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The effect of habitual waterpipe tobacco smoking on pulmonary function and exercise capacity in young healthy males: A pilot study

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ABSTRACT

Background: Evidence regarding the health effects of habitual waterpipe smoking is limited, particularly in young smokers. Respiratory health and cardiopulmonary exercise tests were compared in young male habitual waterpipe smokers (WPS) versus non-smokers.

Methods: 69 WPS ($\geq$3 times/week for three years) and 69 non-smokers were studied. Respiratory health was assessed through the American Thoracic Society and the Division of Lung Diseases (ATS-DLD-78) adult questionnaire. Pulmonary function and cardiopulmonary exercise tests were performed. Self-reported respiratory symptoms, forced expiratory volume in first second (FEV_1), forced vital capacity (FVC), FEV_1/FVC ratio, forced expiratory flow between 25 and 75% of FVC ($FEF_{25-75\%}$), peak expiratory flow (PEF), exercise time, peak end-tidal CO_2 tension ($PetCO_2$), subject-reported leg fatigue and dyspnea; peak O_2 uptake (VO_2 max), and end-expiratory lung volume (EELV) change from baseline (at peak exercise) were measured.

Results: WPS were more likely than non-smokers to report respiratory symptoms. WPS also demonstrated: shorter exercise time; lower peak VO_2; higher perceived dyspnea at mid-exercise; lower values of the following: FEV_1, FVC, PEF, and EELV change.

Conclusion: Habitual waterpipe tobacco smoking in young seemingly healthy individuals is associated with a greater burden of respiratory symptoms and impaired exercise capacity.

1. Introduction

Various toxic chemicals have been found in waterpipe smoke [1], and waterpipe smoking has been associated with several detrimental health outcomes such as cardiovascular and respiratory diseases, as well as cancer [2–6].

Despite its toxic content [1], waterpipe use has been growing globally, and is particularly popular among youth, the main driving force behind a new worldwide epidemic [7,8]. Waterpipe use also has been shown to predispose its users to cigarette smoking initiation [6,9]. However, knowledge with regards to the health effects of waterpipe on such a young population remains limited [10]. Beyond measuring heart rate and blood pressure, few studies [11–13] have attempted to characterize the cardiopulmonary effects of acute waterpipe smoke exposure in young users, and none have evaluated the early onset effects (if any) of habitual and extended waterpipe smoking. This is an important and timely subject to begin examining. The waterpipe is becoming increasingly popular, even among young groups that were traditionally deemed low-risk for tobacco use (such as athletes) [14]. It is therefore not implausible, as some data are already suggesting [15], that waterpipe use may become more habitual among its users. Providing evidence that can preempt or deter this trend is judicious.

In an exploratory pilot study, we sought to assess the range of effects that habitual waterpipe smoking may exert on the cardiopulmonary health of young smokers. Such research is in line with the call for more efforts to elucidate the harmful nature of waterpipe smoking [10]. Specifically, we compared habitual waterpipe smokers (WPS) to non-users of tobacco (non-smokers) in three areas: burden of respiratory symptoms, lung function, and

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cardiopulmonary exercise capacity. We anticipated that WPS would fare worse than non-smokers across all these measures.

2. Methods

There is scarce clinical data on waterpipe health effects specifically in habitual young users. Our clinical study was designed as a pilot to prospectively examine the effect of waterpipe on young, habitual users, and generate hypotheses with regards to the potential clinical effect size as a result of habitual waterpipe use (thereby informing future waterpipe clinical research studies with regards to which specific endpoints should be incorporated).

The study was conducted in accordance with the amended Declaration of Helsinki. The institutional review board at King Hussein Cancer Center (KHCC) approved the protocol and written informed consent was obtained from all participants. Data collection spanned approximately two years (from August 2013 through to June 2015).

2.1. Participants

Participants were recruited through announcements made within several universities in Jordan. Initial contact and screening were conducted via phone. All males who reported being healthy and between the ages of 18 and 26, and who reported either never using tobacco or being WPS who smoked three or more times a week for the past three years atleast (with no other form of tobacco used) were invited to join the study. Those who agreed to participate were invited to a single testing session at KHCC's Cardiopulmonary Exercise Testing (CPET) laboratory. A session lasted approximately two and a half hours. Participants were asked to avoid strenuous exercises or activities, and refrain from smoking for 48 hours prior to their visit.

Participants were confirmed healthy by a medical examination. The following exclusion criteria were applied: body-mass index (BMI) of 40.0 kg/m^2 or more; active chronic medical conditions; use of chronic prescription medications; illicit drug use; abnormal heart rhythm or abnormal resting heart rate; (>100 or < 50 beats per minute); high blood pressure (>140/90 mmHg); or low oxygen (O_2) saturation (<95%).

2.2. Procedures and data collection

Body plethysmograph spirometry (using the Vmax series 777360B © 2005 VIASYS Healthcare Inc.) and cardiopulmonary testing using a bicycle ergometer (Ergoselect 100/200, Cardiosoft v6.2) were conducted. Reference spirometric and cardiopulmonary exercise values were based on widely used sources [16–18]. All procedures were conducted according to the American Thoracic Society/European Respiratory Society guidelines for spirometry and cardiopulmonary measures [19,20]. The following variables were measured:

1. General health information (including weight, height, medical history and exercise habits) and socio-demographic factors were recorded.
2. To evaluate general respiratory health, the American Thoracic Society and the Division of Lung Diseases (ATS-DLD-78) adult questionnaire was administered by staff [21]. The following measured variables were specifically of relevance: bringing up phlegm; shortness of breath upon exertion; suffering from cough; having a chest illness in the past three years that kept a participant off work; coughing and phlegm lasting three or more weeks; colds that usually went to the chest; having a wheezy chest whilst having a cold; having a wheezy chest most of the time; having a wheezy chest without a cold; and having a wheezing attack that left a participant breathless.
3. To evaluate lung function, spirometry was used to measure: forced expiratory volume at the end of first second (FEV_1); forced vital capacity (FVC); forced expiratory flow during mid (25–75%) portion of FVC ($FEF_{25-75\%}$); FEV_1/FVC; peak expiratory flow (PEF); and total lung capacity (TLC).
4. Cardiopulmonary exercise testing was conducted using a standardized symptom-limited CPET protocol (two-minute baseline with no resistance, two-minute warm-up at a 20-Watt resistance, and a 30-Watt increase every two-minutes thereafter until exhaustion). Variables measured included: peak systolic blood pressure (SBP); peak diastolic blood pressure (DBP); peak heart rate (HR); peak heart rate reserve (HRR); peak breathing reserve (BR); exercise time in minutes; oxygen consumption adjusted for body weight (VO_2); linear relation of heart rate to oxygen consumption (HR/VO_2); end-tidal oxygen and carbon dioxide tension (peak $PetO_2$ and peak $PetCO_2$, respectively); ventilatory equivalent ratio for oxygen and carbon dioxide (VE/VO_2 and VE/VCO_2, respectively); oxygen pulse (O_2 pulse); shortness of breath (dyspnea) at mid (taken at a fixed time point for all subjects, at six minutes) and peak exercise (using 0–10 Borg scale), and leg fatigue at mid (at six minutes) and peak exercise (using 6–20 Borg scale) [22,23]; change from baseline at peak exercise in the end-expiratory lung volume (EELV, using the inspiratory capacity maneuver as described by Yan et al.) [24]; O_2 saturation; minute ventilation (VE); and anaerobic threshold as percentage of peak VO_2.

Investigators and technicians within the study were not blinded to group assignment.

2.3. Analysis

Basic univariate statistics were used to describe respiratory health and cardiopulmonary measures at peak exercise. T-tests were used to compare non-smokers and WPS across all measures, and p-values were generated (a cut-off of 0.05 was used).

Exercise duration (as a proxy for exercise performance) was a main outcome of interest. Multivariable regression analysis was performed to evaluate the effect of being in the WPS group on exercise duration, while adjusting for baseline differences between subjects that may have influenced exercise duration (e.g. age, general respiratory healthy, being physically active, and BMI). With regards to general respiratory health, reporting of dyspnea upon exertion was specifically used as a proxy measure.

3. Results

In total, 138 subjects (69 WPS and 69 non-smokers) were recruited for the study. Table 1 presents the baseline characteristics of the sample of male participants. WPS had been smoking the waterpipe habitually for 4.9 years. Notably, WPS (mean age 22.1) had a higher BMI than non-smokers (mean age 21.4).

With regards to respiratory symptoms (Fig. 1), a significantly greater proportion of WPS (72.5%) than non-smokers (21.7%) reported any respiratory symptoms (e.g. bringing up phlegm, having shortness of breath upon exertion, cough, chest illness in the past three years that kept a participant off work, and coughing with phlegm that lasted at least three weeks).

CPET and PFT results also revealed differences between non-smokers and WPS (Table 2). WPS had significantly lower FEV_1, FVC, PEF and TLC. At peak exercise, WPS had lower VO_2 ml/kg and HR; lower degree of change in EELV; and higher HRR, Pet CO_2, and VE/VCO_2. WPS also reported higher shortness of breath and leg