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Respiratory Flow Rates of Metal Welders Compared to a Population Not Exposed to Metal Welding Dust

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Abstract

Background: The welding trade includes many industrial activities in both the formal and informal sectors. Workers in this professional environment do not have access to individual and collective means of protection adapted to the activity, which exposes them to the dust emitted during their activity and therefore contributes to increasing the risk of developing respiratory disorders in this population. **Objective**: Our study aimed to evaluate the ventilatory function of metal welders in the city of Dakar. **Method**: This was a comparative study based on the analysis of the spirometric parameters of metal welders working in the city of Dakar (Senegal) with those of a control group of the same kind, selected from the general population. Measurements of forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), peak expiratory flow (PEF) and maximum mid expiratory flow (MMEF) were measured. **Results**: A total of 75 men between the ages of 19 and 61 were recruited and divided into two groups (43 controls and 32 welders). The welding population had more frequent distal and central obstructions and pulmonary restriction compared to the control group. The metals most commonly used by welders were aluminum for welders who had an obstruction, while for those who had a restriction, iron was the most used metal. Signs of metal fever were frequently found in welders, especially those with ventilatory disorders. **Conclusion**: The prevalence of respiratory disorders observed is

close to that observed in industrial environments, where exposure levels are the highest. The lack of personal protective equipment could also be a significant risk factor in the development of these disorders.

Keywords

Welder, Occupational Exposure, Spirometric Disorder, Metal Fever, Dakar

1. Introduction

Exposure to heavy metals is an ongoing concern around the world. It usually occurs during a variety of circumstances, including exposure in the environment, during medical treatment, or as a result of an industrial accident or criminal act [1] [2] [3]. However, like lead (Pb) and aluminum (Al), some of these metals are among those used in the manufacture of kitchen utensils and metallurgy, among others, with health and environmental effects that have long remained unknown [4].

During the transformation of its metals, it is sometimes necessary to use processes to join metal elements using welding. This system consists of an assembly by fusion of metal parts in contact through a heat source useful for melting and an external contribution of a metal that may be of the same nature or of a composition different from that of the base material; this is also called metal welding [5] [6].

The welding trade is practiced all over the world, and especially in Senegal. It brings together many industrial activities in both the formal and informal sectors. In addition, workers in these sectors of activity do not always have the means of individual and collective protection adapted to the activity [7]. In fact, welding is generally practiced in open-air workshops. It is most often a tack weld that unfortunately presents inherent risks associated with the use of these metals. The surfaces of welding are involved in the occurrence of various pathologies, including metal fever and chronic pneumonia in welders [8] [9]. In most cases, these welders do not benefit from medical care that can help monitor activity-related exposure. In a social context where the wearing of appropriate protective equipment is not always respected, the risk of developing manifestations such as respiratory disorders, dyspnea, or fever within 8 hours of exposure to metal fumes is permanent. Therefore, these welders appear to be more prone to respiratory problems than part of the general population. Thus the objective of our study was to evaluate the ventilatory function of metal welders in the city of Dakar.

2. Materials and Methods

The study was carried out between the Laboratory of Toxicology and Hydrology and the Laboratory of Physiology and Functional Explorations of the Faculty of Medicine, Pharmacy and Odonstomatology of the Cheikh Anta Diop University

of Dakar (UCAD). The protocol was designed in accordance with the guidelines established by the Declaration of Helsinki and was approved by the Ethics Committee of the Cheikh Anta Diop University of Dakar (reference number 0239/2017/CER/UCAD). Participants, after being informed of the voluntary and unpaid nature of their participation, the objectives and modalities of the study, as well as the expected benefits, gave their written and informed consent.

2.1. Surveys and Anthropometric Data

This was a comparative study based on the analysis of the spirometric parameters of metal welders working in the Dakar region (Senegal) with those of a control group of the same kind, selected from the general population. Study participants had to be over 18 years of age and lived in the city of Dakar. The survey included the seniority in the job and the exposure time.

Spirometric examinations were performed in the Pulmonary Function Tests room of the Physiology and Functional Exploration Laboratory.

2.2. Spirometric Measurements

The spirometric examination was carried out using a Jaeger Sentry Suite V2.10 spirometer, and the quality and reproducibility criteria of the spirometric maneuvers were validated from the 2005 ATS/ERS standard [10]. At the end of the spirometric examination, the forced expiratory volume in the first second (FEV1), the forced vital capacity (FVC), the peak expiratory flow (PEF) and the maximum mid expiratory flow (MMEF) that explores the distal bronchi were measured at baseline and after administration of bronchodilator. The FEV1/FVC ratio was then calculated.

From these values, restrictive syndrome was defined as an FVC less than 80% of the predicted value associated with a value of the FEV1/FVC ratio greater than 70%. The diagnosis of proximal obstructive syndrome was defined as a decrease in FEV1 to 80% of its theoretical mean value and the FEV1/FVC ratio to less than 70% [11]. Distal obstruction was defined when the MMEF value was reduced by more than 20% of its theoretical mean value. Central obstruction was assessed using a FEV1/PEF ratio > 8 $ml \cdot l^{-1} \cdot min^{-1}$ [12].

3. Statistical Analysis

The data were analyzed using the R software version 3.2.3. Results were expressed as a mean ± standard deviation and as a percentage. Student's t test was used to compare the means of the parameters between the groups. The Chi^2 test was used for percentage comparison. The Pearson correlation test was used to find links between the parameters. The significance threshold was established at a $p <$ value of 0.05.

4. Results

A total of 75 men between the ages of 19 and 61 were recruited and divided into

two groups (43 controls and 32 welders). Table 1 shows the anthropometric parameters for these two groups.

Analysis of this table showed that our two groups of subjects were comparable in anthropometric data and no significant differences were found between the two groups of subjects. Their spirometric parameters measured at the basal level are shown in Table 2.

Analysis of this table showed that subjects of control group had significantly higher spirometric parameters than welders. However, no significant differences were found for the FEV1/FVC ratio between the two groups.

Comparison of measured values with the reference standards allowed us to find these spirometric syndromes (Table 3).

Table 1. Anthropometric parameters of control subjects and welders.

Anthropometric parameters	Control N = 43	Welders N = 32	p
Age (year)	29.49 ± 4.22 [21.0; 45.0]	31.84 ± 11.50 [19.0; 61.0]	0.29
Height (cm)	178.1 ± 8.46 [161.0; 195.0]	180.4 ± 7.66 [165.0; 196.0]	0.21
Weight (kg)	70.1 ± 11.92 [53.0; 105.1]	68.83 ± 9.06 [54.0; 87.6]	0.6
BMI (kg/m²)	22.03 ± 2.71 [17.11; 29.3]	21.15 ± 2.49 [16.76; 26.74]	0.15

Table 2. Spirometric parameters measured at the basal level in both groups.

Spirometric Parameters	Control N = 43	Welders N = 32	p
FVC (L)	4.79 ± 0.44 [3.73; 5.43]	4.15 ± 0.69 [2.24; 5.67]	3.5×10^{-5}
FVC % predicted	112.2 ± 11.11 [82.0; 137.0]	92.35± 18.01 [40.8; 141.5]	1.4×10^{-6}
FEV1 (L)	4.27 ± 0.412 [3.33; 5.15]	3.69 ± 0.39 [2.77; 4.51]	4.1×10^{-8}
FEV1 % predicted	120.3 ± 11.15 [90.0; 142.0]	97.75 ± 13.04 [65.5; 127.5]	8.05×10^{-11}
FEV1/FVC (%)	89.14 ± 4.77 [79.05; 100.0]	87.02 ± 6.51 [72.1; 98.5]	0.12
MMEF (L)	5.17 ± 1.15 [3.44; 9.23]	4.38 ± 0.92 [2.37; 6.53]	0.001
MMEF % predicted	135 ± 30.5 [87; 251]	97.73 ± 24.79 [47.8; 156.5]	1.4×10^{-7}

FVC: Forced expiratory volume; FEV1: forced expiratory volume in the first second; MMEF: Maximum mid expiratory flow.

Table 3. Distribution of the different spirometric syndromes between the two groups of subjects.

Syndromes	Control N = 43	Welders N = 32	p
Proximal obstruction n (%)	1 (2.32)	5 (15.62)	0.09
Distal obstruction n (%)	0 (0)	8 (25)	0.001
Central Obstruction n (%)	0 (0)	12 (37.5)	4.8×10^{-5}
Restriction n (%)	0 (0)	6 (18.75)	0.01

Analysis of this table showed that welders had more frequent distal and central obstruction and pulmonary restriction. It should be noted that spirometry returned to normal in 14 welders. The seniority in the job was on average 17 years with extremes ranging from 3 to 46 years for welders who experienced proximal obstruction. It was on average 18.5 years for those who had restrictions and extremes ranging from 1 to 34 years. For welders with central obstruction, the seniority in the job was on average 8 years with extremes ranging from 2 to 42 years. The metals most commonly used by welders were aluminum for welders who had an obstruction, while for those who had a restriction, iron was the most used metal.

The most common means of protection were glasses (66%) associated or not with gloves and, to a lesser extent, masks. It should be noted that there was a significant number (25%) of welders who did not use protective equipment. In fact, 6 (19%) of the welders who had presented a ventilatory disorder on spirometric examination did not use a means of protection.

Few welders were smokers (7), 22%. But the majority had a ventilatory disorder 6/7 smokers.

In terms of symptomatology, signs of metal fever were frequently found in welders, especially those with ventilatory disorders. Headache was found in 23 welders (72%), followed by metallic taste in 20 subjects (62.5%), cough in 16 welders (50%), dizziness in 15 welders (46.8%), and nausea in 10 welders (31.2%).

Figure 1 showed the correlogram of spirometric parameters with the seniority in the job.

The analysis of this figure showed that the seniority in the job was not significantly correlated with spirometric parameters such as FVC ($r = -0.03$; $p = 0.84$), FVC % predicted ($r = 0.14$; $p = 0.44$), FEV1 ($r = -0.21$; $p = 0.24$), FEV1 % predicted ($r = 0.19$; $p = 0.30$), FEV1/FVC ($r = -0.26$; $p = 0.15$), MMEF ($r = -0.1$; $p = 0.6$) and MMEF % predicted ($r = 0.19$; $p = 0.3$).

5. Discussion

Exposure to metal fumes during welding is common and a major public health problem, and the risks inherent in this phenomenon are enormous. In fact, various pathologies have been found in metal welders, including respiratory disorders and metal fever. Several studies have examined exposure to metal fumes

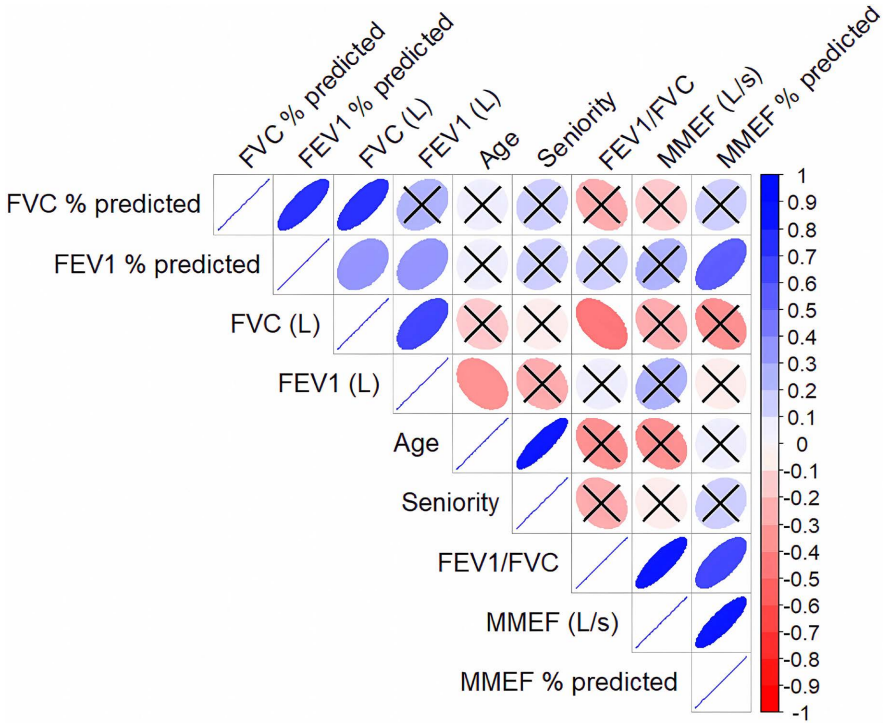

Figure 1. Correlogram of spirometric parameters with duration in the trade. The vertical line represents the correlation coefficient between the parameters. It is colored red if it is negative and blue for positive values. Circles with crosses represent the absence of significant correlation while those without crosses represent significant correlations.

among welders around the world [13] [14] [15]. In Senegal, few studies have focused on the damage associated with exposure to metal dust in welders, and more specifically on the comparison of the frequency of respiratory disorders with subjects free of all metal poisoning [7].

Spirometric parameters were mostly lower in the welder group than in control group. However, the FEV1/FVC ratio was comparable in both groups. This significant reduction in FEV1, FVC and MMEF had already been found in previous studies [16] [17] [18]. In addition, in a 2010 study by Gomes *et al.* [19], a significant decrease in the FEV1/FVC ratio was found in employees exposed in ferrous metal smelters in the United Arab Emirates. This reduction in the ratio predisposes employees to develop bronchial obstruction more frequently. This difference, unlike ours, could be methodological. Indeed, these studies were often carried out in populations where the degree of exposure is high compared to those in our welding shops. The small size of our study population could also explain the lack of difference observed in our study.

Regarding ventilatory disorders, distal obstruction and central obstruction were found at percentages of 25% and 37.5%, respectively. The restriction, on the other hand, was found in 18.75% of our study population. Of the 7 smokers, only one did not have any respiratory disorder. It should be noted, however, that this last patient did not last in the profession compared to other smokers. This leads us to believe that smoking welders were more predisposed to develop ven-

tilatory disorders than nonsmokers. Various authors had tried to find this link between smoking and the occurrence of ventilatory disorders in welders. In 1991, Rastogi *et al.* found similar percentages of proximal obstruction (12%) and restriction (16%) comparable to ours. They also showed that all patients with ventilatory disorder were smokers [20]. However, another study conducted in Italy, involving 68 welders, showed lower percentages of ventilatory disorders. They had only found two smoking patients with obstruction for one and restriction for the other [21]. The working conditions of our study population was also different from those of studies regularly found in the literature, which in itself may explain the results obtained. The absence of wearing personal protective equipment in our context, and particularly the absence of mask use, could explain the high percentage of ventilatory disorders observed in our population, which worked under conditions that seemed less polluting than the industrial level.

Signs of metal fever such as headache (72%), dizziness (46.8%), nausea (31.2%), metallic taste (62.5%) and cough (50%) were frequently found in welders who had a ventilatory disorder. Acute exposure to toxic metal vapors has been shown to lead to the occurrence of metal fever [22] [23]. The most common signs may differ depending on the case of exposure. In fact, in a study conducted among 32 welders at the "Sugar Factory" in Ankara, the most frequently found symptoms were cough (65.6%), sputum (84.4%), dyspnea (68.8%) [24]. This difference could be explained by several factors. Their study population consisted only of welders who worked in a sugar factory. The latter most often used welding processes different from those used in Senegal, such as gas or torch welding. These are welding processes where the melting temperatures are higher, as well as the amount of fume released.

Limitation: There were limitations to our study. First, we did not measure, identify and chemically characterize the pollutants present in the air, which would have made it possible to establish a causal link between occupational exposure to these pollutants and the variation in respiratory volumes in welders.

Secondly, it was not possible to carry out research into biological matrices such as blood and urine for pollutants such as heavy metals, which would have revealed the level of impregnation.

Thirdly, we did not carry out medical follow-up for subjects who presented with ventilatory disorders.

6. Conclusions

The lack of adequate equipment exposes welders to metal-vapor poisoning. The latter could be the cause of an impairment of pulmonary function in these workers who work in precarious working conditions. In this context, we conducted a study to evaluate the ventilatory function of metal welders working in the Dakar region by comparing them to subjects free of metal vapor poisoning.

Our two groups were anthropometrically comparable. Most of the spirometric

parameters studied were lower in the welder group with the exception of the FEV1/FVC ratio. Ventilatory disorders were found more frequently in the welder group, except for proximal obstruction, which was not significantly different between the two groups. This prevalence was not negligible.

These results showed that the impairment of ventilatory function and metal fever in the metal welder population is a real public health problem. The prevalence of ventilatory disorders was sometimes close to that found in the industrial environment where exposure levels were the highest. However, the lack of personal protective equipment could be an explanatory factor for the high incidence of ventilatory disorders.

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Conflicts of Interest

The authors have no conflicts to disclose.

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