainties remain for humans or for different pollutants, and more research should be conducted to elucidate such pathways.

The strength is that it comprehensively and quantitatively assesses the relationship between long-term exposure to air pollutants and childhood obesity. Previous ones focused on the whole population [12]or adults [28], with limited on children and adolescents [43][44]. Meanwhile, the majority of the original ones that were included were published in the past three years, and the results are relatively new. Thirdly, the exposure doses in the original ones were mostly different, thus it is difficult to compare the effects, and it was converted the data in a standardized way to improve the comparability of the data. Finally, analyses and collations were performed according to the standard methods that are required by the PRISMA checklist.

However, there are many limitations that need to be noted. Firstly, although it was systematically searched the currently that is available epidemiological evidence, the amount was still limited and the potential sources of heterogeneity remain to be explored. When it was integrated the results across ones, the quality of the articles varied, exposure was not measured and estimated in a standardized way, analytical methods were imperfect, and the certainty of the evidence in the articles was generally poor, so caution should be exercised in interpreting the results as well. Secondly, the findings were based on numerous cross-sectional ones; therefore, causality was difficult to be determined accurately. According to GRADE system, the level of evidence for observational studies was still low. Thirdly, due to the complexity of growth patterns, the BMI that was applied to measure obesity in adults may not be applicable to a certain extent to children and adolescents. Fourth, for younger children (before two years of age), early obesity may be associated with the subsequent catch-up growth of low birth weight due to maternal exposure to air pollution [45], and the mechanisms for infants need to be further probed. Finally, obesity is a disease with complex causes, the magnitude of the direct role that is contributed by air pollution was unclear, and residual bias (for example, socio-economic conditions, physical activity) may still influence the outcomes. For example, high-income families (or parents with higher education levels) tend to live in more privileged residential areas with relatively lower levels of air pollution, better green spaces and have a more structured diet, while low-income families tend to be the opposite. Likewise, parents who live in more polluted areas may restrict their children's outdoor activities to reduce the exposure to air pollutants. These potentially confounding variables were not comprehensively captured and reasonably explained in studies

It was further revealed the risk of air pollution on childhood obesity. The implications of air pollutants are direct and significant, not only for human health but also for the climate. Therefore, policy-makers can also benefit from these findings that economic development and urbanization can create a number of problems, especially in developing countries, and require reflection on how to develop appropriate policies to balance economic development and environmental pollution. A synergistic approach to air pollution and climate change management that is based on global cooperation is essential. Important sectors such as transportation, energy, and manufacturing are the main focus of high emissions of PM, SO2, NOx, and GHG. It is imperative to accelerate the transformation of the energy mix and use technology to drive low-carbon production. At the same time, it is essential to establish an integrated system of atmospheric monitoring, emissions supervision, and pollution remediation.

It was also provides insights for future studies. Firstly, long-term cohort ones with large samples of children and adolescents across age, gender, and ethnicity are required in order to provide more representative and convincing results. Secondly, the diagnosis of childhood obesity requires more diverse anthropometric measures such as waist circumference, waist-to-hip ratio, subcutaneous fat, and total and high-density lipoprotein cholesterol. In addition, the health effects of ultrafine particulate matter still need to be clarified. Finally, interactions between multiple pollutants and their effects on humans also require estimation.

References

1. Ezzati, M.; Bentham, J.; Di Cesare, M.; Bilano, V.; Bixby, H.; Zhou, B.; Stevens, G.A.; Riley, L.M.; Taddei, C.; Hajifathalian, K.; et al. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. Lancet 2017, 390, 2627–2642.
2. WHO. Obesity and Overweight; World Health Organizaiton: Geneva, Switzerland, 2020.
3. Afshin, A.; Forouzanfar, M.H.; Reitsma, M.B.; Sur, P.; Estep, K.; Lee, A.; Marczak, L.; Mokdad, A.H.; Moradi-Lakeh, M.; Naghavi, M.; et al. Health Effects of Overweight and Obesity in 195 Countries over 25 Years. N. Engl. J. Med. 2017, 377, 13–27.
4. Wormser, D.; Kaptoge, S.; Di Angelantonio, E.; Wood, A.M.; Pennells, L.; Thompson, A.; Sarwar, N.; Kizer, J.R.; Lawlor, D.A.; Nordestgaard, B.G.; et al. Separate and combined associations of body-mass index and abdominal adiposity with cardiovascular disease: Collaborative analysis of 58 prospective studies. Lancet 2011, 377, 1085–1095.

5. Singh, G.M.; Danaei, G.; Farzadfar, F.; Stevens, G.A.; Woodward, M.; Wormser, D.; Kaptoge, S.; Whitlock, G.; Qiao, Q.; Lewington, S.; et al. The age-specific quantitative effects of metabolic risk factors on cardiovascular diseases and diabetes: A pooled analysis. PLoS ONE 2013, 8, e65174.
6. Simmonds, M.; Llewellyn, A.; Owen, C.G.; Woolacott, N. Predicting adult obesity from childhood obesity: A systematic review and meta-analysis. Obes. Rev. Off. J. Int. Assoc. Study Obes. 2016, 17, 95–107.
7. Han, J.C.; Lawlor, D.A.; Kimm, S.Y. Childhood obesity. Lancet 2010, 375, 1737–1748.
8. Jerrett, M.; McConnell, R.; Wolch, J.; Chang, R.; Lam, C.; Dunton, G.; Gilliland, F.; Lurmann, F.; Islam, T.; Berhane, K. Traffic-related air pollution and obesity formation in children: A longitudinal, multilevel analysis. Environ. Health 2014, 13, 49.
9. Cohen, A.J.; Brauer, M.; Burnett, R.; Anderson, H.R.; Frostad, J.; Estep, K.; Balakrishnan, K.; Brunekreef, B.; Dandona, L.; Dandona, R.; et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: An analysis of data from the Global Burden of Diseases Study 2015. Lancet 2017, 389, 1907–1918.
10. United States Environmental Protection Agency. Criteria Air Pollutants. EPA; 2017. Available online: https://www.epa.gov/criteria-air-pollutants (accessed on 1 March 2022).
11. WHO. Global Urban Ambient Air Pollution Database; WHO: Geneva, Switzerland, 2016.
12. An, R.; Ji, M.; Yan, H.; Guan, C. Impact of ambient air pollution on obesity: A systematic review. Int. J. Obes. 2018, 42, 1112–1126.
13. Xu, Z.; Xu, X.; Zhong, M.; Hotchkiss, I.P.; Lewandowski, R.P.; Wagner, J.G.; Bramble, L.A.; Yang, Y.; Wang, A.; Harkema, J.R.; et al. Ambient particulate air pollution induces oxidative stress and alterations of mitochondria and gene expression in brown and white adipose tissues. Part. Fibre Toxicol. 2011, 8, 20.
14. Sun, Q.; Yue, P.; Deiuliis, J.A.; Lumeng, C.N.; Kampfrath, T.; Mikolaj, M.B.; Cai, Y.; Ostrowski, M.C.; Lu, B.; Parthasarathy, S.; et al. Ambient air pollution exaggerates adipose inflammation and insulin resistance in a mouse model of diet-induced obesity. Circulation 2009, 119, 538–546.
15. Keith, S.W.; Redden, D.T.; Katzmarzyk, P.T.; Boggiano, M.M.; Hanlon, E.C.; Benca, R.M.; Ruden, D.; Pietrobelli, A.; Barger, J.L.; Fontaine, K.R.; et al. Putative contributors to the secular increase in obesity: Exploring the roads less traveled. Int. J. Obes. 2006, 30, 1585–1594.
16. Hu, L.; Zhu, L.; Xu, Y.; Lyu, J.; Imm, K.; Yang, L. Relationship Between Air Quality and Outdoor Exercise Behavior in China: A Novel Mobile-Based Study. Int. J. Behav. Med. 2017, 24, 520–527.
17. Neidell, M. Information, Avoidance Behavior, and Health The Effect of Ozone on Asthma Hospitalizations. J. Hum. Resour. 2009, 44, 450–478.

18. Alderete, T.L.; Habre, R.; Toledo-Corral, C.M.; Berhane, K.; Chen, Z.; Lurmann, F.W.; Weigensberg, M.J.; Goran, M.I.; Gilliland, F.D. Longitudinal Associations Between Ambient Air Pollution With Insulin Sensitivity, β-Cell Function, and Adiposity in Los Angeles Latino Children. Diabetes 2017, 66, 1789–1796.
19. Chen, Y.C.; Chen, P.C.; Hsieh, W.S.; Portnov, B.A.; Chen, Y.A.; Lee, Y.L. Environmental factors associated with overweight and obesity in taiwanese children. Paediatr. Perinat. Epidemiol. 2012, 26, 561–571.
20. Zheng, H.; Xu, Z.; Wang, Q.; Ding, Z.; Zhou, L.; Xu, Y.; Su, H.; Li, X.; Zhang, F.; Cheng, J. Long-term exposure to ambient air pollution and obesity in school-aged children and adolescents in Jiangsu province of China. Environ. Res. 2021, 195, 110804.
21. Zhang, Z.; Dong, B.; Chen, G.; Song, Y.; Li, S.; Yang, Z.; Dong, Y.; Wang, Z.; Ma, J.; Guo, Y. Ambient air pollution and obesity in school-aged children and adolescents: A multicenter study in China. Sci. Total Environ. 2021, 771, 144583.
22. de Bont, J.; Casas, M.; Barrera-Gomez, J.; Cirach, M.; Rivas, I.; Valvi, D.; Alvarez, M.; Dadvand, P.; Sunyer, J.; Vrijheid, M. Ambient air pollution and overweight and obesity in school-aged children in Barcelona, Spain. Environ. Int. 2019, 125, 58–64.
23. Fioravanti, S.; Cesaroni, G.; Badaloni, C.; Michelozzi, P.; Forastiere, F.; Porta, D. Traffic-related air pollution and childhood obesity in an Italian birth cohort. Environ. Res. 2018, 160, 479–486.
24. Huang, J.V.; Leung, G.M.; Schooling, C.M. The association of air pollution with body mass index: Evidence from Hong Kong's "Children of 1997" birth cohort. Int. J. Obes. 2018, 43, 62–72.
25. Wang, Z.; Zhao, L.; Huang, Q.; Hong, A.; Yu, C.; Xiao, Q.; Zou, B.; Ji, S.; Zhang, L.; Zou, K.; et al. Traffic-related environmental factors and childhood obesity: A systematic review and meta-analysis. Obes. Rev. Off. J. Int. Assoc. Study Obes. 2021, 22, e12995.
26. Zhang, J.S.; Gui, Z.H.; Zou, Z.Y.; Yang, B.Y.; Ma, J.; Jing, J.; Wang, H.J.; Luo, J.Y.; Zhang, X.; Luo, C.Y.; et al. Long-term exposure to ambient air pollution and metabolic syndrome in children and adolescents: A national cross-sectional study in China. Environ. Int. 2021, 148, 106383.
27. Seo, M.Y.; Kim, S.-H.; Park, M.J. Air pollution and childhood obesity. Clin. Exp. Pediatrics 2020, 63, 382–388.
28. Huang, S.; Zhang, X.; Huang, J.; Lu, X.; Liu, F.; Gu, D. Ambient air pollution and body weight status in adults: A systematic review and meta-analysis. Environ. Pollut. 2020, 265, 114999.
29. Parasin, N.; Amnuaylojaroen, T.; Saokaew, S. Effect of Air Pollution on Obesity in Children: A Systematic Review and Meta-Analysis. Children 2021, 8, 327.
30. Skinner, A.C.; Ravanbakht, S.N.; Skelton, J.A.; Perrin, E.M.; Armstrong, S.C. Prevalence of Obesity and Severe Obesity in US Children, 1999–2016. Pediatrics 2018, 141, 3.

31. Spinelli, A.; Buoncristiano, M.; Kovacs, V.A.; Yngve, A.; Spiroski, I.; Obreja, G.; Starc, G.; Pérez, N.; Rito, A.I.; Kunešová, M.; et al. Prevalence of Severe Obesity among Primary School Children in 21 European Countries. Obes. Facts 2019, 12, 244–258.
32. Aiello, A.M.; Marques de Mello, L.; Souza Nunes, M.; Soares da Silva, A.; Nunes, A. Prevalence of Obesity in Children and Adolescents in Brazil: A Meta-analysis of Cross-sectional Studies. Curr. Pediatr. Rev. 2015, 11, 36–42.
33. Greenstone, M.; Hanna, R. Environmental Regulations, Air and Water Pollution, and Infant Mortality in India. Am. Econ. Rev. 2014, 104, 3038–3072.
34. North, C.M.; Rice, M.B.; Ferkol, T.; Gozal, D.; Hui, C.; Jung, S.H.; Kuribayashi, K.; McCormack, M.C.; Mishima, M.; Morimoto, Y.; et al. Air pollution in the Asia-Pacific Region: A Joint Asian Pacific Society of Respirology/American Thoracic Society perspective (Republication). Respirology 2019, 24, 484–491.
35. Klompmaker, J.O.; Hoek, G.; Bloemsma, L.D.; Wijga, A.H.; van den Brink, C.; Brunekreef, B.; Lebret, E.; Gehring, U.; Janssen, N.A.H. Associations of combined exposures to surrounding green, air pollution and traffic noise on mental health. Environ. Int. 2019, 129, 525–537.
36. Li, N.; Georas, S.; Alexis, N.; Fritz, P.; Xia, T.; Williams, M.A.; Horner, E.; Nel, A. A work group report on ultrafine particles (American Academy of Allergy, Asthma & Immunology): Why ambient ultrafine and engineered nanoparticles should receive special attention for possible adverse health outcomes in human subjects. J. Allergy Clin. Immunol. 2016, 138, 386–396.
37. Ustulin, M.; Keum, C.; Woo, J.; Woo, J.T.; Rhee, S.Y. Effects of climatic variables on weight loss: A global analysis. Sci. Rep. 2017, 7, 40708.
38. Wei, Y.; Zhang, J.J.; Li, Z.; Gow, A.; Chung, K.F.; Hu, M.; Sun, Z.; Zeng, L.; Zhu, T.; Jia, G.; et al. Chronic exposure to air pollution particles increases the risk of obesity and metabolic syndrome: Findings from a natural experiment in Beijing. FASEB J. 2016, 30, 2115–2122.
39. Toledo-Corral, C.M.; Alderete, T.L.; Habre, R.; Berhane, K.; Lurmann, F.W.; Weigensberg, M.J.; Goran, M.I.; Gilliland, F.D. Effects of air pollution exposure on glucose metabolism in Los Angeles minority children. Pediatr. Obes. 2018, 13, 54–62.
40. Shen, Y.L.; Liu, W.T.; Lee, K.Y.; Chuang, H.C.; Chen, H.W.; Chuang, K.J.; Billings, M.E.; Gold, D.; Szpiro, A.; Aaron, C.P.; et al. Association of PM(2.5) with sleep-disordered breathing from a population-based study in Northern Taiwan urban areas. Environ. Pollut. 2018, 233, 109–113.
41. Billings, M.E.; Gold, D.; Szpiro, A.; Aaron, C.P.; Jorgensen, N.; Gassett, A.; Leary, P.J.; Kaufman, J.D.; Redline, S.R. The Association of Ambient Air Pollution with Sleep Apnea: The Multi-Ethnic Study of Atherosclerosis. Ann. Am. Thorac. Soc. 2019, 16, 363–370.
42. Chen, Z.; Herting, M.M.; Chatzi, L.; Belcher, B.R.; Alderete, T.L.; McConnell, R.; Gilliland, F.D. Regional and traffic-related air pollutants are associated with higher consumption of fast food and

trans fat among adolescents. Am. J. Clin. Nutr. 2019, 109, 99–108.

43. Wang, Z.; Zhao, L.; Huang, Q.; Hong, A.; Yu, C.; Xiao, Q.; Zou, B.; Ji, S.; Zhang, L.; Zou, K.; et al. Traffic-related environmental factors and childhood obesity: A systematic review and meta-analysis. Obes. Rev. Off. J. Int. Assoc. Study Obes. 2021, 22, e12995
44. Qureshi, R.; Jadotte, Y.; Zha, P.; Porter, S.A.; Holly, C.; Salmond, S.; Watkins, E.A. The association between prenatal exposure to environmental tobacco smoke and childhood obesity: A systematic review. JBI Database Syst. Rev. Implement. Rep. 2018, 16, 1643–1662.
45. Reilly, J.J.; Armstrong, J.; Dorosty, A.R.; Emmett, P.M.; Ness, A.; Rogers, I.; Steer, C.; Sherriff, A. Early life risk factors for obesity in childhood: Cohort study. BMJ 2005, 330, 1357.