Smoking and pollution cause an increase in expired carbon monoxide in kiosk workers

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Key words
Carbon monoxide; atmospheric pollution; smoking

Summary
Background: *The measurement of expired carbon monoxide (CO) is a direct and non-invasive method for the detection of exposure to CO.* **Objective:** *Our aim was to investigate the impact of atmospheric pollution and smoking on expired CO in kiosk workers in Thessaloniki, Greece.* **Methods:** *Twenty kiosks were selected in the commercial centre of city. The workers were all men aged 30.5±5.5 years. Measurements of expired CO and environmental CO were carried out twice per day, during two different seasons of the year, summer and winter. Expired CO was measured via a MicroCOMeter equipped with a fuel cell type electrochemical sensor. The CO levels in ambient air were determined using the method of Non-Dispersive Infra-Red analysis.* **Results:** *Ambient CO levels were 2.11±0.64 ppm at h. 17:00 and 3.64±1.45 at h. 21:00 in winter and 1.26±0.17 ppm at h. 17:00 and 1.73±0.22 at h. 21:00 in summer. Expired CO in non-smokers was 3.2±2.7 ppm at h. 17:00 and 4.2±3.2 at h. 21:00 in winter and 1.3±1 ppm at h. 17:00 and 2.2±1.4 at h. 21:00 in summer. In smokers it was 9±5.2 ppm at h. 17:00 and 13.9±7.5 at h. 21:00 in winter and 10±4.8 ppm at h. 17:00 and 18±7 at h. 21:00 in summer. All these differences were statistically significant. The concentrations of expired CO were significantly correlated with the number of the cigarettes smoked.* **Conclusions:** *The levels of expired CO in kiosk workers increase mainly due to smoking and to a lesser degree due to environmental pollution.*

Riassunto
«Il fumo di tabacco e l'inquinamento atmosferico provocano un aumento del CO espirato nei lavoratori in chioschi». *La determinazione del monossido di carbonio (CO) espirato rappresenta un metodo diretto e non invasivo per la valutazione dell'esposizione a CO. Scopo dello studio è stato studiare l'impatto dell'inquinamento atmosferico e del fumo di tabacco sul CO espirato tra i lavoratori nei chioschi di Salonicco, Grecia. Sono stati selezionati 20 chioschi ubicati nel centro commerciale della città. I lavoratori erano tutti maschi di età 30,5±5,5 anni. Le determinazioni del CO espirato e del CO ambientale sono state eseguite due volte al giorno, in due diverse stagioni dell'anno, estate ed inverno. Il CO espirato è stato determinato mediante un MicroCOMeter dotato di un sensore elettrochimico. I livelli di CO nell'aria ambiente sono stati determinati mediante analisi infrarossa non dispersiva. I livelli di CO ambientali sono risultati 2,11±0,64 ppm alle h. 17:00 e 3,64±1,45 alle h. 21:00 in inverno e 1,26±0,17 ppm alle h. 17:00 e 1,73±0,22 alle h. 21:00 in estate. Il CO espirato nei non-fumatori è 3,2±2,7 ppm alle h. 17:00*

Pervenuto il 20.12.2006 - Accettato il 13.3.2007
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e 4,2±3,2 alle h. 21:00 in inverno e 1,3±1 ppm alle h. 17:00 e 2,2±1,4 alle h. 21:00 in estate. Nei fumatori i livelli sono 9±5.2 ppm alle h. 17:00 e 13,9±7,5 alle h. 21:00 in inverno e 10±4,8 ppm alle h. 17:00 e 18±7 alle h. 21:00 in estate. Tutte queste differenze sono risultate statisticamente significative. Le concentrazioni di CO espirato sono risultate significativamente correlate con il numero di sigarette fumate. I livelli di CO espirato fra i lavoratori in chioschi aumentano principalmente a causa del fumo di tabacco e, in modo minore, a causa dell'inquinamento atmosferico.

Introduction

Carbon Monoxide (CO) as an atmospheric pollutant is emitted as a product of incomplete combustion of hydrocarbons. It mainly emanates from the internal combustion engines of automobiles and to a lesser degree from other sources (central heating, industry). The most important source is vehicle transport, so the concentration is high in city centres. The urban road canyons trap the pollutants as the high buildings block the air flow (2).

Even if the concentration of CO in the air is not particularly high, it can cause headache, a feeling of fatigue and affects individuals with coronary heart disease (24). The long-lasting effects of CO in residents of large cities are unknown.

The cigarette smoke constitutes an important source of CO. Carboxyhemoglobin (HbCO) in the blood (9) usually lies at a level of ~10% in smokers, while in non-smokers it is ~1%.

According to data of the European Environmental Agency, Thessaloniki is one of the most polluted cities in Europe from particulate matter with diameter smaller than 10 μm (PM_{10}) (10). Certain peculiarities of the city (dense and unorganized layout, high buildings, narrow streets, daily traffic congestion, and long periods of calm) contribute to the accumulation and stagnation of pollutants. CO levels, mainly during winter, show an increasing trend from h. 7:00 to h. 11:00 in the morning and from h. 17:00 to h. 21:00 in the evening because of the traffic peak. The employees of kiosks in the centre of Thessaloniki are exposed more than other people to atmospheric pollution. Measurement of expired CO is a non-invasive method that is cheap, fast and without particular technical difficulties. Even though the clinical role of measurement of expired CO has not been determined precisely, important technical improvements have rendered it a useful "tool" for research purposes (4). The levels of expired CO correlate well with the level of carboxyhemoglobin in the blood (20).

The aim of the present study was to investigate the effect of smoking and atmospheric pollution on the CO level of expired air in exposed workers in the commercial centre of the city of Thessaloniki. We speculated that the effect of smoking on expired CO levels would be greater than that of atmospheric pollution.

Methods

Twenty kiosks were selected in the commercial centre of Thessaloniki situated at major crossroads close to traffic lights. Of these kiosks the first was selected randomly. The research covered a large area, given that the studied kiosks were quite far one from the other. More precisely, 1 kiosk every 4 was selected. Due to the fact that certain employees did not fulfill the inclusion criteria, the selection continued up to a total of 20 employees. All persons gave their written consent to participate in the study. The study protocol was reviewed and approved by the Scientific Committee of the "G. Papanicolaou" Hospital, Thessaloniki.

Individuals with chronic obstructive pulmonary disease, bronchiectasis, cystic fibrosis, asthma and acute respiratory infections were excluded from the study. The "active" area of every kiosk was roughly 3 m^3, with two or three small openings.

The workers were all men (aged 30.5±5.5 years) and stayed in the kiosks for more than 8 hours a day. The measurements were carried out on two different working days of the week (Tuesday and Thursday) twice per day, one at h. 17:00 (hour of relative traffic calm) and the second at h. 21:00 (hour of traffic peak). The measurement period covered two different seasons of the year, summertime during the months of May-June and wintertime during November-December. The subjects who smoked recorded the number of cigarettes that they had smoked during the four hours from the first up to the second measurement.

The measurements of CO were made on expired air with a MicroCOMeter instrument manufactured by Micro Medical Ltd, England, equipped with an electronic sensor (fuel cell type electrochemical sensor). The device has the possibility of measurement up to 500 ppm CO with a resolution of 1 ppm. The calibration was carried out each month with a bottle of gas containing 50 ppm CO (15). The examined subjects executed a complete inspiration, held their breath for 20 seconds and then exhaled slowly and completely in the muzzle of the instrument (22). In this way, a better mixture of alveolar air was achieved. There were two successive measurements and the higher value of expired CO was recorded. The response time of the equipment was shorter than 20 seconds. Before repeating a measurement the unit was turned off and the mouthpiece and adapter with one-way valve were removed, to allow re-equilibration with ambient air, for approximately 1 minute. The difference between the two successive measurements was statistically insignificant (0-1 ppm).

Environmental CO was determined with the automated method of Non- Dispersive Infra-Red Analysis (NDIR). The sensitivity of the method is 1 ppm with possibility of measurement up to 50 ppm. This method is incorporated in the CO 11 M analyzers manufactured by Environement SA, France. The measurements of environmental air pollution were carried out at two stations of the air quality monitor network operated by the Municipality of Thessaloniki in the commercial centre of city.

Since data were fitted to normal distribution, the student t-test was used to calculate the differences of CO levels in expired air, and in the ambient air between h. 17:00 and h. 21:00, as well as between winter and summer in smokers and in non-smokers. A multiple regression model was applied in order to determine the relationship between the seasons of the year, smoking and changes in environmental CO as independent variables (independently correlated) and the change in expired CO at h. 17:00 and h. 21:00 as dependent variable (7). Results were expressed as mean values ± standard deviation.

Results

The environmental study showed that the levels of CO in the atmosphere were 2.11±0.64 and 3.64±1.45 ppm at h. 17:00 and h. 21:00, respectively, in winter and 1.26±0.17 and 1.73±0.22 ppm respectively in summer. The change in levels at h. 17:00 compared to h. 21:00 was 1.52±1.07 for the winter and 0.47±0.23 ppm for the summer months (figure 1). The differences between the two hours of the day and between the two seasons were statistically significant ($p<0.01$ and $p<0.001$ respectively).

In smokers, the levels of expired CO were 9±5.2 and 13.9±7.5 ppm at h. 17:00 and h. 21:00, respectively, in winter and 10±4.8 and 18±7 ppm respectively in summer. The difference between the two seasons at h. 17:00 was not significant, while at h. 21:00 it was statistically significant ($p<0.05$). The changes that were observed at h. 17:00 compared to h. 21:00 were 4.93±3.68 ppm in the winter and 7.97±3.59 in the summer ($p<0.001$), see figure 2.

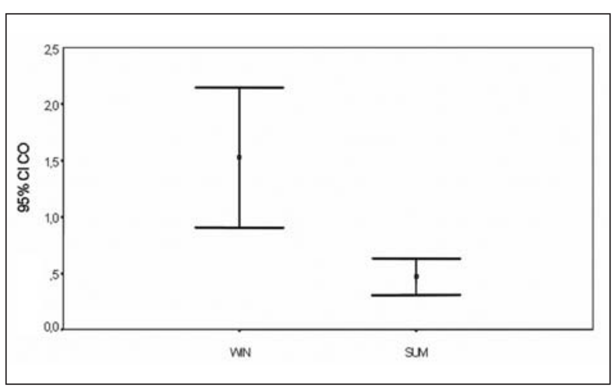

Figure 1 - Difference in ambient CO levels between h. 17:00 and h. 21:00 in the two seasons studied (mean value and 95% confidence interval)
WIN=winter, SUM=summer

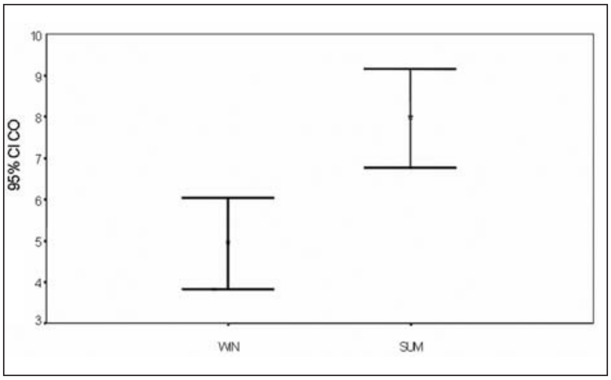

Figure 2 - Difference in expired CO between h. 17:00 and h. 21:00 in the two seasons studied (mean value and 95% confidence interval) in smokers

In the summer, during the four hours between the measurements the smokers smoked 8.97±5.31 cigarettes on average, while in the winter they smoked 4.82±3.74 ($p<0.001$).

The change in expired CO in the smokers from h. 17:00 until h. 21:00 was related to the number of cigarettes that they had smoked in the interval between the two measurements and the correlation coefficients were found to be statistically significant ($p<0.001$) (figure 3).

In non-smokers the levels of expired CO were 3.2±2.7 and 4.2±3.2 ppm at h. 17:00 and h. 21:00, respectively, in winter and 1.3±1 and 2.2±1.4 ppm, respectively, in summer. The differences between the two seasons were statistically significant both at h. 17:00 and h. 21:00 ($p<0.001$) The changes observed at h. 17:00 compared to h. 21:00 were 1.02±1.11 in winter and 0.92±1.01 ppm in summer

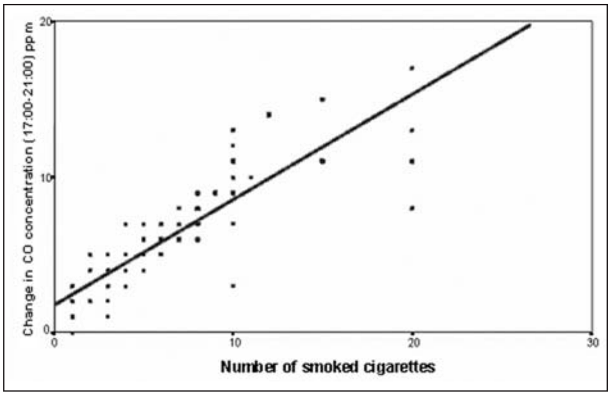

Figure 3 - Correlation between changes in expired CO and the number of cigarettes smoked

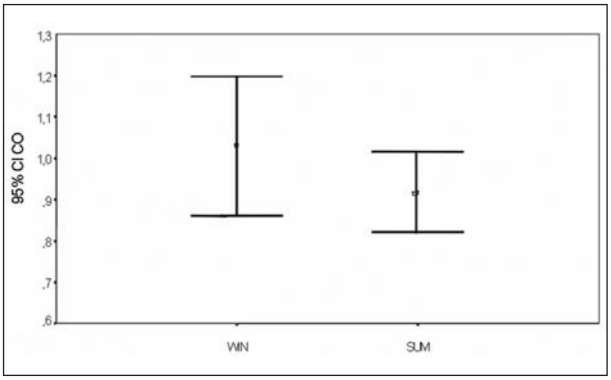

Figure 4 - Changes in expired CO between two measurements, four hours apart, in the two seasons studied (mean value and 95% confidence interval) in non-smokers

Table 1 - *Model of multiple regression with the change of expired CO as dependent variable and season, smoking status and change in environmental CO as independent variables only in smokers*

	b	Standard Error	p
Constant	2.019	1.019	0.051
Season	0.045	0.591	0.94
CO in environmental air	-0.193	0.247	0.436
Number of cigarettes	0.664	0.052	<0.001

b=partial progression coefficient; p=probability

(figure 4), a difference that was not statistically significant.

A multiple regression model was applied for smokers. As dependent variable the change in expired CO in the four hours between the examinations was taken, and as independent variables the season (winter, summer), smoking status (number of cigarettes in the 4 hours) and environmental CO change were imported in the model (table 1).

It was found that the changes in expired CO were related only with smoking ($p<0.001$) and not with the season or the environmental changes in CO.

Discussion

The results of this study show that the change in expired CO, in smokers and non-smokers, corresponds with the change in CO level in the atmospheric air and consequently can be useful as a biological indicator of exposure to CO pollution. The level of CO in the atmosphere rose between h. 17:00 and h. 21:00 in parallel with the increase in expired CO both during summer and winter. In smokers this change increased in proportion to the number of the cigarettes smoked meanwhile.

Until recently measurement of expired CO was used to assist anti-smoking campaigns (11, 19) and to detect cases of CO poisoning (6) in emergency hospital departments (21) or in case of fire (5). It has also been used to control the reliability of answers to questionnaires concerning smoking habits in schools (1), to measure pollution of indoor air from cigarette smoke (12) and to detect airways inflammation in asthma (25), bronchiectasis (14), chronic obstructive pulmonary disease (16, 18) as well as in upper airways infections (23) and cystic fibrosis (17). The existence of these diseases constituted a criterion of exclusion from the present study.

The environmental measurements showed relatively low levels of CO without exceeding permissible limits despite the fact that Thessaloniki is a heavily polluted city. It is speculated that such levels do not negatively influence the health of the exposed subjects unless they suffer from cardiovascular diseases (13, 24).

The levels of expired CO in the non-smokers working in the kiosks at h.17 were relatively low and usually within the accepted limits of expired CO in normal individuals, in whom the levels vary from 0 to 6 ppm (6). However, at h. 21:00 the levels increased above the normal level (up to 10 ppm in 26,5% of the subjects), mainly in the winter because of the increased concentration of CO in atmospheric air, as was observed from the corresponding environmental measurements. The increase in the difference in levels between expired CO and environmental CO during winter in contrast to summer can be attributed to the lack of good airing of the workplaces in winter. During summer, large openings exist in the kiosks (e.g. the door and the windows of the kiosk are kept open). These levels changed in parallel with the values of environmental CO, probably due to the resulting increase in CO concentration in the internal air of the kiosks. A cross-correlation in levels of CO indoor air in houses around and external atmosphere has already been observed (3).

The same tendency was observed in smokers, but as it was expected that the level of expired CO would not keep pace with the environmental CO level, because of the effect of smoking. The lower levels of expired CO in the smokers during the winter months can be attributed to the fact that the workers smoked less because cigarette smoke creates a stifling situation inside the limited space of the kiosks. In smokers the model of multiple cross-correlation showed that the increase in expired CO is explained mainly by smoking. Indeed, the increase in expired CO shows a powerful cross-correlation with the number of cigarettes smoked. Moreover, an important cross-correlation between levels of expired CO and daily consumption of cigarettes has been observed (8).

We believe that the method of measuring expired CO that we used can furnish reliable results and can be used in epidemiological studies of air pollution. This can be reasonably inferred from the parallel change in both expired CO in non-smokers and the ambient CO levels, although we had no data from current measurements of HbCO in the examined subjects. Lastly, our results showing the disproportional negative effect of smoking compared to air pollution add another argument for the campaign against smoking.

Our conclusion is that expired CO in the workers of kiosks is increased by environmental CO pollution that is produced mainly from traffic, sometimes at pathological levels. In smokers the effect of smoking on the increase in expired CO is multiplicative compared with that produced by atmospheric pollution.

No potential conflict of interest relevant to this article was reported

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Acknowledgements: *The authors wish to thank the students of Aristotle University of Thessaloniki O. Kaiafa, S. Kaouri, A. Karamanlidis, D. Kalkanis, L. Athanasiadis, K. Gerontziafa, E. Zoi and Th. Kantara for their assistance in carrying out this study*