

# Diurnal variation in peak expiratory flow rate among grain elevator workers

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**ABSTRACT** The diurnal variation (DV) in peak expiratory flow rate (PEFR) has been studied among 132 grain elevator workers who accomplished three daily measurements of PEFR during three weeks. DV was calculated as the difference between the highest and the lowest PEFR as a percentage of the mean PEFR on each day. For the whole group the median was 5.9%. DV was higher among smokers and among workers with work related pulmonary symptoms. Analysis of variance showed that only age ( $p = 0.012$ ) and smoking ( $p = 0.016$ ) had a significant effect on DV. Pulmonary symptoms, total IgE, and duration of occupation had no independent impact on DV, whereas the exposure level of grain dust tended ( $p = 0.082$ ) to have an independent effect. Twelve workers had an abnormally high DV ( $> 20\%$ ), of whom seven showed no signs of obstructive respiratory disease by spirometry. If only a single spirometric test had been performed the tentative diagnosis of bronchial asthma could have been missed in these seven workers.

The lung function of grain elevator workers has been examined in several epidemiological studies, especially in the United States and Canada.<sup>1-4</sup> In these studies lung function was measured on a single occasion or, in two studies,<sup>2,4</sup> before and after a workshift and a whole working week. Deterioration in lung function was found in all the controlled studies.

The diurnal variability in peak expiratory flow rate (PEFR) has been studied among normal subjects and asthmatics. It has a limited range in normal subjects ( $< 20\%$ ) but varies considerably in patients with unstable asthma (approximately 50%).<sup>5</sup>

We have studied the diurnal variation (DV) in PEFR in grain elevator workers with or without respiratory symptoms. We aimed to detect those factors, whether personal or related to occupation, that are associated with increased DV and to compare the results obtained by PEFR recording with spirometric values.

## Material and methods

PEFR recording and spirometry were carried out among 139 male workers (71% of the available workforce) in four grain elevator stores in Aalborg, Denmark. Most of the workers (69%) were grain elevator operators, 14% were craftsmen, 12% were

truckdrivers, and 5% had other functions. The median age was 44 and the median duration of employment 11 years. Thirty workers (22%) worked in three shifts, the rest worked in ordinary shifts.

Each participant was given a mini-Wright peak flow meter and instructed in its correct use. He was asked to perform three blows after maximal inspiration on each occasion and to record the best result on a form. Three daily recordings, taken first thing in the morning, in the afternoon after work (before work for workers on evening shifts), and in the evening before bedtime (before work for workers on night shifts) were made for three weeks, including days off and weekends. All recordings took place at home. All participants were contacted by telephone about one week after the start to ensure good compliance at the recordings.

Each peak flow meter was tested for incorrect display after use with a modified calibrator.<sup>6</sup> In the case of significant discrepancy (on 5% level two tailed) compared with reference values determined at two fixed pressures, the recordings were corrected before analysis.

The DV in PEFR was calculated as the difference between the highest and the lowest PEFR values as a percentage of the mean PEFR on each day. A DV less than 20% was considered normal.<sup>5</sup> Only records where three daily recordings were noted in at least half the 21 days were included. For each worker the mean DV for the three week period was calculated and used in the analysis.

At the chest clinic at Aalborg Hospital, forced expiratory volume in 1 s (FEV<sub>1</sub>), vital capacity (VC), and forced vital capacity (FVC) were measured on an 8 l Vitalograph 20-400 S dry wedge spirometer. The measurements were made in the afternoon between 1500 and 1900, immediately before the PEFr recording began. All volumes were corrected to BTPS. Abnormal pulmonary function test including PEFr were present with a value less than 1.64 residual standard deviation below the predicted value corrected for age and height.<sup>7</sup>

Data were corrected by interview on pulmonary symptoms, smoking habits, specific occupation, gradation of exposure to grain dust, and duration of occupation in the grain industry. Pulmonary symptoms (wheezing, cough, chest tightness, dyspnoea, expectoration, and chronic bronchitis) were graded into work related and not work related. Work related symptoms were those brought on or aggravated by exposure to dust at work and which occurred at least several days a month. Exposure to grain dust was graded into low, variable, and high, based on an individual estimation of the participant's occupation. Serum total IgE was measured by Phadebas IgE PRIST.

## Results

Altogether 132 (95%) subjects produced an acceptable PEFr record and contributed on average 19.7 days with three daily recordings.

The smoking habits of these 132 participants were: 61% smokers, 20% ex-smokers (previously smoked more than one year), and 19% non-smokers. Twenty six per cent complained of work related pulmonary symptoms and 19% of pulmonary symptoms not related to work, whereas 55% were free of pulmonary symptoms. More details on the frequencies of respiratory symptoms are given elsewhere.<sup>8</sup> Exposure to grain dust was designated as high in 59% (most of the grain elevator workers), variable in 23% (drivers and craftsmen), and low in 18% (a proportion of grain elevator operators and workers with other functions).

Table 1 Diurnal variation in peak expiratory flow rate (%) in relation to smoking habit

	Smoking habit		
	Non-smokers (n = 25)	Ex-smokers (n = 26)	Smokers (n = 81)
Median	4.6	5.0	6.3
IQR*	3.6-7.4	3.6-6.7	4.8-9.3

\*Interquartile range.  
p = 0.011 Kruskal-Wallis test

Table 2 Diurnal variation in PEFr (%) in relation to pulmonary symptoms (work related and not work related)

	Pulmonary symptoms		
	Symptomless (n = 73)	Not work related (n = 25)	Work related (n = 34)
Median	5.6	5.9	7.0
IQR	3.7-7.5	4.6-8.6	5.2-10.7

p = 0.043 Kruskal-Wallis test

## DIURNAL VARIATION IN PEFr

For the whole group of workers the median DV amounted to 5.9%. The Kruskal-Wallis test showed that the diurnal variation was higher among smokers than ex-smokers and non-smokers (p = 0.011) (table 1) and among workers with work related pulmonary symptoms compared with workers with no work related pulmonary symptoms, or symptomless workers (p = 0.043) (table 2). High exposure to grain dust was associated with a higher DV in PEFr (p = 0.030) (table 3), although the difference between the high and the low exposure group was small.

The combined effects of age, duration of occupation in the grain industry, total IgE, smoking, presence of pulmonary symptoms, and level of exposure to grain dust on DV was estimated using a parametric analysis of variance. Age (p = 0.002) and smoking (p = 0.016) had a significant effect on DV; exposure level to grain dust was not significant (p = 0.082). Pulmonary symptoms, total IgE, and duration of occupation had no independent impact on DV. The test for interaction between smoking, pulmonary symptoms, and exposure level to grain dust was negative.

Twelve (9%) workers had a DV of 20% or more on two or more days; of these, eight had an abnormally high DV on three or more days. Three other workers had a constantly depressed PEFr.

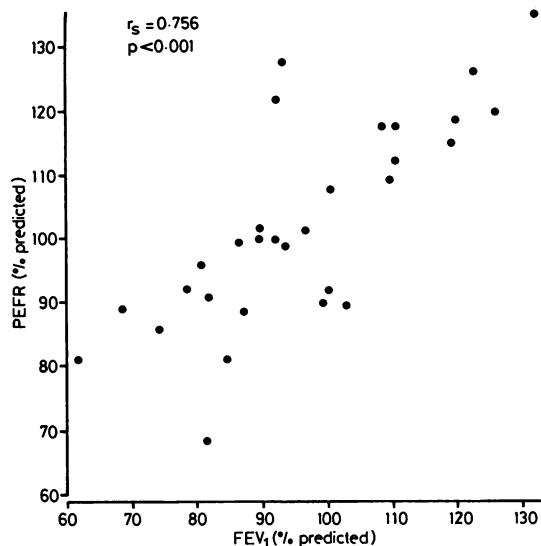
## PEFR AND SPIROMETRY

On spirometry 13 subjects (10%) had bronchial obstruction (abnormally low FEV<sub>1</sub> and FEV<sub>1</sub>/VC), two of whom improved considerably after inhaling sal-

Table 3 Diurnal variation in PEFr (%) in relation to exposure to grain dust

	Grain dust exposure level		
	Low (n = 24)	Variable (n = 30)	High (n = 78)
Median	6.0	4.9	6.3
IQR	3.2-7.5	3.8-6.8	4.6-9.2

p = 0.030 Kruskal-Wallis test.



Relation between mean PEFR (on Monday after work free weekend) and FEV<sub>1</sub> in random sample on 30 grain elevator workers. Relative values are indicated.

butamol (three doses Salbuvent 0.1 mg/dose) with 27% and 19% improvement.

The mean PEFR and the afternoon PEFR measured on the first Monday of a morning shift after a work free weekend were compared with FEV<sub>1</sub> and FEV<sub>1</sub>/VC in a random sample of 30 of the participating grain workers. All values were corrected for age and height. We found that the self reported PEFR correlated well with the spirometric FEV<sub>1</sub> (Spearman rank correlation coefficient  $r_s = 0.756$ ,  $p < 0.001$ ) (figure) and FEV<sub>1</sub>/VC ( $r_s = 0.520$ ,  $p < 0.01$ ). The afternoon PEFR also correlated with FEV<sub>1</sub> ( $r_s = 0.737$ ,  $p < 0.001$ ).

## Discussion

In previous studies DV in PEFR has been calculated as (1) the difference between the morning PEFR and the highest recording during the rest of the day as a percentage of the highest recording,<sup>9</sup> (2) the difference between the mean high PEFR and the mean low PEFR as a percentage of the mean PEFR,<sup>10</sup> (3) the coefficient of variation in PEFR (standard deviation as a percentage of the mean),<sup>11,12</sup> or (4) two times the amplitude in PEFR rhythm, derived from a so called cosinor analysis, as a percentage of the mean PEFR.<sup>5</sup> Obviously these methods are not comparable without modifications.

In our study DV was calculated in a way different from those mentioned above: as the difference between

the highest and the lowest PEFR as a percentage of the mean PEFR on each day. This resembles the first method<sup>9</sup> as the lowest PEFR in most participants appeared in the morning. It seems that we found a lower DV in our material compared with normal subjects. Using cosinor analysis to detect a statistically significant circadian rhythm in PEFR, Hetzel and Clark state the mean amplitude to reach 8.3% compared with 5.6% (median) among our symptomless workers.<sup>5</sup> This is remarkable as cosinor analysis is a conservative estimate of amplitude.<sup>13</sup> Two reservations must be raised, however: mean amplitude and DV on the one hand and median and mean on the other hand are not directly comparable.

In the analysis of variance we found that age and smoking were the only factors that significantly correlated with DV in PEFR, so that higher age and smoking led to higher DV. These factors were the main sources of variation besides the variation that stems from the individual participants (residual variation). Age and smoking have previously been shown to have statistically significant negative effect on different pulmonary function indices (FEV<sub>1</sub>, FVC, FEV<sub>1</sub>/FVC, CV, DL<sub>CO</sub>, and other) among grain elevator workers.<sup>2,3</sup> In our study smoking was associated with a lower FEV<sub>1</sub> ( $p = 0.020$ , Kruskal-Wallis test) and FEV<sub>1</sub>/VC ( $p = 0.021$ ). This may partly explain the relation between smoking habit and DV, as a certain absolute difference in PEFR leads to a higher DV when the mean PEFR is depressed than when the mean PEFR is normal.<sup>14</sup>

The tentative gradation of level of exposure to grain dust tended ( $p = 0.082$ ) to have an independent direct proportional effect on DV in PEFR. This result is interesting, as a previous controlled study on acute effects of exposure to grain dust during a workshift found that grain handling tended to have a negative effect on the fall in FEV<sub>1</sub> over a workshift independent of smoking, height, and age.<sup>4</sup>

It may be disputed that three daily recordings are sufficient to cover the extremes of airway resistance rhythm. Hetzel and Clark, however, have calculated that the lowest PEFR among normal subjects and asthmatics in convalescence appears between 0240 and 0515 and the highest PEFR between 1400 and 2200.<sup>5</sup> They suggest that three daily readings (at waking, at 1600, and at bedtime, as used in our study) would be a convenient protocol of measurements that would give a good approximation of the amplitude of the PEFR rhythm.

In support of this viewpoint we obtained a high success rate, as 95% accomplished the PEFR recording with on average four (6.3%) single measurements missing. PEFR was easily measured with the available peak flow meters and, in addition, PEFR correlated well with FFEV<sub>1</sub> and FEV<sub>1</sub>/VC. This implies that the

participants were serious with the home measurements.

A total of 12 grain workers had an abnormally high DV, of whom seven (58%) showed no sign of obstructive respiratory disease on spirometry. If a single spirometric test had been performed the tentative diagnosis of bronchial asthma could have been missed in these seven subjects. Only three of the seven, however, complained of pulmonary symptoms.

We conclude that measurement of DV in PEFr based on a longitudinal recording is a valuable and reliable tool in surveys of respiratory health among workers in the grain industry.

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