Analysis of Air Pollutions’ Effects on Chinese Children, Adolescents, and Young Adults

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Abstract. In recent years, air pollution in China is becoming more and more serious. Due to air pollution, people were forced to wear masks on streets and some schools even suspended their classes. Many researches had proved that air pollution will cause severe damages to human health. This research focused on reviewing the previous studies on the air pollution’s effects on Chinese children, adolescents, & young adults (the target population), and tried to provide suggestions for future research. The previous researches conducted on this topic were searched on cnki.net and Pubmed and collected. The obtained papers are selected and analyzed. It can be concluded that air pollution had huge effects on the target population’s respiratory system, cardiovascular system, and mental state.

1. Introduction
The problem of air pollution in China is extremely serious. The middle and small cities were speeding up their development in the recent years, and the local governments’ focus was on the economic prosperity rather than on the environmental protection, causing severe air pollution [1]. The large cities are also suffering from the air pollution caused by massive traffic emission.
Air pollutions will bring a lot of negative influences to this society. The pollutants will damage the human body by harming respiratory systems, worsening the existing diseases, and causing various of damages [2]. In 2016, 11.1% of total deaths in China were due to air pollution [3]. Among all the groups of people, the children & adolescents appeared to be more threatened. Because their resistance ability is weaker than the adults. The high breathing rate of them also result in higher damage from air pollutions. The damages emerged in adolescents’ stage may further affect children’s physical and mental development in their future life [4].
This paper focus on reviewing the studies that researched ambient air pollution’s impacts on Chinese children, adolescents and young adults specifically. The paper will comprehensively analyze the air pollution’s effects on respiratory system, cardiovascular system, mental states, and will provide suggestions for future research.

2. Effects on respiratory system
Among all the damages caused by air pollution, the harms to human health and life security are significantly urgent and obvious. Because the air is an essential resource for human living. It is impossible to isolated people from air, which means that people are connected with threats in the air directly [1]. There are many studies that studied the respiratory damages of Chinese adolescents due to air pollution. And they focused their research studies on the damages of lung functions.
One study conducted by Cui Guo’s team investigated how will long-term exposures to ambient PM2.5s affect lung functions in Taiwan, China. It is an analysis of general lung functions changes in correlation with air pollution. The pollutant they focused on was PM2.5, and they found significant
associations between the long-term ambient exposure to PM2.5 and lung functions. As shown in Figure 1, they defined the “lung function” with 3 parameters: forced vital capacity (FVC), forced expiratory volume in 1s (FEV1), and maximum midexpiratory flow (MMEF). They analyzed their results in two ways: baseline (cross-sectional) & longitudinal. According to the data they obtained, in baseline analysis, a 10-\( \mu \text{g/m}^3 \) increase in PM2.5 can result in the following changes of lung functions: 1.67% decrease of FVC, 1.86% decrease of FEV1, and 2.36% decrease of MMEF [4], which are presented in Figure 1. When the time schedule is considered, the damage to lungs’ functions increased significantly. But it also yielded similar associations. In addition to certain parameters that represent lungs’ functions, the team also tried to build connections between exposure to PM2.5 and poor lung function in children, adolescents, and young adults. It turned out that the overall odds ratio of these two events is 1.20, which means they are partially associated [4]. There were other 5 papers also providing evidence for the lung function damages of adolescents from various places in China is associated positively with exposures to Air pollution [5,6,7,8,9]. Other studies investigated the correlation between respiratory diseases of adolescents and air pollution. For instance, one study conducted by researchers from Tsinghua University and Central South University tried to find the effects of air pollutants on the incidence rate of getting rhinitis in children and adolescents. They conducted their investigations in Changsha. They collected data from 4988 children and the data of air pollutants, such as PM10, SO2, and NO2 from 2006 to 2011. The results of their research suggested that the morbidity of children’s rhinitis is positively correlated with the individual cumulative exposure concentration: the increase of 10 \( \mu \text{g/m}^3 \) of PM10 can result in 2.1%, the increase of 10 \( \mu \text{g/m}^3 \) of SO2 can result in 2.6%, and the increase of 10 \( \mu \text{g/m}^3 \) of NO2 concentration can result in 3.7% [10]. In another analysis made by scholars from The First Affiliated Hospital of Chongqing Medical University, the group studied the effects of air pollution on the risk of children & adolescents getting allergic rhinitis. The statistical results showed that both NO2 (adjusted odds ratio=1.22,) and PM10 (adjusted odds ratio=1.13,) will cause the risk to increase. And the authors also pointed out that NO2 and another nitric oxide, NO, are both major pollutants that will positively correlate with respiratory diseases including allergic rhinitis [11]. The summarization of these two research is presented in Figure 2.

**Figure 1.** The adjusted overall percentage of Change of Different Lung Functions Due To 10\( \mu \text{g/m}^3 \) Increase of Air Pollutants [4]
Figure 2. The Adjusted Overall Percentage of Increase of Morbidity of Rhinitis Due to 10μg/m3 Increase of Each Air Pollutants [10, 11]

Not only the postnatal exposure to ambient exposure to air pollution will affect the risks of getting diseases, but the research also suggested that prenatal exposures to pollutants will also contribute to increasing the morbidity of getting respiratory diseases. Chan Lu and the colleagues concentrated on whether prenatal exposure to air pollution will increase the incidence of childhood pneumonia. They studied 1510 cases (0-14 years old children) in Changsha, China, with 699 cases of patients and 811 “control” individuals. After the multivariate logistic regression model analysis, the team found out that prenatal exposure to industrial-related air pollutant SO2 was strongly correlated. The odds ratios of this event for 1 year before conception, for 3 months before conception and for the total pregnant period are 4.01, 4.06, and 6.51 respectively [12]. In addition, they concluded from their data that the parents of children with pneumonia had a higher average exposure level of PM10 during prenatal periods than the healthy children’s parents [12].

In a brief conclusion, exposure to the air pollutants with major pollutants of PM2.5, PM10, nitric oxides, and sulfide oxides is evidently correlated with the changes of children & adolescents’ respiratory systems. Air pollution contributed to the decrease of lung functions and to the increases of risks to respiratory diseases.

3. Effects on cardiovascular system

The impacts on the respiratory system are common and well-known by the public. But academic researches further revealed that the cardiovascular system’s function will also be affected by air pollutants.

There are 3 papers analyzing the potential correlation between blood pressure and exposure to air pollutants. One paper studied the possible association between the exposure to air pollution and vasoconstriction in students’ bodies. The research was to measure the levels of certain cytokines and the miRNAs that target them during the intervention period. After field research and statistical analysis, they concluded that higher exposure to PM2.5 (in dormitories) was positively correlated with the expression of the EDN1 gene [13]. EDN1 gene coded for endothelin, a potent factor that worked as vasoconstrictor and presser substance [14]. This showed that the increase in the exposure level to PM2.5 will increase the level of vasoconstrictor in blood vessels, and further increase the blood pressure. In another research paper that recorded an investigation of exposure to ambient particulate air pollutants’ effects on blood pressure in children and adolescents, they conducted a cross-sectional analysis of 43,745 children and adolescents on the scale of a nation. Their adjusted statistical results suggested that the blood pressure will increase as the concentration of air pollutants increases [15].
Also, PM10 (an increase of per 10 μg/m\textsuperscript{3}) specifically was related to a larger population of hypertension [15]. The odds ratio for this event is 1.45. In the third paper, the researchers from Peking University and the National Health Commission of the PRC did an observational survey on the association of PM2.5 in school residences with childhood hypertension (HBP). It was a large-scale research, which included 53,289 participants aged 6-18 years old from 6 cities in China. The conclusive results were that the increased annual mean of PM2.5 concentration contributed to 1.16% of the participants with HBP, and the increased ratio of polluted days will contribute to 2.82% of the HBP participants [16]. The results of these research are concluded in Table 1 below.

| Table 1. The Overall Data of HBP & Air Pollutants Collected from Cited Papers [13,14,15,16] |
|----------------------------------|----------------|----------------|
| The pollutants (10μg/m\textsuperscript{3} increase) | PM2.5 | PM10 |
| The Increase of Systolic Blood Pressure (mmHg or Percentage) | 2.80~5.78 | 1.36% |
| The Increase of Diastolic Blood Pressure (mmHg or Percentage) | 0.77~2.66 | N/A |
| Odds ratio associated with hypertension | 1.21~1.92 | 1.45 |

4. Effects on mental health

In addition to physical influences, air pollution will also bring mental damages to humans. Especially for children & adolescents, because their minds and thoughts are yet not fully-developed. It is important to focus on the mental health influences brought by modern air pollution. Two studies suggested that air pollution can cause the sleep-disorder in Chinese children & adolescents. One study conducted in Northeastern cities of China revealed that sleep disorder was generally associated with most air pollutants, including PM1, PM2.5, PM10, SO2, NO2, CO, and O3. They pointed out that one major disturbance caused by air pollution was disorders of excessive somnolence, with an odds ratio of 1.43 [17]. In other words, the air pollution will cause the time Chinese children & adolescents spent on sleep to significantly increase. Another research in the Beijing region obtained the same results. A longitudinal study conducted by R An and H Yu studied the impact of air pollution on the behavior of Chinese young adults. Their research sample was 12,000 newly admitted college students at Tsinghua University from 2012 to 2015. The results of the survey suggested that the ambient PM2.5 concentration was positively related to the daily average hours of the respondents’ sleep, both nighttime and daytime. The odds ratio of this event was 1.07 [18]. It can be concluded that exposure to air pollution can increase the sleep time of Chinese adolescents.

The researches about the disturbance of Chinese adolescents’ mental state caused by air pollution were searched. Three papers surveyed the mental influences caused by air pollution among Chinese students. Zu Daqing’s team evaluated the impacts of air pollution on Chinese students’ mental health. Their overall finding was that the negative mental health was strongly related to poor air quality [19]. Another study led by Rajper, conducted a questionnaire-based research in 13 megacities in China. The results of the survey suggested that most students realized their mental states were affected by the long-term exposure to air pollution. And the respondents’ behavior will further be changed severely [20]. They concluded that there are significant negative impacts that the air pollution had negative effects on respondents, both physical and psychological aspects [20]. In the analysis conducted by Wen-Hsu Lin’s group, the data suggested that the adolescents’ happiness level was related to the level of air pollution. The teams analyzed 3 kinds of the pollutants: PM2.5, PM10, and NO2. The results reflected that a higher concentration of these 3 pollutants was associated with the lower level of adolescents’ happiness level in Taiwan, China [21]. It had been proved that exposure to air pollution will decrease the mental state of Chinese adolescents.

Further studies suggested a potential relationship between exposure to air pollution and self-injury...
behaviors. Two papers conducted related researches. Weina Liu’s team investigated the association between non-suicidal self-injury (NSSI) and air pollution among 54,923 Chinese students. They analyzed that a 10 $\mu$g/m$^3$ increase in annual average concentration of PM2.5, O3, and 0.1mg/m$^3$ increase in CO, was positively related with the increases of odds ratio of NSSI (13.9%, 10.5%, 4.8%, respectively) [22]. One more terrifying fact was revealed by Beifang Fan’s team. After investigation and cross-sectional studies, they found that the exposure to PM2.5 together with sleep disturbances was positively related to suicide attempts. The odds ratio specifically of PM2.5 was 1.25 [23]. The summarized results of these investigations of the relationship between air pollution and each kind of the mental disturbance investigated are presented in Figure 3 below.

Figure 3. The Odds Ratio of Different Mental Disturbance Related to Air Pollution [17,18,22,23]

In short conclusion, exposure to air pollution has various negative affections on Chinese adolescents’ mental health.

5. Discussion

In the so far analysis, we have synthesized researches from various potential aspects of the affections on Chinese adolescents due to the air pollution. There are three major kinds of them: impacts on respiratory system, impacts on cardiovascular system, and impacts on mental health.

Five papers confirmed that lung functions will decrease as the exposure level to the air pollution increases. The papers used similar 3 measurements for lung functions: FVC, FEV1, and MMEF. Apparently, these three parameters are currently the major standards that are used to examine the overall lung functions in the human body. However, multiple tests should be conducted in order to comprehensively identify the changes in lung functions. The amount of oxygen content in blood is a practical standard to test the lung’s functions. Also, without effective lung functions, the CO2 inside the human blood will accumulate. Thus, testing the amount of CO2 content is another standard that can test whether the longs’ functions are affected. Future research on the association between air pollution exposures and these two parameters should be conducted. The part that analyzed the association between air pollution and rhinitis is further synthesized from an article that analyzed the results of 17 articles in total (6 for NO2, 5 for SO2, and 6 for PM10) statistically. Therefore, we can conclude that the results obtained are fairly reliable and comprehensive. The paper that we analyzed about the relationship between the prenatal exposure to air pollution and Chinese children’s respiratory damages was the only related research paper. Further investigations should be held so that the relationship can be confirmed with more evidences.
The existing research can illustrate the relationship between air pollution and high blood pressure in Chinese adolescents' bodies clearly and evidently. The mechanism of how increasing air pollution will increase blood pressures was found and investigated. Two general surveys proved the statistical fact that in the real life, HBP of Chinese children was significantly associated with the serious air pollution. Together these researches formed a strong argument.

A relatively large sum of the research papers was collected as I searched for the mental health changes associated with air pollution. This reflected that in recent years the impacts of air pollution on Chinese adolescents' mental health were getting more and more focus. However, the current studies focused on obtaining the statistical results. The current results lacked supportive findings of mechanisms. In order to clarify the current obtained relationship, studies of “how air pollution leads to excessive somnolence” and “how air pollution lead to suicide attempts” among the Chinese adolescents should be conducted.

Finally, the potential future research fields of this topic (air pollutions’ impact on Chinese children, adolescents, and young adults) should be pointed out. In the searching process on Pubmed and cnki.net, it was found that there were a lot of studies that were conducted on the adults’ group or other groups of people, but yet didn’t investigate the adolescents. These include the relationships between air pollution and glucose level in blood [24], relationships between air pollution and cardiac conduction abnormalities [25], relationships between air pollution and cardiac arrhythmias [26], and relationships between air pollution and kidney disabilities [27]. These kinds of researches should be conducted in the future.

6. Conclusion
In conclusion, from the previous studies, it can be analyzed that air pollution have various negative impacts on the health of Chinese children, adolescents, and young adults. It will affect the respiratory functions and cause disabilities & diseases. It will affect the cardiovascular system by significantly increasing the blood pressure. It will also affect the mental state of the children and young adults by expanding their sleeping time, disturbing their sleeping pattern, causing depressions and even leading to suicide attempts. Further researches should be conducted to clarify these results. And more researches should be designed so that more kinds of influences of air pollution on Chinese adolescents’ bodies (multiple systems) will be revealed and be further studied for resolutions. It can be concluded that since the severe modern-day air pollution, it’s every one’s responsibility to protect the environment and to reduce the emission of pollutants. In this way, the teenagers of China can grow and develop in a healthy environment.

7. References
[1] Li P, Zhou X. Analysis on The Present Situation and Prevention of Urban Air Pollution in China. Youth and Society. 2018, 30(10): 284.
[2] Zhang D. The Current Situation of Air Pollution in China and The Prevention & Control Countermeasures. China Resources Comprehensive Utilization. 2019, 37(12): 156-158.
[3] Yang J, Yin P, Zeng XY, You JL, Zhao YF, Wang ZQ, Zhou MG. [Deaths attributed to ambient air pollution in China between 2006 and 2016]. Zhonghua Liu Xing Bing Xue Za Zhi. 2018 Nov 10;39(11):1449-1453.
[4] Guo C, Hoek G, Chang LY, Bo Y, Lin C, Huang B, Chan TC, Tam T, Lau AKH, Lao XQ. Long-Term Exposure to Ambient Fine Particulate Matter (PM2.5) and Lung Function in Children, Adolescents, and Young Adults: A Longitudinal Cohort Study. Environ Health Perspect. 2019 Dec;127(12):127008.
[5] Liu L, Zhang J. Ambient air pollution and children's lung function in China. Environ Int. 2009 Jan;35(1):178-86.
[6] Xing X, Hu L, Guo Y, Bloom MS, Li S, Chen G, Yim SHL, Gurram N, Yang M, Xiao X, Xu S, Wei Q, Yu H, Yang B, Zeng X, Chen W, Hu Q, Dong G. Interactions between ambient air pollution and obesity on lung function in children: The Seven Northeastern Chinese Cities (SNEC) Study. Sci Total Environ. 2020 Jan 10;699: 134397.
[7] He B, Huang JV, Kwok MK, Au Yeung SL, Hui LL, Li AM, Leung GM, Schooling CM. The association of early-life exposure to air pollution with lung function at ~17.5 years in the "Children of 1997" Hong Kong Chinese Birth Cohort. Environ Int. 2019 Feb;123: 444-450.

[8] Chang YK, Wu CC, Lee LT, Lin RS, Yu YH, Chen YC. The short-term effects of air pollution on adolescent lung function in Taiwan. Chmosphere. 2012 Mar;87(1): 26-30.

[9] Zhang J, Feng L, Hou C, Gu Q. How the constituents of fine particulate matter and ozone affect the lung function of children in Tianjin, China. Environ Geochem Health. 2020 Oct;42(10): 3303-3316.

[10] Lu C, Deng Q, Ou Cui, Liu W, Sundell J. The Influence of Air Pollution on The Incidence of Rhinitis in Children. Science China Press. 2013, 58(25): 2577-2583.

[11] Zou Q, Shen Y, Hong S, Kang, H. Meta-Analysis of The Effect of Air Pollution on The Risk of Allergic Rhinitis in Children. CHIN ARCH OTOLARYNGOL HEAD NECK SURG. 2018 Feb, 25(2): 93-97.

[12] Lu C, Peng W, Kuang J, Wu M, Wu H, Murithi RG, Johnson MB, Zheng X. Preconceptional and prenatal exposure to air pollution increases incidence of childhood pneumonia: A hypothesis of the (pre-)fetal origin of childhood pneumonia. Ecotoxicol Environ Saf. 2021 Mar 1:210: 111860.

[13] Chen R, Li H, Cai J, Wang C, Lin Z, Liu C, Niu Y, Zhao Z, Li W, Kan H. Fine Particulate Air Pollution and the Expression of microRNAs and Circulating Cytokines Relevant to Inflammation, Coagulation, and Vasoconstriction. Environ Health Perspect. 2018 Jan 17;126(1):017007.

[14] Miyachi T, Sakai S. Endothelin and the heart in health and diseases. Peptides. 2019 Jan;111: 77-88.

[15] Zhang Z, Dong B, Li S, Chen G, Yang Z, Dong Y, Wang Z, Ma J, Guo Y. Exposure to ambient particulate matter air pollution, blood pressure and hypertension in children and adolescents: A national cross-sectional study in China. Environ Int. 2019 Jul;128: 103-108.

[16] Wang X, Zou Z, Dong B, Dong Y, Ma Y, Gao D, Yang Z, Wu S, Ma J. Association of School Residential PM2.5 with Childhood High Blood Pressure: Results from an Observational Study in 6 Cities in China. Int J Environ Res Public Health. 2019 Jul 14;16(14):2515.

[17] Lawrence WR, Yang M, Zhang C, Liu RQ, Lin S, Wang SQ, Liu Y, Ma H, Chen DH, Zeng XW, Yang BY, Hu LW, Yim SHL, Dong GH. Association between long-term exposure to air pollution and sleep disorder in Chinese children: The Seven Northeastern Cities study. Sleep. 2018 Sep 1;41(9).

[18] An R, Yu H. Impact of ambient fine particulate air pollution on health behaviors: a longitudinal study of university students in Beijing, China. Public Health. 2018 Jun;159: 107-115.

[19] Zu D, Zhai K, Qiu Y, Pei P, Zhu X, Han D. The Impacts of Air Pollution on Mental Health: Evidence from the Chinese University Students. Int J Environ Res Public Health. 2020 Sep 16;17(18):6734.

[20] Rajper SA, Ullah S, Li Z. Exposure to air pollution and self-reported effects on Chinese students: A case study of 13 megacities. PLoS One. 2018 Mar 16;13(3): e0194364.

[21] Lin WH, Pan WC, Yi CC. "Happiness in the air?" the effects of air pollution on adolescent happiness. BMC Public Health. 2019 Jun 21;19(1):795.

[22] Liu W, Sun H, Zhang X, Chen Q, Xu Y, Chen X, Ding Z. Air pollution associated with non-suicidal self-injury in Chinese adolescent students: A cross-sectional study. Chemosphere. 2018 Oct;209: 944-949.

[23] Fan B, Wang T, Wang W, Zhang S, Gong M, Li W, Lu C, Guo L. Long-term exposure to ambient fine particulate pollution, sleep disturbance and their interaction effects on suicide attempts among Chinese adolescents. J Affect Disord. 2019 Nov 1;258: 89-95.

[24] Liu F, Guo Y, Liu Y, Chen G, Wang Y, Xue X, Liu S, Huo W, Mao Z, Hou Y, Lu Y, Wang C, Xiang H, Li S. Associations of long-term exposure to PM1, PM2.5, NO2 with type 2 diabetes mellitus prevalence and fasting blood glucose levels in Chinese rural populations. Environ Int. 2019 Dec;133(Pt B):105213.
[25] Cao H, Li B, Peng W, Pan L, Cui Z, Zhao W, Zhang H, Tang N, Niu K, Sun J, Han X, Wang Z, Liu K, He H, Cao Y, Xu Z, Shan A, Meng G, Sun Y, Guo C, Liu X, Xie Y, Wen F, Shan G, Zhang L. Associations of long-term exposure to ambient air pollution with cardiac conduction abnormalities in Chinese adults: The CHCN-BTH cohort study. Environ Int. 2020 Oct;143:105981.

[26] Feng B, Song X, Dan M, Yu J, Wang Q, Shu M, Xu H, Wang T, Chen J, Zhang Y, Zhao Q, Wu R, Liu S, Yu JZ, Wang T, Huang W. High level of source-specific particulate matter air pollution associated with cardiac arrhythmias. Sci Total Environ. 2019 Mar 20;657:1285-1293.

[27] Xu X, Wang G, Chen N, Lu T, Nie S, Xu G, Zhang P, Luo Y, Wang Y, Wang X, Schwartz J, Geng J, Hou FF. Long-Term Exposure to Air Pollution and Increased Risk of Membranous Nephropathy in China. J Am Soc Nephrol. 2016 Dec;27(12):3739-3746.

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