COMPARISON OF PULMONARY FUNCTION TESTING AMONG NON-SMOKERS, HAND-ROLLED CIGARETTE SMOKERS AND FACTORY MADE CIGARETTE SMOKERS

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Abstract. Tobacco use causes significant health problems. The aim of this study was to compare the following factors among factory-made cigarette (FMC) smokers, hand-rolled cigarette (HRC) smokers and non-smokers (NS): demographic characteristics, pulmonary function testing (PFT) and carboxyhemoglobin (COHb) levels. PFT included checking: forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC, forced expiratory flow from 25-75% of the vital capacity (FEF25-75) and peak expiratory flow (PEF). We wanted to determine the impact of smoking on pulmonary function testing and to determine any differences in PFTs and COHb levels between FMC and HRC smokers. A total of 182 participants (all males) were included in the study. The subjects in the study were randomly chosen from emergency service admissions which had complaints other than respiratory system. The mean age of study subjects was 40.8 (range: 22-92) years. Mean age of starting smoking among HRC smokers was not significantly different from FMC smokers (95% CI: -0.55-2.37, p=0.220). HRC smokers had significantly lower economic and education levels than FMC smokers (95% CI: 9.0-45.2, p<0.01). NS had highest economic and educational levels (95% CI: 35.9-66.6, p<0.01) of the 3 study groups. The mean [±standard deviation(SD)] FEV1/FVC was 76.66 (±7.45) among FMC smokers (95% CI: 74.82-78.51), 77.36 (±8.14) among HRC smokers (95% CI: 75.36-79.36) and 83.13 (±5.08) among NS (95% CI: 81.70-84.56, p<0.01). The mean (±SD) FEV1 was 84.50 (±17.80) among FMC smokers (95% CI: 80.12-88.92), 89.4 (±15.8) among HRC smokers (95% CI: 85.56-93.32) and 95.30 (±13.3) among NS (95% CI: 91.59-99.07, p<0.01). The mean (±SD) PEF was 81.90 (±19.30) among HRC smokers (95% CI: 77.19-86.69), 78.10 (±18.70) among FMC smokers (95% CI: 73.47-82.74) and 86.20 (±16.0) among NS (95% CI: 81.70-90.69, p=0.06). The mean FVC, FEV1, FEV1/FVC, FEF25-75%, and PEF values among NS were significantly (p<0.05) higher for each variable than the mean of these values among FMC and HRC smokers. The mean COHb

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level among NS was significantly (p<0.05) lower than the mean COHb levels in the two smoking groups. There were no significant differences in PFT results or COHb levels between the two smoking groups (p>0.05). Cigarette smoking cause impairment of pulmonary function equally independent of the cigarette type (FMC, HRC) smoked.

Keywords: hand rolled cigarette, tobacco, pulmonary functions, carboxyhemoglobin

INTRODUCTION

Tobacco use is associated with 4 million deaths annually worldwide and may kill more than 10 million people per year by 2030 unless preventive measures are taken (Gupta, 2001). In 2008, the World Health Organization (WHO) estimated there were over one billion smokers worldwide (WHO, 2008). In 2008, there were an estimated 16 million smokers (31.3% of the population) in Turkey; three times more men than women smoke (PHIT, 2012). In 2012, the estimated prevalence of smoking in Turkey had decreased from 31.3% to 27.1% due to the adoption of antismoking policies (PHIT, 2012). The prevalence of smoking is declining in developed countries but rising in many developing countries (CDC, 2008).

Tobacco use is associated with a number of serious health problems including: chronic obstructive pulmonary disease (COPD), lung cancer, tuberculosis, stroke, ischemic heart disease, diabetes mellitus and peripheral vascular disease (Gupta, 2001; van Zyl-Smith *et al*, 2013). All tobacco products are unhealthy and addictive. Tobacco smoking, tobacco chewing and mixing tobacco with other ingredients all result in similar health problems (Pednekar, 2008).

Factory made cigarettes (FMC) constitute 96% of all tobacco sales worldwide (Pednekar *et al*, 2011; Gallus *et al*, 2013). According to an International Tobacco Control Center (ITCC) survey conducted in 2002, hand-rolled cigarette (HRC) smoking comprised 28.4% of tobacco sold in the United Kingdom, 24.2% of that sold in Australia, 17.1% of that sold in Canada, 6.7% of that sold in the US, 8.7% of that sold in Spain and 9.7% of that sold in Turkey (Young *et al*, 2006; de Grandá-Orive and Jiménez-Ruiz, 2011; PHIT, 2012).

Some smokers are under the false impression that HRC containing fewer additives are healthier and less addictive than FMC (Laugesen *et al*, 2009). However, one study reported HRC contained higher levels of tar and nicotine than FMC (Fowles, 2008). Possible reasons for HRC use include enjoying the ritual of rolling a cigarette, assuming there is less tobacco in a HRC and the lower cost of HRC (Laugesen *et al*, 2009). In some countries, HRC cost half as much as FMC (Gallus *et al*, 2013).

HRC are commonly smoked in Malatya, Turkey where this study was conducted. The present study aimed to compare the demographic characteristics, pulmonary function test (PFT) results and carboxyhemoglobin (COHb) levels among non-smokers (NS), FMC smokers and HRC smokers. Smoking cause impairment of pulmonary function, but we hypothesized there might be differences in PFT results and COHb levels between HRC and FMC smokers.

MATERIALS AND METHODS

This study was approved by the Inonu University Clinical Research ethics committee (approval no: 2015/94). Informed consent was obtained from all participants prior to inclusion in the study.

The smoking subjects in our study were chosen from patients who presented to the Inonu University Hospital Emergency Department with any complaint other than dyspnea, cough or sputum production and their volunteer companions. The NS in our study were chosen from patients seeking emergency service who had never smoked or been exposed to second hand smoke before. Those with a history of chronic lung or heart diseases were excluded from the study. Only those who had smoked for at least 10 years prior to presentation were included in the smoking groups in our study. Smokers were divided into 2 groups: those who smoked HRC and those who smoked FMC. Only male subjects were included in the study. The following data were obtained from each subject: age, profession, education level, body mass index, age of starting smoking, smoking duration and annual number of cigarettes smoked. HRC smokers do not use packets for cigarattes, so we calculated 20 HRC were equivalent to one pack of FMC.

We measured a carboxyhemoglobin (COHb) level in each subject using a portable device (MasimoSET rainbow Rad-57 Pulse CO-Oximeter, Masimo, Irvine, CA). We performed lung function testing on each subject using a spirometer (Vmax 22: SensorMedics, Yorba Linda, CA). The following measurements were included in the spirometer testing: forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC, forced expiratory flow from 25-75% of the vital capacity (FEF25-75) and peak expiratory flow (PEF).

Statistical analysis included percentages, means, standard deviations (SD) and the chi-square test depending on the type of variable. Distribution of data was assessed with the Kolmogorov-Smirnov test and numerical data were assessed with the one way ANOVA test and the Student's *t*-test. Multiple comparisons were made with the Duncan test. A p-value <0.05 was considered statistically significant. Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS), version 25.0 (IBM, Armonk, NY) and 95% confidence intervals (CI) were calculated using an online calculator (Evan's Awesome-http://www.evanmiller.org/). The associations between PFT results and smoking rate, the age of starting smoking and body mass index were made using Pearson correlation coefficients.

RESULTS

The total of 182 subjects (all males) were included in the study and were comprised of 51 NS, 65 FMC smokers and 66 HRC smokers. The mean age of the study subjects was 40.8 (range: 22- 82) years. The mean (SD) ages of the FMC smokers, HRC smokers and NS was 41.7 (±11.4), 42.8 (±12.3) and 36.8 (±10.8) years, respectively. There was no significant difference ($p>0.05$) in mean age between HRC and FMC smokers, but there was a significant difference between smokers (HRC and FMC) and NS. The mean (SD) age of starting smoking was 16.5 (±4.2) years among FMC smokers and 15.2 (±4.0) years among HRC smokers. No significant difference ($p>0.05$) was seen in the mean age of starting smoking between HRC and FMC smokers. No significant

Table 1
Age, BMI, smoking duration and age at starting smoking among study participants.

Variables	NS (n=51)	FMC (n=65)	HRC (n=66)	p-value
Mean age in years(±SD)	36.8 ± 10.8[a]	41.7 ± 11.4[b]	42.8 ± 12.3[b]	0.016
Mean age started smoking in years	N/A	16.5 ± 4,2[a]	15.2 ± 4.0[a]	0.220
Smoking duration in pack-years	N/A	32.5 ± 23.5[a]	28.5 ± 21.9[a]	0.324
Mean BMI (kg/m^2)	25.6 ± 3.1[a]	26.8 ± 5.1[a]	25.6 ± 3.2[a]	0.150

Each different superscript letter (a or b) denotes that the variables of study groups differ significantly from each other. NS, non smokers; FMC, factory-made cigarette; HRC, hand-rolled cigarette; BMI, body mass index; SD, standard deviation; kg, kilograms; m, meters; N/A; not applicable.

Table 2
Educational and occupational characteristics of study participants.

Characteristics	NS n (%)	FMC n (%)	HRC n (%)	p-value
Education level				
Primary school	9 (13.4%)[a]	22 (32.8%)[a,b]	36 (53.7%)[b]	<0.01
High school	23 (29.5%)[a]	29 (37.2%)[a]	26 (33.3%)[a]	
University	19 (51.4%)[a]	14 (37.8%)[a]	4 (10.8%)[b]	
Profession				
Farmer	7 (20.0%)[a,b]	8 (22.9%)[b]	20 (57.1%)[a]	<0.01
Laborer	24 (37.5%)[a]	17 (26.6%)[a]	23 (35.9%)[a]	
Trades person (shopkeeper, barber, etc)	2 (5.9%)[a]	20 (58.8%)[b]	12 (35.3%)[a,b]	
Officer (doctor, teacher, policeman, etc)	18 (36.7%)[a]	20 (40.8%)[a]	11 (22.4%)[a]	

Each different superscript letter (a or b) denotes the variables differ significantly from each other. NS, non-smokers; FMC, factory-made cigarette; HRC, hand-rolled cigarette.

difference (p>0.05) was seen in smoking duration (packs/year) between HRC and FMC smokers (Table 1).

The percentages of primary school graduates among HRC smokers, FMC smokers and NS were 53.7%, 32.8%, and 13.4%, respectively. The percentages of high school graduates among HRC smokers, FMC smokers and NS were 33.3%, 37.2%, and 29.5%, respectively. The percentages of university graduates among HRC smokers, FMC smokers and NS were 10.8%, 37.8%, and 51.4%, respectively. The number of HRC smokers was significantly higher (p<0.05) than NS among primary school educated participants. The number of HRC smokers was significantly lower (p<0.05) than FMC smokers and NS among university graduate subjects. No significant difference (p>0.05) was seen among high school graduate subjects (Table 2).

The percentages of farmers among HRC smokers, FMC smokers and NS were 57.1%, 22.9%, and 20.0%, respectively. The percentages of laborers among HRC

Table 3
Mean (standard deviation) pulmonary function testing levels and carboxyhemoglobin levels by study groups.

Variables	NS	FMC	HRC	*p*-value
COHb	2.50 ± 1.70[a]	3.70 ± 2.40[b]	3.70 ± 2.20[b]	<0.01
FEV1/FVC	83.13 ± 5.08[a]	76.66 ± 7.45[b]	77.36 ± 8.14[b]	<0.01
FEV1	95.30 ± 13.30[a]	84.50 ± 17.80[b]	89.4 ± 15.80[b]	<0.01
FVC	93.80 ± 14.20[a]	90 ± 16.40[a]	94.9 ± 14.60[a]	0.17
PEF	86.20 ± 16.0[a]	78.10 ± 18.70[b]	81.90 ± 19.30[a,b]	0.06
FEF25-75%	96.70 ± 24.70[a]	69.30 ± 28.40[b]	71.50 ± 25.60[b]	<0.01

Each different superscript letter (a or b) denotes the variables of the study groups differ significantly from each other. NS, non-smokers; FMC, factory-made cigarette; HRC, hand-rolled cigarette; COHb, carboxyhemoglobin; FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF25-75, forced expiratory flow from 25-75% of the vital capacity; PEF, peak expiratory flow.

smokers, FMC smokers and NS were 35.9%, 26.6%, and 37.5%, respectively. The percentages of tradespeople among HRC smokers, FMC smokers and NS were 35.3%, 58.8%, and 5.9%, respectively. The percentages of officers among HRC smokers, FMC smokers and NS were 22.4%, 40.8%, and 36.7%, respectively. The number of HRC smokers was significantly higher (p<0.05) than the number of FMC smokers among farmers. The number of FMC smokers was significantly higher (p<0.05) than the number of NS among tradespeople. No significant difference (p>0.05) was seen among the three study groups among laborers and officers (Table 2).

The mean (SD) FEV1/FVC among NS (83.13±5.08) was significantly higher (p<0.05) than the mean FEV1/FVC among FMC smokers (76.66±7.45) and HRC smokers (77.36±8.14). The mean FEV1/FVC values among the 2 smoking groups were not significantly different from each other. The mean (SD) FEV1 among NS (95.30±13.30) was significantly higher (p<0.05) than the mean (SD) FEV1 among FMC smokers (84.50±17.80), and HRC smokers (89.40±5.80). The mean FEV1 values among the 2 smoking groups were not significantly different from each other. The mean (SD) PEF among NS (86.20±16.0) was significantly higher (p<0.05) than the mean (SD) PEF among FMC smokers (78.10±18.70) and HRC smokers (81.90±19.30). The mean PEF values in the 2 smoking groups were not significantly different from each other. The mean (SD) FEF25-75% among NS (96.70±24.70) was significantly higher than among FMC smokers (69.30±28.40) and HRC smokers (71.50±25.60). The mean FEF25-75% values among the 2 smoking groups were not significantly different from each other. The mean FVC values among HRC smokers and FMC smokers were not significantly different from each other (p>0.05). The mean (SD) COHb level among NS (2.50±1.70) was significantly lower (p<0.05) than among FMC smokers (3.70±2.40) and HRC smokers (3.70±2.20). The mean COHb values in the 2 smoking groups were not significantly different from each other (Table 3).

Table 4
Comparison of pulmonary function testing results and carboxyhemoglobin results by selected variables.

Variables		FEF25-75%	FEV1	FEV1/FVC	FVC	PEF	COHb
Smoking history in pack-years	FMC	-0.55*	-0.38*	-0.52*	-0.21	-0.17	-0.03
	HRC	-0.54*	-0.22	-0.52*	-0.06	-0.08	-0.08
Age started smoking in years	FMC	0.08	0.10	0.04	0.04	0.11	-0.01
	HRC	0.16	0.19	0.06	0.16	0.07	0.09
BMI (kg/m^2)	FMC	-0.08	-0.15	0.07	-0.26*	-0.06	-0.18
	HRC	0.18	0.03	0.29*	-0.09	0.28*	0.02

FMC, factory-made cigarette; HRC, hand rolled cigarette; COHb, carboxyhemoglobin; FVC, forced vital capacity; FEV1, forced expiratory volume in one second; FEF25-75, forced expiratory flow from 25-75% of the vital capacity; PEF, peak expiratory flow; BMI, body mass index; kg, kilogram; m, meters. * Correlation is significant at 0.05 level (2 tailed).

The smoking duration in FMC smokers had a significant negative correlation ($p<0.05$) with FEF25-75%, FEV1, and FEV1/FVC, values. Among HRC smokers, smoking duration had a significant negative correlation ($p<0.05$) with FEF25-75% and FEV1/FVC values. No significant differences were seen between age of starting smoking and PFT results ($p>0.05$) between the 2 smoking groups. The body mass index (BMI) of the FMC smokers had a significant negative correlation with FVC values ($p<0.05$). Among HRC smokers, the BMI had a significant negative correlation with FEV1/FVC and PEF values. COHb had no significant correlation with smoking duration, age of starting smoking or BMI (Table 4).

DISCUSSION

We determined that both forms of cigarettes (HRC and FMC) were unhealthy. All the PFTs and COHb levels in the NS group were better than the smokers (FMC and HRC). There was a significant difference between NS and smokers in FVC, FEV1, FEV1/FVC, FEF25-75%, PEF and COHb results. In the literature, it was clearly evidenced that the use of tobacco and tobacco products damage the pulmonary functions (Kiter *et al*, 2000; Ozkurt *et al*, 2000; Alderete *et al*, 2010; Hassett *et al*, 2014).

We had hypothesized there might be differences in PFT or COHb levels between the 2 smoking groups but this turned out to be incorrect. There were no significant difference between the 2 smoking groups. This is the first study comparing PFT between HRC and FMC smokers. Previous studies reported HRC smoking, cigars smoking and waterpipes all caused chronic obstructive pulmonary disease (Alderete *et al*, 2010) and lung cancer (Rolke *et al*, 2009; CDC, 2014) at higher rates than FMC smoking because these forms of tobacco can deliver higher doses of carbonmonoxide, nicotine and tar (Alderete *et al*, 2010). Smokers inhale less smoke due to the presence of the filter and the tobacco used in FMC may be different. HRC are consumed without a filter and the tobacco in these cigarettes

is selected randomly and has not been analyzed. Tobacco in HRC is picked up from the field, dried under the sun and consumed without any additive chemical compounds. HRC is prepared with natural methods in all stages. However, we found no significant differences between the 2 study groups.

In our study, smokers had higher COHb levels than NS. COHb levels have been reported to be up to 10 times higher in smokers than non-smokers (Kobayashi *et al*, 2015). We found no significant differences in COHb levels between HRC and FMC smokers. However, several studies have reported the amount of carbon-monoxide inhaled per gram of tobacco is significantly higher in HRC than FMC (Laugesen *et al*, 2009; Alderete *et al*, 2010; de Granda-Orive *et al*, 2011).

We found no significant difference in the age at onset of smoking between those who smoked in our study. Some studies have reported HRC use was greater among young individuals and those with lower income due to its cheapness (Leatherdale *et al*, 2009; Rolke *et al*, 2009; Leatherdale and Burkhalter, 2012). Initiating smoking during peak growth (ages 10-18 years) can damage pulmonary function and affect FEV1, FVC and FEF25-75 (Gold *et al*, 1996). Early onset smoking increases the risk for smoking in the future (Wellman *et al*, 2016).

In our study, HRC smokers mostly had a primary school education, FMC smokers mostly had a high school education and NS mostly had a high school or university education. HRC smokers and their parents commonly tend to have lower education levels worldwide (Gothi *et al*, 2007; Alderete *et al*, 2010; de Granda-Orive *et al*, 2011; Joossens *et al*, 2014). The majority of HRC smokers in our study were farmers, the majority of FMC smokers were tradespeople and the majority of NS were officers. This finding is consistent with other studies that found HRC smokers had lower income levels (de Granda-Orive *et al*, 2011). HRC are consumed by individuals with lower education and financial levels.

There was no significant difference in ages in our study between HRC and FMC smokers, the mean age of NS was significantly lower than smokers although this did not appear to affect our results. In our study, subjects were selected randomly, so an age difference occurred between NS and smokers.

The main limitation of our study was the difference in the grams of tobacco consumed among HRC and FMC smokers, since this amount varies from one individual to the next. However, both smoking groups had similar PFT results and COHb levels, suggesting this did not have a major effect on our study results.

In conclusion, HRC and FMC caused abnormal PFT among both groups of smokers equally and resulted in higher COHb levels among both groups, which were significantly worse than NS. This information needs to be communicated to both groups of smokers.

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