Waterpipe effects on pulmonary function and cardiovascular indices: a comparison to cigarette smoking in real life situation

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Abstract

Introduction: Smoking is known to have physiological effects on biological systems. The purpose of this study is to evaluate acute and chronic effects on pulmonary functions and cardiovascular indices of waterpipe (WP) smoking in real life circumstances.

Methods: Three groups were included in the study: non-smokers (N = 42), WP smokers (N = 42) and cigarette smokers (N = 48). A questionnaire was completed for each participant, in addition to pulmonary function [forced expiratory volume at 1 s (FEV1), 6 s (FEV6), percentage of FEV1/FEV6], and cardiovascular [diastolic blood pressure (DBP), systolic blood pressure (SBP) and heart rate (HR)] measures, taken before and after smoking.

Results: Mean values of FEV1, FEV6, FEV1/FEV6, DBP and SBP in WP and cigarette smokers were very close. However, WP smoking significantly increased HR compared to cigarette smokers (p = 0.007); duration of smoking, age at first WP and quantity of smoking affected pulmonary function and cardiovascular values. In the subgroup of WP smokers, DBP was acutely increased by a larger WP size (p = 0.011), while the FEV6 was acutely increased by a smaller WP size (p = 0.045).

Conclusion: WP smoking affected the cardiovascular system more than cigarette smoking, while it had similar effects on pulmonary function.

Keywords
Blood pressure, cigarette, heart rate, pulmonary function, WP

Introduction
Tobacco consumption is one of the leading causes of deadly diseases in the world (World Health Organization, 2008), with causal associations clearly established between active cigarette smoking, chronic obstructive pulmonary and cardiovascular diseases [International Agency for Research against Cancer (IARC), 2002]. The global surveillance effort shows that whereas cigarette smoking is showing either stable or declining trends globally, other forms of tobacco use are showing a rising trend, particularly among youth (Chaaya et al., 2004; El-Roueiheb et al., 2008; Waked et al., 2009).

WP smoking characteristics are being studied nowadays. An important difference between cigarette and WP smoking is the combustion: in a cigarette, tobacco burns at several hundred degrees Celsius, while in a WP; tobacco is heated at temperatures <200°C. In addition, a filtration and cooling of smoke takes place in the WP (Varsano et al., 2003). WP smoking is however an efficient means of delivering toxicants to the smoker; researches reveal that, relative to a single cigarette, a single WP session exposes the smoker to 3–9 times the CO and 1.7 times the nicotine (Eissenberg & Shihadeh, 2009). One experimental study was conducted in Beirut, showing that in vitro collected smoke of 100 puffs of WP contained nicotine, tar and heavy metals in alarming quantities, in some cases exceeding several fold those found in a single cigarette (Harfouche et al., 2003; Maziak et al., 2009). Given that WP smoke contains many of the same toxicants as cigarette smoke, it may theoretically carry similar health risks to smoking cigarettes (Prignot et al., 2008): cardiovascular diseases due to carbon monoxide (CO), lung diseases due to volatile aldehydes, cancer related to polycyclic aromatic hydrocarbons and nicotine dependence (Shihadeh & Saleh, 2005).
Experimental studies showed impairment of pulmonary function on spirometry (El-Nachef & Hammond, 2008), increased pulmonary epithelial permeability (Eissenberg & Shihadeh, 2009) and in terms of cardiovascular response, two laboratory studies demonstrate that WP tobacco smoking produced cardiovascular changes (Akl et al., 2010; World Health Organization, 2005). However, experimental studies and smoking machines have been criticized as not representing real life circumstances (Chaouachi, 2006, 2009). While there is a growing literature investigating WP smoke toxicant content and exposure, relatively few studies have examined the acute effects of WP tobacco smoking in natural environments. One of such studies on WP smokers in Lebanon has demonstrated that WP smokers, like cigarette smokers, were exposed to nicotine and CO. Thus, nicotine is not filtered by water in the bottle where smoke passes, and WP smokers were exposed to harmful levels of CO (Aoun Bacha et al., 2007). A recent study by St Helen et al. (2014) confirmed the exposure to nicotine and other carcinogens.

The objective of this study was to further compare the acute and chronic effects of WP smoking on respiratory function and cardiovascular indices in real life circumstances of Lebanese WP smokers, compared to cigarettes smokers and non-smokers.

Materials and methods

Study design

This study compared measures before and after smoking among WP and cigarette smokers, with a negative control group of non-smokers. This study was carried out between March 2013 and June 2013, at restaurants in Beirut and Mt Lebanon. The Lebanese University waived approval of the study since it is an observational non-invasive study that respects participants’ autonomy and anonymity; the study followed principles of the Declaration of Helsinki for such types of studies (World Medical Assembly, 2008).

Study population

The inclusion criteria included being Lebanese, aged ≥18 years and a regular WP smoker (defined as current smoking of ≥1 WP per week) or a regular cigarette smoker (defined as currently smoking ≥1 cigarette per day) or a non-smoker. We excluded mixed smokers of WP and cigarettes from our study.

Procedure

We implemented the testing process at restaurants in Beirut and Mt Lebanon where smoking cigarettes and WP are allowed. We explained the objective of the study to the participants, and they gave an oral consent. The WP tobacco smoked was only of the “muassel” type, which is a mixture of tobacco and glycerol, to which several flavors could be added (Chaouachi, 1999). The charcoal used was of the commercially available quick-lighting type. The WP smoking session typically lasted 60–90 min; during this time, the smoker usually takes 50–200 puffs, ranging from ~0.15–1 L each (Shihadeh et al., 2004). According to their will, smokers were free to smoke a WP alone or to share it with up to three other persons. In all cases, 20 g of tobacco were used. On another hand, cigarette smokers were allowed to choose the brand they wanted, with no filter. In such a natural environment, both cigarette and WP have been previously demonstrated to give similar nicotine metabolite measurement (Aoun Bacha et al., 2007).

Before smoking started, subjects underwent a first spirometry using a vitalograph (COPD-6 Model 4000®, Vitalograph Ltd, North Buckinghamshire, UK), allowing us to evaluate their forced expiratory volume at 1 s (FEV1), 6 s (FEV6) and FEV1/FEV6 ratio. The latter measure is now considered an excellent predictor of lungs obstruction, even better than FEV1/FVC (forced vital capacity) (Bhatt et al., 2014). Moreover, we measured their systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR), using a tensiometer (Beurer BM16®; Beurer GmbH, Ulm, Germany). The second spirometric and tensiometric measurements were taken 45 min after the beginning of smoking the WP, or after one cigarette. Measurements were conducted by two trained technicians. For all measurements, the highest value out of three trials was taken into account; difference between first and second value, termed delta (Δ), was also calculated for all measurements. Non-smokers had the same measurements once.

In addition, a questionnaire using questions from the standardized questionnaire of the American Thoracic Society was given to all participants (Ferris, 1978). The questionnaires were administered in Arabic local language; details about the translation process were presented in a study conducted by Waked et al. (2009).

Statistical analysis

Data entry and analysis were performed on SPSS software (version 17.0; SPSS Inc., Chicago, IL). A p value of ≤0.05 was considered significant. For quantitative variables, the independent-sample t-test was used when comparing two groups, while the one-way analysis of variance and Kruskal–Wallis test were used when comparing three groups when applicable. For categorical variables, the χ² and Fisher exact tests were used when applicable.

When all measurements were introduced in the same global model, introduced covariates were age, height in centimetres, duration of living in a house close to a heavy traffic road, duration of living in a house close to an electricity generator, passive smoking indoor, passive smoking at work, education, work situation and city of residence. The independent variables of interest were: age of first WP, duration of smoking WP in years, number of WP per week, age of first cigarette, duration of smoking a cigarette in years and number of cigarettes per day.

In addition, multiple regressions were performed for subgroup analysis. For WP smokers, variables introduced in the model were the following: age of first WP, duration in years of smoking WP, number of WPs per week, height of individual, WP size (small, medium and large), number of persons with whom he or she was sharing the WP with and the number of persons he or she was passively exposed to; in addition, work situation, education, marital status, sex and city residence were taken into account. For cigarette
smokers, we took as independent variables the number of cigarettes per day, duration in years of smoking cigarette, age of first cigarette, smokers at work, work situation, eating vegetables and fruits, height, age, sex and city of residence.

Results

One hundred thirty-two persons participated in the study: non-smokers ($n = 42$), WP smokers ($n = 42$) and cigarette smokers ($n = 48$).

Baseline characteristics of study participants

Sociodemographic characteristics of the three groups' individuals are presented in Table 1. There was a gender difference between the three groups of comparison ($p = 0.008$), but no gender difference between the two groups of smoking and a trend was visible toward more smoking in males than females, for both WP and cigarette. WP smokers were relatively younger than cigarette smokers and non-smokers ($p = 0.01$), while there were no differences in height and weight ($p > 0.05$).

There were significantly more smokers indoor in the group of cigarette smokers (66.7%) in comparison with other groups ($p = 0.028$). The percentage of WP and cigarette smokers who worked was 85.7 and 68.8%, respectively, while non-smokers who worked were 50% ($p = 0.002$). There were significantly more family smokers that individuals were passively exposed to among cigarette smokers (54.2%) and WP smokers (40.5%) than non-smokers (23.8%) ($p = 0.014$). There was no significant difference in the city of residence between the three groups of smoking ($p = 0.178$) but a trend was visible toward more city residence in cigarette smokers (81.3%) than in WP smokers (64.3%) ($p = 0.069$).

Smoking characteristics and measurement values

Smoking characteristics for WP smokers are reported in Table 2. The mean number of WP smoked per week is $11.12 \pm 17.27$ and the mean time elapsed from the last WP was $48.7 \pm 65.73$ h. For cigarette smokers, a mean of $25.25 \pm 12.95$ cigarettes per day was smoked. Moreover, 29.16% cigarette smokers had an obstruction index of 1 ($\% FEV_1^{\text{pred}} \leq 80\%$; pred, predicted), 4.16% had an obstruction index of 2 ($\% FEV_1^{\text{pred}} \leq 50\%$) and 2.08% had an obstruction index of 3 ($\% FEV_1^{\text{pred}} \leq 30\%$), compared with 42.85% of WP smokers had an obstruction index of 1 ($\% FEV_1^{\text{pred}} \leq 80\%$) and 26.19% of non-smokers had an obstruction index of 1 ($\% FEV_1^{\text{pred}} \leq 80\%$). The rest of individuals had no obstruction.

There were significant differences in $FEV_{6\text{ac}}/FEV_6^{\text{pred}}$ (ac, actual) and HR values, but a trend to significance was seen in $FEV_1/FEV_6$ ratio and DBP values. Before smoking, for $FEV_1/FEV_6$ ratio, non-smokers had the lowest levels (110.14), cigarette smokers intermediate levels (111.42), while WP smokers had the highest levels (115.71) ($p = 0.05$); for $FEV_{6\text{ac}}/FEV_6^{\text{pred}}$, non-smokers had the highest levels (82.9) versus WP smokers (73.83) and cigarette smokers (70.34).

Table 1. Sociodemographic characteristics of smokers and non-smokers in Lebanon.

| Variable                  | Type of smoker |   |   |   |   |   |
|---------------------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                           | Non-smokers ($N = 42$) n (%) | WP smokers ($N = 42$) n (%) | Cigarette smokers ($N = 48$) n (%) | $p$ Value (three groups) | $p$ Value (cigarette versus WP) | Total ($N = 132$) n (%) |
| Sex                       | Male           | 20 (47.6)       | 33 (78.6)       | 34 (70.8)       | 0.008           | 0.401           | 87 (65.9)       |
|                           | Female         | 22 (52.4)       | 9 (21.4)        | 14 (29.2)       | 0.13            | 0.161           | 45 (34.1)       |
| Marital status            | Married        | 23 (54.8)       | 14 (33.3)       | 23 (47.9)       | 0.13            | 0.161           | 60 (45.5)       |
|                           | Unmarried      | 19 (45.2)       | 28 (66.7)       | 25 (52.1)       | 0.084           | 0.029           | 72 (54.5)       |
| Education                 | Low            | 21 (50)         | 14 (33.3)       | 27 (56.3)       | 0.084           | 0.029           | 62 (47)         |
|                           | High           | 21 (50)         | 28 (66.7)       | 21 (43.8)       | 0.084           | 0.029           | 70 (53)         |
| Work situation            | Not working    | 21 (50)         | 6 (14.3)        | 15 (31.3)       | 0.002           | 0.058           | 42 (31.8)       |
|                           | Working        | 21 (50)         | 36 (85.7)       | 33 (68.8)       | 0.002           | 0.058           | 90 (68.2)       |
| Residence                 | City           | 29 (69)         | 27 (64.3)       | 39 (81.3)       | 0.178           | 0.069           | 95 (72)         |
|                           | Village        | 13 (31)         | 15 (35.7)       | 9 (18.8)        | 0.178           | 0.069           | 37 (28)         |
| Smoking family            | ≤1 person      | 32 (76.2)       | 25 (59.5)       | 22 (45.8)       | 0.014           | 0.195           | 79 (59.8)       |
|                           | >1 person      | 10 (23.8)       | 17 (40.5)       | 26 (54.2)       | 0.014           | 0.195           | 53 (40.2)       |
| Smoking indoor            | No             | 25 (59.5)       | 23 (54.8)       | 16 (33.3)       | 0.028           | 0.041           | 64 (48.5)       |
|                           | Yes            | 17 (40.5)       | 19 (45.2)       | 32 (66.7)       | 0.028           | 0.041           | 68 (51.5)       |
| Mean (SD)                 | Age (years)    | 34.64 (14.09)   | 29.26 (9.78)    | 36.04 (14.54)   | 0.09            | 0.01            | 33.44 (13.29)   |
|                           | Height (cm)    | 170.9 (8.94)    | 175.4 (8.02)    | 173.46 (8.80)   | 0.055           | 0.411           | 173.47 (8.80)   |
|                           | Close to road$^a$ | 16.88 (17.83)   | 7.7 (10.14)     | 13.6 (16.79)    | 0.037           | 0.045           | 12.77 (15.70)   |
|                           | Close to generator$^b$ | 9.78 (9.17)   | 5.02 (7.77)     | 8.79 (10.31)    | 0.03            | 0.052           | 7.90 (9.35)     |

$^a$Duration in years of living in a house close to a road (<100 m). $^b$Duration in years of living in a house close to an electrical generator (<100 m). SD, standard deviation.
smokers (76.08) \( (p = 0.01) \). For DBP \( (p = 0.05) \) and HR \( (p = 0.02) \), non-smokers had the lowest levels versus WP and cigarette smokers. However, the difference between the two types of smokers did not reach statistical significance.

According to the variables mentioned previously, there was a major variation in selective results pre- and post-smoking a WP or a cigarette. There was a trend to significant acute variation between the three groups for DBP \( (p = 0.05) \) and a significant variation for HR \( (p < 0.001) \): DBP increased in WP smokers while it decreased in cigarette smokers. However, the HR increased in both WP and cigarette smokers after the smoking session, but much more with WP. With respect to \( \Delta FEV_{1ac}/FEV_{1pre} \) \( (p = 0.07) \), \( \Delta FEV_{6ac}/FEV_{6pre} \) \( (p = 0.07) \), \( \Delta FEV_{6}/FEV_{6} \) ratio \( (p = 0.56) \) and \( \Delta SBP \) \( (p = 0.13) \), there was no significant variation between the three groups before and after smoking. However, there was a significant decrease for \( \Delta FEV_{6ac}/FEV_{6pre} \) \( (p = 0.04) \) in the subgroup of WP versus non-smokers.

### Multivariate analysis

FEV\(_{1}/FEV_{6}\) ratio decreased significantly \( (p = 0.003) \) with a younger age of first WP, i.e. a longer duration of smoking WP, similarly, \( FEV_{1ac}/FEV_{1pred} \) ratio was also proportional to the age of first WP and inversely proportional to the duration of cigarette smoking. In addition, the long duration of smoking WP significantly increased \( \Delta HR \) \( (p = 0.01) \) and the high number of WP significantly increased \( \Delta DBP \) \( (p < 0.001) \).

FEV\(_{6ac}/FEV_{6pred} \) pre- and post-smoking were significantly decreased with a high age at first WP smoking \( (p = 0.007 \) and \( p < 0.001 \), respectively) and a longer duration of smoking a cigarette in years \( (p = 0.027 \) and \( p < 0.001 \), respectively). Moreover, \( \Delta FEV_{6ac}/FEV_{6pre} \) \( (p = 0.007) \) was significantly lower with a longer duration of smoking cigarette in years, while a higher \( \Delta FEV_{6ac}/FEV_{6pre} \) \( (p < 0.001) \) was significantly associated with a high number of cigarettes per day.

In the WP subgroup (Table 4), prior to smoking, a higher FEV\(_{1ac}/FEV_{1pred} \) was significantly related to young age at first WP smoking \( (p = 0.017) \). \( \Delta FEV_{6ac}/FEV_{6pred} \) was mainly decreased by the small size of the head of a WP \( (p = 0.045) \). \( \Delta DBP \) was mainly increased by the high number of WP per week \( (p = 0.004) \) and with the smaller size of the head of a WP \( (p = 0.011) \). A younger age at first WP smoking was significantly associated with higher \( \Delta HR \) \( (p = 0.001) \).

For cigarette smokers, a longer duration of smoking cigarettes per year was significantly responsible for lower levels of FEV\(_{1ac}/FEV_{1pred} \) pre- \( (0.003) \) and post-smoking \( (p = 0.001) \) and lower FEV\(_{6ac}/FEV_{6pred} \) post-smoking \( (p = 0.008) \). While the high number of cigarette was significantly associated with higher \( \Delta FEV_{ac}/FEV_{1pred} \) \( (p = 0.003) \) and \( \Delta FEV_{6ac}/FEV_{6pred} \) \( (p = 0.033) \).

### Discussion

We demonstrated in our study that WP smoking, like cigarette smoking, affected lung function tests and cardiovascular indices. For the percentage of FEV\(_{1ac}/FEV_{1pred} \), we found that mean levels in WP and cigarette smokers in
FEV1ac/FEV1pre was similar between the two groups of cigarette and WP smokers (87.3 ± 14.23). Raad et al. (2011) had demonstrated that FEV1 were close and lower than that of non-smokers (96.82 ± 8.19 for non-smokers). As FEV6 is a measure of forced expiratory volume in 6 seconds (FEV6), it is also possible to calculate FEV6ac/FEV6pre, which is the acute change in FEV6 post-smoking versus others. These outcomes might be due to our young sample of WP smokers. It is also possibly attributable to the enlargement of airways of the lung in WP smokers in some individuals. Similarly, Kiter et al. (2000) showed a higher FEV6ac/FEV6pre among WP smokers (98.16 ± 13.28 versus 96.82 ± 8.19 for non-smokers).

For the percentage of FEV1ac/FEV1pred in the chronic measurements, we found that mean levels among smokers were close and lower than those of non-smokers (87.3 ± 14.23). Raad et al. (2011) had demonstrated that FEV1 was similar between the two groups of cigarette and WP smoking.

Our results for non-smokers were close to what found Al-Fayez et al. (1988), where FEV1ac/FEV1pred were 88.43 ± 6.4 and 87.06 ± 9.08, respectively (Al-Fayez et al., 1988). Mean values of FEV1 in smokers were in the normal range, possibly due to the young mean age of individuals. A post-smoking decrease in FEV1ac/FEV1pred of 1.21 ± 8.7 was shown in WP smoking versus an increase of 0.64 ± 7.51 in cigarette smokers. This acute effect of smoking contradicted results of Kiter et al. (2000), who demonstrated that pulmonary function test parameters (such FEV1, FEV6 and FEV1ac/FEV6bc), standard for defining airway obstruction, was more significantly affected in cigarette smoker than WP smokers, when compared to non-smokers (Kiter et al., 2000). However, similar to our results, Blank et al. (2011) reported a decrease in FEV1 from pre- to post-smoking in a single 45 min smoking episode of WP. Furthermore, several previous studies showed a reduction of different values of pulmonary function tests among smokers compared to normal subjects (Aparici et al., 1993; Aydin et al., 2008; Bosken et al., 1990; Eidelman et al., 1989; Lange et al., 1989; Lubinski et al., 2000; Nemery et al., 1982; Prokhorov et al., 1996; Welty et al., 1984).

The FEV1ac/FEV1pred was found to be accurate and reliable for diagnosing airways obstruction in large groups of patients (Swanney et al., 2000). We found that all FEV1ac/FEV1pred values in chronic and acute measurements in the three groups were >80%; they were significantly higher among WP smokers versus others. These outcomes might be due to our young sample of WP smokers. It is also possibly attributable to the enlargement of airways of the lung in WP smokers in some individuals. Similarly, Kiter et al. (2000) showed a higher FEV1ac/FEV1pred among WP smokers (98.16 ± 13.28 versus 96.82 ± 8.19 for non-smokers).

For the percentage of FEV1ac/FEV1pred in the chronic measurements, we found that mean levels among smokers were close and lower than those of non-smokers. As FEV6 is a standard for defining airway restriction, and since the decrease sharpens in post-smoking setting for WP (ΔFEV6ac/FEV6pred = 2.28 ± 7.25), versus an increase in pre–post smoking in cigarette smokers (ΔFEV6ac/FEV6pred = −0.81 ± 11.79), we may conclude that these results contradict the common belief that the water of the WP renders the smoke harmless (Kiter et al., 2000), and confirm what was already proven experimentally (Harfouche et al., 2003; Shihadeh & Saleh, 2005).

Comparing WP to cigarette smoking, there was no statistically significant difference for all the pulmonary function variables in chronic and acute measures, except for FEV1ac/FEV1pred post-smoking. A meta-analysis of six cross sectional studies reported that there was no statistically significant in FEV1, FVC and FEV1ac/FVC with methodological limitations (Raad et al., 2011). Indeed, recent evidence has shown that water does not significantly filter out the nicotinic products produced by WPs (Neergaard et al., 2007).
Consequently, WP smokers seem as affected as cigarette smokers for the pulmonary functions values.

Our results also revealed that all cardiovascular indices (HR, DBP and SBP) were higher than those of non-smokers. Two studies, on 20 and 202 male healthy volunteers smoking WP, reported significant increases in HR, SBP and DBP levels (Al-Kubati et al., 2006; Shaikh et al., 2008). A similar increase in HR and BP levels were also reported for cigarette smoking (Shaikh et al., 2008). These hemodynamic changes were suggested to be mediated by nicotine, which activated the sympathetic nervous system with a release of norepinephrine, epinephrine and vasopressin, or by nicotine’s direct effect on the endothelium (Shaikh et al., 2008). It was shown that sympathetic stimulation in cigarette smokers contributes to cardiovascular morbidity and mortality (Shaikh et al., 2008). These physiological changes might also be related to CO concentrations changes (Stieb et al., 2009), the latter being shown to be higher for WP in comparison with cigarette in such a natural environment circumstance (Aoun Bacha et al., 2007).

For the pre–post variations (acute effect) on DBP and SBP, our study demonstrated an increase in SBP and a significant increase in DBP for WP smoking. Cobb et al. (2012) indicated that WP smoking acutely compromised cardiac autonomic function. Oppositely, we demonstrated a decrease in SBP and DBP for cigarette smokers. This is possibly a consequence of depressant effects played chronically by ephrine, epinephrine and vasopressin, or by nicotine’s direct effect on the endothelium (Shaikh et al., 2008). Moreover, an increase in HR levels was shown in both groups: 7.09 ± 9.88 beats per minute (bpm) for WP smokers (p < 0.001) and 0.28 ± 13.15 bpm for cigarette smokers. These results were similar to the study conducted by Eissenberg & Shihadeh (2009) that indicated an increase on average of HR (6 bpm) in a single 45 min WP smoking episode.

The differences in reduction of different PFT values in different studies could be due to the age of studied population, duration of smoking and quantity of smoking (Buijt et al., 1995). For the predictors of lung function tests, we found results similar to Buijt et al. (1995) (Table 3): a significant decrease of FEV1 chronic (β = −0.386; p < 0.001) and acute effect: (β = −0.451; p < 0.001) and FEV6 chronic (β = −0.252; p = 0.027) and acute effect (β = −0.372; p < 0.001) with a long duration of smoking cigarettes. Boskabady et al. (2003) also indicated a correlation between PFT values and duration of smoking, and established significant negative relationships between duration of smoking with all PFT values: FEV1 (β = −0.282; p < 0.001) and FEV6 (β = −0.224; p < 0.01) (Boskabady et al., 2011).

However, our study has shown no correlation between the duration of smoking WP per se and acute decline in FEV1 and other PFT. Two studies reported the same results for FEV1 (Al-Mutairi et al., 2006; Bosken et al., 1990). Nevertheless, we demonstrated a significant decrease of FEV1 acute effect (β = 0.195; p = 0.045) and FEV1/FEV6 acute effect (β = 0.276; p < 0.003) with a younger age of smoking the first WP, showing that FEV1 and FEV6/FEV6 were decreased by smoking a session of WP at an earlier age. In addition, all the variations pre–post smoking (acute effect) on HR (β = 0.253; p = 0.01), DBP (β = 0.396; p < 0.001) and FEV6 (β = 0.525; p < 0.001) were significantly increased by a longer duration of smoking WP, a higher number of WP per week and a higher number of cigarettes, respectively.

In the subgroup of WP smokers, we demonstrated that ΔDBP (β = −0.418; p = 0.011) (acute effect of smoking on DBP) increased with a lower size of the head of WP. In addition, ΔDBP increased with a higher number of WP per week while ΔFEV6 decreased when the size of the head of WP decreased. To our knowledge, this is the first epidemiological study that determined PFT, cardiovascular indices and the link with WP smoking.

There are limitations to this study. Our first difficulty was that we had no way to compare the amounts of smoke inhaled by the subjects in the WP and cigarette groups. Of course, the aim of the study was not to specifically compare this amount (this was done in laboratory studies) (Eissenberg & Shihadeh, 2009; Harfouche et al., 2003; Mazik et al., 2009); we wanted to see what happens in real life, taking mean common exposure into account. This difficulty is unavoidable in studies of the use of tobacco products other than cigarettes (e.g. e-cigarettes, smokeless and dissolvable tobacco products). Furthermore, we showed that there was a dose-effect relationship showing a unit per unit effect (exposure versus effect); the latter concept could overcome the previously described difficulty. We also had no biomarker of exposure, such as nicotine measurement, to confirm the declared exposure of individuals; however, in such natural environment circumstances, the smoking behavior was visible to the investigators, and both cigarette and WP have been previously demonstrated to give similar nicotine metabolite measurement, as stated above (Aoun Bacha et al., 2007). Moreover, the clinical significance of the physiological changes that we found cannot be ascertained; a prospective study would be necessary to evaluate whether the observed changes would have deleterious effect on health.

The response rate in the present study was 34.1% for women versus 65.9% for men. The main reason for non-response was linked to non-motivation, ignorance or maybe due to disease status that women did not want to reveal. There is also a possibility of information bias due to the methods we used, such as the standardized questionnaire that might involve a recall bias (for smoking history and passive smoking reporting) or a subjectivity bias (for weight and height). Furthermore, there is a possibility of a classification bias due to the portable spirometer used that may not be as sensitive as the one that are used in hospitals. However, these errors are expected to be non-differential. In addition, we could have missed some associations due to the low numbers of individuals per group of comparison. Our data results may also not be generalized to the Lebanese population or to the general worldwide population. Additional studies would be necessary to confirm these results.

**Conclusion**

This is the first study conducted in Lebanon which compares the chronic and acute effect of cigarette and WP smoking on PFT and cardiovascular indices, in real life circumstances. This study indicates that WP smokers seem as affected as cigarette smokers for the pulmonary values and that acute effect of WP increases DBP and SBP; however, acute effect of
cigarette decreases DBP and SBP, while both cigarette and WP smoking increase HR. The reduction of most PFT values could be due to the long duration of smoking, younger age of smoking the first WP and quantity of smoking. It differs between cigarette and WP, and between chronic and acute effect of smoking.

**Declaration of interest**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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