Original Research

Relationship between inter-city air pollution levels and physical fitness parameters among sixth-grade Mongolian primary school boys, China, 2013–2016

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ABSTRACT

Objectives: Adverse health effects due to air pollution have recently been recognized as a serious social problem in China. In this study, we investigated inter-city relationships between air pollution and physical fitness levels among Mongolian elementary school boys in five cities of the Inner Mongolia Autonomous Region (IMAR), China.
Study design: Retrospective cross-sectional cohort study.
Methods: Physical fitness measurements of 1443 male Mongolian sixth-grade children were obtained from an existing dataset from the year 2013–2016, and correlations were calculated between these measurements and the percentage of good air quality days for five different cities: Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot.
Results: Significant differences in the percentage of good air quality days from 2013 to 2016 were observed among the five cities studied. Statistical analysis showed a significantly positive correlation between good days and students' vital capacity, and a significantly negative correlation between good days and 50 m × 8 shuttle run time for the students included in this study. Differences in the extent of air pollution among the study cities might account for differences in lung function and cardiovascular endurance levels in these Mongolian children.
Conclusions: There is an urgent need for policy intervention to reduce air pollution levels in the IMAR. It is necessary to improve school physical education classes and physical training considering the current air pollution situation. Future research needs to replicate school year survey results from other cities, include longitudinal studies, and clarify the relationship between air pollution, physical exercise, and overall health.

I. Introduction

Economic development has proceeded rapidly in the Inner Mongolia Autonomous Region (IMAR), China. Along with this development, the IMAR has joined other developed cities such as Beijing and Tianjin as one of the most polluted areas in China [1]. Furthermore, inter-city differences in outdoor air pollution levels currently exist within the IMAR due to both the vast extent of land and unequal development among regional economies [2]. The World Health Organization (WHO) has published air quality guidelines for urban cities worldwide based on air quality monitoring and scientific evidence of the impact of air pollution on human health [3]. Over 80% of the global population live in urban areas that monitor air pollution and are exposed to air quality levels that exceed the WHO limits [4]. Reducing air pollution has become a national

priority in the world's largest developing economies, including China [5]. However, later-developed regions in China like the IMAR have not seen a consistent improvement in air pollution and there are inter-city differences among urban cities in the IMAR [4]. In Hohhot City, a provincial capital in the IMAR that is the earliest developed urban area in the IMAR, mean annual sulfur dioxide (SO_2) concentrations fluctuated but remained above the WHO standard from 2010 to 2016 and showed an increase in winter and decrease in summer every year [5]. In the IMAR in 2016, the greatest difference in the mean annual values of SO_2 concentration was approximately 30 mg/m^3 between Hohhot and Xilinhot, the cities with the lowest and highest levels of pollution, respectively.

Air pollution may prevent adults from engaging in regular physical activity, and promote sedentary behavior [6]. Exposure to air pollutants has been linked to decreased lung function, elevated blood pressure, and other cardiovascular and respiratory symptoms, resulting in impaired

Abbreviations

Analysis of variance   ANOVA
Carbon monoxide   CO
Chinese National Student Physical Fitness Standard   CNSPFS
Fine particulate matter   (PM2.5)
Inhalable particles   (PM10)
Inner Mongolia Autonomous Region   IMAR
Nitrogen dioxide   NO2
Ozone   O3
Sulfur dioxide   SO2
World Health Organization   WHO

exercise capacity and performance [7]. Furthermore, outdoor air pollution problems contributed to the deterioration of athlete performance in the 2008 Beijing Olympics [8,9]. The formation of smog is likely to discourage people from engaging in outdoor activities [10]. Improving the availability of indoor exercise facilities has become a national policy, as highlighted in China's Twelfth Five-Year Plan (2011–2015) for the Sports Industry [11]. Outdoor air pollution has been linked to the exacerbation of respiratory illness, infant mortality, the development of asthma, atopy, and a reduction in lung development in children [12].

As most Mongolian children living in the IMAR frequently play outdoors, except during the coldest season, they may experience a gradual reduction in their physical fitness, mainly with respect to cardiovascular endurance and body composition. Increased annual exposure to ozone (O_3)and particulate matter with aerodynamic diameter under 10 μm (PM10) significantly increases diastolic blood pressure and reduces lung function [13]. Recent research suggests that prenatal and early postnatal stages might be critical windows of air pollution exposure leading to possible reductions in adult lung function [14]. Limited physical activity in response to air pollution may soon lead to decreased general health and poor physical fitness of Mongolian children in the IMAR. This research has the potential to improve people's awareness about the harmful effects of air pollution on human health, and also raise awareness about environmental protection and health guidelines.

The purpose of this study was to investigate the relationships between the inter-city air pollution levels and physical fitness levels among male Mongolian elementary schoolchildren in the IMAR, China.

2. Methods

2.1. Research regions in the IMAR

This was a retrospective cross-sectional cohort study of five cities in the IMAR. Data from these cities were collected from the Inner Mongolia Statistical Yearbook (2017) and compared for analysis. The five cities, with varying degrees of economic development and air pollution, had the following mean populations as of 2016 [15]: Hohhot (3,089,000), Baotou (2,857,000), Chifeng (1,062,000), Bayannur (550,000), and Xilinhot (265,000). The mean annual temperatures in each city are 7.3, 7.7, 7.8, 8.7, and 3.0 °C, respectively [16].

2.2. Physical fitness status

Physical fitness was assessed using the revised 2014 Chinese national student physical fitness standard (CNSPFS) [17] which considers aerobic capacity, upper body strength, flexibility, body mass index, abdominal strength, and trunk strength. Annual physical fitness records from 2013 to 2016 of 1443 sixth-grade male Mongolian elementary schoolchildren from seven Mongolian elementary schools across the five study cities

were examined: Hohhot, 483 students from two schools; Baotou, 214 students from two schools; Chifeng, 243 students from one school; Bayannur, 98 students from one school; and Xilinhot, 405 students from one school. The following data from physical fitness measurements conducted every September were included: height (cm), weight (kg), body mass index (BMI, kg/m^2), vital capacity (ml), 50 m sprint (s), sit and reach (cm), 50 m × 8 shuttle run (s) (shuttle run), timed sit-ups (number of times per minute), and timed rope-skipping (number of times per minute).

2.3. Analysis

The statistical package IBM SPSS Statistics for Windows version 24.0 (IBM Corp., Armonk, N.Y., USA), was used to analyze data.

(1) Inter-city differences in air pollution levels

Differences in air pollution levels for the study cities were analyzed by comparing the official mean annual air pollution data from the annual report of the Chinese government from 2013 to 2016 for Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot. Air pollution levels were assessed with percentage of good days as the main indicator. Average concentration values in SO_2, nitrogen oxide (NO_2), and PM10 were all treated as supplementary indicators. "Good days" were defined as having an air quality index (AQI) of either "excellent" (AQI 0–50) or "good" (AQI 51–100) according to the China Air Quality Standard (2012) [18]. According to the Technical Regulation on Ambient Air Quality Index, AQI is divided into six levels in total, with Level One being the best and Level Six being the worst. The AQI levels are as follows: 0–50, Excellent; 51–100, Good; 101–150, Lightly Polluted; 151–200, Moderately Polluted; 201–300 Heavily Polluted; 301–500, Severely Polluted [19]. AQI is calculated using the existing levels of the following major pollutants: fine particulate matter (PM2.5), inhalable particles (PM10), SO_2, NO_2, O_3, and carbon monoxide (CO).

For the purposes of analysis, the air quality "good days" calculation was accomplished by taking the mean of the percentage of good days (AQI 0–100) every month for 4 years. Average values of SO_2, NO_2, and PM10 were calculated by averaging the mean annual values over 4 years. Those differences were statistically examined with a one-way analysis of variance (ANOVA), and post hoc comparisons were made using the Bonferroni correction. Statistical significance was set at p < 0.05.

(2) Differences in physical fitness

Differences in physical fitness among the students in the study cities were compared using the mean values of annual physical fitness data from 2013 to 2016. The differences between the children in different cities were examined statistically via a one-way ANOVA and post hoc comparisons were made using the Bonferroni correction. Statistical significance was set at p < 0.05.

(3) Relationships between air pollution and physical fitness levels

Pearson correlation coefficient was calculated to examine the relationship between air pollution severity and physical fitness levels of the children across the study cities, and the significant correlation coefficient values (p < 0.05) between air pollution indices and physical fitness elements were reported.

(4) Ethical issues

Ethical approval was obtained from the Research Ethics Committee of Chukyo University, study approval number 2019-043.

3. Results

3.1. Air pollution levels

The number of air pollution good days from 2013 to 2016 varied across the five cities studied, and are listed here in the increasing order: Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot. There were significantly fewer good days in Hohhot and Baotou than in Bayannur and Xilinhot. The average concentration of SO_2 in Chifeng and Baotou was significantly higher than that in Xilinhot. The average concentration of NO_2 in Hohhot and Baotou was significantly higher than that in Chifeng, Bayannur, and Xilinhot. Further, the average NO_2 concentration in Chifeng and Bayonne was also significantly higher than that in Xilinhot. Finally, the average concentration of PM10 in Hohhot and Baotou was significantly higher than that in Xilinhot. Table 1 summarizes the air pollution differences across the five cities, with F and significant p values from the ANOVA and post hoc analyses indicated.

3.2. Differences in physical fitness

Physical fitness parameters were compared by one-way ANOVA with city as the fixed factor, and the F and p values are shown in Table 2, with statistically significant differences from post hoc comparisons indicated for each parameter. The average vital capacity in Baotou was significantly lower than that in Chifeng and Xilinhot. The mean vital capacity in Hohhot was significantly lower than that in Chifeng, Bayannur, and Xilinhot. The average shuttle run time in Hohhot was significantly slower than in the other four cities. Finally, the average shuttle run time in Baotou was significantly slower than that in Chifeng and Xilinhot.

3.3. Relationship between the extent of air pollution and physical fitness

Table 3 shows the correlation between air pollution indices and physical fitness parameters. The percentage of good days showed a significantly positive correlation with vital capacity and timed rope-skipping, and a significantly negative correlation with shuttle run and 50 m sprint times. Conversely, SO_2, NO_2, and PM10 concentrations showed significantly negative correlations with vital capacity and timed rope-skipping, but significantly positive correlations with shuttle run and 50 m sprint times.

The relationship between vital capacity and percentage of good days across the study cities in the IMAR showed a significantly positive correlation ($r = 0.27$, $p < 0.01$), with vital capacity and percentage of good days increasing in the order of Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot (see Fig. 1). In contrast, shuttle run time showed a significantly negative correlation with percentage of good days ($r = -0.27$, $p < 0.01$) across the same cities (see Fig. 2).

Table 1
Air pollution parameter levels from 2013 to 2016 in the IMAR.

	Hohhot	Baotou	Chifeng	Bayannur	Xilinhot	F values by ANOVA (p value)
Good days (%)	67.3 ± 8.5 (4) (5)	68.0 ± 12.0 (4) (5)	81.0 ± 8.2	88.2 ± 7.5 (1) (2)	96.0 ± 1.2 (1) (2)	9.17 (<0.0001)
SO_2 (µg/m³)	42.0 ± 13.2	46.0 ± 13.9 (5)	45.5 ± 10.0 (5)	30.5 ± 3.3	22.0 ± 5.1 (2) (3)	4.43 (<0.0001)
NO_2 (µg/m³)	41.3 ± 2.2 (3) (4) (5)	41.8 ± 3.0 (3) (4) (5)	22.0 ± 3.5 (5)	23.5 ± 4.4 (5)	10.8 ± 1.0 (1) (2) (3) (4)	77.39 (<0.0001)
PM10 (µg/m³)	116.3 ± 22.3 (5)	119.5 ± 21.2 (5)	90.3 ± 15.2	86.5 ± 12.9	58.3 ± 6.6 (1) (2)	9.00 (<0.0001)

(1) p < 0.05 vs Hohhot, (2) p < 0.05 vs Baotou, (3) p < 0.05 vs Chifeng, (4) p < 0.05 vs Bayannur, (5) p < 0.05 vs Xilinhot.

4. Discussion

There were significant differences in air pollution parameters among the five study cities. Air pollution in Hohhot and Baotou was higher than that in Chifeng, Bayannur, and Xilinhot. The SO_2 levels in Hohhot (42 µg/m³) and Baotou (46 µg/m³) were above the WHO standard (24 µg/m³) but below that of China (60 µg/m³). Annual mean NO_2 concentration in Hohhot (41.3 µg/m³) and Baotou (41.8 µg/m³) exceeded the standard values of both the WHO and China (40 µg/m³). Further, the annual mean concentration of PM10 (58.3 µg/m³ ~ 119.5 µg/m³) in the five study cities was mostly above both the WHO reference value of 20 µg/m³ and the average in China (70 µg/m³). Studies suggest that differences in air pollution levels might lead to differences in physical fitness levels, reduced lung function, and an overall reduction in physical activity in more polluted regions [20]. Lung dysfunction due to air pollution is prevalent in children in Shenyang, in northeast China near the IMAR [21]. Moreover, the 2016 Chinese ranking of air pollution in Hohhot was higher than that in Shenyang [22]. This suggests that similar lung dysfunction may also occur in Hohhot.

This study was limited to sixth-grade male Mongolian elementary schoolchildren and, therefore, factors of ethnicity, gender, and age had little effect on differences in physical fitness levels. Long-term exposure to air pollution negatively influences lung development in 10 to 18-year-old and has led to clinically significant deficits in forced expiratory volume by adulthood [23], and children in more polluted regions have shown higher impairment in lung function [20]. A positive correlation between air pollution and vital capacity was observed in the present study. Although a positive correlation between height and vital capacity is well known, a significant inverse correlation between height and air pollution level was found in this study. Children from more polluted cities demonstrated impaired forced vital capacity, indicating that vital capacity may be affected by exposure to air pollution.

A significant correlation was found between the percentage of good days and shuttle run times. The effect of air pollution on shuttle run times was also verified by significant correlations with SO_2, NO_2, and PM10 concentrations. However, there was no significant correlation between BMI and air pollution levels; suggesting that BMI contributes little to the effect of air pollution on shuttle run times. Lowered cardiovascular endurance reflected in slower shuttle run times might not have been caused by obesity but instead by impaired lung function.

Children in the IMAR traditionally enjoy regular outdoor activity, and the correlation between levels of air pollution and decreased physical fitness suggested by our data is of grave concern. There may be differences in outdoor play by gender or region, but those differences could not be explored due to the limits of our participant sample. By engaging in physical activity outdoors, children may experience higher exposure to pollution than adults. Air pollution is likely to have a greater impact on asthmatic children if they do not have access to routine medical care [21]. This study revealed that the degree of air pollution in the IMAR is one of the factors potentially contributing to decreased vital capacity and cardiovascular endurance in male schoolchildren. These findings indicate the importance of physical education and medical checks in elementary school in areas where the air pollution level is severe, such as in Hohhot and Baotou.

Although various local governments have built many indoor fitness venues equipped with a variety of fitness equipment, given the large general population, the per capita access to such places for indoor exercise is still severely limited. This limited access to exercise space is one of the main reasons why primary school students have reduced physical activity [24]. Most primary schools place a heavy emphasis on intellectual education, with only minimal focus on participation in sports. In this critical stage of primary school students' physical growth and development, most schools neglect students' training in physical fitness.

The primary limitations of this study were as follows: (1) Monthly data of SO_2, NO_2, and PM10 concentrations in the air pollution data could not be obtained for this study, so the effects of year-round outdoor

Table 2
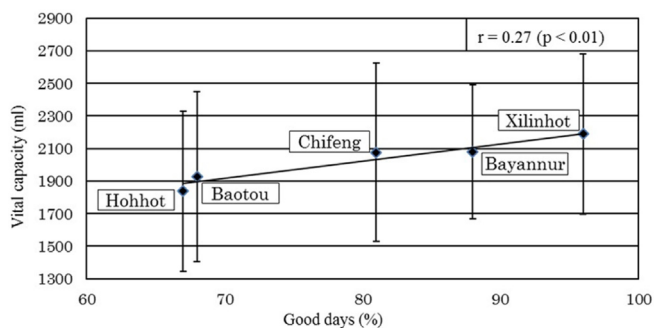Physical fitness parameters from 2013 to 2016 in the IMAR.

	Hohhot	Baotou	Chifeng	Bayannur	Xilinhot	F values by ANOVA (p value)
Height (cm)	152.3 ± 7.7 (2) (4) (5)	150.5 ± 6.7 (1)	152.4 ± 7.8 (4) (5)	149.9 ± 7.2 (1) (3)	149.5 ± 7.5 (1) (3)	10.57 (<0.0001)
Body weight (kg)	47.1 ± 9.3 (2) (3) (5)	43.9 ± 10.9 (1)	44.7 ± 10.5 (1)	46.0 ± 11.7	44.0 ± 10.5 (1)	6.71 (<0.0001)
BMI (kg/m^2)	20.3 ± 3.2 (3)	19.2 ± 3.9 (3)	19.1 ± 3.3 (1) (2)	20.3 ± 3.9	19.6 ± 3.8	6.38 (<0.0001)
Vital capacity (ml)	1837 ± 492 (3) (4) (5)	1927 ± 522 (3) (5)	2076 ± 548 (1) (2)	2081 ± 412 (1)	2189 ± 493 (1) (2)	30.21 (<0.0001)
50 m sprint (s)	9.4 ± 0.8 (3) (5)	9.6 ± 1.1 (3) (5)	8.8 ± 0.9 (1) (2) (4) (5)	9.5 ± 0.9 (3)	9.3 ± 1.1 (1) (2) (3)	23.75 (<0.0001)
Sit and reach (cm)	8.3 ± 4.4 (2)	5.8 ± 5.2 (1) (3) (4) (5)	8.0 ± 5.2 (2)	8.3 ± 4.2 (2)	7.8 ± 4.8 (2)	11.19 (<0.0001)
Shuttle run (50 m × 8) (s)	119 ± 17.4 (3)	112 ± 18.0 (3) (5)	102 ± 13.0 (1) (2) (5)	107 ± 11.0	107 ± 15.3 (2) (3)	56.02 (<0.0001)
Timed sit-ups (n)	35 ± 6.1 (2) (4) (5)	30 ± 6.3 (1) (3) (5)	34 ± 8.0 (2)	31 ± 8.7 (1)	33 ± 7.7 (1) (2)	19.22 (<0.0001)
Timed rope-skipping (n)	108 ± 25.0 (2) (4) (5)	63 ± 29.7 (1) (3) (4) (5)	109 ± 30.5 (2) (4) (5)	99 ± 28.8 (1) (2) (3)	100 ± 26.9 (1) (2) (3)	113.14 (<0.0001)

(1) p < 0.05 vs Hohhot, (2) p < 0.05 vs Baotou, (3) p < 0.05 vs Chifeng, (4) p < 0.05 vs Bayannur, (5) p < 0.05 vs Xilinhot.

Table 3
Correlation between air pollution and physical fitness parameters.

	Good days (%)	SO$_2$ (μg/m^3)	NO$_2$ (μg/m^3)	PM10 (μg/m^3)
Height (cm)	−0.13**	0.14**	0.11**	0.12**
Body weight (kg)	−0.08**	0.05*	0.09**	0.08**
BMI (kg/m^2)	−0.04	−0.01	0.05	0.04
Vital capacity (ml)	0.27**	−0.21**	−0.27**	−0.26**
50 m sprint (s)	−0.07**	−0.03	0.11**	0.08**
Sit and reach (cm)	0.04	−0.04	−0.04	−0.04
Shuttle run (50 m × 8) (s)	−0.27**	0.12**	0.29**	0.26**
Timed sit-ups (n)	0.04	0.03	0.04	0.04
Timed rope-skipping (n)	0.08**	−0.07*	−0.11**	−0.10**

**p < 0.01, *p < 0.05.

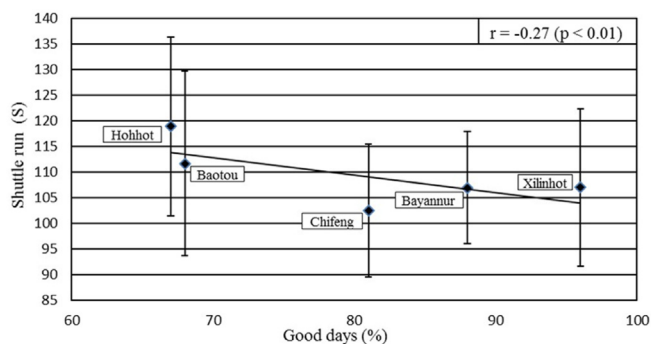Fig. 2. Correlation between shuttle run and good days in the study cities during the period of 2013–2016.

Fig. 1. Correlation between vital capacity and good days in the study cities during the period of 2013–2016.

air pollution fluctuation on physical fitness could not be investigated. (2) As this study applied only cross-sectional analysis in the period from 2013 to 2016, longitudinal analysis would be needed to discuss any long-term or latent effects of air pollution on physical fitness. (3) We could not evaluate daily physical activities for the children in this study. Future studies should conduct an assessment into the city differences in the quality and quantity of daily physical activities for children of the IMAR.

Through air pollution control, improving urban air quality is a long-term and arduous process, which may take a long time. Reducing coal consumption in the IMAR is a major project to improve air pollution. Improvement in air pollution control should can also be done by strengthening basic research on air pollution prevention, carrying out atmospheric environmental assessment, and adjusting air pollutant control strategies.

Furthermore, the socioeconomic status of the city and family income have been considered, but the retrospective nature of the study, makes it impossible to assess the economic income of each family. The percentage of Mongolians in the city is exceedingly small, and the income of Mongolians and Han people is vastly different. This study only studied the relationship between air pollution and physical fitness of students. Therefore, the economic status of the city is not discussed.

Primary schools' managements should first ensure the allocation of land and facilities for student sports and other physical activities, and reserve enough time for physical education and extracurricular exercise in the school curricula. They should also actively formulate physical exercise programs, while holding teachers responsible for the supervision and management, to ensure students' exercise time. For example, schools could arrange half-hour large-scale physical activities every morning, organize students to do gymnastics exercises accompanied by instructions and music on the radio, arrange competitive sports activities, or organize students to participate in various sports after school every day. School sports venues should also be open to students during school holidays.

5. Conclusion

The relationship between the air pollution levels and physical fitness parameters was examined for each of the five study cities. Vital capacity and shuttle run times showed the strongest correlation with pollution levels among sixth-grade male Mongolian elementary schoolchildren in the IMAR. Differences in air pollution levels among the study cities might account for these observed differences in lung function and cardiovascular endurance levels in Mongolian children. More research is needed that focuses on the relationship between air pollution, physical exercise,

and health. In the future, we will study lung function in children by measuring forced expiratory volume per second (FEV1) and forced vital capacity (FVC).

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Unblinded ethical statement

Ethical approval was obtained from the Research Ethics Committee of Chukyo University, study approval number 2019-043.

Declaration of conflicting interest

The authors have no conflicts of interest to declare.

Declaration of competing interest

The authors declare no conflicts of interest associated with this manuscript.

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