The Health Impact of Air Pollution and Outdoor Physical Activity on Children and Adolescents in Mainland China

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Children and adolescents accrue substantial health benefits by engaging in 60 minutes or more of moderate or vigorous physical activity (MVPA) 5 or more days per week (eg, improved physical and psychological health, prevention of chronic diseases).[1-4] Nevertheless, many Chinese youth are not very active, especially outside of school. For example, although a large majority of school children (72%) appear to participate in in-school MVPA, only a small percentage appear to do so outside of school (≈8%).[5] Physical inactivity and sedentary living also are risk factors for developing overweight and obesity, which are growing problems among Chinese youth.[6,7] Specifically, between 1993 and 2009 the prevalence of obesity among Chinese children and adolescents more than doubled, from 6.1% to 13.1%.[8]

Starting in the 1980s, China's extensive economic reforms have led to rapid industrialization and urbanization, which have exerted an unhealthy impact on the living environment (including air pollution, desertification, loss of biodiversity, and water pollution).[9] In addition to adverse environmental impacts, industrialization also is linked to adverse health impacts on children. For example, according to the World Health Organization, 36% of deaths among children worldwide are attributable to environmental problems, and 43% of the total environmental burden of disease falls on children younger than 5 years old.[10] In 2010, ambient air pollution in China was ranked the fourth leading risk factor for mortality, contributing to 1.2 million premature deaths, nearly 40% of the global total.[11]

Exposure to air pollution among children and adolescents is a serious public health dilemma in China. For example, efforts to increase levels of MVPA among children include school-based sports and/or exercise activities, which typically occur in outdoor settings (eg, playgrounds, running tracks), where sustained exposure to air pollution during physical activity can lead to serious health consequences, such as reduced lung function[12] and asthmatic symptomatology.[13] With the need to increase the level of physical activity among children and adolescents on the one hand and concerns about air quality on the other, China faces a distinctive public health challenge.[14]

The purpose of this paper is to describe patterns of outdoor physical activity among Chinese children and adolescents, discuss the potential health effects of outdoor physical activities when coupled with air pollution, and identify research gaps that must be addressed to promote physical activity and reduce the health risks of children and adolescents. Developing appropriate prevention strategies aimed at reducing health risks from air pollution and creating safe living environments—environments in which children and adolescents safely can partake in physical activity without having to worry about the air they are breathing and/or otherwise compromising their health—conclude the paper.

MVPA Moderate or vigorous physical activity

Patterns of Outdoor Physical Activity among Children and Adolescents in China

Children and adolescents spend more time in selected outdoor locations doing various activities (eg, exercising and doing active sports; using playgrounds, parks, outdoor pools, and spas; spending time in the yard or other areas outside of the house) than do adults. Spring is the most common season for children and adolescents to do outdoor physical activities, and they spend more time doing so on weekends compared with weekdays.[15-17]

According to the China Health and Nutrition Survey, active commuting and in-school physical activities performed outdoors were the most common forms of MVPA among Chinese youth 6-18 years of age.[5] Relatively few boys and even fewer girls participated in MVPA outside of school. In part this is because of high parental expectations that require them to focus instead on academic achievement.[6] In China, a good education and high academic performance are greatly valued,[18] and children and adolescents often are required to devote virtually all of their leisure time to developing and improving their academic talents and capabilities rather than participating in extracurricular physical activities, which are, more often than not, viewed as a "waste of time."[19] This seems to be especially true for girls and women.[20]

The proportion of children and adolescents in China considered to be physically inactive on the basis of the current physical activity recommendations[2] is 44% overall, including 37% of boys and 53% of girls.[21] Physical activities promoting the health of children and adolescents in western countries often are carried out both indoors and outdoors,[22,23] but in China they primarily are conducted in outdoor settings such as school playgrounds, community open areas, and green spaces.[24,25] The most common types of seasonal outdoor physical activities

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reported among Chinese youth are walking, jogging, and cycling in the spring and walking, jogging, and exercising to music in the fall.[21] The more time children spend outdoors, the more physically active they tend to be.[26] Outdoor physical activity participation also can affect their attention, concentration, and emotions positively.[27] Therefore, engaging in physical activity in a healthy and natural environment may be conducive to children's health[28]; however, by exposing children to air pollution, their health can be compromised.[29,30]

The Impact of Air Pollution on Health of Children and Adolescents

Although the benefits of physical activity for children and adolescents are clear, it is important to consider the potential adverse health impacts of air pollution, as children and adolescents are particularly susceptible and physical activity most often occurs outdoors. Worldwide, children bear the highest rate of death attributable to environmental factors, with more than 4 million young people dying yearly due to environmental causes.[31] Even though urbanization in China has in some cases led to better healthcare and improved quality of life, it has also led to increased health risks resulting from environmental factors such as air pollution, occupational and traffic hazards, and water contamination.[32,33] For example, across more than 100 cities in mainland China, there were, on average, 29.9 smoggy days (ie, days with high air pollution) during both 2013 and 2014.[34] When extremely poor air quality was reported (ie, ambient air quality index values 201-300 or >300), many outdoor school physical activities and physical education classes had to be canceled in cities such as Beijing, Harbin, and Nanjing.[35,36]

Children have different behavioral patterns, favorite activities, and developmental stages that result in different exposure levels compared with adults,[37] for example, by playing closer to the ground, engaging in more contact activities,[38] spending more time outdoors,[39] and having greater rates of inhalation per unit of body weight.[40] Understanding these differences is crucial in the development of evidence-based and targeted prevention strategies for children.

Studies have reported that exposure to air pollution affects the health of children and adolescents in 3 different ways: pre- and perinatal effects, acute effects, and long-term effects.[41] In addition, prenatal exposure is associated with early fetal loss,[42] preterm delivery,[43] lower birth weight for infants,[44] and increased likelihood of birth defects.[45] Short-term exposure to air pollution is associated with changes in the pulmonary health of children and adolescents, such as a decline in lung function during episodes of air pollution,[12] peak flow decrements in children with asthma (or asthma symptomatology),[13] hospital admissions, physician and emergency department visits,[46-48] serious asthma exacerbation, pneumonia exacerbation,[49] and lung inflammation.[50]

Long-term exposure to air pollution also can lead to the development of chronic diseases or impairments in children, including chronic cough and bronchitis.[30,51] In addition, long-term exposure to air pollution negatively influences lung development in those 10-18 years old and has led to clinically significant deficits in attained forced expiratory volume by the time children reach adulthood.[52] The health impact of air pollution on children and adolescents is complex and also may increase the risk of heart disease,[53] mortality,[54] and neurologic disorders,[55] and it may play a role in childhood cancer.[55] In China, exposure to air pollution has been associated with increased prevalence of chronic cough, persistent phlegm, and current asthma[56]; wheezing, daytime and nocturnal attacks of breathlessness[57]; and asthma, bronchitis symptoms, and chronic cough.[58,59]

There are genuine concerns related to physical activity participation in environments containing polluted air, especially for children and adolescents. Coupled with declining physical activity levels[60] and the increasing prevalence of obesity and overweight among children and adolescents in mainland China,[6] this raises a significant constellation of public health issues requiring urgent attention (eg, understanding the beneficial effects of physical activity in conjunction with the detrimental effects of air pollution).[61]

The Research Gap on the Health Impact of Air Pollution and Outdoor Physical Activity on Children and Adolescents

Giles and Koehle[62] conducted a systematic review of the negative health impact of physical activity in environments in which there is air pollution, including the effects on pulmonary, cardiovascular, and cognitive systems. Their review documents the important role physical activity plays in improving human physiology and health outcomes, which are exacerbated by exposure to air pollution. Despite the potential adverse effects of being physically active in air-polluted environments, their review suggests that physical activity may reduce the likelihood of mortality related to air pollution.[62] Moreover, obesity and low levels of physical fitness increase the negative effects of air pollution on blood pressure, and greater levels of physical activity may counteract these effects among some segments of the population.[63]

Evidence regarding the overall health outcomes brought on by short- and long-term exposure to air pollution in combination with physical activity remains inconclusive, however, especially for Chinese children and adolescents. To close this gap, research is urgently needed in several areas, including:

- Studies related to the health effects resulting from air pollution in various microenvironments (eg, schools that are near heavily traveled roads), at different times of the day (eg, morning and afternoon rush hours), and in different seasons (eg, winter vs summer).
- Investigations that evaluate dose-response relationships for children and adolescents who engage in physical activity in varying levels of air pollution. Similarly, research is needed to examine the relationship between rates of ventilation during physical activity and levels of exposure to air pollution.[62] Although physical activity coupled with low exposure to air pollution may not have a severe negative health