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Journal of Community Medicine and Public Health Reports ISSN: 2692-9899

Research article Volume 2 Issue 2

Impact of air pollution levels on the physical fitness levels of 6th-grade elementary school students in the Inner Mongolia Autonomous Region of China- Comparison of inter-city influences between boys and girls from 2013 to 2016.

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Received date: 25 March 2021; **Accepted date:** 03 April 2021; **Published date:** 07 April 2021

Citation: Man C, Watanabe T, Oshimura K, Nandingbaolige, Li S. Impact of air pollution levels on the physical fitness levels of 6th-grade elementary school students in the Inner Mongolia Autonomous Region of China- Comparison of inter-city influences between boys and girls from 2013 to 2016. J Comm Med and Pub Health Rep 2(2): https://doi.org/10.38207/jcmphr20210029

Abstract

In this study, we investigated gender differences in the effects of air pollution levels on physical fitness levels of 6th-grade students at Mongolian elementary schools in five cities in Inner Mongolia, an autonomous region of China. Significantly, a weak negative correlation between the 50m x 8 shuttle run execution time and good day rate for both boys and girls was found. There was a significant weak positive correlation between the vital capacity and the percentage of good days for boys, while almost no correlation was found for girls. Therefore, it was suggested that the degree of air pollution may cause a decrease in cardiovascular endurance due to a decrease in daily physical activity in both boys and girls, and a decrease in lung function in boys due to an increase in exposure to air pollutants by playing outside.

Keywords: Mongolian children, air pollution, vital capacity, cardiovascular endurance, gender differences.

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 (NO_2), ozone (O_3), sulfur dioxide (SO_2), World Health Organization (WHO)

Introduction

Since its reform and opening-up in 1978, China has made remarkable economic progress. This has been accompanied by air pollution that has become a serious social problem. During the massive smog outbreak in 2013 that spread across a quarter of the total area of China, an estimated 600 million people was affected **[1]**. The Chinese government suspended operations at thousands of factories and imposed strict regulations on private cars; however, because the causes of pollution are complicated, a solution has not yet been found **[2]**. The association between air pollution and health has been drawing attention globally. In China, air pollution is estimated to kill an average of 4,000 people daily, accounting for 17 % of all deaths **[3]**. Moreover, 38 % of the population is exposed to "unhealthy" air, according to the U.S. environmental standards **[3]**. Long-term exposure to polluted air adversely affects the development of lung function in children aged 10 - 18 years, reduces forced vital capacity by adulthood, and increases the prevalence of lung dysfunction in children living in contaminated areas **[4]**. The level of air pollution is thought to lead to lower physical fitness levels, lower lung function, and a general decrease in physical activity **[5]**.

In recent years, with the development of the market economy, the expansion of international trade, and the diversification of culture, many ethnic festivals, such as Madam, have been held on a large and small scale in the Inner Mongolia Autonomous Region (IMAR) of China. In Naadam, the traditional games that captivate boys such as "horse racing", "archery", and "Mongolian wrestling" remain deep-rooted. As boys in Inner Mongolia prefer an active, outdoor lifestyle in a traditional cultural context, there is a concern that the level of air pollution may affect their physical fitness levels. At school, boys spend most of their time outside when not in class, while girls spend most of their time in the classroom. Boys prefer to play soccer and basketball, while Mongolian wrestling is a very popular sport.

In a comparison of five cities, the authors found that the degree ofair pollution was associated with a lower vital capacity and systemic endurance in sixth-grade boys in Inner Mongolia, China **[6]**. However, the effects of sex and age on children's physical fitness levels cannot be ignored. Internationally, girls around age 12 was found to be less physically active and more inactive than boys of the same age **[7]**. In China, although few areas was surveyed, it was reported that elementary and middle school male students in Shanghai performed exercise and sports for longer than girls **[8]**, indicating that the reduction in the amount of physical activity in daily life

may be because of air pollution on the health status as well as the physique and physical fitness levels of Mongolian children living in the IMAR and that this effect may be different between boys and girls.

Therefore, the purpose of this study was to compare the physique and physical fitness levels of Mongolian children living in five cities with different levels of air pollution in the IMAR and to clarify how the effects of air pollution on the physique and physical fitness levels differ between boys and girls by comparing the physique and physical fitness levels of Mongolian children attending the 6th-grade in elementary schools in those cities.

Methods

Geographical and demographic characteristics of the Inner Mongolia Autonomous Region

Founded in 1947, the IMAR is in the east and west of the northern frontier region of China. The total area of the autonomous region is 1.183 million km², about three times the size of Japan. The IMAR is a vast expanse of land far from the sea, with a temperate monsoon climate and an average elevation of 1,500 to 2,200 m above sea level. In winter, January is the coldest month, and the average monthly temperature ranges from -10 °C to -32 °C. Summer, which is short at approximately 1–2 months, is not very hot, and the average monthly temperature ranges from 16 °C to 27 °C. However, in the hottest month of July, the temperature can rise to approximately 36 °C–43 °C. At the end of 2014, according to the 2015 IMAR Statistical Yearbook, the total population of IMAR was 25.048 million of which 77.54 % was Han Chinese and 18.65 % was Mongolian **[9]**.

Selection of participants

Based on the IMAR Environmental Mass Report **[10]**, in each of the western, central, and eastern regions with different levels of economic development and air pollution, five cities, Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot, where Mongolian elementary schools had been established, was selected **(Figure 1)**. At the end of 2014, the population of each city was 3,089,000 in Hohhot, 2,857,000 in Baotou, 1,062,000 in Chifeng, 550,000 in Bayannur, and 265,000 in Xilinhot **[9]**. All the sixth graders (average age, 12.0 ± 0.5 years old) attending all the Mongolian elementary schools in each city was selected as the participants in this study. The total number of participants for the 4 years from 2013 to 2016 was: Hohhot City, 1,031 (483 boys and 548 girls); Baotou City, 437 (214 boys and 223 girls); Chifeng City, 486 (243 boys and 243 girls); Bayannur City, 188 (98 boys and 90 girls); and Xilinhot City, 791 (405 boys and 386 girls); with a total of 2,933 (1,443 boys and 1,490 girls) participants.

Figure 1: Geographical location of five cities in the IMAR selected for the study.

Physique and physical fitness measurements

(1) Physique and physical fitness measurements was carried out every September for four years from 2013 to 2016 at each school according to the Chinese Education Department's "National Student Constitution Health Standard" **[11]**.

(2) There was nine measurement items for both boys and girls, namely, height (cm), weight (kg), BMI (kg/m2), vital capacity (ml), 50 m sprint (s), sit and reach (cm), 50m × 8 shuttle run (s), timed sit-ups (number of times per minute), and timed rope skipping (number of times per minute). In China, the 50m × 8 shuttle run time is used as an evaluation of the overall endurance of 6th-grade elementary school students.

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

Analytical methods

Comparison of the air pollution levels between cities.

The determination of the air pollution level was based on the "Environmental Air Mass Index (Air Quality Index, hereinafterAQI) Technical Regulation (HJ633-2012) **[12]**", and "Excellent Day", "SO2", "NO2", and "PM10" (fine particles below 10 μm particle size) was used as evaluation indices. The annual average air pollution data between cities was compared using annual government-published reports from 2013 to 2016. The proportion of "good days" (hereinafter referred to as "good days") was used as the main air pollution index of this study. A "good day" was defined as an AQI of "excellent" (0–50) or "good" (51 – 100) based on the "Environmental Air Mass Standard (GB3095 - 2012) "**[13]**. The AQI is classified into six stages, with 101–150 rated as "mild pollution", 151 – 200 as "moderate pollution", 201 – 300 as "severe pollution", and 301 – 500 as "very severe pollution " **[13]**. The AQI is an index that was created independently by the Chinese Ministry of Environmental Protection and its value is calculated using the concentration values of six types of target substances as PM10, PM2.5, SO2, NO2, CO, and O3, and set so that the higher the AQI, the higher the air pollution level, and the greater the health hazard to the human body. The average concentration values of SO2, NO2, and PM10 were treated as supplementary indicators in this study. The average of the percentage of good days per month for four years was used as the percentage of good days; for the average of SO2, NO2, and PM10, the average of the annual averages for four years was used as representative values of each city. For the comparison of mean values between cities, a one-way analysis of variance (ANOVA) was performed. For items where the F values was recognized as significant, multiple comparison tests using the Bonferroni method were performed. The statistical significance level was set at $P < 0.05$.

Comparison of physique and physical fitness level between cities:

The average physical fitness for boys and girl's data for each year from 2013 to 2016 was compared among cities. A one - way ANOVA was used to compare the average physique and physical strength of the participants from each city, and the Bonferroni method was used for the subsequent multiple comparisons. The statistical significance level was set at $P < 0.05$.

Relationship between air pollution level, physique, and physical fitness level

Pearson correlation analysis was used to calculate the correlation coefficient between the level of air pollution in the surveyed cities and the physique and physical fitness levels of the children. Moreover, a regression analysis was performed, and the difference in the regression coefficients between boys and girls was tested.

Results

Air pollution levels in target cities

From 2013 to 2016, the average percentage of good days from the lowest was in the order of Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot. The average percentage of good days in Hohhot and Baotou cities was significantly lower than that in Bayannur and Xilinhot. The average concentration of SO2 in Chifeng City and Baotou the city was significantly higher than that in Xilinhot. The average concentration of NO2 in Hohhot and Baotou cities was significantly higher than that in Chifeng, Bayannur, and Xilinhot. In addition, the NO2 average pollution concentration in Chifeng and Bayannur was significantly higher than that in Xilinhot. The mean concentration of PM10 in Hohhot and Baotou cities was significantly higher than those in Xilinhot. (**Table 1)** summarizes the levels of air pollution in each of the five target cities and shows the results of multiple comparisonsof ANOVA F values and post-analysis.

Table 1: Air pollution levels in cities in the IMAR from 2013 to 2016

	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 ($\mu g/m^3$)	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 ($\mu g/m^3$)	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 ($\mu g/m^3$)	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

Physique and physical fitness level

To compare the average physique and physical fitness among the cities, a one-way ANOVA analysis using cities as a fixed factor was carried out, and the results according to boys and girls are shown in **(Table 2)**.

For boys, the average height in Hohhot was significantly higher than that observed in Baotou, Bayannur, and Xilinhot. The average height in Chifeng was significantly higher than that observed in Bayannur and Xilinhot. The average body weight in Hohhot was significantly higher than that observed in Baotou, Chifeng, and Xilinhot. The mean BMI in Hohhot and Baotou was significantly higher than that observed in Chifeng. The mean vital capacity in Baotou was significantly lower than that observed in Chifeng and Xilinhot. The mean vital capacity in Hohhot was significantly lower than that observed in Chifeng, Bayannur, and Xilinhot. The average running time of the 50m×8 shuttle run-in Hohhot was significantly higher than that observed in Chifeng, while the times observed in Baotou were significantly higher than the times in Chifeng and Xilinhot. Significant differences between cities for other physical fitness indicators, namely, the 50 m sprint, sit and reach, timed sit-ups, and timed rope skipping was also observed.

For girls, the average height in Hohhot, Baotou, and Chifeng was significantly higher than that observed in Xilinhot. The average body weight in Hohhot was significantly higher than that observed in Chifeng and Xilinhot. Significant differences was observed between the cities about the mean BMI. The average body weight in Hohhot was significantly lower than that observed in Chifeng and Bayannur. The average running time of the 50 m × 8 shuttles run in Hohhot was the highest compared with the times observed in the other four cities, although it was significantly lower in the order of Baotou, Bayannur, Xilinhot, and Chifeng, with no significant difference being observed for the times between Bayannur and Xilinhot. Significant differences between cities in other physical fitness indicators, namely, the 50 m sprint, sit and reach, timed sit-ups, and timed rope skipping was also observed.

Table 2: Comparison of physique and physical fitness averages between cities by boys and girls

Sex	Hohhot	Baotou	Chifeng	Bayannur	Xilinhot	F values by ANOVA (p-value)
Height (cm)						
Boy	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)
Girl	153.6 ± 8.5 (5)	152.1 ± 6.8 (5)	153.0 ± 6.7 (5)	152.0 ± 6.3	150.2 ± 6.7 (1)(2)(3)	10.57 (< 0.0001)
Body weight (kg)						
Boy	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)
Girl	46.3 ± 9.2 (3)(5)	44.3 ± 10.7	43.9 ± 7.8 (1)	45.9 ± 10.0	42.9 ± 9.1 (1)	6.71 (< 0.0001)
BMI (kg/m^2)						
Boy	20.3 ± 3.2 (3)	19.2 ± 3.9 (3)	19.1 ± 3.3	20.3 ± 3.9	19.6 ± 3.8	6.38 (< 0.0001)
Girl	19.6 ± 3.1	19.1± 3.9	18.9 ± 2.7	19.7 ± 3.4	19.0 ± 3.5	6.36 (< 0.0001)
Vital capacity (ml)						
Boy	1837 ± 492 (3)(4)(5)	1822 ± 534 (3)(5)	2076 ± 548 (1)(2)	2081 ± 412 (1)	2189 ± 493 (1)(2)	30.21 (< 0.0001)
Girl	1747±491 (3)(4)	1927 ± 522	1927 ± 506 (1)	1905 ± 393 (1)	1836 ± 441	6.96 (< 0.0001)
50 m sprint (s)						
Boy	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)
Girl	10.1 ± 0.7 (3)	10.0 ± 1.3 (3)	9.1 ± 0.7 (1)(2)(4)(5)	10.0 ± 0.9 (3)	10.1 ± 0.9 (3)	67.69 (< 0.0001)
Sit and reach (cm)						
Boy	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)

Girl	9.3 ± 4.8 (2)	7.5 ± 5.3 (1)(3)(4)(5)	11.3 ± 5.3 (2)	10.2± 4.7 (2)	9.6± 4.7 (2)	18.16 (< 0.0001)
Shuttle run (50 m × 8) (s)						
Boy	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)
Girl	120 ± 15.4 (2)(3)(4)(5)	116 ± 15.4 (1)(3)(4)(5)	102 ± 13.0 (1)(2)(4)(5)	111 ± 10.1 (1)(2) (3)	108 ± 14.4 (1)(2)(3)	67.75 (< 0.0001)
Timed sit-ups (n)						
Boy	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)
Girl	34 ± 5.7 (2)(3)(4)(5)	29 ± 7.1 (1)(5)	30 ± 8.0 (1)	30 ± 7.5 (1)	31 ± 5.5 (1)(2)	39.24 (< 0.0001)
Timed rope-skipping (n)						
Boy	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)
Girl	111 ± 25.5 (2)(4)(5)	71 ± 25.4 (1)(3)(4)(5)	115 ± 27.8 (2)(4)(5)	101± 26.8 (1)(2)(3)	105 ± 24 (1)(2)(3)	113.22(< 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

Relationship between air pollution level, physique, and physical fitness level:

(Table 3) shows the results for the correlation analysis of the air pollution levels, physique, and physical fitness levels by boys and girls. In boys, the percentage of good days showed a significant positive correlation of r = 0.27, with vital capacity values and a significant negative correlation of r = -0.27, with 50m × 8 shuttle run times. Vital capacity showed significant negative correlations with SO2, NO2, and PM10 concentrations (r = -0.21; r = -0.27; r = -0.26, respectively) The 50m × 8 shuttle run time showed significant positive correlations with SO2, NO2, and PM10 concentrations (r = 0.12, r = 0.29; r = 0.26, respectively).

In girls, there was a significant positive correlation of r = 0.08 between the percentage of good days and vital capacity, and a significant negative correlation of r= -0.32 with the 50 m × 8 shuttle run times. Vital capacity showed significant negative correlations with SO2, NO2, and PM10 concentrations (r = -0.02; r = -0.09; r = -0.07, respectively) The 50m × 8 shuttle run time showed significant positive correlations with SO2, NO2, and PM10 concentrations at r= 0.16; r = 0.34; r = 0.31, respectively)

Table 3: Results of the correlation analysis between air pollution level, physique, and physical fitness level by boys and girls

	Sex	Good days (%)	SO_2 (μg/m^3)	NO_2 (μg/m^3)	PM10 (μg/m^3)
Height (cm)	Boy	-0.13**	0.14**	0.11**	0.12**
	Girl	-0.16**	0.16**	0.15**	0.16**
	Boy	-0.08**	0.05*	0.09**	0.08**
Body weight (kg)					
	Girl	-0.12**	0.09*	0.13**	0.12**
BMI (kg/m^2)	Boy	-0.04	-0.01	0.05	0.04
	Girl	-0.06*	-0.25	0.06*	0.06*
Vital capacity (ml)	Boy	0.27**	-0.21**	-0.27**	-0.26**
	Girl	0.08**	-0.02	-0.09**	-0.07**
50 m sprint (s)	Boy	-0.07**	-0.03	0.11**	0.08**
	Girl	-0.04	-0.15**	0.10**	0.04
Sit and reach (cm)	Boy	0.04	-0.04	-0.04	-0.04

	Girl	0.09**	-0.03	-0.12**	-0.10**
	Boy Girl	-0.27**		0.29**	0.26**
Shuttle run (50 m × 8) (s)		-0.32**	0.12**	0.34**	0.34**
			0.16**		
Timed sit-ups (n)	Boy	0.04	0.03	0.04	0.04
	Girl	0.13**	0.04	0.13**	0.11**
	Boy	0.08**	-0.07*	-0.11**	-0.10**
Timed rope-skipping (n)					
	Girl	0.08**	-0.07*	-0.12**	-0.11**

**p < 0.01, *p < 0.05

(Figure 2) shows the relationship between the average vital capacity and the percentage of good days by boys and girls. In boys, the mean vital capacity was higher in the order of Baotou, Hohhot, Chifeng, Bayannur, and Xilinhot. Meanwhile, in girls, the relationships observed in boys was not observed. In the regression analysis of the vital capacity and the percentage of good days, the regression equations for boys y = 11.47 x + 1097.63 and girls y = 3.12 x + 1575.77 was obtained. The regression coefficient obtained for boys was significantly higher than that obtained for girls. **(Figure 3)** shows the relationship between the 50 m×8 shuttle run time and the percentage of good days for both boys and girls. The average run time of the 50m×8 shuttle run was higher in Hohhot and Baotou than the times in Bayannur, Xilinhot, and Chifeng. No significant differences was observed between boys and girls. In the regression analysis, the regression equations for boys y = -0.38 x + 140.72 and girls y = -0.40 x + 144.75 was obtained. There was no significant difference in the regression coefficients between the boys and girls.

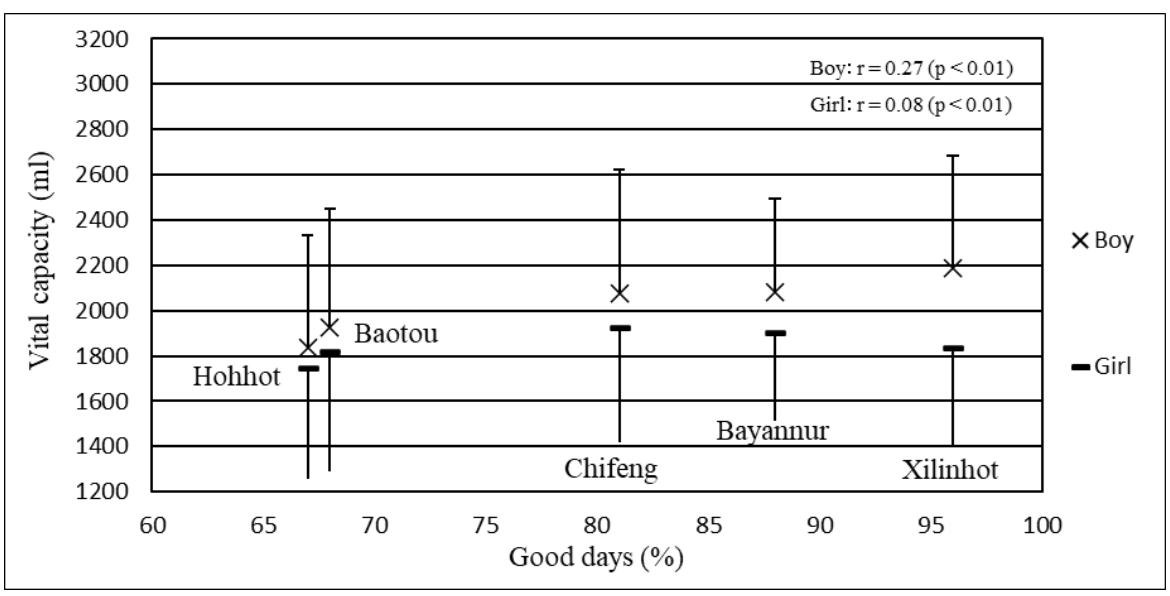

Figure 2: Relationship between vital capacity and percentage of good days by boys and girls

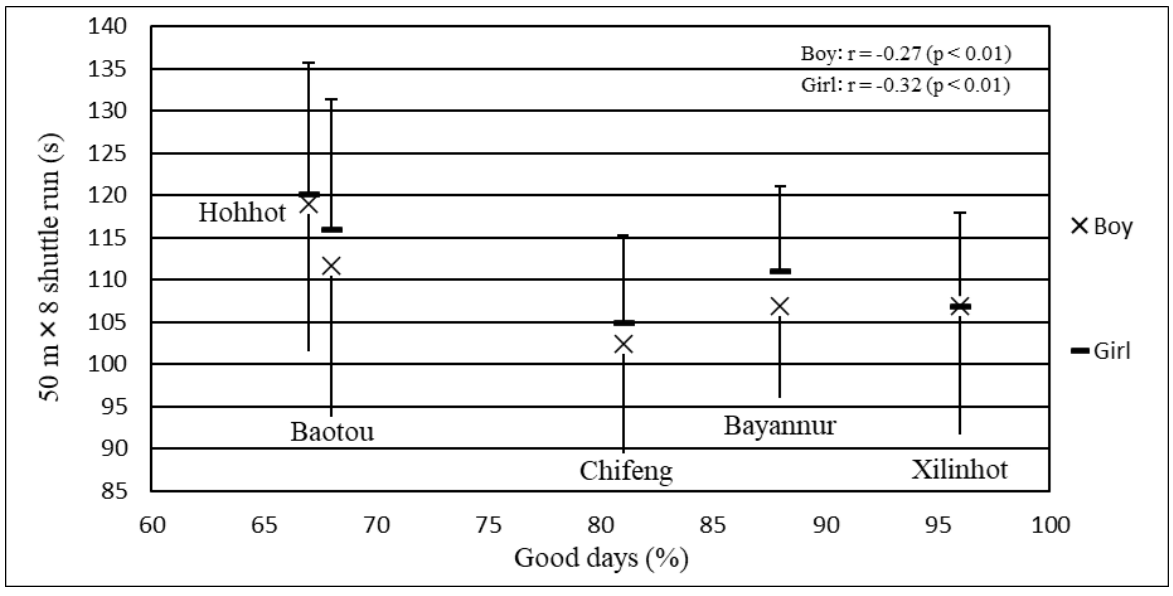

Figure 3: Relationship between the 50m × 8 shuttle run times and percentage of good days by boys and girls.

Discussion

Among the five cities in the IMAR, China, that was the targets in this study, there was a clear difference in the percentage of good days, the main indicator of air pollution level. The air pollution in Hohhot and Baotou was more pronounced than the air pollution in Chifeng, Bayannur, and Xilinhot. The average annual concentration of SO2 was 42 µg/m3 in Hohhot and 46 µg/m3 in Baotou, exceeding the WHO reference value (24 µg/m3), but below the Chinese reference value (60 µg/m3). The average annual concentration of NO2 was 41.3 µg/m3 in Hohhot and 41.8 µg/m3 in Baotou, exceeding the WHO and Chinese reference values (40 µg/m3). In addition, the annual average concentration of PM10 in the five cities was in the range of 58.3 µg/m3–119.5 µg/m3, exceeding both the WHO reference value of 20 µg/m3 and the Chinese reference value of 70 µg/m3. Children in Shenyang, which is adjacent to the IMAR, experienced pulmonary dysfunction caused by air pollution **[14]**, and according to 2016 China Air Pollution ranking, Hohhot experienced more severe air pollution than Shenyang **[15]**. This suggested that the same pulmonary dysfunction may have occurred in Hohhot, thus, it was a suitable city selection to elucidate the present research topic.

In a comparison of five cities, the authors found that the degree of air pollution is associated with a lower vital capacity and 50m×8 shuttle runs among the sixth-grade boys in IMAR, China **[6].** Furthermore, in the present study, a significant weak positive correlation was observed between vital capacity and the percentage of good days in boys; however, this was observed to a negligible extent in girls. On the other hand, both boys and girls showed a significant weak negative correlation between the 50m × 8 shuttle run time and the percentage of good days. The differences in air pollution levels between cities was weakly but non-negligible associated with a decrease in vital capacity in boys and a decrease in systemic endurance in both boys and girls.

It has been reported that the height and weight measurements of Chinese elementary school children in cities where economic development is progressing are greater than that of urban children where economic development is lagging for both boys and girls in any grade **[16]**. This finding was supported by the results of this study. We observed that children in Hohhot and Baotou cities, where economic development had progressed, tended to be larger in size than both boys and girls in the other cities. Among Mongolian children in the IMAR, the economic development of the cities that they resided in was believed to affect their physique. There is also a difference in lifestyles among those cities.

Although the positive correlation between vital capacity and height is well known, the present study found that boys living in areas with high levels of air pollution tended to have a higher average height. Thus, in boys, differences in air pollution levels among the cities may be more strongly associated with differences in vital capacity than they appear to be. In fact, Mongolian male elementary school students tended to prefer outside play daily. On the other hand, for girls, the social and cultural concepts in Mongolian society **[17]** (such as the idea that "men are outside, women are inside") may have influenced their daily behavior. Also, performing physical activity outdoors, makes children more likely to be exposed to pollution than adults, and the longer they spend outdoors, the greater the effect of air pollution on the development of their lung function **[18,19]**. Lung dysfunction caused by air pollution is widespread among children in Shenyang, northeastern China **[14]**, which is adjacent to the IMAR, and a similar situation may be present in the IMAR. Differences in the Mongolian-specific ways of playing and hours of outdoor activity was believed to have been reflected in the differences in the effects on vital capacity obtained in this study between boys and girls through the differences in the conditions of exposure to air pollution in the environment.

Meanwhile, the effects of air pollution on systemic endurance, represented by the running time of the 50m × 8 shuttle run, showed a similar weak association for both boys and girls. An increase in obesity and a low amount of physical activity in daily life are known lifestyle factors that are related to a decreased systemic endurance **[20]**. In the present study, there was no difference between cities with regards to the average BMI, which is an obesity index, in both boys and girls. Thus, the effects of air pollution on systemic endurance may have inter-city differences depending on the way children live. According to the "2016 Chinese Exercise Report", the average number of steps per day for students aged 10 to 18 years was 4,879 steps, the number of steps by people aged 10 and over was 5,112 steps. Among the cities, Children in Guiyang had the highest number of steps at 5,941, followed by Beijing at 5,136 steps, and Shanghai at 5,034 steps. In the urban exercise index ranking, Shanghai ranked 20th and Beijing 25th, and the top cities in the ranking had high air mass **[21]**. As such, the degree of air pollution is thought to be associated with a decrease in the amount of physical activity in daily life. Among the cities selected for the present study, Hohhot and Baotou, which had relatively strong air pollution levels, was the earliest to develop and they remain the most advanced areas in the IMAR. Therefore, the association between systemic endurance decline observed in both boys and girls and the degree of air pollution may be the reason for a decrease in physical activity in daily life to an extent that does not lead to an increase in obesity.

China has been implementing long-term forward strategies and effective policies to reduce air pollution, strengthen the monitoring of air pollution control, and raise public awareness of environmental protection; however, air pollution control has not been sufficiently discussed in school education. In addition, school sports facilities are being developed faster in large cities than those in regional cities, and disparities between cities and regions are becoming a serious problem **[22]**. In the 2019 Sports Facility Survey, Shanghai ranked No. 1 and Beijing No. 2, Hohhot No. 72, Baotou No. 151, Chifeng No. 207,

Bayannur No. 284, and Xilinhot No. 282 **[23]**. Although indoor sports facilities at elementary schools in the IMAR are now being built successively, there is a large disparity in terms of the state of sports facilities compared to that in major cities such as Beijing and Shanghai as well as a shortage of facilities in terms of the number of facilities that can be used per person **[23]**. Indoor sports facilities in the IMAR are insufficient, and it is necessary to promote the expansion of indoor sports facilities in cities and regions of the IMAR where development is lagging.

This study had some limitations. First, In the IMAR, the seasonal variation in the level of air pollution caused by coal heating in winter was large **[9]**. It is, therefore, necessary to examine the relationship with seasonal fluctuations using at least the monthly average of air pollution indicators. Second, this was a cross-sectional study of sixth graders in a relatively short period from 2013 to 2016. To obtain clarity on the chronic effects of air pollution, a longer-term study design, including longitudinal observations from at least grade 1 to grade 6, should be implemented. Third, this study did not evaluate the amount of physical activity or activity intensity of daily life directly. In the future, it is necessary to clarify the actual conditions about the amount and intensity of the daily physical activities of Mongolian children.

Conclusions

In this study, we examined the relationship between air pollution levels and physical fitness levels of children in five cities in the IMAR, China, and the difference between Mongolian elementary school boys and girls in the 6th grade. From 2013 to 2016, the proportion of air pollution levels on good days was higher in the order of Hohhot, Baotou, Chifeng, Bayannur, and Xilinhot, and differences in air pollution levels was observed between each city. There was a significant weak positive correlation between vital capacity and the percentage of good days in boys, but this was observed to a negligible extent in girls. Both boys and girls showed a significant weak negative correlation between the 50m × 8 shuttle run time and the percentage of good days. Therefore, it is suggested that the degree of air pollution may be the reason for the decrease in systemic endurance resulting from a decrease in daily physical activity in both boys and girls, and the decrease in lung function in boys resulting from increased exposure to pollutants in daily outdoor play.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethical considerations

This study was approved by the Ethics Review Committee of the Graduate School of Physical Education, Chukyo University (research approval number: 2019 - 1).

Declaration of Conflicting Interest: The authors have no conflicts of interest to declare.

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