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EXERCISE-INDUCED BRONCHOCONSTRICTION AND EXERCISE-INDUCED RESPIRATORY SYMPTOMS IN WORKERS EXPOSED TO TEA DUST

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Assuming that airborne particles and pollutants are important contributing factors in the development of exercise-induced bronchoconstriction (EIB), we performed a case-control study including 63 tea workers (36 men and 27 women, aged 36-55, duration of employment 3-30 years) and an equal number of office workers, matched by sex and age. Exercise-induced respiratory symptoms were recorded in a questionnaire. Skin prick tests, spirometry, as well as exercise and histamine challenge were carried out. Environmental measurements were performed on site during the work shifts.

The prevalence of self-reported exercise-induced respiratory symptoms and EIB did not differ significantly between the exposed and control group (41.6 % vs 36.8 %, and 6.4 % vs 4.8 %, respectively). In both exposed and control workers, EIB was strongly linked to asthma ($P<0.01$). In the exposed workers it was significantly associated with positive family history of asthma ($P<0.01$) and positive family history of atopies ($P<0.05$), whereas in the exposed smokers it was significantly related to smoking duration ($P<0.05$). Bronchial reaction to exercise in the exposed smokers was significantly greater than in control smokers ($P<0.05$). Self-reported exercise-induced respiratory symptoms were weakly associated with EIB, with a large proportion of false positive and a low proportion of false negative results in both groups.

KEY WORDS: *air pollutants, dust, exercise test, exercise-induced asthma, occupational environment, smoking*

Exercise-induced bronchoconstriction (EIB), also referred to as exercise-induced bronchospasm and exercise-induced asthma, is defined as a transient constriction of the airways that occurs as a consequence of vigorous exertion in subjects who have heightened bronchial reactivity (1). It occurs in about 70 % to 90 % of patients with symptomatic asthma and 40 % of patients with allergic rhinitis or atopic dermatitis, but it is also found in 5 % to 10 % of nonasthmatic and nonallergic subjects (2, 3).

Controversy remains about the causative mechanism in the bronchoconstrictive response to exercise. The most plausible current theory emphasizes airway dehydration and hyperosmolarity that lead to mast cell degranulation and release of mediators (histamine, leukotrienes, and prostaglandins) (4, 5). The occurrence of EIB depends on the degree of airway hyperresponsiveness (underlying chronic inflammation), exercise intensity and ambient conditions (6). Stimulants that contribute to EIB are cold and dry air, airborne particles and pollutants such as dust, tobacco smoke and automobile exhausts, and airborne allergens such as pollens and moulds (7).

The diagnosis of EIB is focused on the history of exercise-induced respiratory symptoms such as shortness of breath, cough, wheezing, chest tightness and decreased exercise endurance, and on pulmonary function testing after standardised exercise on a treadmill, cycle ergometer or free running. A drop in forced expiratory volume in 1 s (FEV_1) or peak expiratory flow rate (PEFR) of 10 % to15 % or greater is generally considered to have a diagnostic significance (2, 7).

Unrecognised and uncontrolled EIB leads affected subjects to avoid general and occupational physical activities and sports. There is a growing interest in EIB occurrence in particular groups of general population (such as children, school children, adolescents, and recruits) and in the athletes (recreational and professional athletes, cross-country runners, figure skaters). However, the effect of workplace exposure to organic dust on EIB development has been investigated only sporadically.

SUBJECTS AND METHODS

Study design

A case-control study was carried out at the Institute of Occupational Health - WHO Collaborating Center for Occupational Health in Skopje, Macedonia from June 2003 to September 2004. The frequency and the characteristics of EIB and exercise-induced respiratory symptoms were compared between a group of workers exposed to vegetable dust (tea workers) and a group of unexposed controls (office workers), matched by sex and age.

Subjects

The exposed group included 63 subjects (36 men and 27 women, aged 36-55) working in tea processing, that is, all the workers in the tea processing plant. Their duration of employment ranged from 3 years to 30 years (≤9 years 61.6 % and ≥10 years 38.4 % of workers), mean duration (12.2±7.9) years.

Tea was processed in two large and closed working areas. Dried flowers, leaves, fruit (peach, strawberry, apple, orange) and/or seed from plants traditionally used for preparing tea (lime, birch, elderberry, chamomile, plantain, mugwort, dog rose, and mint) were cleaned and sorted. After that, each preparation was roughly ground and packed as a single-component tea or a mixture. During processing, the employees were protected by their outfit, gloves and masks. According to the classification of occupational muscular work, tea processing was classified as moderate muscular work (8).

The controls group included an equal number of office workers randomly selected from the general population, matched to the exposed workers by sex and age.

There were no subjects in whom exercise challenge or histamine challenge were contraindicated in either group (9, 10), nor were there subjects with the upper respiratory viral infection within three weeks before the challenge test was performed. None of the subjects took asthma medications or antihistamines at least one month before the challenge tests and skin-prick tests.

Questionnaire

The questionnaire was designed using a model list of questions for the diagnosis of exercise-induced asthma proposed by the National Jewish Medical and Research Center, Denver, Colorado (11).

The subjects were considered having exercise-induced respiratory symptoms if one or more symptoms were reported: coughing during or after exercise, wheezing during or after exercise, inability to get a deep breath after exercise, noisy breathing after exercise and chest tightness after exercise.

The questionnaire included questions about the presence of asthma diagnosed by a physician, asthma medication use, presence of symptoms suggestive of asthma in the last 12 months (episodic breathlessness, wheezing, cough and/or chest tightness), asthma triggers, as well as about family history of asthma and atopies, taking into account the first-degree relatives. Detailed smoking history, including lifetime cigarette smoking in years (≤5, 6 to 10, 11 to 20, and ≥21) and daily mean of cigarettes smoked (≤10, 11 to 20, and ≥21), accompanying disease, and medication use were also evaluated.

Skin prick tests

Skin prick tests (SPT) to workplace allergens were performed in all subjects on the volar part of the forearm using commercial allergen extracts (Torlak, Serbia and Montenegro) of lime (5000 PNU mL^{-1}), birch (5000 PNU mL^{-1}), plantain (5000 PNU mL^{-1}), and mugwort pollen (5000 PNU mL^{-1}), fungi mixed (4000 PNU mL^{-1}), peach (1:20 v/v), and strawberry (1:20 v/v; $P<0.05$). The allergens were selected according to the presence of consequent plants in the working process. All tests included positive (histamine 1 mg mL^{-1}) and negative (saline 0.9 %) controls. Prick tests were considered positive if the mean wheal diameter 20 min after allergen application was at least 3 mm larger than the size of the negative control (12).

Spirometry

Spirometry, including measures of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, maximal expiratory flow at 50 % of FVC (MEF_{50}), maximal expiratory flow at 25 % of FVC (MEF_{25}), and maximal expiratory flow at 25 % to 75 % of FVC (MEF_{25-75}), was performed in all subjects using spirometer Ganshorn SanoScope LF8 (Ganshorn Medizin Electronic GmbH, Germany). We recorded the best of three measurements. Spirometry results were expressed as percentages of the predicted values, according to the European Community for Coal and Steel (ECCS) norms (13).

Exercise challenge

The constant submaximal exercise challenge test (ECT) was performed in all subjects using cycle ergometer Hellige-dynavit Meditronic 40 (Hellige GmbH, Germany). According to the recommendations of the European Respiratory Society (ERS) and American Thoracic Society (ATS) subjects exercised 8 min to10 min achieving 90 % of the predicted heart rate in the last four minutes of exercise (9, 10). The predicted heart rate for each subject was determined by sex, age, and body weight, using the WHO standards (14). ECT was conducted in an air-conditioned room with ambient temperature of 20 °C to 25 °C and relative air humidity of 50 % or less. Heart rate was monitored continuously throughout exercise and for five minutes after its completion from a three-lead electrocardiographic configuration. The subjects had the nose clipped to ensure mouth breathing. The measurements of FEV_1 were performed before and 1 min, 3 min, 5 min, 7 min, 10 min, and 15 min after exercise, with inhaled bronchodilator application upon completion of the protocol.

The response to exercise was expressed as fall index FEV_1 (fall index FEV_1=100 % x (pre-exercise FEV_1-lowest post-exercise FEV_1/preexercise FEV_1). EIB was defined as fall index $FEV_1 \geq 10$ % (9). Bronchial reactions after challenge in tea workers and controls, as well as in smokers and nonsmokers of each group, were expressed as mean values.

Histamine challenge

The histamine challenge tests were performed in all subjects according to the ERS/ATS recommendations (9, 10). Histamin (10 mL, 20 mg mL^{-1}; Torlak, Serbia and Montenegro) was diluted with buffered saline to prepare concentrations of 0.5 mg mL^{-1}, 1 mg mL^{-1}, 2 mg mL^{-1}, 4 mg mL^{-1}, and 8 mg mL^{-1}. The doses of aerosol generated by Pari LC nebulizer (Pari GmbH, Germany) were inhaled through a mouthpiece. The subjects inhaled increasing concentrations of histamine using a tidal breathing method until FEV_1 fell by more than 20 % of its base value or the highest concentration was reached. According to the ATS recommendations the test was considered positive if PC20 was equal or less than 4 mg mL^{-1} (10).

Asthma diagnosis

The subjects were considered having current asthma in the cases of asthma diagnosed by physician and/or in the presence of symptoms suggestive of asthma in the previous 12 months and positive histamine challenge according to the Global Initiative for Asthma (GINA) and ATS recommendations (10, 15).

Environmental measurements

Airborne vegetable dust was sampled on site during the eight-hour work shift. An APA 30 sampler (Hygitest, Bulgaria) was used to estimate total dust exposure by the gravimetric method. In addition, respirable fraction (particles with diameter less than 5 μm) was determined by photometric method using a MINIRAM PDM-3 device (GCA Corporation, USA). Temperature and relative air humidity were measured using a Testo 400 (Testo, Germany). The data obtained were presented as minimal, maximal, and mean values.

Statistical analysis

SPSS version 11.0 for Windows was used for data description and analysis. The data were presented as a mean value with standard deviation. The chi-square test was used for testing differences in the prevalence of exercise-induced respiratory symptoms among the groups. Spirometric measurements and the levels of fall index FEV_1 were compared using the independent-sample *t*-test. Associations between variables were analysed using the chi-square test (or Fisher's exact test where appropriate) and Mann-Whitney *U*-test, whereas the interactive influence of current smoking, smoking experience and cigarettes per day on exercise-induced respiratory symptoms and EIB were tested using the linear regression analysis. A P-value of less than 0.05 was considered statistically significant.

RESULTS

The anthropologic data and smoking habit of the subjects enrolled in the study are given in Table 1. The prevalence of the most frequent accompanying diseases (arterial hypertension, dyspeptic symptoms, and diabetes mellitus type 2) was similar in tea workers and controls (12.7 % vs. 14.6 %, 11.2 % vs. 12.8 %, and 4.8 % vs. 3.2 %, respectively).

Table 1 *Characteristics of the subjects*

Variable	Tea workers (n=63)	Controls (n=63)
Sex (M/W ratio)	1.3	1.3
Age / years (mean ± SD)	45.6±5.5	45.8±6.1
BMI / kg m^{-2} (mean ± SD)	26.5±3.7	27.7±3.8
Current smokers	25	20
Smoking experience years (mean ± SD)	18.7±6.1	16.4±6.2
Cigarettes per day (mean ± SD)	22.2±9.8	19.3±10.2
Ex-smokers	5	7
Passive smokers	9	11

M: men; W: women; BMI: body mass index.

The prevalence of positive SPT to workplace allergens was not significantly different between the tea workers and controls (24 % vs. 19.2 %; P=0.382; chi-square test). The highest prevalence of positive SPT was obtained for lime pollen in tea workers (19.2 %) and for birch pollen in controls (14.4 %) (Figure 1.).

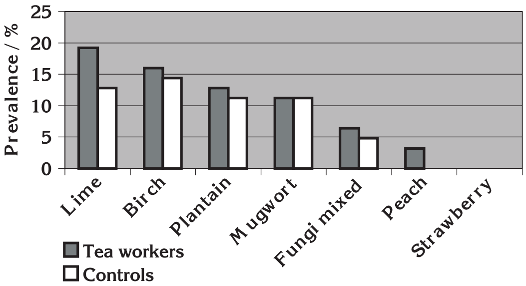

Figure 1 *Prevalence of positive skin prick tests to seven workplace allergens in tea workers and controls: lime 19.2 % vs 12.8 %; birch 16.0 % vs 14.4 %; plantain 12.8 % vs 11.2 %; mugwort 11.2 % vs 11.2 %; fungi mixed 6.4 % vs 4.8 %; peach 3.2 % vs 0.0 %; strawberry 0.0 % vs 0.0 %. Statistically non-significant difference in the prevalence of positive skin prick tests to workplace allergens between the two groups.*

The mean values of spirometric parameters (FVC, FEV_1, FEV_1/FVC%, MEF_{50}, MEF_{25}, and MEF_{25-75}) were significantly lower in tea workers (P<0.01) (Table 2).

Table 2 *Spirometric parameters in tea workers and controls*

Spirometric parameter	Tea workers (n=63) Mean±SD	Controls (n=63) Mean±SD	*t*-value#	P-value#
FVC (% pred)	95.4±10.5	103.4±9.8	4.52	0.000
FEV1 (% pred)	88.4±8.7	97.3±9.2	7.86	0.000
FEV1/FVC%	75.6±4.5	79.2±3.1	6.79	0.000
MEF50 (% pred)	68.9±10.7	90.5±11.9	10.68	0.000
MEF25 (% pred)	58.0±9.5	81.0±11.0	12.72	0.000
MEF25-75 (% pred)	81.1±16.7	104.5±12.9	8.82	0.000

FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 second; MEF_{50}, MEF_{25}, MEF_{25-75}: maximal expiratory flow at 50 %, 25 % and 25-75 % of FVC, respectively;% pred: % of predicted value.
Compared using the independent-sample t-test.

The prevalence of asthma was similar in tea workers and controls (8.0 % vs. 6.4 %; P=0.540; chi-square test). Positive family history of asthma and positive family history of atopic disease were not significantly different between tea workers and controls (9.6 % vs. 11.2 %, respectively; P=0.362; chi-square test) (12.8 % vs 8.0 %, respectively; P=0.609; chi-square test).

The prevalence of self-reported exercise-induced respiratory symptoms, overall and individual, did not differ significantly between the compared groups (Table 3.).

Table 3 *Prevalence of self-reported exercise-induced respiratory symptoms in tea workers and controls*

Self-reported exercise-induced respiratory symptoms	Tea workers (n=63)	Controls (n=63)	P-value*
Any exercise-induced respiratory symptom	26	23	0.393
Cough	16	13	0.314
Inability to get deep breath	19	15	0.300
Wheezing	9	6	0.560
Chest tightness	8	7	0.473
Noisy breathing	6	4	0.860

* Tested using the chi-square test.

Exercise-induced respiratory symptoms were non-significantly associated with sex, age, accompanying disease, smoking habit, positive SPT, and baseline FEV_1 (FEV_1 less or more than 80 % of the predicted value) in both tea workers and controls. The association between exercise-induced respiratory symptoms in tea workers and duration of exposure was also non-significant (P=0.104; chi-square test). Joint effect of current smoking, smoking experience, and cigarettes per day on exercise-induced respiratory symptoms in both groups was statistically non-significant.

In the group of tea workers, four subjects (6.4 %) had the fall index $FEV_1 \geq 10$ %, whereas in controls, positive ECT was noted in three subjects (4.8 %). Table 4 shows the mean exercise load, mean fall index FEV_1, and mean time of EIB occurrence in the subjects with positive ECT.

Table 4 *Mean exercise load, mean fall index FEV_1 and mean time of EIB occurrence in the subjects with positive ECT*

Variable	Tea workers (n=63) Mean ± SD	Controls (n=63) Mean ± SD
Exercise load / Watt	104.3±20.9	108.0±19.9
Fall index FEV_1 in the subjects with positive ECT / %	24.7±7.9	21.2±6.2
Time of EIB occurrence / min after exercise	7.2±2.1	7.3±2.5

FEV_1: forced expiratory volume in 1 second; fall index FEV_1: 100 % x (preexercise FEV_1-lowest post-exercise FEV_1/pre-exercise FEV_1); ECT: exercise challenge test; EIB: exercise-induced bronchoconstriction.

The difference between the fall index FEV_1 in tea workers and controls was not statistically significant. Statistical significance was found between the fall index FEV_1 in the exposed and control smokers (Table 5).

Table 5 *Mean fall index FEV_1 in all subjects, smokers, and non-smokers in both tea workers and controls*

	FEV_1 / % Mean ± SD			
	Tea workers	Controls	*t*-value*	*P*-value*
All examinees	5.8±5.3	4.5±4.3	1.29	0.200
Smokers	9.3±7.9	4.6±4.4	2.31	0.026
Nonsmokers	4.8±4.6	4.2±4.0	0.33	0.739

*Compared using the independent-sample t-test.

In both tea workers and controls, EIB was significantly related to asthma (P=0.0000; Fisher's exact test) and positive histamine challenge (P=0.0000; Fisher's exact test). In both groups, EIB was not significantly associated with sex, age, positive SPT and baseline FEV_1.

EIB was significantly related to family history of asthma in both tea workers (P=0.002; Fisher's exact test) and controls (P=0.030; Fisher's exact test). The association between EIB and family history of atopies was significant in tea workers (P=0.032; Fisher's exact test) and not significant in controls (P=0.223; Fisher's exact test). Current smoking was not significantly associated with EIB in either tea workers (*P*=0.168; Fisher's exact test) or controls (P=0.689; Fisher's exact test), nor was the duration of exposure significantly associated with EIB in tea workers (P=0.506; Fisher's exact test).

EIB in exposed smokers was significantly associated with smoking duration (P=0.027; Mann-Whitney *U*-test), whereas the association with cigarettes per day was not statistically significant (P=0.229; Mann-Whitney *U*-test). A joint effect of current smoking, smoking duration, and cigarettes per day on EIB in tea workers was statistically significant (P=0.014; linear regression analysis). EIB in control smokers was not significantly associated with smoking experience (P=0.236; Mann-Whitney *U*-test) and daily cigarette smoking (P=0.738; Mann-Whitney *U*-test). The joint effect of current smoking, smoking experience and cigarettes per day on EIB in controls was also not significant (P=0.244; linear regression analysis). Passive smoking, as well as exsmoking were not significantly associated with EIB in either group.

With the exception of exercise-induced wheezing in tea workers (P=0.008; Fisher's exact test), the association between EIB and exercise-induced respiratory symptoms was not statistically significant in either tea workers or controls. There was a high frequency of false positive results of self-reported exercise-induced respiratory symptoms in EIB diagnosis in both tea workers (76 %) and controls (72 %). The frequency of false negative results was low in both groups (2.2 % vs. 2.8 %, respectively).

Table 6 *Environmental measurements in the tea processing plant*

Measurement	Mean ± SD	Range	Limit value
Respirable dust / mg m^{-3}	3.1±0.8	1.9-4.4	3.0
Air humidity / %	41.0±4.6	37.0-45.0	40.0-75
Temperature / °C	20.5±0.6	20.0-21.0	17.0-22.0

The data from environmental measurements suggested that workers employed in tea processing were exposed to respirable dust concentrations slightly over the national standards for organic dust and to relative air humidity that inclined towards lower limit value (Table 6.).

DISCUSSION

EIB is a common condition that can impede physical activity, particularly for children, adolescents, and young adults. In our study the anthropologic data in the compared groups were similar. There was a large proportion of current smokers in both the exposed and control subjects. We found a similar prevalence of positive SPT to workplace allergens in both groups. Epidemiological studies suggest that vegetable dust from dried fruit, tea and spice plants have a considerable biologic effect on the airways and that exposure to organic aerosols is associated with frequent respiratory symptoms and functional and immunologic changes (16, 17). On the other hand, skin reactivity depends on allergogenic potential of an allergen, on the standardisation and potency of the allergen extract, on the applied method, as well as on the age of the tested subject (18). Controls exhibited similar prevalence of positive SPT with tea workers, probably as a consequence of the wide distribution of these plants in non-occupational environments. The spirometric parameters in tea workers were significantly lower, which confirms the constrictor effect of vegetable dust, predominantly affecting the smaller airways. There is increasing evidence that exposure to organic dust, such as cotton, grain and other vegetable dusts is associated with chronic airway obstruction and obstructive ventilatory pattern development (19).

We found high prevalence of exercise-induced respiratory symptoms in both tea workers and controls. High prevalence of exercise-induced respiratory symptoms is also reported in several studies that analysed the effect of organic and mineral dust on respiratory health. *Sauini et al.* (20) reported cold air, physical exercise and all types of dust and smoke as the most common causes of respiratory symptoms in construction workers with asthma. *Gautrin et al.* (21) reported high frequency of exercise-induced respiratory symptoms in apprentices of various trades exposed to organic dust. In a 44-month follow-up study, they reported the highest incidence of exercise-induced respiratory symptoms in pastry-makers (7.7 %) and the lowest in animal technicians (1.8 %). The highest prevalence of exercise-induced respiratory symptoms was reported in professional and recreational athletes (22, 23). The proportion of major complaints in our study was within the range of published data (24). There were no differences concerning sex, age, smoking habit, accompanying disease in both groups, as well as concerning the duration of exposure in tea workers.

We found a similar frequency of EIB in tea workers and controls. Many studies report that EIB development depends on the degree of bronchial hyperresponsiveness, on the type, intensity and duration of exercise, and on ambient conditions. EIB is more likely to occur in subjects with moderate to severely increased airway responsiveness. In many patients with intermittent asthma, who have a mildly increased airway responsiveness, even a strenuous exercise does not cause bronchoconstriction (5). According to *Hermansen and Kirchner* (1), any activity can lead to symptoms in susceptible subjects, but certain activities have a higher propensity to trigger bronchospasm, which is referred to as the asthmogenic potential. Highly asthmogenic are considered activities with high-intensity muscular work associated with cold, dry air, such as cross country skiing, ice hockey, long-distance running, basketball, and soccer, whereas mildly asthmogenic are tennis, volleyball, swimming, baseball, and weight lifting (7). The prevalence of EIB is found to be at least 10 % in professional athletes, 12 % in basketball players, at least 14 % in cross-country runners, and up to 55 % in cross-country skiers (25-27). Even though environmental dust exposure is believed to contribute to EIB development, in available literature we did not find data about EIB prevalence in occupations exposed to organic or mineral dust.

In both groups in our study, there was a strong association between EIB and asthma. EIB may occur in non-asthmatic persons, but it is commonly related to asthma, being a sign of uncontrolled disease (4, 15). We found a significant association between positive exercise challenge and positive histamine challenge in both groups. In a study of bronchial reactivity to exercise in allergic asthma patients, allergic rhinitis patients, and healthy subjects, *Klepac-Pulanić et al.* (28) also reported a significant association between the results of histamine and exercise challenge. However, many comparisons of two bronchial challenge types produced somewhat variable results. In general, there is a low, if statistically significant, correlation between results of different challenge tests due to differences in patomechanisms of bronchial hyperreactivity to histamine and EIB (29, 30).

We found no positive association between EIB and sex, age, and baseline FEV_1 value in either group. We also found no significant association between EIB and sensitisation to workplace allergens detected by SPT. The complex relationship between atopy and EIB is still not clear. EIB may occur in both allergic and non-allergic asthmatics, as well as in non-atopic non-asthmatics (2). The results from studies of the relationship between EIB and atopy are controversial. In a study which included 58 professional runners, *Helenius et al.* (31) found a strong association between EIB and atopy, reporting seasonal variability in EIB occurrence and the odds ratio increasing with number of positive SPT. *Koh et al.* (32) reported a significant correlation between atopy (detected by SPT and specific serum IgE measurements) and EIB prevalence and a non-significant correlation with EIB severity in a study which included 77 men aged 18 years to 23 years. On the other hand, in a study with 793 school children, Penny et al. (33) reported a non-significant association of positive SPT results and specific IgE levels with respiratory symptoms, positive exercise tests and asthma.

In our study, EIB was significantly related to positive family history of asthma in both tea workers and controls. In tea workers, a significant association was also found with positive family history of atopies. As many studies suggest, EIB may be considered an expression of the complex relationship between inherited genetic characteristics and exposure to different environmental factors (workplace exposure, outdoor and indoor pollution, infectious episodes, etc.) (5, 6).

Airborne dust and tobacco smoke are considered important contributing factors in EIB development (5, 7, 34). However, only a few studies have focused on the relationship between the type of exposure and its intensity, duration and cumulative exposure. In this study, we did not find significant association between EIB in workers exposed to relatively low concentrations of organic dust and the duration of exposure, whereas the effect of cumulative exposure has not been assessed because we lacked data. Analysing the effect of the level of exposure to common outdoor pollutants (PM_{10}, SO_2, NO_2, and O_3) on EIB in a study with 649 high school students, Vacek (35) found that significantly different levels of pollutants did not correlate with EIB prevalence. The relationship between EIB and smoking also remains unclear. In this study, the relationship between EIB and current and passive smoking was not significant in either group. We found a significant association between EIB and the duration of smoking in the exposed smokers, and a significant joint effect of current smoking, duration of smoking and daily cigarette smoking on EIB development in tea workers. We also found a significantly greater bronchial reaction after challenge in the exposed smokers than in control smokers. In a study with 136 school children with EIB, *Agudo et al.* (36) reported a significant association between EIB prevalence and exposure to environmental tobacco smoke from the mother, as well as a significantly higher risk regarding the intensity, duration and cumulative exposure. We did not find relevant data in the available literature about the effect of the interaction between workplace exposure to organic dust and smoking on EIB development. However, in a survey which included 1,906 subjects aged 20-71 as a Dutch contribution to the European Community Respiratory Health Survey (ECRHS) which studied this interaction, *de Meer et al.* (37) reported non-significantly greater risk of the joint effect than the separate effects of organic dust exposure and smoking on respiratory impairment. Similar results were reported by the Spanish contribution to the ECRHS (38).

With the exception of the significant association with exercise-induced wheezing in tea workers, we found no significant correlation between overall and individual self-reported exercise-induced symptoms and the results of exercise challenge in either group, which is confirmed by many EIB assessment studies (39-41). Respiratory symptoms seemingly related to exercise may not be due to EIB. Other diagnostic considerations include cardiac conditions (arterial hypertension, coronary artery disease, congestive heart failure), gastroesophageal reflux, anxiety, vocal cord dysfunction, medical side effects (ACE inhibitors, beta-blockers), as well as physical unfitness (42, 43). In a study by *Hammerman et al.* (23), which included 800 students, the reported positive and negative predictive values of the questionnaire in EIB assessment were 42 % and 97 %, respectively. The large proportion of false positive and low proportion of false negative results for self-reported exercise-induced respiratory symptoms in our study confirm their suggestion that questionnaires may serve as good negative screening tools for EIB.

In conclusion, the prevalence of EIB in tea workers exposed to respirable dust concentrations slightly over the national standards, aged 35 years to 55 years and working in conditions of moderate muscular demand, was similar to the EIB prevalence in control subjects. EIB in both groups was strongly related to asthma. In the exposed workers, EIB was significantly associated with positive family history of asthma and atopies, whereas in the exposed smokers, it was significantly associated with the duration of smoking. Bronchial reaction after exercise was greater in the exposed smokers. We found a high frequency of self-reported exercise-induced respiratory symptoms with a high negative and low positive predictive value. Our study confirms the need of regular medical examinations in order to identify affected workers and implement preventive measures. We also suggest reviewing exposure limits to improve health protection. We would also like to emphasise the need to control tobacco smoking at the workplace, to prevent the combined adverse effects of smoking and workplace environment on respiratory health.

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Sažetak

BRONHOKONSTRIKCIJA I RESPIRATORNI SIMPTOMI UZROKOVANI TJELESNIM OPTEREĆENJEM U RADNIKA IZLOŽENIH ČAJNOJ PRAŠINI

Polazeći od pretpostavke da čestice nošene zrakom i onečišćivači bitno pridonose razvoju bronhokonstrikcije uzrokovane tjelesnim opterećenjem, ispitano je 63 radnika u tvornici čaja (36 muškaraca i 27 žena u dobi od 36 do 55 godina sa stažem od 3 do 30 godina) i 63 kontrolna ispitanika, administrativna službenika koji su izloženoj skupini odgovarali po spolu i dobi. Podaci o respiratornim simptomima uzrokovanim opterećenjem prikupljeni su s pomoću upitnika. Također su napravljeni *skin-prick* test, spirometrija te test tjelesnim opterećenjem i bronhoprovokativni test histaminom. Mjerenja u zraku radnoga okoliša napravljena su za trajanja smjene. Izloženi radnici nisu se statistički značajno razlikovali od kontrolne skupine u prevalenciji prijavljenih respiratornih simptoma odnosno bronhokonstrikcije uzrokovane opterećenjem (41,6 % naspram 36,8 %, odnosno 6,4 % naspram 4,8 %). U obje je skupine bronhokonstrikcija uzrokovana opterećenjem bila izrazito povezana s astmom ($P<0,01$). U izloženoj skupini, bronhokonstrikcija uzrokovana opterećenjem bila je statistički značajno povezana s pozitivnom obiteljskom anamnezom astme ($P<0,01$) i atopije ($P<0,05$). U izloženih pušača ona je značajno bila povezana s trajanjem pušenja ($P<0,05$). Bronhalne reakcije na opterećenje u izloženih pušača bile su značajno jače od onih u kontrolnih pušača ($P<0,05$). Zamijećena je slaba povezanost između prijavljenih respiratornih simptoma i bronhokonstrikcije uzrokovane opterećenjem, s velikim udjelom lažno pozitivnih i malim udjelom lažno negativnih nalaza u obje skupine.

KLJUČNE RIJEČI: *astma uzrokovana opterećenjem, onečišćivači zraka, prašina, pušenje, radni okoliš, test tjelesnog opterećenja*

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