Transient changes in the pulmonary function of welders: a cross sectional study of Monday peak expiratory flow

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Abstract

***Objectives*—The aim was to compare the peak expiratory flow (PEF) of welders and non-welders over a 12 hour period from the start of work on Monday.**

***Methods*—The two study groups consisted of 20 welders and 20 non-welders, all men who had essentially never smoked, with no significant difference in age, height, ethnicity, or baseline spirometry between the groups. The PEF was measured for each welder before the start of work and 15 minutes, 30 minutes, and 1, 2, 4, 7, and 12 hours after the start of welding. The same method was applied to the non-welders, for whom a proxy time for the start of welding was used.**

***Results*—The percentage change in baseline PEF was calculated for each subject at each of the recording times. The welder and non-welder group means for these results were significantly different at 15 minutes (p = 0·028). Also, the group mean for maximum fall in PEF (at any of the recording times during the 12 hour period) was significantly greater for the welders (p = 0·011). 50% of the welders (10/20), but only 5% of the non-welders (1/20), experienced a fall in PEF in excess of 5% (p = 0·0046). 25% of the welders (5/20) experienced drops of greater than 5% within the first 15 minutes.**

***Conclusion*—The results are suggestive of an immediate type reaction in welders, similar to that seen in some cases of occupational asthma, although not so severe. Studies to determine if these reactions reflect non-specific bronchial hyper-responsiveness would be useful. It is recommended that future studies also undertake breathing zone measurements to relate the response to particular constituents of the welding plume, especially the gases ozone and nitrogen dioxide.**

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Occupational asthma is now the most common diagnosis in new cases of occupational respiratory disease in both Britain and Quebec.[1 2] Although the scientific literature contains several case reports of occupational asthma in welders, there have been no epidemiological studies as yet.[3–8]

It is biologically plausible that components of the welding plume might cause asthma. Ozone and nitrogen dioxide have been measured within the breathing zone of welders at concentrations known to cause bronchial hyper-responsiveness (and in the case of ozone, airways inflammation) in normal subjects.[9–17] Also, the allergens nickel and chromium, both reported causes of asthma, are present in the plume when stainless steel is welded.[18–24]

The aim of the present study was to investigate the peak expiratory flow (PEF) over a 12 hour period from the start of work on a Monday, to determine if significant reversible airways obstruction occurred in temporal relation to welding. A group of welders and a comparison group of non-welders were studied.

Previous studies of acute ventilatory function in welders have been cross shift in design, with measurements taken before and after the working shift.[25–28] None of these studies was intended to examine the possibility of occupational asthma in welders and none showed a significant reduction in cross shift ventilatory function. It is likely, however, that any immediate or late asthmatic responses would have been missed by the cross shift measurements. This is because immediate responses may have resolved before the end of the shift and late ones may not have developed until after the end of the shift.

Materials and methods

SUBJECT SELECTION CRITERIA

To avoid confounding due to smoking, subjects were only selected if they had never smoked, or had smoked a maximum of 20 packs of cigarettes in a lifetime, or one cigarette per day for a year, or one cigar per week for a year, and not smoked at all in the last two months. Only men were studied. Those with a history of asthma before employment were excluded even if they claimed not to have asthma currently. This was because any acute ventilatory impairment was likely to be due at least in part to their pre-existing condition. In other words their occupation may have been exacerbatory but could not have been causal.

To ensure a period of recovery before the study, welders were only selected if they had ceased welding by noon on the Saturday preceding the study Monday. This allowed for a minimum recovery period of 44 hours. To measure any dose-response, workers were not required to be full time welders, and the duration of welding on the study day and number of years spent welding were recorded in each

Table 1 Age, height, ethnicity, start time, FEV_1, FVC, and FEV_1/FVC results

	Welders (n = 20) Mean (95% CI)	Non-welders (n = 20) Mean (95% CI)	p Value
Age (y)	32·6 (28·0–37·2)	27·9 (24·4–31·4)	0·11
Height (m)	1·79 (1·75–1·83)	1·80 (1·76–1·84)	0·69
Ethnicity (n):			
Caucasian	17	17	
Maori	1	1	
Polynesian	2	2	
Start time	0923 (0857–0948)	0919 (0904–0933)	0·81
FEV_1 (l)	4·0 (3·69–4·31)	4·12 (3·92–4·32)	0·53
FVC (l)	4·86 (4·46–5·26)	4·87 (4·59–5·15)	0·97
FEV_1/FVC (%)	82·8 (79·6–86·0)	84·8 (82·5–87·1)	0·32

case. The welders included in the study were required to be welding on the morning of the Monday study.

Subjects in the non-welder comparison group were required to have never worked as a welder or undertaken any welding in their leisure time.

STUDY GROUPS

Group 1: welders

Twenty one male electric arc welders who fulfilled the selection criteria were selected from eight engineering companies in Dunedin. Twenty (95%) agreed to participate in the study. The participating companies were of a similar size and undertook similar work to others in Dunedin. Table 1 lists the age, height, ethnicity, and baseline spirometry data for the welders. One welder gave a history of hay fever or eczema but none gave a history of asthma. All welding was performed in large workshops with no confined space or outdoor welding.

Group 2: comparison group of non-welders

Twenty one non-welders who fulfilled the selection criteria were selected from two companies in Dunedin. Twenty (95%) agreed to participate in the study. Table 1 lists the age, height, ethnicity, and baseline spirometry data for the non-welders. The companies from which the non-welders were derived were selected (1) because they employed workers who were exposed to a similar temperature environment and undertook a similar level of physical exercise, factors both known to influence bronchial responsiveness; (2) because they did not involve exposure to agents known to cause occupational asthma; (3) because they employed workers of a similar socioeconomic background to the welders.

One of the companies employed workers in a large factory working on a slow assembly line and the other employed workers who were outside most of the time undertaking maintenance of the grounds. Three of the non-welders gave a history of hay fever or eczema but none gave a history of asthma. Both groups were studied for a three month period so as to minimise any seasonal variation in the ambient temperature.

MEASUREMENTS OF VENTILATORY FUNCTION

Baseline spirometry was undertaken on the morning of the study just before the start of work. Each worker's height was measured with a steel tape measure and recorded to the nearest cm. Spirometry was performed with a calibrated Microlab 3300 electronic spirometer. After ensuring that each subject was able to perform a satisfactory forced expiratory manoeuvre, the forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were recorded for three such manoeuvres. Then baseline peak expiratory flows (PEF) were measured with Mini Wright peak flow meters. Similarly three recordings of PEF were made for each subject on each occasion. For the analysis of the spirometry and PEF data, the best of the three results was used.

Welders were then requested to report when they were ready to start welding. They were followed to the area of the workshop in which they were working and the time at which they first started welding for the day was recorded. Subsequently three PEF measurements were taken at each of the following times after the start of welding: 15 minutes, 30 minutes, one hour, two hours, four hours, seven hours, and 12 hours. To ensure the accurate recording of both time and PEF, each welder was approached in the workshop at the correct time and the results were recorded. The final 12 hour recordings were made by the welders at home. All of the PEF measurements for any given worker were made with the same Mini Wright meter, which was assigned to him at the start of the study day and taken home for the final 12 hour recordings. The 12 hour recordings and Mini Wright meters were then collected the next morning.

The procedure was identical for the non-welders except that an arbitrary start time was assigned to each worker at a time similar to that at which welding generally started. The same seven Mini Wright meters were used for the entire study.

STATISTICAL ANALYSIS

The significance of differences between the mean values of study variables for the two groups were calculated by t test; 95% confidence intervals (95% CIs) were also calculated for these study variables. The significance of differences in the prevalence of falls in peak flow in excess of 5% were calculated by χ^2 test. The 5% level was selected as it clearly divided the results of the two groups.

ETHICS COMMITTEE APPROVAL

The study was given approval by the Otago Area Health Board ethics committee. All subjects gave their informed written consent.

Results

Table 1 lists the age, height, ethnicity, start time, and baseline spirometry data for the two groups. The start time is the time at which welding began, or the proxy for this, in the non-welder group. None of these characteristics was significantly different for the two groups.

Table 2 lists for each welder the maximum percentage fall in PEF sustained on the study

Table 2 Individual welder data

Subject	*Max drop in PEF (%)*	*Welding time today/h*	*Number of years of welding*	*Welding method*	*Base metal*	*Respirator*	*Atopy*
1	−1·64	1	7	MIG/MAG	MS	Nil	No
2	−2·90	4	9	MIG/MAG	MS	Nil	No
3	−9·72	6·5	8	MMA, MIG/MAG	MS	DHM	No
4	−6·35	6	5	MIG/MAG	MS	Nil	No
5	−6·67	4·5	25	MIG/MAG	MS	Nil	No
6	−4·35	3·5	2	MMA, MIG/MAG	MS	Nil	No
7	2·50	4	3	MMA	MS	Nil	No
8	−1·64	2	4	MIG/MAG	MS	Nil	No
9	−8·45	3	5	MIG/MAG	MS	Nil	No
10	−3·23	4	3	MMA	MS	Nil	No
11	−1·56	3·5	20	TIG	SS	Nil	No
12	−3·51	1	3	MIG/MAG, TIG	MS, SS	Nil	No
13	−9·52	0·25	9	TIG	SS	Nil	No
14	−1·39	2	5	TIG	SS	Nil	No
15	−12·24	2·5	32	MMA	MS	Nil	No
16	−8·00	7	9	MMA	MS	DHM	Yes
17	1·47	7	14	MMA	MS	DHM	No
18	−6·67	3·5	25	MMA, TIG	MS, SS, GALV	Nil	No
19	−6·67	0·5	36	MMA	MS	Nil	No
20	−6·45	3	15	MIG/MAG	GALV	PAP	No
Mean	−4·8	3·4	12·0				
95%CI	−6·5 to −3·2	2·6 to 4·3	7·6 to 16·4				

For Max drop in PEF (%), values with negative sign represent decreases in PEF from baseline. MMA = manual metal arc welding; MIG = metal inert gas welding; MAG = metal active gas welding; TIG = tungsten inert gas welding; MS = mild steel; SS = stainless steel; GALV = galvanised; DHM = disposable half mask; PAP = powered air purifier; Atopy determined by a history of hayfever or eczema.

day, the duration of welding on the study day, the number of years of welding experience, the welding method(s) and base metal(s) used on the study day, the details of any respirator use, and the atopic state.

The percentage change in baseline PEF was calculated for each subject at each of the recording times by:

$$\% \text{ change} = ((\text{PEFt}—\text{PEFb})/\text{PEFb}) \times 100$$

where PEFt = PEF at recording time t;
PEFb = PEF at baseline.

Table 3 gives the group data. The welder and non-welder group means for these results were significantly different at 15 minutes ($p = 0·028$). The difference between the means was of a similar magnitude at 30 minutes, one hour, and two hours. p Values are not given for these as the interdependence of the results at different times could invalidate their use. Also the group mean for maximum drop in PEF (at any of the recording times during the 12 hour period) was significantly greater for the welders ($p = 0·011$).

None of the welders had the 20% drop in PEF regarded as diagnostic of asthma; however 50% of the welders (10 of 20) but only 5% of the non-welders (one of 20) experienced a drop in PEF in excess of 5% ($p = 0·0046$). Five of these welders experienced falls of greater than 5% within the first 15 minutes.

No correlation was found between individual maximum falls in PEF and either years of welding experience or number of hours spent welding on the study day (see discussion). No subject reported any acute respiratory symptoms during the study.

Table 3 Percentage changes of baseline PEF at specified times

	Welders Mean (95% CI)	*Non-welders Mean (95% CI)*	*p Value*
15 min	−1·67 (−3·45 to 0·11)	+0·79 (−0·29 to 1·87)	p =0·028
30 min	−1·17 (−3·00 to 0·66)	+1·35 (0·41 to 2·29)	
1 h	−1·40 (−3·03 to 0·23)	+1·00 (−0·35 to 2·35)	
2 h	−0·89 (−3·04 to 1·26)	+1·95 (0·69 to 3·21)	
4 h	−1·13 (−3·07 to 0·81)	+0·98 (−0·45 to 2·41)	
7 h	−0·57 (−2·93 to 1·79)	+0·55 (−0·62 to 1·72)	
12 h	−1·59 (−3·25 to 0·07)	+0·32 (−1·40 to 2·04)	
Maximum decline	−4·85 (−6·50 to −3·20)	−2·14 (−3·19 to −1·09)	p = 0·011

Discussion

These findings are to the best of our knowledge new. The group of welders experienced significantly greater maximum falls in PEF. The group mean fall in PEF was significantly greater for the welders at 15 minutes. The results suggest an immediate type reaction in welders similar to that seen in some cases of occupational asthma, although not so severe. Previous studies examined ventilatory function in welders at only the beginning and end of a shift, (cross shift), thereby missing the immediate falls found in this study.[25–28] Because the falls in PEF were less than the 20% regarded as diagnostic of asthma, it would be useful in future to determine if these smaller falls reflect non-specific bronchial hyper-responsiveness by using methacholine challenges.

Seven of the 10 welders to experience a fall in PEF in excess of 5% were welding exclusively with mild steel on the day of the study. This suggests that in many cases nickel or chrome allergy is not the cause. As we pointed out earlier, welders are exposed to nitrogen dioxide and ozone at concentrations known to cause bronchial hyper-responsiveness (and in the case of ozone, airways inflammation) in normal subjects. It is possible that these gases are the cause. The falls in PEF were not restricted to any one form of welding. They were seen in MMA, MIG/MAG, and TIG welding.

All the welders worked in large workshops similar to the factory in which the non-welders worked. The non-welders working outside could possibly have been exposed to lower temperatures than the welders, but this would have tended to minimise any difference in PEF. Exercise levels were similar in the two groups.

The complete absence of local exhaust ventilation and low use of personal respiratory protection was disappointing. Only 20% of the welders (four of 20) used some form of respiratory protection and only 10% (two of 20) used devices with activated charcoal for the removal of ozone. It is interesting that despite their protection, three of these four welders had falls in PEF of −9·72%, −8·00%, and −6·45%. This suggests that their protection was inadequate and that possibly the falls would have been greater without the use of protection. We did not retest them without respiratory protection for ethical reasons. It seems that better personal respiratory protection and effective local exhaust ventilation are needed.

No correlation was found between individual maximum falls in PEF and either years of welding experience or hours of welding on the study day. Also the falls in PEF were not specific to either the base metal or the welding method. This suggests that variations in individual exposures to the causative agent(s) are not adequately described by these variables. Measurements of breathing zone concentrations are therefore required in future studies, to see if there is a response to particular constituents of the welding plume, especially the gases ozone and nitrogen dioxide. There is also the possibility that individual susceptibility is important in determining the response. If this is the case, then the factors determining susceptibility are unlikely to include atopy as only one of the welders declared a history of hay fever or eczema. The healthy worker effect is not regarded as a possible explanation as it would have resulted in larger falls in PEF in the welders with less years of welding experience.

In summary, statistically significant immediate reversible airways obstruction was found in workers welding on a Monday morning. This is suggestive of occupational asthma, although the severity of the obstruction was not sufficient to be diagnostic. It is possible that a greater degree of reversible airways obstruction may occur in either a group of more sensitive welders, or in a group exposed to more provocative welding conditions. Further studies are recommended in which breathing zone concentrations are undertaken for ozone, nitrogen dioxide, chromium, nickel, and total particulates, to see if there is a response to particular constituents of the welding plume. Studies of non-specific bronchial hyper-responsiveness would also be useful. In the meantime the use of local exhaust ventilation and personal respiratory protection with activated charcoal for the removal of ozone is recommended.

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