




Disponible en ligne sur
 ScienceDirect
www.sciencedirect.com

Elsevier Masson France
 EM|consulte
www.em-consulte.com



ORIGINAL ARTICLE

Spirometric profile of narghile smokers

H. Ben Saad^{a,b,g,*}, M. Khemis^a, I. Bougmiza^c,
C. Prefaut^b, H. Aouina^d, N. Mrizek^e, A. Garrouche^f,
A. Zbidi^a, Z. Tabka^a

^a Service de physiologie et des explorations fonctionnelles, EPS Farhat Hached, Sousse, Tunisia

^b Inserm, équipe ERI 25, « muscle et pathologies », service central de physiologie clinique, hôpital Arnaud-de-Villeneuve, 34295 Montpellier, France

^c Département de médecine communautaire, faculté de médecine de Sousse, university of Sousse, 4003 Sousse, Tunisia

^d Service de pneumologie, EPS Charles-Nicolle, 1006 Tunis, Tunisia

^e Service de médecine du Travail, EPS Farhat Hached, 4003 Sousse, Tunisia

^f Service de pneumologie, EPS Farhat Hached, Sousse, Tunisia

^g Laboratoire de physiologie, faculté de médecine « Ibn Eljazzar » de Sousse, avenue Mohamed-Karoui, 4003 Sousse, Tunisia

Received 4 April 2008; accepted 19 October 2008

Available online 26 July 2011

KEYWORDS

Spirometry;
Tobacco;
Narghile;
Deficit;
Ageing

Summary

Introduction. – Studies of the spirometric profiles of narghile smokers are few, have some methodological limits (i.e. small sample size), and present contradictory conclusions.

Aims. – (i) To determine the percentage of narghile smokers with obstructive ventilatory defect (OVD) and/or restrictive ventilatory defect (RVD) or static hyperinflation (SHI); (ii) to compare the chronological and estimated lung ages.

Population and methods. – Inclusion criteria: men aged 20 to 60 years, narghile smokers (> 1 narghile-year [NY]). Exclusion criteria: cigar or cigarette smokers and comorbidity. Narghile use quantification: NY and kg of cumulative tobacco use (1 NY = 9.125 kg of cumulative tobacco use).

Definitions. – Large airway obstructive ventilatory defect (OVD): forced expired volume in one second (FEV₁) / forced vital capacity (FVC) less than lower limit of normal (LLN). Small airway OVD: FVC more than LLN and decrease (less than LLN) of one or more peripheral flows. RVD: total lung capacity (TLC) less than LLN. SHI: residual volume (RV) more than upper limit of normal.

Spirometric measures. – (Vmax 22 Series/6200 Autobox, SensorMedics, Yorba Linda, California, USA with measurement of functional residual capacity by nitrogen washout). Measurements were made according to international recommendations.

Results. – One hundred and ten narghile smokers were included (34 ± 10 years; 1.76 ± 0.07 m; 84 ± 14 kg). Thirty-six percent of the subjects had SHI; 14% had small airway OVD; 14% had RVD, and 6% had large airway OVD. Estimated lung age was higher than chronological lung age (47 ± 18 years vs. 34 ± 10 years, *P* < 0.05).

* Auteur correspondant. Tel.: +21 698697024; fax: +21 673224899.
E-mail address: helmi.bensaad@rns.tn (H. Ben Saad).

Conclusion. – Narghile use accelerates lung ageing. This study provides the health authorities with valid arguments to fight this blight on society, which increasingly involves children and pregnant women.

© 2011 SPLF. Published by Elsevier Masson SAS. All rights reserved.

Abbreviations list

B	non-standardized regression coefficient
BMI	body mass index
CO	carbon monoxide
COPD	chronic obstructive pulmonary disease
DLCO	diffusing capacity of the lung for carbon monoxide
FEV ₁	forced expired volume in one second
FRC	functional residual capacity
FVC	forced vital capacity
MMEF	maximal midexpiratory flow
n	number of subjects
N	normal corresponding to a 95% confidence interval
N ₂	nitrogen
NY	narghile-year
OVD	obstructive ventilatory defect
O ₂	oxygen
PEF _{x%}	peak expiratory flow rate at the x% point of total volume (FVC) to be exhaled
PEFR	peak expiratory flow rate
PHI	public health institution
r	correlation coefficient
RV	residual volume
RVD	restrictive ventilatory defect
SHI	static hyperinflation
SVC	slow vital capacity
TLC	total lung capacity
VV	ventilatory variable

Introduction

The last decade has seen the emergence of large-scale narghile use. The social phenomenon of narghile smoking has developed to a worrying extent. To date the number of smokers is estimated at 100 million worldwide, mainly in North Africa, Asia and the Middle East [1–4]. For example, male narghile smokers are respectively 22% in Egypt, 50% in Syria, and 57% in Kuwait [1–4]. Faced with the ‘‘globalization’’ of this phenomenon that increasingly affects women and children [5,6], the World Health Organization has taken up the case and stressed that ‘‘the narghile is not only a health risk, but is also a gateway to smoking for a number of young people’’ [7]. Unlike cigarette smokers, narghile smokers are not likely to consider quitting, and this indicates a serious and profound lack of information about the real nature and toxicity of narghile smoke [2,6–9].

Usually, public opinion, and especially the medical world, underestimates the damaging effects of this water pipe, despite its harmful effects on health [1,6]. Indeed, it has been proven that its smoke is rich in hundreds of substances potentially hazardous to health [10–13]. In addition,

narghile use is frequently associated with several diseases [14–26] (i.e.; cancers, infectious diseases, genetic disorders, cardiovascular diseases). Furthermore, compared with cigarette smoke, narghile smoke has a higher level of nicotine (1–3% vs. 2–4%, respectively), CO (0.41% vs. 1.40%, respectively) and tar (11 mg vs. 802 mg, respectively) [2,8,12,13,27–29]. Moreover, narghile smokers have high blood levels of free radicals, known to be mediators involved in bronchopulmonary lesions [30,31]. Finally, narghile smoking impairs mucociliary clearance in the respiratory system [32]. All this led us to believe that deterioration in the spirometric profile of narghile smokers was possible.

To the best of our knowledge, studies of the spirometric profiles of narghile smokers are rare [8,32–41]. Indeed, only three studies have been published as original articles [8,32,33], whereas other approaches to the subject have been presented as abstracts at international conferences [34–37]. The majority of these studies used limited methodology: low sample size (19, 20, 65 and 82 subjects exclusively narghile smokers respectively for studies by Altinisik et al. [35], Köseoglu et al. [32], Bayindir et al. [34] and Kiter et al. [8]), inclusion of subjects both cigarette and narghile smokers [2,33], elderly subjects [8], or with diseases that affect lung function [38–40], measures of expiratory flows only and not lung volumes [8,34,35], non-application of recent recommendations and spirometric definitions [8,41]. These methodological shortcomings explain some discrepancies in the findings: lack of respiratory function impairment [32,35–37], minimal small airways impairment [8], or large airways impairment [34,42].

Ignoring the harmful effects of narghile smoke on lung function will certainly lead to a global public health problem [1,2,7,43], which we can now undertake to prevent. The aims of this study of narghile smoker spirometric profile were:

- to compare VV measured with the reference values;
- to determine the percentage of narghile smokers with VV outside the normal range, or OVD, and/or RVD, or SHI;
- to compare estimated lung age with chronological age.

Population and methods

Type of study

This was a cross-sectional study spread over three months (December 2006 to February 2007). It was conducted in the Department of Physiology and Functional Explorations of the Farhat Hached PHI in Sousse, Tunisia. This study, without direct benefit to the subjects, obtained the approval of the ethics committee of the local PHI. If a ventilatory defect was discovered, the subject was referred to a chest physician.

Population

Only male subjects who were current narghile smokers were included in the study. These subjects were recruited from the staff of the Faculty of Medicine and the Farhat Hached PHI in Sousse, as well as acquaintances of people involved in the study. The exclusion criteria were numerous: age under 20 or over 60, cigarette smokers, cigar or pipe smokers, history of asthma, allergies, pulmonary tuberculosis or recent respiratory tract infection, presence of comorbidities (cardiovascular diseases, diabetes, neoplasia) and imperfect performance of the respiratory manoeuvres requested.

Sample size

It was calculated using the following predictive equation [44]: $n = (Z^2 \times p \times q) / \Delta^2$. n : number of subjects necessary. Z : 95% confidence level ($Z = 1.96$). p : estimation of spirometric impairment in narghile smokers. According to the literature [45], 25 to 40% of narghile smokers have a diminished PEFR. $q = 1 - p = 0.75$. Δ : precision = 8%. According to this formula the number of subjects required was 112.

Data collection procedures

Data were collected using a questionnaire modelled on that of the American Thoracic Society [46]. This non-validated questionnaire was composed of questions written in French and put to the subjects in Arabic. These questions, asked by the same operator using the same form, were mainly closed questions, usually dichotomous.

Study protocol: welcome and provision of an information sheet; explanation of the study objectives; signature of the informed consent form; completion of medical questionnaire, and anthropometric and spirometric measures.

The following data were collected: narghile use quantified in narghile-years (NY) and kg of cumulative tobacco use [1,47], anthropometric data (age, weight, height, BMI), spirometric data (FVC, FEV₁, PEFR, MMEF, PEF at the 75, 50 and 25% point of total volume [FVC] to be exhaled, PEF_{75%}, PEF_{50%}, and PEF_{25%} respectively), SVC, FRC, RV, TLC, FEV₁/SVC, FEV₁/FVC, RV/TLC and FRC/TLC ratios) and estimated lung age.

Definitions used

The definitions used were based on the identification of a lower limit of normal for the VV in question. For this reason, we used the two interpretation methods the most commonly used in current practice [41,48,49].

The first method was based on "fixed threshold values" beyond which the VV were considered to be abnormal [48,49]. For FEV₁ and lung volumes, the VV were considered to be reduced when below 80% of their reference value, normal between 80 and 120%, and increased when above or equal to 120%. For peak expiratory flows, and because of their great variability, the VV were considered to be reduced when below 50% of their reference value, normal between 50 and 120%, and increased when above or equal to 120%. For the FEV₁/FVC ratio, the threshold was set at 0.70.

The second method was based on determination of a 95% confidence interval, and therefore the application of

lower and upper limits of normal [41]. For simplicity in this article, we have defined ventilatory abnormalities as above (> N) or below (< N) normal; with the normal corresponding to the confidence interval. Proximal OVD was defined as an "FEV₁/FVC ratio less than N" [41]. The recent International classification of OVD severity, based on FEV₁ as a percentage of its reference value, was used (mild: FEV₁ ≥ 70%; moderate: 60% ≤ FEV₁ < 69%; moderately severe: 50% ≤ FEV₁ < 59%; severe: 35% ≤ FEV₁ < 49%, and very severe: FEV₁ < 35%) [41]. Distal OVD was defined as the association of a "normal FVC" with a reduction (< N) in peripheral flows (PEF_{25%}, and/or PEF_{50%}, and/or PEF_{75%}, and/or MMEF) [48]. RVD was defined as a "TLC less than N" [41]. The International classification of RVD severity, based on TLC expressed as a percentage of its reference value, was used (mild: 70% ≤ TLC ≤ N; moderate: 60% ≤ TLC < 70%; severe: TLC < 60%) [49]. Mixed ventilatory defect was defined as the association of a "TLC less than N" and an "FEV₁/FVC ratio less than N" [41]. SHI was defined as a "RV greater than N" [50]. The international classification for SHI severity was used (stage I: RV ≥ N but normal FRC and TLC; stage II: RV and FRC ≥ N but TLC normal; stage III: RV, FRC and TLC ≥ N) [50]. Non-specific ventilatory defect was defined as a decrease (< N) in FVC and/or FEV₁, with a normal FEV₁/SVC ratio and TLC.

Estimated lung age was calculated from the following equation [51]: estimated lung age is equal to $0.072898 \times \text{height (m)} - 31.250 \times \text{measured FEV}_1 \text{ (l)} - 39.375$.

Depending on BMI (ratio of weight to height squared), we distinguished between [52]: underweight (BMI < 18.5), normal weight ($18.5 \leq \text{BMI} < 25$), overweight ($25 \leq \text{BMI} < 30$) and obesity (BMI ≥ 30). The latter was either moderate ($30 < \text{BMI} < 35$), or severe ($35 \leq \text{BMI} < 40$), or massive (BMI ≥ 40).

Narghile: description, operation, smoke composition, and evaluation of use.

The narghile is a water pipe which enables the smoking of a tobacco preparation, flavoured or not, burned by charcoal embers; the smoke is cooled by passing through water before being inhaled. The different parts of the narghile, ranging in size from 40 to 100 cm, are indicated on Fig. 1. The bowl is made of earthenware or metal. It contains the tobacco and is perforated to let the smoke pass in the stem. The tray is used to catch charcoal ash. The stem is the central part of the narghile (1 cm in diameter). The bowl is fixed at the top of the stem and is sealed with a grommet. The lower extremity of the stem is submerged in water. The assembly is either pushed or screwed into the vase. The vase is made of glass or acrylic, and is filled with water to half its height. The hose (75–150 cm) is used to smoke the narghile. The proximal extremity of the hose arrives in the air space between the water in the vase and the junction with the stem.

Operation of the narghile can be summarized as follows [9]: inhaling through the hose lowers the pressure inside the vase. Air passes through the stem and bubbles through the water thus enabling combustion of the tobacco. The smoke produced passes through the stem and the water, fills the top of the vase as air bubbles, and then passes into the hose.

We considered that a smoked narghile contained 25 g of tobacco and thus 1 NY (one narghile a day for one year) = 9.125 kg of cumulative tobacco use. Subjects were

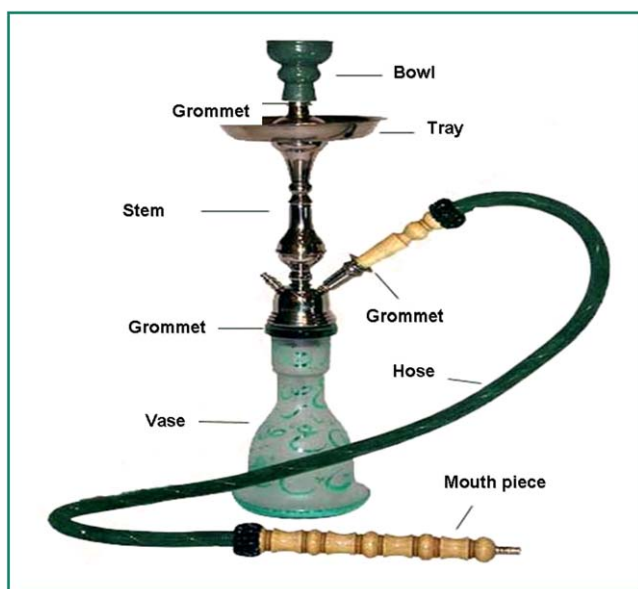


Figure 1. Different parts of the narghile.

classified as non-smokers (less than 1 NY) or current smokers (above or equal to 1 NY).

Spirometry technique

We used a rapid response spirometer with measure of FRC and nitrogen washout (22 Series/6200 Vmax Autobox, SensorMedics, Yorba Linda, California, USA). After entering anthropometric data, reference values were automatically calculated according to the local equations [53]. Measurements were made in accordance with the international guidelines [54,55].

The spirometer is calibrated according to atmospheric conditions recorded daily [56]. The accuracy of flow-meter measures for flow and output volume were confirmed once a day using a three litre syringe [54]. Before testing each subject, the N_2 analyser was set at zero with 100% oxygen (O_2) and then exposed to ambient air to confirm calibration.

The operator supervised the respiratory manoeuvres and strongly encouraged the subjects to provide maximal effort. The correct technique was demonstrated and measurement procedures were followed.

Measurement of FVC was performed in four distinct phases:

- quiet breathing for five cycles;
- slow and sustained expiration to FRC;
- maximal inhalation;
- ‘‘explosive’’ and complete expiration.

We retained the forced expiratory flow curve with a satisfactory PEFR and the best total ($FVC + FEV_1$).

Measurement of FRC using the nitrogen washout technique was based on the washing out of all nitrogen in the lungs while the patient was breathing 100% O_2 [55]. The procedure for measuring FRC was explained to the subject, emphasizing the need to avoid leaks around the mouthpiece during washout. The subject breathed ambient air, nose clip in place for 30 to 60 seconds to get used to the device and to obtain a stable end-tidal level. When respiration was stable and regular, the subject was connected to the circuit allowing him to breathe 100% O_2 instead of ambient air. The

washout was considered to be complete when the concentration of N_2 was less than 1.5% for at least three successive breaths. At least one technically satisfactory measurement was obtained. If more than one measurement was made, the value retained was the average of the acceptable technically similar results within 10%.

Statistical analysis

The analysis of variable distribution was performed using the Kolmogorov-Smirnov test [44]. When the distribution was normal and variances were equal, the results were expressed as mean \pm standard deviation. Otherwise, the results were expressed by their medians (1st to 3rd quartile).

The Student *t* test was used to compare the VV measured with reference values and to compare estimated lung age with chronological age.

We performed simple linear regressions between the VV (dependent variables) and narghile use expressed in kg (independent variable). The VV (examples: MMEF, RV) varied by a factor equal to ‘‘ $B \times$ narghile use’’. *B* being the non-standardized regression coefficient. Example: MMEF diminished by B_1 mL per kg of narghile use and RV increased by B_2 mL per kg of narghile use. The correlation coefficient (*r*) between the VV and narghile use expressed the quantity of variation common to the two variables.

We then performed multiple linear regressions between the VV influenced by narghile use (dependent variables) and the following independent variables: age, height, weight and narghile use in kg.

The significance threshold of 5% was retained.

Data acquisition and processing was performed using Statistica software (Statistica Kernel version 6; Stat Soft, France).

Results

One hundred and ten of the 150 subjects examined (73%) were included in the study. The exclusion criteria were: cigarette or cigar smokers ($n=17$), imperfect performance of the respiratory manoeuvres requested ($n=12$), comorbidities ($n=6$), age less than 20 years or more than 60 years ($n=5$).

The median (1st to 3rd quartile) of narghile use was 14 NY (4–28) and accumulated tobacco use was 128 kg (37–256).

The means \pm standard deviations (minimum–maximum) for age, height, weight and BMI, were respectively 34 ± 10 years (20–60), 1.76 ± 0.07 m (1.58–1.90), 84 ± 14 kg (57–125) and 27 ± 4 kg/m² (19–39). Thirty-six subjects (33%) had normal weight, 47 (43%) were overweight, and 27 (25%) were obese. Twenty-four subjects (22%) were moderately obese and three (3%) were severely obese.

Fig. 2 shows the distribution of the sample in 10-year age brackets.

Comparison of ventilatory variable (VV) measured with reference values

All forced expiratory flows were reduced (Table 1).

The increases in the RV, FRC, RV/TLC and FRC/TLC ratios indicated SHI in narghile smokers.

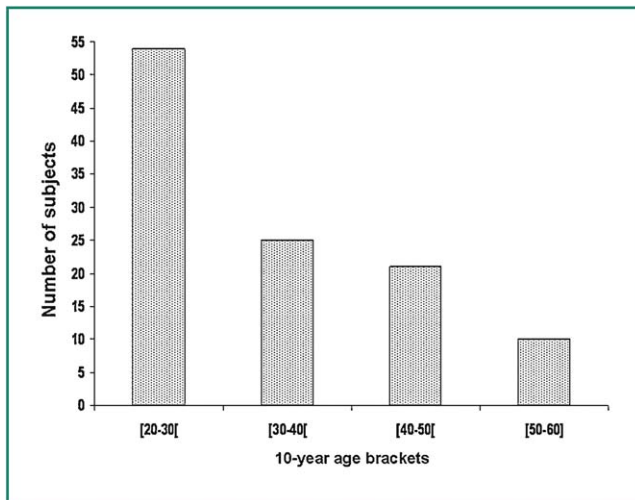


Figure 2. Distribution of the sample in 10-year age brackets.

Number of subjects presenting ventilatory deficits

None of the subjects showed strictly normal spirometry.

Fig. 3 presents the number of smokers distributed according to the method based on "fixed threshold values". Five smokers (5%) had an FEV₁/FVC less than or equal to 0.70.

Table 2 shows, according to the method based on a confidence interval of 95%, the number (%) of smokers with VV outside the normal range and/or ventilatory deficits. Analysis of this table reveals the following:

- only six subjects (6%) had proximal OVD (mild and moderate);

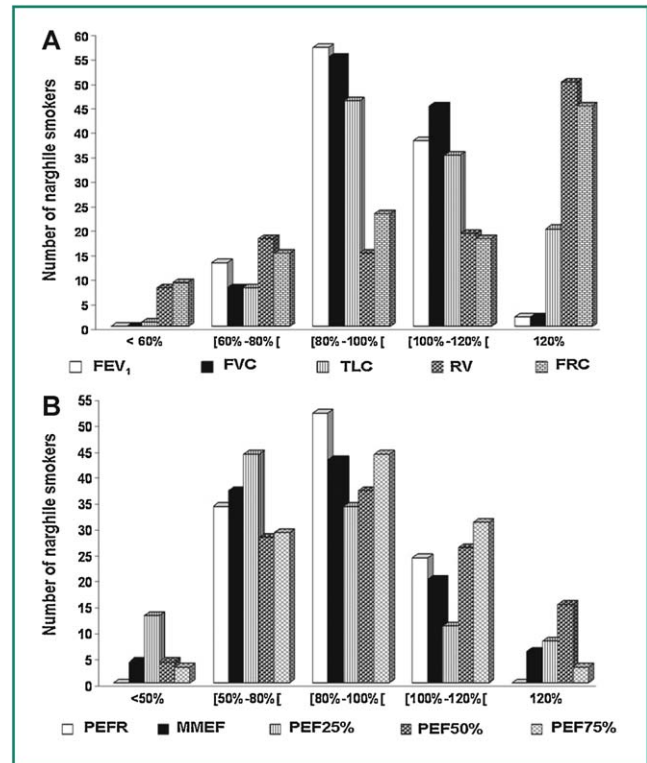


Figure 3. Number of smokers distributed according to the method based on "fixed threshold values". The "fixed threshold values" are expressed in percentage of reference value. A. FEV₁, FVC, TLC, RV and FRC. B. PEFR, MMEF and PEFx%. For abbreviations, see abbreviations list.

Table 1 Comparison of ventilatory variables (VV) measured with reference values ($n = 110$).

VV	Measured value (absolute value)	Measured value (expressed in percentage of reference value)	<i>P</i>
<i>Forced expiratory flows</i>			
FEV ₁ (L)	3.87 ± 0.69	94 ± 12	0.004
PEFR (L s ⁻¹)	8.27 ± 1.64	87 ± 15	< 0.001
PEF _{25%} (L s ⁻¹)	1.93 ± 0.79	81 ± 32	< 0.001
PEF _{50%} (L s ⁻¹)	4.84 ± 1.27	92 ± 23	< 0.001
PEF _{75%} (L s ⁻¹)	7.30 ± 1.70	89 ± 19	< 0.001
MMEF (L s ⁻¹)	4.05 ± 1.07	87 ± 21	< 0.001
<i>Lung volumes</i>			
FVC (L)	4.80 ± 0.84	97 ± 12	0.218
SVC (L)	4.45 ± 0.83	87 ± 13	< 0.001
FRC (L)	3.80 ± 1.61	114 ± 48	0.002
TLC (L)	7.22 ± 1.75	104 ± 24	0.148
RV (L)	2.40 ± 1.44	132 ± 50	< 0.001
<i>Ratios</i>			
FEV ₁ /FVC	0.81 ± 0.06	100 ± 12	0.519
FEV ₁ /SVC	0.88 ± 0.10	95 ± 12	< 0.001
RV/TLC	0.31 ± 0.11	117 ± 39	< 0.001
FRC/TLC	0.51 ± 0.10	101 ± 20	0.812

Values are expressed as their mean ± standard deviations. *P* (Student *t* test): measured value (absolute value) vs. measured value (expressed in percentage of reference value). For abbreviations, see abbreviations list.

Table 2 Spirometric profile of narghile smokers ($n = 110$).

Number (%) of subjects with ventilatory variables outside the normal range		
Forced expiratory flows or ratios $\leq N$		
FEV ₁ (L)	14 (13%)	
PEFR (L s ⁻¹)	31 (28%)	
PEF _{25%} (L s ⁻¹)	8 (7%)	
PEF _{50%} (L s ⁻¹)	9 (8%)	
PEF _{75%} (L s ⁻¹)	9 (8%)	
MMEF (L s ⁻¹)	18 (16%)	
FEV ₁ /FVC	6 (6%)	
FEV ₁ /SVC	2 (2%)	
Ratios $\geq N$		
RV/TLC		33 (30%)
FRC/TLC		16 (14%)
Lung volumes		
	$\geq N$	$\leq N$
FVC (L)		7 (6%)
SVC (L)		40 (36%)
FRC (L)	36 (33%)	14 (13%)
TLC (L)	23 (21%)	15 (14%)
RV (L)	40 (36%)	9 (8%)
Number (%) of subjects with distal obstructive ventilatory defect		
Definitions		
Normal FVC and	(PEF _{25%} or PEF _{50%} or PEF _{75%} or MMEF) < N	15 (14%)
	PEF _{25%} < N	8 (7%)
	PEF _{50%} < N	9 (8%)
	PEF _{75%} < N	9 (8%)
	MMEF < N	15 (14%)
Number (%) of subjects with non-specific ventilatory defect		
FVC < N and (FEV ₁ /FVC and TLC) within the normal range		3 (3%)
FEV ₁ < N and (FEV ₁ /FVC and TLC) within the normal range		5 (5%)
(FVC < N or FEV ₁ < N) and (FEV ₁ /FVC and TLC) within the normal range		5 (5%)
N: normal corresponding to the confidence interval of 95%. For abbreviations, see abbreviations list.		

- fifteen subjects (14%) had distal OVD;
- forty subjects (36%) had SHI. Seven (6%), 13 (12%) and 20 (19%) subjects were classified respectively as stage I, stage II and stage III SHI;
- fifteen subjects (14%) had RVD. Eleven (10%), three (3%) and one (1%) subjects were classified respectively as having mild, moderate and severe RVD;
- no subjects presented mixed ventilatory defect;
- between 3 and 5% of the subjects had a non-specific ventilatory defect.

Relationships between the ventilatory variable (VV) and narghile use

There was no significant correlation between PEF_{25%}, FVC, VC, TLC and FRC/TLC ratio and narghile use.

Fig. 4 presents the correlation coefficient (r) between the measured VV and narghile use. Narghile use accelerates the decline in FEV₁ ($p < 0.001$) (Fig. 4A) and peak expiratory flow (Fig. 4B, C, D and E). Similarly, it accelerates the increase in FRC ($p = 0.049$) (Fig. 4F) and RV ($p = 0.004$) (Fig. 4G), indicating a trend towards SHI. Finally, it accelerates the decline in FEV₁/FVC ratio ($p = 0.04$) (Fig. 4H).

Multiple linear regressions between VV and anthropometric data in addition to narghile use showed that the more the latter increases, the more maximal expiratory flow and FEV₁/FVC ratio decline, and the more FRC, RV and VR/TLC ratio increase.

Estimated lung age

Estimated lung age was higher than chronological age (respectively, 47 ± 18 years against 34 ± 10 years; $P < 0.05$).

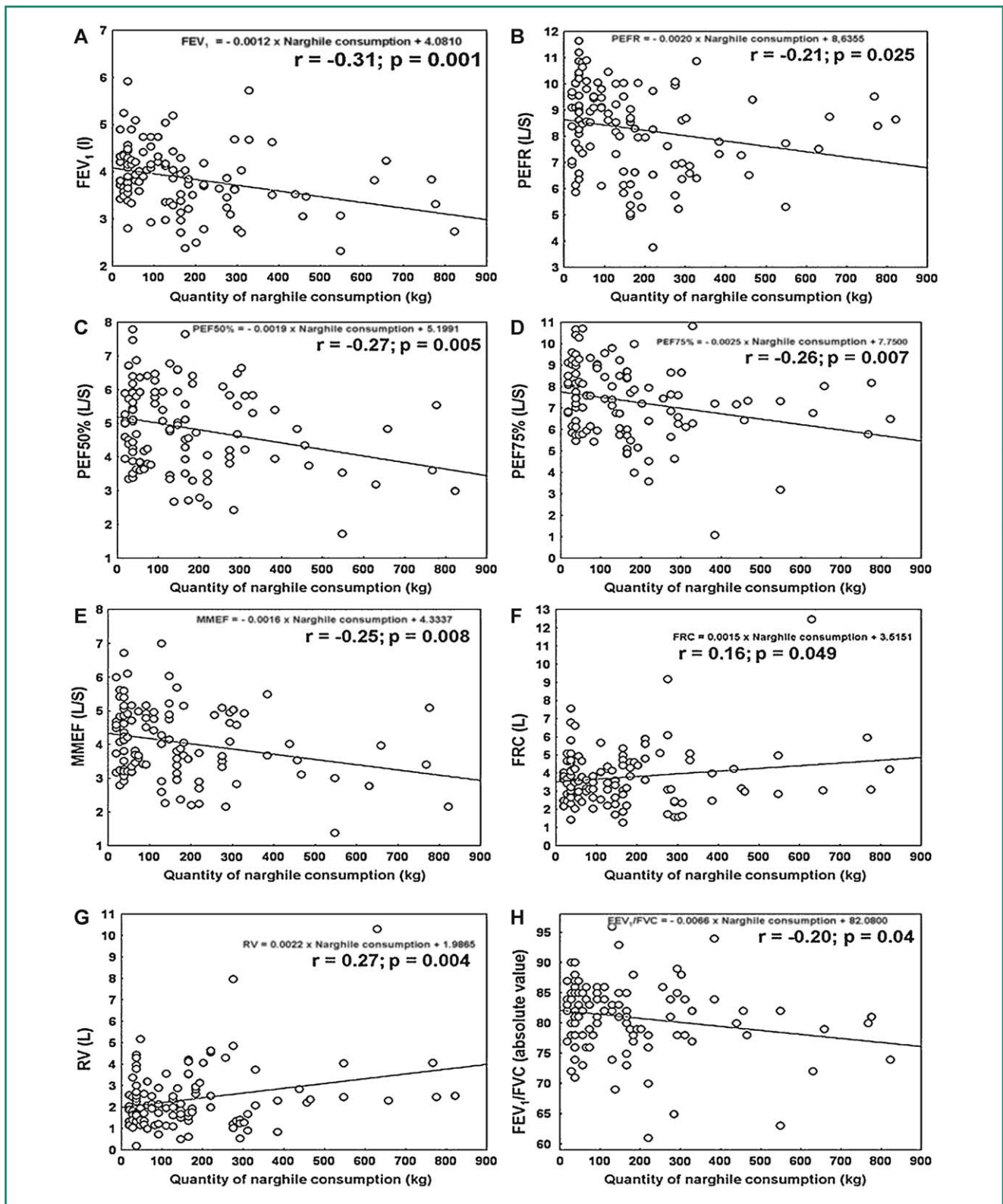


Figure 4. Correlation coefficient (r) between the ventilatory variables and narghile use expressed in kg of accumulated tobacco use ($n=110$). A. FEV₁. B. PEF_R. C. PEF_{50%}. D. PEF_{75%}. E. MMEF. F. FRC. G. RV. H. FEV₁/FVC ratio. For abbreviations, see abbreviations list.

Discussion

The spirometric profile of narghile smokers is deteriorated, with in particular the presence of OVD, SHI and acceleration in lung ageing.

Methodological discussion

Nosology

Narghile is the generic name for any method of tobacco use featuring the passage of smoke through water before being inhaled. In the literature, the name of this mode of smoking depends on the country of origin and includes the following terms: narghile, arghila, argileh, shisha, chicha, gozh, goza, chilam, ghelyan, hookah, hooka, hukka, or hubble-bubble. We preferred the term "narghile".

Type of study

This cross-sectional study was economical and easy to perform. It required less time than a longitudinal study and provided much useful information [57]. We decided to compare the measured values of VV in narghile smokers with the reference values established in a local population of healthy non-smokers [53]. Other methods have been used, such as the comparison with a group of cigarette smokers or a group of non-smokers [8,32].

Recruitment method

For purely practical reasons, we recruited our subjects from the staff of the Faculty of Medicine and the Farhat Hached PHI in Sousse, as well as acquaintances of people involved in the study. As in any study using volunteers, there was a possibility of selection bias [58]. Other recruitment methods have been used. For example, Kiter et al. [8] visited all the narghile cafés in the city of Izmir (Turkey), where 15 to 20 narghile smokers per café were approached to answer a questionnaire and have expiratory flows measured.

Criteria for inclusion and exclusion

Some precautions were taken during this study. To avoid misinterpretation we only included men, current narghile smokers, not smokers of cigars, cigarettes or pipes, clinically stable and free of comorbidities.

As in the study by Kiter et al. [8], we did not include women in our study despite the fact that the "narghile" phenomenon is affecting more and more women (69% of women in Kuwait are narghile smokers [4]).

As the average age of initiation into narghile use is 19 ± 5 years [3,47], we only included smokers aged 20 and over with a use of over 1 NY. However, this "narghile" phenomenon affects more and more children [6].

As life expectancy in healthy Tunisians was 61 years in 2002 [7], we were unlikely to find narghile smokers over 60, free of comorbidity and clinically stable. This explains the low number of subjects aged 50 to 60 years included in our study (Fig. 2). The upper age limit was not respected in the study by Kiter et al. [8] who included subjects aged between 18 and 85 years.

According to the recommendations, subjects unable to correctly perform the requested respiratory manoeuvres, after eight trials, were not included in the study [54].

It is possible that other criteria not assessed in this study, such as occupational exposure and obesity, could have influenced our results. However, when answering the medical questionnaire, no subjects reported being followed by an occupational physician. The deterioration in lung function associated with obesity appears only in the case of severe or massive obesity without any proven pulmonary disease [59]. In our study, only 3% of the subjects presented severe obesity; they were not excluded.

Sample size

Sample size ($n=110$) "seemed" to be satisfactory [44], in accordance with international recommendations [41]. Our sample was larger than that used in some studies of exclusive narghile smokers [8,32,34,35]. However, it was not as large as that used for a study [33] conducted on a mixed population of cigarette and narghile smokers ($n=595$).

Quantification of narghile use

In the absence of a specific international codification, we quantified narghile use as in the study by Kiter et al. [8], NY and accumulated tobacco use in kg. We considered that a smoked narghile contained 25 g of tobacco. The tobacco used for a narghile weighs between 10 and 25 g [2] and is available in three main types: "Moassel" or "maasel" (sweet, mostly used in Tunisia), which contains 30% tobacco and 70% molasses and is often flavoured (apple, strawberry, banana, etc.). "Tombak" or "Tumbak" or "Ajami" which is a pure black tobacco paste. "Jurak", an intermediate form that often contains fruits or oils [2].

Based on an experimental model, Salah and Shihadeh evaluated narghile use in number of puffs [60]. A standard session of 20 g of narghile tobacco lasts 45 minutes. It consists of an average of 171 puffs, each lasting 2.6 seconds (the volume of each puff being 530 mL), spaced 17 seconds apart (cycle of 19.6 seconds) [60].

However, according to the subjects, the volume of each puff varies from 500 to 1000 mL, against 30 to 50 mL for a cigarette [60,61]. A narghile session lasts on average between 45 and 60 minutes with a cumulative volume of smoke inhaled of 100 L [2,61]. Similarly, it has been demonstrated that the concentration of CO in narghile smoke is significantly higher in small narghiles than the larger ones [62].

Since the narghile is the most often smoked in groups in relatively confined areas such as cafés and tearooms, we think that the actual amount of smoke inhaled is underestimated [2].

Composition of narghile smoke

We were faced with another methodological problem, namely the variability of the composition of the tobacco used in the narghile (Table 3). According to published data, the chemical composition of narghile smoke (production from one gram of tobacco) includes: CO (145 mg), nicotine (2.96 mg), tar (802 mg), polycyclic aromatic hydrocarbons (fluoranthracene [221 ng], phenanthrene [748 ng], chrysene [112 ng]), heavy metals (arsenic [165 ng], cobalt [70 ng],

Table 3 Composition of narghile smoke according to experimental models. Data for cigarette smoke are shown for comparison.

	Shihadeh and Saleh [60]	Shihadeh [13]	Rakower and Fatal [17]	Hoffmann and Hoffmann [79]
Type of tobacco	Moassel	Moassel	Tombak	Cigarettes
Number of puffs	171	100	Not mentioned	
Puff volume, mL	530	300	200	35
Puff duration, s	2.6	3	5	
Interval between puffs, s	17	30	60	
Tar, mg	802	242	84	1–27 (11.2)
Nicotine, mg	2.96	2.25		0.1–2 (0.77)
Carbon monoxide, mg	145			1–22 (12.6)
<i>Polycyclic aromatic hydrocarbons (ng)</i>				
Benzopyrene				20–40
Phenanthrene	748			200–400
Flouranthracene	221			9–99
Chrysene	112			4–41
<i>Heavy metals (ng)</i>				
Arsenic		165		40–120
Beryllium		65		300
Nickel		990		0–600
Cobalt		70		0.13–0.2
Chromium		1340		4–70
Lead		6870		34–85

chromium [1340 ng], lead [6870 ng], nickel [990 ng] and beryllium [65 ng]) [2,10,12,13,27–29].

Spirometric measurements

Unlike the majority of other studies [8,32,34,35], we measured static lung volumes.

Contrary to the study by Kiter et al. [8] that used the old definitions [63], we applied the recent international definitions based on a confidence interval of 95% [41]. When interpreting the spirometry data, we compared the values measured with the reference values established in a “normal” population and thus standardized according to factors determining lung size [64]. Values outside the confidence interval of 95% were considered to be “abnormal” [64,65].

Limitations of this study

The International Classification of Functioning, Disability and Health specifies three development stages, each requiring assessment with one of more specific examinations: impairment, disability and social disadvantage [66].

In this study, we only evaluated impairment. We analysed the effects of narghile use on the respiratory system using only the VV as markers. However, there are other markers such as measurement of CO in expired air, or carboxyhaemoglobinemia, or the study of respiratory mucociliary clearance [32,67,68]. It has been demonstrated that narghile smokers have a high end-expiratory CO level [67], and, compared with cigarette smokers and non-smokers, have a higher carboxyhaemoglobin level (10, 6 and 2% respectively) [68], and show a decline in mucociliary clearance rate [32]. Completion of the evaluation with

a bronchial reversibility test and/or measurement of DLCO would also have been useful. The reversibility test was not performed because it was difficult to ask a volunteer who thought he was “healthy” to inhale a bronchodilator. DLCO was not measured. In the absence of correction for haemoglobin and carboxyhaemoglobin values, the DLCO results would have been distorted [41,67–69]. Similarly, it would have been useful to perform, as part of an evaluation of disability and handicap, a six-minute walk test, and a quality of life questionnaire. These evaluations are part of future prospects for our team.

In this study, we focused only on the purely functional aspects of narghile use. However, narghile smokers may complain of some clinical signs such as dyspnoea or wheezing.

Discussion of the results

The harmful effects of narghile use on ventilatory function highlighted in this study are part of a more general phenomenon. This use is often associated with several diseases [14–26,32]: bronchopulmonary, oral, gastrointestinal and bladder cancer, tuberculosis, chromosomal aberrations, atherosclerosis and coronary heart disease and impaired mucociliary clearance.

Comparison of VV measured with reference values

In comparison with the reference values, the forced expiratory flows of narghile smokers were significantly decreased (Table 1). The results of key studies analyzing VV exclusively in narghile smokers are presented in Table 4.

In comparison with expiratory flow rates in non-smokers, Kiter et al. [8] only found a significant decrease in PEFR.

Table 4 Values of ventilatory variables (VV) for this study and published studies.

VV ^a	This study	Kiter et al. [8]	Köseoglu et al. [32]	Zahran and Baig [42]	Bayindir et al. [34]	Altinisik et al. [35]
FVC	97 ± 12	94 ± 27	102 ± 17	Not mentioned	Not measured	Not decreased
FEV ₁	94 ± 12 ^b	87 ± 19	106 ± 19			
PEFR	87 ± 15 ^b	66 ± 23 ^b	95 ± 21		Decreased ^b	
PEF _{25%}	81 ± 32 ^b	71 ± 26	Not mentioned		Not measured	
PEF _{50%}	92 ± 23 ^b	79 ± 28				
PEF _{75%}	89 ± 19 ^b	Not mentioned				
MMEF	87 ± 21 ^b	79 ± 26	97 ± 27	Decreased ^b		
FEV ₁ /FVC	100 ± 12	98 ± 13	82 ± 5	Decreased ^b		
SVC	87 ± 13 ^b	Not measured	Not measured	Not measured	Not measured	Not measured
FRC	114 ± 48 ^b					
TLC	104 ± 24					
RV	132 ± 50 ^b					
FEV ₁ /SVC	95 ± 12 ^b					
RV/TLC	117 ± 39 ^b					
FRC/TLC	101 ± 20					

For abbreviations, see abbreviations list.

^a Expressed in percentage of their reference values (means ± standard deviations).

^b Statistically significant decrease.

They also showed that narghile smokers, compared to cigarette smokers, had a significantly greater decrease in FEV₁, PEF_{50%}, MMEF, and FEV₁/FVC ratio [8]. For Zahran and Baig [42], the significant decrease in FEV₁/FVC ratio and MMEF was the result of small airways obstruction. Two Turkish studies, performed on two small samples and presented at international conferences, showed results different from ours [34,35]. In a study of 595 Saudis, average VC, FVC and FEV₁ were lower in narghile smokers compared to cigarette smokers [33].

The increase in lung volumes indicates a trend towards SHI (Table 1). To the best of our knowledge, this result has never been shown before.

Number of subjects with ventilatory defects (Table 2, Fig. 3)

Contrary to some studies [32,35–37], in which no narghile smokers showed respiratory function impairment, in our study no subject had strictly normal spirometry.

Only 6% of narghile smokers had proximal OVD, and thus probably presented COPD. This percentage is close to that found by Kiter et al. [8], thus supporting the idea that COPD post-narghile is rare. However, this percentage is lower than that described in unpublished studies on exclusive narghile smokers [26,70] or on cigarette smokers. Indeed, using a spirometric definition, the percentage of cigarette smokers with proximal OVD varies from 8 to 11% [71,72].

Distal OVD varied from 7% (FVC > N and PEF_{25%} < N) to 36% (SHI) (Table 2). On the one hand, our results are different from those of Kiter et al. [8]. Kiter et al. found that distal OVD is uncommon in narghile smokers compared to cigarette smokers. They concluded that narghile use did not deteriorate respiratory function as severely as cigarette use [8]. They explained this by the following three facts:

- intermittent narghile use enables repair of small airways between two periods of inflammation;
- narghile smoke, because of the type of use, does not reach the deep airways;
- narghile smoke, because of the phenomenon of water filtration, is less harmful to the lungs [8].

On the other hand, our results are similar to those obtained in cigarette smokers: 15–20% develop distal OVD [73]. As in cigarette smokers, we believe that the distal OVD is the consequence of chronic inflammatory lesions with remodeling of bronchiolar mucosa [73].

Fourteen per cent of narghile smokers had RVD. This result, rarely observed in cigarette smokers, cannot be explained by the inclusion in our study of obese subjects. Indeed, it is known that impaired respiratory function only appears in cases of severe or massive obesity without any proven pulmonary disease [59]. Moreover, in our total sample, only 3% of the subjects presented severe obesity. The average BMI of these 15 smokers was 29 ± 5 kg m⁻² and only five of these 15 smokers had a BMI greater than 30 kg m⁻². The hypothesis of obesity as the origin of the RVD can thus be ruled out. This RVD could perhaps be explained by the particular composition of narghile smoke. This smoke is rich in heavy metals such as lead, arsenic and nickel [13] known to be risk factors for lung cancer [14–17]. A study performed in India showed that 22 men in 25 followed for bronchial carcinoma were narghile smokers [14]. In addition, chronic exposure to low levels of heavy metals can cause fibrosis and pneumoconiosis [74].

Relationships between the VV and narghile use (Fig. 4)

Contrary to the study by Kiter et al. [8], which had not found any significant correlation between narghile use and

PEFRs, we found that peak expiratory flows, except for PEF_{25%} diminished with increased narghile use (Fig. 4). This negative correlation (Fig. 4 A, $r = -0.31$; $P = 0.001$ between FEV₁ and quantity of narghile use expressed in kg) is similar to that observed in cigarette smokers ($r = -0.50$; $P < 0.05$; for FEV₁ and cigarette use expressed in pack-years) [8]. Kiter et al. [8] explained the absence of correlation as a problem with quantification of narghile use and advised that the results should be interpreted with extreme caution.

FRC (Fig. 4F) and RV (Fig. 4G) increased with increasing narghile use, again indicating a trend towards SHI.

Estimated lung age

One of the major results of this study was that narghile use accelerated lung ageing: estimated lung age was higher than chronological age (48 ± 18 years vs. 34 ± 10 years; $P < 0.05$). This effect, reported by Al-Fayez et al. [33] in 1988: "water-pipe smokers were at greater risk than cigarette smokers for decreased pulmonary function", was confirmed in 2007 by Lipkus et al. [75] in cigarette smokers. Lipkus et al. showed that estimated lung age was greater than chronological age in cigarette smokers (35 ± 16 years vs. 20 ± 1 years). Our results can be used to encourage smoking cessation [51].

How can the harmful effects of narghile use on lung function be explained?

As in cigarette smokers [76,77], the answer to this question requires the study of bronchial biopsies, induced sputum samples, bronchoalveolar washings and assays. To the best of our knowledge, in narghile smokers, these explorations are rarely performed. It is known that narghile use is associated with biochemical changes in bronchoalveolar lavage fluid [78]. Similarly, there is evidence that narghile smokers, compared with non-smokers, have very high free radical levels, increased anion superoxide production, higher leucocyte counts, and a high plasma prostaglandin 8-epi-PGF_{2a} level [2,30,31]. This indicates the presence of greater oxidative stress in regular narghile smokers. These changes can cause lung tissue lesions and thus play a role in the pathogenesis of ventilatory deficits [30,31].

In conclusion, the spirometric profile of exclusive narghile smokers are deteriorated, in particular with the presence of distal OVDs, SHI and acceleration of lung ageing. To the best of our knowledge, this is the first study to objectively establish, and according to recent international recommendations, the spirometric profile of exclusive narghile smokers. This study thus provides the public health authorities with valid arguments to fight this ever-spreading scourge on society, which increasingly involves adolescents and women.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgements

The authors express their gratitude to Dr Abdelaziz Hadj Mtir (primary care physician), Dr Radhia Zayani (chest physician), Dr Raoudha Sfaxi (chest physician) and Dr Mohamed Moez Ben Sayah (chest physician) for their participation in this study.

References

- [1] Maziak W, Ward KD, Affi Soweid RA, et al. Tobacco smoking using a water pipe: a re-emerging strain in a global epidemic. *Tob Control* 2004;13:327–33.
- [2] Knishkowsky B, Amitai Y. Water-pipe (narghile) smoking: an emerging health risk behavior. *Pediatrics* 2005;116:e113–9.
- [3] Maziak W, Fouad MF, Hammal F, et al. Prevalence and characteristics of narghile smoking among university students in Syria. *Int J Tuberc Lung Dis* 2004;8:882–9.
- [4] Memon A, Moody PM, Sugathan TN, et al. Epidemiology of smoking among Kuwaiti adults: prevalence, characteristics, and attitudes. *Bull World Health Org* 2000;78:1306–15.
- [5] Maziak W, Ward KD, Eissenberg T. Measuring exposure to environmental tobacco smoke: a developing country's perspective. *Prev Med* 2006;42:409–14.
- [6] Varsano S, Ganz I, Eldor N, et al. Water-pipe tobacco smoking among school children in Israel: frequencies, habits, and attitudes. *Harefuah* 2003;142:736–41.
- [7] World Health Organisation report on the global tobacco epidemic, 2008. The mpower package. www.who.int/tobacco/mpower. Accessed on 18 March 2008.
- [8] Kiter G, Ucan ES, Ceylan E, et al. Water-pipe smoking and pulmonary functions. *Respir Med* 2000;94:891–4.
- [9] Chaouachi K. *Tout savoir sur le narguilé. Société, culture, histoire et santé*. Paris: Maisonneuve et Larose; 2007. ISBN: 978-2-7068-1954-4. 256.
- [10] Lakier JB. Smoking and cardiovascular disease. *Am J Med* 1992;93:8–12.
- [11] Hecht S. Tobacco smoke carcinogens and lung cancer. *J Natl Cancer Inst* 1999;91:1194–210.
- [12] US Department of Health and Human Services. The health consequences of smoking: nicotine addiction. A report of the Surgeon General, 1988. Rockville, Maryland: Public Health Service, Centers for Disease Control, Office on Smoking and Health; 1988. DHHS Publication No. (CDC) 88-8406.
- [13] Shihadeh A. Investigation of mainstream smoke aerosol of the argileh water pipe. *Food Chem Toxicol* 2003;41:143–52.
- [14] Nafae A, Misra SP, Dhar SN, et al. Bronchogenic carcinoma in Kashmir Valley. *Indian J Chest Dis* 1973;15:285–95.
- [15] Lubin JH, Qiao YL, Taylor PR, et al. Quantitative evaluation of the radon and lung cancer association in a case control study of Chinese tin miners. *Cancer Res* 1990;50:174–80.
- [16] Gupta D, Boffetta P, Gaborieau V, et al. Risk factors of lung cancer in Chandigarh, India. *Indian J Med Res* 2001;113:142–50.
- [17] Rakower J, Fatal B. Study of narghile smoking in relation to cancer of the lung. *Br J Cancer* 1962;16:1–6.
- [18] El-Hakim IE, Uthman MAE. Squamous cell carcinoma and keratoacanthoma of the lower lip associated with "Goza" and "Shisha" smoking. *Int J Dermatol* 1999;38:108–10.
- [19] Roohullah, Nusrat J, Hamdani SR, et al. Cancer urinary bladder - 5-year experience at Cenar Quetta. *J Ayub Med Coll Abbottabad* 2001;13:14–6.
- [20] Bedwani R, el-Khwsy F, Renganathan E, et al. Epidemiology of bladder cancer in Alexandria, Egypt: tobacco smoking. *Int J Cancer* 1997;73:64–7.

- [21] Gunaid AA, Sumairi AA, Shidrawi RG, et al. Oesophageal and gastric carcinoma in the Republic of Yemen. *Br J Cancer* 1995;71:409–10.
- [22] Onder M, Oztas M, Arnavut O. Nargile (Hubble-Bubble) smoking-induced hand eczema. *Int J Dermatol* 2002;41:771–2.
- [23] Szyper-Kravitz M, Lang R, Manor Y, et al. Early invasive pulmonary aspergillosis in a leukemia patient linked to aspergillus contaminated marijuana smoking. *Leuk Lymphoma* 2001;42:1433–7.
- [24] El-Barrawy MA, Morad MI, Gaber M. Role of *Helicobacter pylori* in the genesis of gastric ulcerations among smokers and non-smokers. *East Mediterr Health J* 1997;3:316–21.
- [25] Yadav JS, Thakur S. Genetic risk assessment in hookah smokers. *Cytobios* 2000;101:101–13.
- [26] Mazen A, Arabia S. The effect of Maassel water-pipe smoking vs. cigarette smoking on pulmonary arterial pressure and left ventricular and right ventricular function indices in COPD patients: an echo-Doppler. *Sci J Al Azhar Med Fac (Girls)* 2002;24:649–86.
- [27] Reis O. Tobacco agriculture. *The Bulletin of Tobacco Experts' Company* 1996;30:4–6.
- [28] Akkoyunlu ZS. Investigations on tobacco. *Reports of Tobacco Institute* 1944; 113–35.
- [29] Gold WM. Pulmonary function testing. In: Murray JF, Nadel JA, editors. *Textbook of respiratory medicine*. 1st vol 2nd ed. Philadelphia: W.B. Saunders Company; 1994. p. 798–900.
- [30] Wolfram RM, Chehne F, Oguogho A, et al. Narghile (water pipe) smoking influences platelet function and (iso-) eicosanoids. *Life Sci* 2003;74:47–53.
- [31] Sharma RN, Deva C, Behera D, et al. Reactive oxygen species formation in peripheral blood neutrophils in different types of smokers. *Indian J Med Res* 1997;106:475–80.
- [32] Köseoglu N, Aydin A, Uçan ES, et al. The effects of water-pipe, cigarette and passive smoking on mucociliary clearance. *Tuber Toraks* 2006;54:222–8.
- [33] Al-Fayez SF, Salleh M, Ardawi M, et al. Effects of sheesha and cigarette smoking on pulmonary function of Saudi males and females. *Trop Geogr Med* 1988;40:115–23.
- [34] Bayindir U, Uçan ES, Sercin B, et al. Effect of waterpipe smoking on peak expiratory flow rate. *Eur Respir J* 1993;6:608 [Abstract].
- [35] Altinisik G, Uçan ES, Akpinar O. Effects of waterpipe smoking on pulmonary functions. *Eur Respir J* 1995;8:233.
- [36] Hamada G, Radwan G, Israel E, et al. Pulmonary dysfunction from large airway vs. small airways among waterpipe smokers. Poster presented at the 11th annual meeting of the Society for Research on Nicotine and Tobacco; 2005 [Abstract].
- [37] Hamada G, Radwan G, Zakaria M, et al. Is peak expiratory flow a good indicator for assessing airway obstruction in waterpipe smokers? Poster presented at the 11th annual meeting of the Society for Research on Nicotine and Tobacco; 2005 [Abstract].
- [38] Tamim H, Terro A, Kassem H. Tobacco use by university students Lebanon, 2001. *Addiction* 2003;98:933–9.
- [39] Maziak W, Rastam S, Eissenberg T, et al. Gender and smoking status-based analysis of views regarding waterpipe and cigarette smoking in Aleppo Syria. *Prev Med* 2004;38:479–84.
- [40] Gad RR, El-Setouhy M, Haroun A, et al. Nicotine dependence among adult male smokers in rural Egypt. *J Egypt Soc Parasitol* 2003;33:1019–30.
- [41] Pellegrino R, Viegi G, Brusasco V, et al. Série du groupe de travail ATS/ERS : « standardisation des explorations fonctionnelles respiratoires » : stratégies d'interprétation des explorations fonctionnelles respiratoires. *Rev Mal Respir* 2006;23:17579–S117.
- [42] Zahran FM, Baig MHA. Long term effects of sheesha and cigarette smoking on respiratory system in Saudi Arabia. In: *Proceeding of the seventh Saudi Medical Meeting*. 1982. p. 160–5.
- [43] Chaouachi K. Narghile (Hookah Shisha) and Public Health. *Tabaccologia* 2006;4:29–38.
- [44] Jencek M, Cleroux R. *Épidémiologie: principes techniques. Applications*. Paris: Edisem inc., Maloigne; 1982, 430 p.
- [45] El-Zahaby MM, Salem ES, Galeb H. Studies on the effect of Goza smoking sublimates on the tonicity of the bronchial tree. *Egypt J Chest Dis Tubercul* 1980;23:23 [Abstract].
- [46] Ferris BG. Epidemiology standardization project II: recommended respiratory disease questionnaires for use with adults and children in epidemiological research. *American Thoracic Society. Am Rev Respir Dis* 1978;118:1–120.
- [47] Fakhfakh R, Hsairi M, Maalej M, et al. Tobacco use in Tunisia: behaviour and awareness. *Bull World Health Organ* 2002;80:350–6.
- [48] ERS/European Respiratory Society. Standardized lung function testing. *Eur Respir J* 1993;6:1–100.
- [49] ATS/American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. *Am Rev Respir Dis* 1991;144:1202–18.
- [50] Stoks J, Quanjer PH. Reference values for residual volume, functional residual capacity and total lung capacity. *ATS workshop on lung volume measurements Official statement of the European Respiratory Society Eur Respir J* 1995;8:492–506.
- [51] Morris JF, Temple W. Spirometric "lung age" estimation for motivating smoking cessation. *Prev Med* 1985;14:655–62.
- [52] World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO Consultation on obesity. Geneva, 3–5 june 1997; 1998 [WHO/NUT/NCD/98.1].
- [53] Tabka Z, Hassayoune H, Guenard H, et al. Spirometric reference values in a Tunisian population. *Tunis Med* 1995;73:125–31.
- [54] Miller MR, Hankinson J, Brusasco V, et al. Série du groupe de travail ATS/ERS : « standardisation des explorations fonctionnelles respiratoires » : standardisation de la spirométrie. *Rev Mal Respir* 2006;23:17523–S117.
- [55] Wanger J, Clausen JL, Coates A, et al. Série du groupe de travail ATS/ERS : « standardisation des explorations fonctionnelles respiratoires » : standardisation de la mesure des volumes pulmonaires. *Rev Mal Respir* 2006;23:17547–S117.
- [56] Miller MR, Crapo R, Hankinson J, et al. Série du groupe de travail ATS/ERS : « standardisation des explorations fonctionnelles respiratoires » : considérations générales sur les explorations fonctionnelles respiratoires. *Rev Mal Respir* 2006;23:17511–S117.
- [57] Berry G. Longitudinal observations, their usefulness and limitations with special reference to the forced expiratory volume. *Bull Physiopathol Respir* 1974;10:643–55.
- [58] Ganguli M, Lytle ME, Reynolds MD, et al. Random vs. volunteer selection for community-based study. *J Gerontol A Biol Sci Med Sci* 1998;53:39–46.
- [59] Dore MF, Orvoen-Frija E. Respiratory function in the obese subject. *Rev Pneumol* 2002;58:73–81.
- [60] Shihadeh A, Saleh R. Polycyclic aromatic hydrocarbons, carbon monoxide, "tar", and nicotine in the mainstream smoke aerosol of the narghile water pipe. *Food Chemical Toxicol* 2005;43:655–61.
- [61] Shihadeh A, Azar S, Antonius C, et al. Towards a topographical model of narghile water-pipe café smoking. *Biochem Pharmacol Behav* 2004;79:75–82.
- [62] Sajid KM, Akhter M, Malik GQ. Carbon monoxide fractions in cigarette and hookah (hubble bubble) smoke. *J Pak Med Assoc* 1993;43:179–82.
- [63] American Thoracic Society. Standardization of spirometry 1987 update. *Am Rev Respir Dis* 1987;136:1285–307.
- [64] Crapo RO. Role of reference values in making medical decisions. *Indian J Med Res* 2005;112:100–2.
- [65] Aggarwal AN, Gupta D, Behera D, et al. Comparison of fixed percentage method and lower confidence limits for defining

- limits of normality for interpretation of spirometry. *Respir Care* 2006;51:737–43.
- [66] <http://www.who.int/icidh> (visité le 14/03/2008).
- [67] Shafagoj YA, Mohammed FI. Levels of maximum end-expiratory carbon monoxide and certain cardiovascular parameters following hubble-bubble smoking. *Saudi Med J* 2002;23:953–8.
- [68] Zahran FM, Ardawi MS, Al-Fayez SF. Carboxyhemoglobin concentrations in smokers of sheesha and cigarettes in Saudi Arabia. *Br Med J* 1985;291:1768–70.
- [69] MacIntyre N, Crapo RO, Viegi G, et al. Série du groupe de travail ATS/ERS : « standardisation des explorations fonctionnelles respiratoires » : standardisation de la détermination de la diffusion du monoxyde de carbone par la méthode en apnée. *Rev Mal Respir* 2006;23:17561–5117.
- [70] Zakaria M, Radwan G, Mohamed M, et al. Who ends up with COPD among smokers in a community setting? Poster presented at the 11th annual meeting of the Society for Research on Nicotine and Tobacco; 2005 [Abstract].
- [71] Viegi G, Pedreschi M, Pistelli F, et al. Prevalence of airways obstruction in a general population: European Respiratory Society vs American Thoracic Society definition. *Chest* 2000;117:5339–45.
- [72] Pena VS, Miravittles M, Gabriel R, et al. Geographic variations in prevalence and underdiagnosis of COPD: results of the IBERPOC multicenter epidemiological study. *Chest* 2000;118:981–9.
- [73] Hogg JC, Wright JL, Wiggs BR, et al. Lung structure and function in cigarette smokers. *Thorax* 1994;49:473–8.
- [74] Konstantin S, Xiaomei L, Morton L. Effect of nickel and iron co-exposure on human lung cells. *Toxicol Appl Pharmacol* 2004;196:258–65.
- [75] Lipkus IM, Prokhorov AV. The effects of providing lung age and respiratory symptoms feedback on community college smokers' perceived smoking-related health risks, worries and desire to quit. *Addict Behav* 2007;32:516–32.
- [76] Jefferey PK. Comparison of the structural and inflammatory features of COPD and asthma. *Chest* 2000;117:5251–60.
- [77] Turato G, Zuin M, Saetta M. Pathogenesis and pathology of COPD. *Respiration* 2001;68:117–28.
- [78] Radwan GN, Mohamed MK, El-Setouhy M, et al. Review on waterpipe smoking. *J Egypt Soc Parasitol* 2003;33:1051–71.
- [79] Hoffmann D, Hoffmann I. Letters to the tobacco smoke components. *Beitr Tabakforsch Int* 2000;18:49–52.