

Review article

Chinese response to allergy and asthma in Olympic athletes

China is going to host the Games of the XXIX Olympiad from 8–24 August 2008 in Beijing. The number of athletes and accompanying individuals expected to arrive at China for the Beijing Olympics is estimated at over 10 000 and among them at least 2 000 (20%) are suspected to suffer from respiratory allergies. It is important to monitor the pollen counts and improve air quality in Beijing because Olympic athletes would be exposed to airborne allergens and pollutants during competitions which could hinder peak performance. The main pollen and spore families in Beijing are *Artemisia*, *Ambrosia*, *Chenopodiaceae* and *Gramineae*. They can reach around 307 000 grains of pollen/1000 m³ of air in August. Economic development in China is usually linked with worsening of air quality. Due to the adoption of various control measures, the ambient air quality in a number of areas in Beijing has actually improved. The ambient air TSP and SO₂ levels in Beijing have been decreasing in the last decade. However, ambient air NO_x level has been increasing due to the increased number of motor vehicles. Nevertheless, dedicated medical facilities in Beijing will provide medical services to athletes and delegations from all over the world during the Beijing Olympic Games.

J. Li¹, Y. Lu², K. Huang², C. Wang²,
J. Lu³, C. Zhang¹, N. Zhong¹

¹The First Affiliated Hospital of Guangzhou Medical College, Guangzhou Institute of Respiratory Diseases, Guangzhou; ²The Department of Respiratory, Beijing Chao-Yang Hospital, Capital Medical University, Beijing; ³The Department of Epidemiology, Guangzhou Medical College, Guangzhou, China

Key words: allergy; asthma; environment; pollens; rhinitis; sports.

N. Zhong
The First Affiliated Hospital of Guangzhou Medical School
Guangzhou Institute of Respiratory Disease
151 Yanjiang Rd. Guangzhou 510120
China

Accepted for publication 8 May 2008

The XXIX Olympic Games will be held in Beijing, China, from 8 to 24 August in 2008. The population of Beijing will increase dramatically during the Games period, with the arrival of athletes, team staff, members of the international media and spectators. Coinciding with the peak of the pollen season and considering for air quality in the city, the performance of Olympic athletes with airway allergic diseases could be jeopardized after years of training and preparation. In view of this situation, Olympic team managers and medical officers need to adequately prepare Olympic athletes for the possibility of exposure to high pollen levels and air pollutants in the weeks leading up to this most important sporting event. Symptoms of rhinoconjunctivitis and exacerbation of asthma could be devastating to athletes expecting peak performance. However, China is making big strides in clearing up its air quality ahead of the 2008 Olympics. Beijing has invested 120 billion yuan (about 17 billion US dollars) to improve its air quality since it won the bidding to host the 2008 Olympics in 2001. The number of 'blue sky' days, or days with fairly good air quality, increased to 246 last year from 100 in 1998.

In this paper, prevalence of allergy in athletes, main airborne allergens in northeast China in August and Chinese response to air quality and allergy in Olympic athletes will be discussed.

Prevalence of allergy in athletes

Several studies have reported that the prevalence of asthma is higher in elite athletes than in the general population and that between 2% and 28% of athletes may suffer from asthma depending on different types of sport and methods of diagnosis (1). The prevalence of asthma in both the Summer and Winter Olympic athletes has been progressively increasing over recent years. Fitch reported 9.7% and 8.5% of asthma in a physical examination in Australian Olympic athletes in the 1976 and 1980 Summer Games (2). Allergy was reported by 10% of the athletes in both Olympic Games. Voy reported more than 11% prevalence of exercise-induced asthma among the US Olympic athletes in 1984 Summer Games and an increase to a prevalence of more than 16% in the 1986 Summer Games reported by Voy (3) and Weiler et al. (4). In the 1998 Winter Games, the asthma prevalence in US athletes was at 21.9% (5). The prevalence of airway hyperresponsiveness (AHR) and exercise-induced bronchoconstriction obtained from objective measures are higher than reported from individual self-reporting of asthma or a diagnosis of asthma previously made by a physician. Langdeau et al. reported 20% prevalence of survey questionnaires-based asthma in long-distance runners and mountain bikers and 32%

prevalence of AHR made with methacholine bronchoprovocation ($PC_{20} \leq 16$ mg/ml) in the same population (6). But the significance of the high prevalence of AHR in athletes and its affect on performance are unclear. Further investigations should be studied to better understanding the long-term consequences of such features.

From all sports, the highest prevalence of asthma was found in endurance athletes, such as cyclists, distance runners, swimmers and winter athletes, including cross-country skiers and figure skaters. In 1996, an asthma prevalence of 45% was reported in cyclist and mountain bikers compared with none in divers and weightlifters (4). The higher prevalence of asthma in athletes is due to the high training loads in athletes combined with the training environment of the athletes, such as the exposure of the airways to cold air, allergens, pollutants and dust, etc.

In addition to asthma, allergic rhinitis or allergic rhinoconjunctivitis have been observed as common among athletes and the prevalence is also increasing. Helbling et al. reported 2961 elite Swiss athletes participating in 68 sports, 16.8% indicated that they had hay fever, and of these, 59% needed medication during the pollen season (5, 7). In Australian Olympic athletes for 2000 Summer Games, 29% had seasonal allergic rhinoconjunctivitis and 41% had positive skin prick test to any one aeroallergen (8). Aquatic athletes were more likely to have allergies compared with nonaquatic ones. Zwick et al. (9) reported that the prevalence of atopy (at least one skin prick test reaction) in swimmers is 50%, and 36% showed increased bronchial responsiveness to histamine. When the two risk factor atopy and swimming were combined in the multivariate analysis, the risk of asthma in a swimmer with atopy was 96-fold as compared with a control subject without atopy.

There have been no published data regarding to the prevalence of allergy and airway allergic diseases in Chinese athletes. However, it is believed that the percentage of allergic diseases in athletes in China is not as high as that in Western countries.

Exacerbations of allergic symptoms during exercises and when exposed to allergens and pollutants in air

Atopy and the presence of allergic disorders are common among top-level athletes from all sporting categories. Athletes with summer events are intensively exposed to airborne allergens (pollen grains, house dust mites and fungi spores) and to pollutants (ozone, sulphur dioxide or particulates, chlorine derivatives) during training and competitions, disabling them to achieve their peak performance (8). When the ventilation level exceeds about 30 l/min there is a shift from nose breathing to combined mouth and nasal breathing (10). This shifting results in a greater deposition of airborne allergens and other inhaled particles to the lower airways; in addition, incompletely conditioned air may reach the mucous

membranes of the lower airways (11). It is also believed that speed and power athletes consume up to 200 l/min of air when they perform in the open air, increased ventilation results in inhalation of huge quantity of aeroallergens as well as pollutants in periods of dense circulation; thus, leading to symptoms of rhinoconjunctivitis and asthma (8, 12). Physical features of the inhaled air also depend on the type of sports and climatic conditions in which exercise is performed, where some athletes are more exposed to others to cold and humid air.

Asthma is most commonly found in athletes performing endurance events such as cycling, swimming or long-distance running (13). Asthma risk is closely associated with atopy and its severity. Compared with nonatopic athletes, the relative risk of asthma was 25-fold higher in an atopic speed and power athlete, 42-fold in an atopic long-distance runner and even 97-fold in atopic swimmers (12). Swimmers (14) and endurance athletes (15) have shown a mixed type of eosinophilic, lymphocyte and neutrophilic inflammation in induced sputum samples and bronchial biopsies. This inflammation correlates with clinical parameters (i.e. exercise-induced bronchial symptoms and bronchial hyperresponsiveness). It was also shown that mild eosinophilic and lymphocytic airway inflammation was aggravated in swimmers who remained active during a 5-year prospective follow-up study. In contrast, swimmers who stopped active training, eosinophilic airway inflammation, bronchial responsiveness and clinical asthma attenuated or even disappeared. This prospective study indicated that intensive training is associated with long-term airway irritation as well as clinical asthma in susceptible individuals, and these changes are at least partly reversible when training is stopped (16).

Main airborne allergens in Northeast China during 2008 Olympic Games

China is going to host the Game of the XXIX Olympiad from 8–24 August in 2008 in Beijing with some matches such as sailing, equestrian and football being held in cities of Qingdao, Hongkong, Tianjing, Shanghai, Shenyang and Qinhuangdao. All the above cities are located in East China. The number of athletes and accompanying individuals expected to arrive at China for the Beijing Olympics is estimated over 10 000 and among them at least 2000 (20%) are suspected to suffer from respiratory allergies, according to the epidemiological survey. This percentage is significantly increasing, taking into consideration all visitors in China during that period, members of the international media, spectators and tourists. Therefore, it is important to monitor the pollen counts and air quality in the above cities. In fact, in China, the studies on pollen analysis and environment are numerous (17–19). One representative study by Cour, Huang and

their colleagues (20) used Cour's dust flux method to obtain a large-scale pollen data set from a continental-wide transect from tropical to temperate areas in eastern China in autumns in four different years. Results of the dust pollen provide a continued modern pollen distribution pattern from south to north of whole China, which can help us tracing the quantitative tendency of pollen dispersal, and clarifying the relation between pollen and climate. The nonarboreal pollen is abundant all along eastern China mostly with the families of Asteraceae (Compositae), Gramineae, Chenopodiaceae, Cannabidaceae, Polygonaceae, Cyperaceae, Brassicaceae (Cruciferae) and Plantagonaceae. The most popular arboreal pollens varied from tropical to cold temperate regions, were Betulaceae, Abietaceae and Salicaceae in the extreme north, Fagaceae, Jugandaceae, Urticaceae, Rosaceae, Ulmaceae and Cupressaceae in the temperate zones and Myrtaceae, Euphorbiaceae, Papilionaceae, Theaceae, Casuarinaceae, Urticaceae, Rubiaceae, Taxodiaceae and Pteridophyte in the subtropical and tropical zones. The most abundant pollen in the dust samples is derived from nonarboreal plants. Among them, Artemisia, Poaceae, Chenopodiaceae, Canabitateae (Cannabaceae) and Cyperaceae are the most frequent taxa and have a continuous distribution in almost the entire transect (Fig. 1). This group also collected 1 year round airborne samples at 10 m height above ground from northeast China (19). They showed that the main pollen and spore families and genera were *Betula*, *Populus*, *Salix*, *Quercus*, *Artemisia*, Chenopodiaceae and Gramineae. There were two peak stages of airborne pollen and spore concentrations throughout the year. One is the peak stage of Xylophyte plants from mid-April to end of May and other herbaceous plants from early-August to mid-September. The maximum count was around 343 000 grains/1000 m³ of air in mid-May. The second high season was in the end of August with 307 000 grains of

pollen/1000 m³ of air and the lowest season was in early February with 100 grains of pollen/1000 m³ of air (Fig. 2). Of those airborne pollen and spores, *Betula* and *Populus* in spring and *Artemisia*, *Ambrosia*, Chenopodiaceae and Gramineae in autumn can induce allergic airway diseases.

Air quality in the city of Beijing

Although the role of air pollution in the development of allergic disease especially in athlete is not clear, several studies have demonstrated an association between increased air pollution and the increased risk of allergic sensitization and prevalence of allergic diseases worldwide. Studies investigating the effect of pollution resulting from vehicle and industrial emissions have shown associations between increased pollution and increased risk/prevalence of airway allergic diseases (21–23). Therefore, air quality in city of Beijing as well as other areas of China during the period of 2008 Olympic Games becomes important issue to Chinese Organization of 2008 Olympic Games.

Ambient air pollution in China was severe in the last century. Chinese public health and environmental science professionals began studying air pollution-related problems in the early 1950s (24). Studies conducted in Shenyang in north eastern China in the 1950s showed total suspended particles (TSP) levels sometimes reaching several hundreds to almost 1000 µg/m³ (25). After China joined the Global Environmental Monitoring System (GEMS) programme in the late 1980s of the last century, regular systematic monitoring of air pollutants has become routine practice and analytical quality control procedure observed (26). From a GEMS report published by UNEP/WHO, ambient SO₂ level in Beijing in the 1980s was around 100–130 µg/m³ (27, 28), TSP level

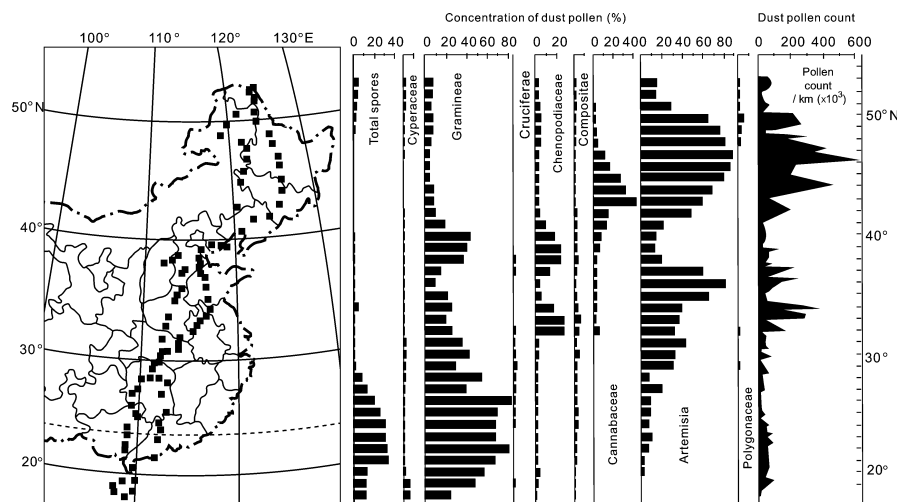


Figure 1. Distribution and counts of dust pollen samples of the principal nonarboreal taxa in the East China.

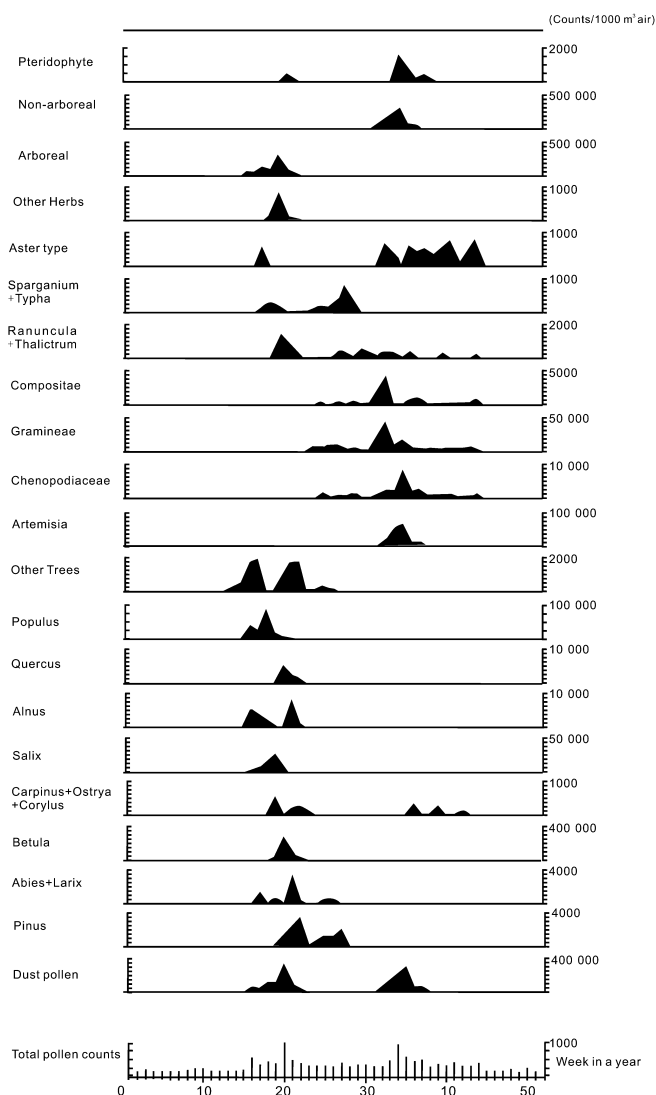


Figure 2. Pollen count diagram in northeast plain of China (grains/1000 m³ air).

250–450 µg/m³ (29, 30). In the past, Beijing and Lanzhou ranked high in TSP level, and Chongqing high in sulphur dioxide level (31–33). In the case of Beijing this might be partly due to sandstorms coming from the north (34). Generally speaking, many Chinese cities were high in suspended particulate level (35–37). On the other hand, the number of motor vehicles increased from 210 000 to 1 040 000, and NO_x level in ambient air increased from 65 to 90 µg/m³ (35). In general, suspended particulate concentration levels in cities in northern China are higher than those in southern China, while SO₂ concentration levels do not differ much. Air pollution in winter is generally more serious than that in summer (38–40).

As the motor vehicle population in China continues to increase at an annual rate of approximately 15%, air pollution related to vehicular emissions has become the focus of attention, especially in large cities (41). There is an urgent need to identify the severity of this pollution in

China. Based on an investigation into vehicle service characteristics, one study used a series of driving cycle tests of in-use Chinese motor vehicles for their emission factors in laboratories, which indicated that CO and HC emission factors are 5–10 times higher, and NO_x 2–5 times higher, than levels in developed countries. Results show that vehicle emission is concentrated in major cities, such as Beijing, Guangzhou, Shanghai and Tianjin (42). Motor vehicle emissions contribute a significant proportion of pollutants in those cities, with contribution rates of CO and NO_x greater than 80% and 40%, respectively, in Beijing and Guangzhou. Urban air quality is far worse than the national ambient air quality standard (42).

Based on air quality data from August 8 to 29, 2007, the International Olympic Committee's (IOC) Medical Commission found that the air quality will be suitable for the health of most athletes competing in the 2008 Olympic Games. The commission spent several weeks analyzing readings on temperature, wind, humidity and the pollutants SO₂, NO₂, CO, ozone and PM₁₀ provided by the Beijing Environment Protection Bureau for the time period indicated. And two other facts further support the finding. First, team physicians for athletes who competed in the August 2007 'Good Luck Beijing' sport events did not report any air quality-related health issues to Beijing Organizing Committee for the Olympic Games (BOCOG) or the IOC. Second, no health issues related to air quality were reported at the International Association of Athletics Federations (IAAF) Junior World Championships, which were held in Beijing in August 2006.

Since 1998, Beijing has seen the number of days with Grade 2 or better air quality increased from 100 in 1998 to 246 days in 2007. A grade of 2 or better marks a 'good' or 'excellent' air quality indicates that the air quality index ranges from 0 to 100. At the meantime, the days with medium to high level of air pollution that with the air quality index exceeds 200 decreased from 141 days in 1988 to 12 days in 2007. The annual average concentration of major air pollutants decreased in 2007 compared with 1998 – sulphur dioxide (SO₂) by 60.8%, carbon monoxide (CO) by 39.4%, nitrogen dioxide (NO₂) by 10.8% and particle pollution by 17.8%. The annual average concentration of SO₂, CO and NO₂ now meet national standards (Fig. 3).

In the late of this July, the Olympic village in Beijing will open to the athletes and team staff. After the Olympic Games, the Paralympic Games will be held in this September. So, we focus the air quality of July to September in recently years. The number of days with Grade 2 or better air quality in Augusts reached 27 and 28 days during 2006 and 2007. And the monthly average Air Pollution Index (API) in July and August were within 100 since 2004. The air quality data of January and February in 2008 were compared with other recently years, we found that the days with Grade 2 or better air quality were increased dramatically in 2008, it reached

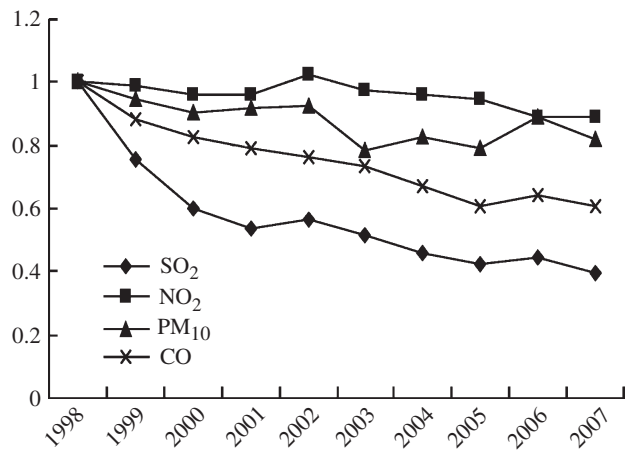


Figure 3. The annual average concentration of major air pollutants decreased during 1998 to 2007.

26 days for both January and February. It indicates that the effect of implementing measures to reduce air pollution in Beijing emerge gradually. Arne Ljungqvist, chairman of the IOCs medical commission, said that the air quality in the Beijing this August will be good enough for Olympians during the Beijing Games (<http://chinadaily.com.cn>).

Measures taken by Chinese Government before and during 2008 Olympic Games

A series of measures have been taken by the Chinese Government to minimize air pollutants, especially during the Olympic Games. These measures include: (1) utility of clean energy sources. By the end of 2006, 78% of terminal energy sources consumed in Beijing had been composed of clean energy sources such as natural gas. About 3.8 billion m^3 of natural gas were supplied to Beijing in the year 2006. About 60 000 boilers had been altered to change energy sources from coal to natural gas. (2) Prevention of pollution from motor vehicles. Stricter standards limiting the level of exhaust fumes discharged by motor vehicles have been adopted by the Government. The second stage of national standards regarding exhaust fumes discharged by motor vehicles (i.e. Euro II standards) was carried out in the year 2002; the third stage of the national standards (i.e. Euro III

Table 1. Air quality standard/guideline values

	Average time (h)	National standard (mg/m^3)	WHO AQG 2000 (mg/m^3)
SO_2	24	0.15	0.125
NO_2	24	0.12	
	1	0.24	0.20
PM_{10}	24	0.15	*

*No specific requirement in WHO AQG 2000.

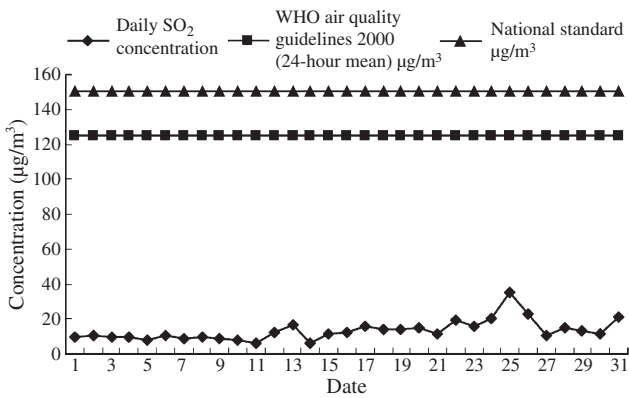


Figure 4. AUG 2006 SO_2 daily concentration. Resources: Construction & Environment Department of Beijing Organizing Committee for the Olympic Games (BOCOG) and Beijing Environmental Protection Bureau.

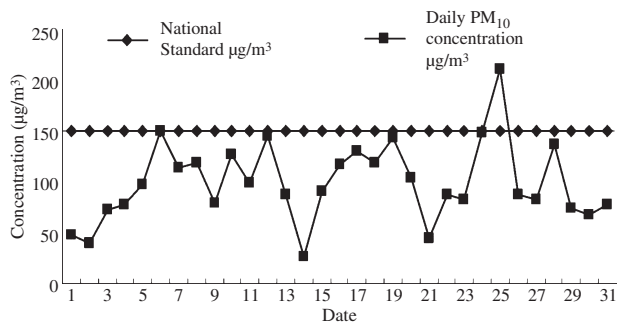


Figure 5. AUG 2006 PM_{10} daily concentration. Resources: Construction & Environment Department of Beijing Organizing Committee for the Olympic Games (BOCOG) and Beijing Environmental Protection Bureau.

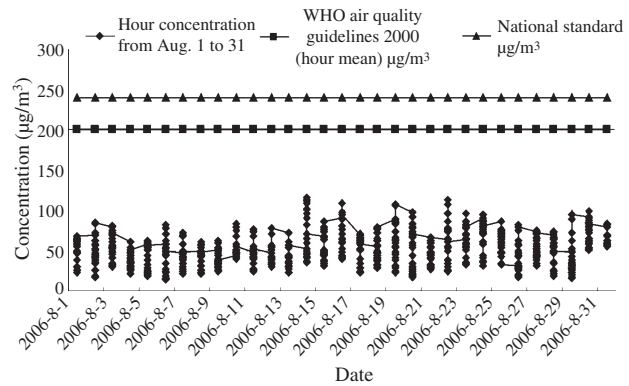


Figure 6. AUG 2006 NO_2 hour concentration. Resources: Construction & Environment Department of Beijing Organizing Committee for the Olympic Games (BOCOG) and Beijing Environmental Protection Bureau.

standards) was executed in the year 2005. The fourth stage of the standards (i.e. Euro IV standards) also has been carried out from March 2008. During the Olympic

Games, the alternative number plate policy will also be adopted by the Beijing Government. (3) Industrial pollution control. More than 140 enterprises causing serious air and/or water pollution had been closed or relocated from the Beijing area. (4) Afforestation. By the year of 2006, 2 years ahead of schedule, the forest coverage in Beijing had reached 51%, and the ecosystem in Beijing has been improved considerably. (5) Reinforcement the control of dust pollution caused by construction sites.

All these measures have achieved good results. The concentrations of air pollutants in Beijing have declined year-by-year. The concentrations of main pollutants (such as SO₂, NO₂ and PM₁₀) in August 2006 had been lower than the national Standards of Air Quality of China and WHO Air Quality Guidelines 2000 (WHO AQG 2000). The detail levels of main pollutants are listed in Table 1, and showed in Figs 4–6.

During the Beijing Olympic Games, 21 dedicated medical facilities will provide medical services to athletes

and delegations from all over the world. The medical teams on site will also been composed of doctors and nurses from these hospitals. A respiratory specialist will also be on duty in the polyclinic in Beijing Olympic Village. Whether on site or in hospital, these doctors are well trained to deal with asthma attacks and anaphylactic allergic reactions and will follow the guidelines of IOC medical commission. The lung function laboratory in Beijing Chao-yang Hospital has been assigned as 'dedicated pulmonary function testing laboratory for the Beijing Olympic Games'. The athletes with symptoms such as wheezing and breathless can receive airway challenge or bronchodilator tests in the laboratory. The doctors there will help the asthmatic athletes apply for therapeutic use exemption.

Conflicts of interest

All authors have no conflicts to disclose of this manuscript.

References

- Langdeau JB, Boulet LP. Is asthma over- or under-diagnosed in athletes? *Respir Med* 2003;**97**:109–114.
- Fitch KD. Management of allergic Olympic athletes. *J Allergy Clin Immunol* 1984;**73**:722–727.
- Voy RO. The U.S Olympic Committee experience with exercise-induced bronchospasm, 1984. *Med Sci Sports Exerc* 1986;**18**:328–330.
- Weiler JM, Layton T, Hunt M. Asthma in United States Olympic athletes who participated in the 1996 Summer Games. *J Allergy Clin Immunol* 1998;**102**:722–726.
- Weiler JM, Ryan EJ III. Asthma in United States olympic athletes who participated in the 1998 olympic winter games. *J Allergy Clin Immunol* 2000;**106**:267–271.
- Langdeau JB, Turcotte H, Bowie DM, Jobin J, Desgagne P, Boulet LP. Airway hyperresponsiveness in elite athletes. *Am J Respir Crit Care Med* 2000;**161**:1479–1484.
- Helbling A, Jenoure P, Muller U. [The incidence of hay fever in leading Swiss athletes] *Schweiz Med Wochenschr* 1990;**120**:231–236.
- Katellaris CH, Carrozzi FM, Burke TV, Byth K. A springtime olympics demands special consideration for allergic athletes. *J Allergy Clin Immunol* 2000;**106**:260–266.
- Zwick H, Popp W, Budik G, Wanke T, Rauscher H. Increased sensitization to aeroallergens in competitive swimmers. *Lung* 1990;**168**:111–115.
- Helenius I. Allergy and asthma in elite athletes [dissertation, PhD]. University of Helsinki. Helsinki, 1998.
- McFadden ER Jr, Pichurko BM, Bowman HF, Ingenito E, Burns S, Dowling N et al. Thermal mapping of the airways in humans. *J Appl Physiol* 1985;**58**:564–570.
- Helenius I, Haahtela T. Allergy and asthma in elite summer sport athletes. *J Allergy Clin Immunol* 2000;**106**:444–452.
- Helenius IJ, Tikkanen HO, Sarna S, Haahtela T. Asthma and increased bronchial responsiveness in elite athletes: atopy and sport event as risk factors. *J Allergy Clin Immunol* 1998;**101**:646–652.
- Helenius IJ, Ryttilä P, Metso T, Haahtela T, Venge P, Tikkanen HO. Respiratory symptoms, bronchial responsiveness, and cellular characteristics of induced sputum in elite swimmers. *Allergy* 1998;**53**:346–352.
- Bonsignore MR, Morici G, Vignola AM, Riccobono L, Bonanno A, Profita M et al. Increased airway inflammatory cells in endurance athletes: what do they mean? *Clin Exp Allergy* 2003;**33**:14–21.
- Helenius I, Ryttilä P, Sarna S, Lumme A, Helenius M, Remes V et al. Effect of continuing or finishing high-level sports on airway inflammation, bronchial hyperresponsiveness, and asthma: a 5-year prospective follow-up study of 42 highly trained swimmers. *J Allergy Clin Immunol* 2002;**109**:962–968.
- Shen CM, Tan LY, Wang SM. Vegetation and climate during the last 250000 years in Zoige Region. *Acta Micropalaeontol Sin* 1996;**13**:373–386.
- Wang FY, Song CQ, Cheng GG, Sun XJ. Paleoclimate reconstruction by adopting the pollen climate response surface model to analysis the Cha Su Qi deposition section. *Bot Sin* 1998;**40**:1067–1074.
- Huang CX, Cour P, Xu QH, Yang XL, Liang WD. The study of airborne pollen and spores in Hailun of northeast China plain. *Prog Geogr (Chin)* 2001;**20**:371–377.
- Deng Y, Zheng Z, Cour P, Huang CX, Duzer D, Calleja M et al. Relation between pollen ratios and climate in east China and an attempt of pelecoclimate reconstruction. *Acta Micropalaeontol Sin (Chin)* 2002;**41**:508–516.
- Hwang BF, Jaakkola JJ, Lee YL, Lin YC, Guo YL. Relation between air pollution and allergic rhinitis in Taiwanese schoolchildren. *Respir Res* 2006;**7**:23.

22. Penard-Morand C, Charpin D, Raheison C, Kopferschmitt C, Caillaud D, Lavaud F et al. Long-term exposure to background air pollution related to respiratory and allergic health in schoolchildren. *Clin Exp Allergy* 2005;**35**:1279–1287.
23. Yu JH, Lue KH, Lu KH, Sun HL, Lin YH, Chou MC. The relationship of air pollution to the prevalence of allergic diseases in Taichung and Chu-Shan in 2002. *J Microbiol Immunol Infect* 2005;**38**:123–126.
24. Chen B, Hong C, Kan H. Exposures and health outcomes from outdoor airpollutants in China. *Toxicology* 2004;**198**:291–300.
25. Chen BH, Kan HD. Methodologh research on the health-based risk assessment on ambient air pollution. *J Environ Health* 2001;**18**:67–69.
26. China State Statistics Bureau, 1990–1998. China Statistical Yearbook from 1990 to 1998 (Chin).
27. Chen XL, Tao XG, Hong CJ. Relationship between ambient sulfur dioxide pollution and common respiratory symptoms in Shanghai. *Chin J Public Health (Chin)* 1993;**12**:1–3.
28. Chen XL, Tao XG, Hong CJ. Effects of ambient SO₂ pollution on pulmonary function of women and children. *J Environ Health* 1993;**10**:152–154.
29. Dong J, Xu X, Chen Y, Dordery DW. Research on the relationship between air pollution and daily mortality in Beijing urban residents in 1990~1991. *J Hyg Res (Chin)* 1995;**24**:212–214.
30. Phillips K. Monitoring personal wxposures to environmental air pollutants. *Chin J Epidemiol (Chin)* 1997;**18**:335–337.
31. Xu XP, Gao J, Dockery DW, Chen Y. Air pollution and daily mortality in residential areas of Beijing, China. *Arch Environ Health* 1994;**49**:216–222.
32. Xu XP, Dockery DW, Christiani DC, Li B, Huang H. Association of air pollution with hospital outpatient visits in Beijing. *Arch Environ Health* 1995;**50**:214–220.
33. Zhou YR, Zhen Q, Xu F. Impact of air pollution on human respiratory system in Chongqing. *Acta Universitatis Scientiae Medicinae Chongqing (Chin)* 1996;**21**(Suppl.):118–122.
34. Yang F, He K, Ma Y, Chen X, Cadle SH, Chan T et al. Characteristics and sources of trace elements in ambient PM-(2.5) in Beijing. *Enviro Scie (Chin)* 2003;**24**:33–37.
35. Li LD, Lu F, Zhang S, Mu R, Sun X. Analysis on the trend on mortality of malignant tumors in recent 20 years in China and the estimation for the near future. *Chin J Oncol (Chin)* 1997;**19**:3–9.
36. Stieb DM, Judek S, Burnett RT. Meta-analysis of time-series studies of air polution and Mortality: effects of gases and particles and the influence of cause of death, age and season. *J Air waste Manag Assoc* 2002;**52**:470–484.
37. Xu ZY, Liu YQ, Yu DQ, Chen BH, Xu XP, Jin LB et al. Effect of air pollution on mortalities in Shenyang city. *Chin J Public Health (Chin)* 1996;**15**:61–64.
38. Ling SB, Song GX, Zhou F. Mortality study of major non-communicable diseases in Shanghai from 1951 to 1988. *Chin J Epidemio (Chin)* 2001;**22**:265–268.
39. Ma HB, Hong CJ. Multifactor analysis of particulate pollution in air of on pulmonary function of children. *Chin J Public Health (Chin)* 1991;**10**:75–77.
40. Kan HD, Chen BH. Meta analysis of exposure–response functions of air particulate matter and adverse health outcomes in China. *J Environ Health* 2002;**19**:422–424.
41. Fu L, Hao J, He D, He K, Li P. Assessment of vehicular pollution in China. *J Air Waste Manag Assoc* 2001;**51**:658–668.
42. Liu H, He K, Wang Q, Huo H, Lents J, Davis N et al. Comparison of vehicle activity and emission inventory between Beijing and Shanghai. *J Air Waste Manag Assoc* 2007;**57**:1172–1177.