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The Significance of an Across-Shift Decrease in Vital Capacity—A Re-Analysis of a Study on Subjects Exposed to Diesel Exhaust

Monica Dahlqvist

Department of Environmental Technology and Work Science, Royal Institute of Technology, Stockholm, Sweden

ABSTRACT

Occupational exposure to diesel exhaust may develop acute as well as chronic lung function impairment. In this study, data from an earlier study on a group of subjects working at tunnel construction site were analyzed. The aim of the analysis was to examine the significance of an across-shift decrease in vital capacity with concern to other lung physiological measurements.

There were no statistically significant differences, either in the average age, time of employment, vital capacity before a working shift after two days of no exposure, or the distributions of smoking habits and respiratory symptoms, between the eight workers who had an across-shift decrease in vital capacity and the five workers who had not.

Subjects with an across-shift decrease in vital capacity had a significantly greater across-shift decrease in residual volume and total lung capacity than subjects without an across-shift decrease in vital capacity. The pathophysiological mechanisms for this across-shift decrease in residual volume is not fully understood. However, an altered defence mechanism in the lung may play a role for a prolonged retention time for the particles in the inhaled diesel exhaust, resulting in the across-shift decrease in residual volume. The results thus suggest that measurements of across-shift vital capacity is of importance in identifying susceptible subjects with occupational exposure to diesel exhaust.

INTRODUCTION

Measurements of lung volumes are powerful measures to examine some features of lung function affection. In a number of studies we have observed acute, temporary effects on lung function in workers exposed to irritating air contaminants (3, 6, 14, 15). These temporary effects were correlated with the concentration of the air contaminants. The measurement of acute effects from irritants on the lung function is of value as a complement to exposure measurements. It is also of great interest to study the medical importance of acute temporary effects with concern to other physiological lung function measurements. This is not the least important matter since some of the lung function variables are highly interrelated (2, 11) and that an acute temporary decrease in lung function has been reported to predict a more accelerated decline in lung function over time (4, 5). If an acute temporary effect on lung function cannot be associated with the exposure, it is possible that subjects who display a decrease are susceptible. By measuring lung function during a working shift or week, such subjects may be identified and measures can be taken to decrease or stop the exposure.

Diesel exhaust contains a number of substances that will effect the health of exposed human beings if the substances are present in concentrations high enough. The respiratory effects of exposure to diesel exhaust include irritative effects on mucous membranes and chronic deterioration in lung function (16). Although the exhaust has usually been diluted with a factor about 50 times or more, acute, temporary lung

function effects have been shown (13). The particles in the diesel exhaust have been reported to induce this acute, temporary decrease in lung function (12, 14).

In order to evaluate possible relationships between an across-shift decrease in vital capacity and other lung physiological variables, data from an earlier published study were re-analyzed (14).

MATERIAL AND METHODS

Fifteen workers subjects, working at a tunnel construction site, took part in the initial examination with the aim to study hazardous effects on lung function caused by exposure to particles in diesel exhaust (14). They were examined before a working shift, after two days of no exposure, and after two working shifts of exposure to diesel exhaust, with and without exposure to particles, respectively. The particles in the diesel exhaust were removed from the inhaled air by using a particulate respirator or a half mask during one of the working shifts. Official leakage value was lower than 0.1%. None of the filters retains gaseous substances to any appreciable extent. The examinations after exposure after a day working shift were carried out at the same time of the day.

Single breath nitrogen wash-out recordings were available in 13 subjects. All subjects were men between 23 and 59 years, with an average age of 39 years. There were 1 never-smoker, 4 ex-smokers and 8 current smokers. The means (standard error of the mean) for pack-years, py, (gram tobacco consumed per day)*(smoking years)/20 were 8 (2), and 11 (4), for the ex- and the current smokers, respectively.

Chronic respiratory symptoms (cough, exertion dyspnea, wheeze) were assessed by means of a standardized questionnaire, translated from the MRCC questionnaire (8).

Recordings on single breath nitrogen wash-out were carried out according to previously described technique (2) and provided values for vital capacity and closing volume. Total lung capacity was determined by planimetry, according to integration of the nitrogen wash-out curve as described by Buist and Ross (1). Residual volume was calculated by subtracting the vital capacity from the total lung capacity. The volumes were corrected to conditions of body temperature and pressure, saturated with water (BTPS).

Standard statistical methods were employed, in conjunction with correlation analyses. The values obtained before a working shift were standardized with concern to age, height and smoking habits (7). The results of the previously published study showed an improvement in lung function when the particles from the diesel exhaust were removed from the inhaled air (14). These values were therefore used as *unexposed values* in order to minimize the effects of the diurnal variation. The values obtained after a working shift when the workers were exposed to particles were used as *exposed values*. Across-shift change in lung function in each individual was calculated according to the formula:

$$\text{change} = 100 * \frac{(\text{exposed} - \text{unexposed})}{0.5 * (\text{exposed} + \text{unexposed})} \ (\%).$$

Since the aim of this study was to evaluate the significance of an across-shift decrease in vital capacity, the across-shift change in vital capacity was dichotomized. A change (calculated according to the aforementioned expression) of $< 0\%$, signifying a decrease in vital capacity, were assigned 1, i.e., indicating an effect. In the same manner, a calculated change corresponding to $\geq 0\%$ in vital capacity, i.e., no decrease, were assigned 0, i.e., indicating no effect. Stated p-values involved two-tailed analysis; differences were considered to be statistically significant at $p \leq 0.05$.

Daily average concentrations of carbon monoxide and nitric oxides, measured in the breathing zone of the workers, were comparable between the working shifts with and without exposure to particles (14).

Table 1. Daily average concentrations of gaseous and particulate air pollutants (mg/m^3) in the breathing zone for workers exposed to diesel exhaust, with and without an across-shift change in vital capacity.

	with, n=8	without, n=5
carbon monoxide	10.7 (1.4)[1]	10.2 (1.4)
nitrogen oxide	4.8 (0.5)	4.9 (0.2)
nitrogen dioxide	1.9 (0.2)	1.9 (0.2)
total dust	2.2 (0.3)	2.6 (0.5)
respirable dust	1.3 (0.1)	1.3 (0.1)

[1] mean (standard error of the mean)

RESULTS

Daily average values for the concentrations of air pollutants were about the same magnitude for the eight subjects who had an across-shift decrease in vital capacity and the five subjects who had not, Table 1. Age, time of employment, standardized vital capacity before a working shift after two days of no exposure did not differ significantly between the workers who displayed an across-shift decrease in vital capacity and those who did not. The distributions of chronic respiratory symptoms and smoking habits were also similar in subjects with and without an across-shift decrease in vital capacity, Table 2.

Table 2. Age, time of employment, vital capacity, percentages of current smokers and subjects with chronic respiratory symptoms for diesel exposed workers, with and without an across-shift decrease in vital capacity.

	with, n=8	without, n=5
age (years)	39 (12)[1]	40 (11)
time of employment (years)	10 (10)	14 (14)
vital capacity (%)[2]	96 (10)	95 (10)
current smokers	50 (4)[3]	80 (4)
cough	25 (2)	20 (1)
exertion dyspnea	38 (3)	40 (2)
wheeze	38 (3)	60 (3)

[1] mean (standard deviation)
[2] vital capacity, before a working shift after two days of no exposure, standardized for age, height and smoking habits
[3] percentage (number of subjects)

Subjects with an across-shift decrease in vital capacity had on the average a significantly greater across-week decrease in residual volume and total lung capacity, Table 3.

The across-shift change in vital capacity was not significantly correlated with the daily average concentrations of the measured air pollutants ($p>0.6$).

Table 3. Across-shift change in lung physiological variables for diesel exposed workers, with and without an across-shift decrease in vital capacity.

%	with, n=8	without, n=5
residual volume	-19.3 (6.5)[1,2]	7.9 (7.3)
total lung capacity	-4.9 (0.8)[3]	4.3 (1.3)
closing volume	-1.2 (8.2)	15.1 (11.0)

[1] mean (standard error of the mean)
[2] $p<0.05$ in comparison with subjects without an across-shift decrease in vital capacity
[3] $p<0.001$ in comparison with subjects without an across-shift decrease in vital capacity

DISCUSSION

Subjects with an across-shift decrease in vital capacity had a significantly greater across-shift decrease in residual volume and total lung capacity, compared to subjects without an across-shift decrease in vital capacity, Table 3. The average age, time of employment, vital capacity before a working shift after two days of no exposure (standardized for age, height, and smoking habits) (7), and the distributions of chronic respiratory symptoms and smoking habits were similar between subjects with and without an across-shift decrease in vital capacity, Table 2. Although the examined background variables may have a limited value, it is not likely that, for instance chronic respiratory diseases should result in an across-shift decrease in vital capacity.

There is still no generally applicable indicator of diesel exhaust exposure available (16). The exposure judgement of diesel exhaust traditionally has been founded on the concentrations of gaseous components, i.e., carbon monoxide and nitrogen dioxide or by measurements of total and respirable dust. Particles in the diesel exhaust have been demonstrated to induce acute temporary lung function impairment (12, 14). The across-shift change in vital capacity could thus have been directly related to the concentration of particulate matter, measured as total or respirable dust. The associations were weak between the across-shift decrease in vital capacity and the daily time-average concentrations of total and respirable dust, however. Daily time-average concentrations of total and respirable dust were also almost identical between subjects with and without an across-shift decrease in vital capacity, Table 1. Despite the limitation of the measured air pollutants in order to describe the level of diesel exhaust exposure it seems not probable that differences in exposure should have influenced the finding that subjects with an across-shift decrease in vital capacity also had a greater across-shift decrease in residual volume and total lung capacity. Therefore, it seems likely to assume that the across-shift decrease in vital capacity indicates a higher susceptibility, independently of the exposure level.

The data available to us are not sufficient to explain the pathophysiological mechanisms behind the across-shift decrease in residual volume and total lung capacity in subjects with a decrease in vital capacity. A decreased residual volume may, besides a decreased vital capacity and total lung capacity, be found in subjects with a restrictive lung function impairment. Occupational exposure to diesel exhaust results mainly in decreased lung volumes, suggesting a restrictive impairment. This seems to be true for acute as well as chronic effects on the lungs (16). Short-term exposure to diesel exhaust may also result in a decreased number of alveolar macrophages and a reduction in the phagocytic activity in humans (9). The altered defence mechanism in the lung may result in a slower clearance and thus a prolonged tissue interaction with the particles. A prolonged time of retention of compounds in the lungs has been suggested to pose a health hazard for humans exposed to organic pollutants in the environment (10). The across-shift

shift decrease in residual volume and total lung capacity, in subjects with an across-shift decrease in vital capacity may thus be the result of a prolonged particle deposition in the alveoli.

In conclusion, the findings in the present analysis suggest that measurements of across-shift vital capacity is of importance in identifying susceptible subjects with occupational exposure to diesel exhaust. However, the result may be interpreted with caution since the number of studied subjects is pretty small.

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Address for reprints:

Monica Dahlqvist

Department of Environmental Technology and Work Science

Royal Institute of Technology

S-100 44 Stockholm