INTRODUCTION
Since the introduction of various machines and electrical equipment into the workplace, electromagnetic fields (EMFs) are present in buildings and the natural environment. Many people have blamed certain symptoms that they have experienced on exposure to EMFs. The term electromagnetic hypersensitivity (EHS) refers to clinical conditions where people complain of health symptoms that are ascribed to exposure to EMFs. Common symptoms include headaches, sleep disorders, skin rash, dizziness, back and hand pain, muscular weakness, skin and eye problems, chest pain, and coughing. It has been suggested that the prevalence of health symptoms differs according to the type and level of exposure to EMFs. The health complaints related to EHS among individuals may also lead to psychological stress.

In a population survey conducted in Stockholm, around 1.5% of the population reported suffering from symptoms of ill health associated with exposure to EMFs. In California, 3.2% of the population reported hypersensitivity to EMFs in a survey conducted in 1998. Similar results were reported in a study that investigated and characterised hypersensitivity by analysing the probability distribution of perception threshold of electric current at 50 Hertz (Hz). The prevalence of EHS was initially estimated at 1.5% in Sweden but, more
recently, it was estimated at 2.6-3.2%. The prevalence in Australia was estimated to be less than 2% in 1994 but had increased to 3.5% by 2001. In 1997, approximately 5% of the population in Switzerland was estimated to suffer from EHS. The symptoms were reported by individuals who were exposed to 50 Hz electric and magnetic fields, and radio frequency fields.

During the World Health Organization (WHO) conference on EHS held in Prague in 2004, a review was commissioned to identify literature in order to describe and define EHS; to provide information on its course, prognosis and treatment; and to examine its connection with other conditions, such as multiple chemical sensitivity. The review reported that EHS symptoms are classified into facial skin symptoms and non-specific symptoms across a range of body systems. Facial skin symptoms are related to exposure to video display units (VDUs) and are dominant in Nordic countries, such as Sweden. It was also reported that there is no consistent association between EHS and EMF sources. However, there is geographical variation in terms of the development of symptoms, attributable sources of exposure, and the estimated prevalence of EHS. The review indicated that there is a connection between EHS and other conditions, known as symptom-based conditions, functional somatic syndromes or idiopathic environmental intolerances. It has been reported that health symptoms are most common in industrialised countries. However, a direct link between exposure to EMFs below recommended exposure levels and self-reported symptoms has not been established. There is no specific symptom profile, nor are there validated diagnostic criteria to diagnose the degree of hypersensitivity to EMFs.

Welding uses relatively high electric currents of up to several hundred amperes. The properties of EMFs depend on the processes, such as shielded arc welding, tungsten inert gas (TIG) welding and metal inert gas (MIG) gas welding, and the power source. Low frequency EMFs, below 1 kHz, are dominant in the welding environment, although higher frequencies of up to several MHz also exist due to ripple currents generated by the welding power source.

Public discussions about hypersensitivity to EMFs have increased since the 1990s and there are concerns that adverse health impacts and some symptoms of ill health are related to EMFs in certain industries, such as the welding industry. There is therefore a need to assess the prevalence of symptoms of ill health related to exposure to EMFs among employees in the welding industry. This study was designed to describe and calculate the prevalence of health symptoms in a group of employees in a welding company, using a questionnaire.

“Most workers . . . reported some neurological, respiratory, musculoskeletal, dermatological and/or ocular-visual symptoms.”

**METHODS**

This was a cross-sectional survey conducted among employees of a heavy engineering CO₂ MIG welding company in the Mangaung Metropolitan Municipality in the Free State province, South Africa. The study population consisted of all full-time welders and fitters, and office workers. At the time of the survey, in November 2011, there were 124 full-time employees working at the welding company.

As described in a previous paper, measurements of EMFs taken in the welding workshops showed that welders and fitters were exposed, on average, to magnetic fields of 7.6 microtesla (μT) while office workers were exposed to magnetic fields of 0.15 μT. Welders and fitters were also exposed, on average, to electric fields of -13.50 volts per metre (v/m) while office workers were exposed to electric fields of 1.80 v/m.

Permission was obtained from the management of the welding company before commencement of the study.
Table 1. General characteristics of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exposed group</th>
<th>Unexposed group</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=58</td>
<td>n=30</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
<td>9</td>
<td>0.607***</td>
</tr>
<tr>
<td>Male</td>
<td>52</td>
<td>21</td>
<td>0.001***</td>
</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smokers</td>
<td>17</td>
<td>8</td>
<td>1.000**</td>
</tr>
<tr>
<td>Non-smokers</td>
<td>41</td>
<td>22</td>
<td>1.000**</td>
</tr>
<tr>
<td>Age in years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>33</td>
<td>37</td>
<td>0.070*</td>
</tr>
<tr>
<td>LQ</td>
<td>29</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>UQ</td>
<td>38</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>Hours of work/week</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>40</td>
<td>40</td>
<td>0.330*</td>
</tr>
<tr>
<td>LQ</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>UQ</td>
<td>44</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Years of service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>4</td>
<td>5</td>
<td>0.129*</td>
</tr>
<tr>
<td>LQ</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>UQ</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

LQ: lower quartile; UP: upper quartile; *Kruskal-Wallis test; **Chi square test; ***Fisher’s exact test

Questionnaires were sent to all 124 employees but only 88 responded, giving a response rate of 71%. The exposed group comprised 37 welders and 21 fitters, while the unexposed group comprised 30 office workers.

Measurement tool

The purpose of the survey and the contents of the questionnaires were explained to the participants beforehand. A self-administered questionnaire, consisting of open- and close-ended questions, and compiled in English, was used to collect data. The questionnaire was piloted among part-time employees (welders, fitters and office workers) in the company before commencement of the survey, and included demographic information such as age, gender, and smoking status, as well as work-related information, such as duration of service, hours of work per week, hours spent welding or fitting, and current position in the company. Questions were asked about health with regard to neurological, musculoskeletal, respiratory, dermatological and ocular-visual symptoms.

Data analysis

Data were captured using Microsoft Excel 2007 and analysed using SAS Version 9.2. Frequencies and percentages were calculated for categorical data; medians and percentiles were calculated for continuous data. The Kruskal-Wallis, Chi square and Fisher’s exact tests were used to test differences between the exposed and unexposed workers.

Ethical clearance was obtained from the Ethics Committee of the University of the Free State (reference number: 170/2011).

RESULTS

The data were skewed and therefore medians, with upper and lower interquartile ranges, are reported, rather than means. The median ages for the exposed and unexposed workers were 33 and 37 years, respectively (Table 1). More of the unexposed workers (30%) were female than the exposed (10.3%). Almost 30% of the employees in both groups were smokers. All employees worked for a median number of 40 hours per week. The median number of years worked was similar for both groups (four for the welders and fitters, and five for the office workers). None of these differences was statistically significant. The median number of hours spent welding and fitting was eight.

Figure 1 shows the comparison of neurological symptoms between the exposed and unexposed groups. Headache was common among all the study subjects (65.5% of the exposed group and 56.6% of the unexposed group). Around a third of both groups reported having sleep disorders. More of the exposed workers reported fatigue and dizziness than the unexposed group (p < 0.05).

Figure 2 shows the comparison of musculoskeletal symptoms between the exposed and unexposed groups. Both groups suffered from back pain, but a higher proportion of the exposed group complained of symptoms than the unexposed group (68.9% and 43.3%, respectively; p < 0.05). More of the exposed than unexposed workers reported hand pain and muscular weakness too (p < 0.05). There was no difference between the groups with regard to neck pain.

Dermatological symptoms were also reported by the study subjects. The exposed group suffered from skin numbness (12.1%), skin redness (25.8%), skin burning sensation (37.3%), skin rash (18.9%), and skin swelling (18.9%). Fewer of the unexposed group suffered from all these symptoms (Figure 3). All these differences were
statistically significant, apart from the skin numbness.

Table 2 shows the differences between the ocular-visual symptoms in the exposed and unexposed workers. The exposed group reported more blurry vision, eye irritation and eye dryness than the unexposed group \((p < 0.05)\). As shown in Table 3, 32.8% and 13.3% of the exposed and unexposed groups, respectively, experienced chest pains \((p < 0.05)\). More of the exposed than the unexposed group reported that they coughed most of the time \((p < 0.05)\).

**DISCUSSION**

Most workers (exposed and unexposed) who participated in this study reported some neurological, respiratory, musculoskeletal, dermatological and/or ocular-visual symptoms. Headache was the most common neurological symptom described, followed by distress and fatigue. Back, hand and neck pain were common complaints, as were skin burning sensation, visual problems, coughing and chest pain.

Welders and fitters were exposed to EMFs from welding, while office workers were exposed to EMFs from office equipment, such as computers. Both groups reported similar health symptoms. Symptoms of EHS, including headaches, concentration difficulty, sleep disorder, and distress were described in persons working on visual display units (VDUs) in the 1980s. In a study by Röösli et al. in 2004, subjects exposed to EMFs also reported sleep disorders (58%), headaches (41%), distress (18%) and concentration difficulty (16%) as the most common health symptoms.

Although all symptoms were more commonly reported in the exposed group, we cannot prove a causal link between the exposure levels measured in our previous study and the reported symptoms. First, the symptoms in this study are non-specific. Second, the results may be biased, either because people with symptoms may have been more inclined to participate in the study than those without symptoms, or very sick people may have left the company (healthy worker effect).

Information from the environment is monitored and integrated by the nervous system. The nervous system is highly sensitive to EMFs. There is evidence that exposure to high levels of EMFs can lead to neurodegenerative diseases, such as Alzheimer’s disease.

The reported symptoms may have been due to other causes. Factors such as medical and psychological conditions, and exposure to other occupational and/or environmental hazards, may also contribute to the development of these symptoms. For example, Poole et al. reported a high incidence rate of depression among subjects whose houses were located closer to power lines. It is possible that some participants were suffering from chronic diseases which could manifest some of the reported symptoms.

**Table 2. Comparison of ocular-visual symptoms in the exposed and unexposed groups**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Exposed group</th>
<th>Unexposed group</th>
<th>(P) value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=58)</td>
<td>(n=30)</td>
<td></td>
</tr>
<tr>
<td>Blurry vision</td>
<td>20 (34.5)</td>
<td>4 (13.3)</td>
<td>0.002</td>
</tr>
<tr>
<td>Eye irritation</td>
<td>34 (58.6)</td>
<td>9 (30.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>Dry eyes</td>
<td>29 (50.0)</td>
<td>7 (23.3)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

* Fisher’s exact test

**Table 3. Comparison of respiratory symptoms in the exposed and unexposed groups**

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Exposed group</th>
<th>Unexposed group</th>
<th>(P) value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=58)</td>
<td>(n=30)</td>
<td></td>
</tr>
<tr>
<td>Chest pain</td>
<td>19 (32.8)</td>
<td>4 (13.3)</td>
<td>0.003</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>9 (15.5)</td>
<td>3 (10.0)</td>
<td>0.145</td>
</tr>
<tr>
<td>Coughing</td>
<td>29 (50.0)</td>
<td>9 (30.0)</td>
<td>0.001</td>
</tr>
<tr>
<td>Wheezing</td>
<td>11 (19.0)</td>
<td>4 (13.3)</td>
<td>0.022</td>
</tr>
<tr>
<td>Irritation of the respiratory tract</td>
<td>12 (20.7)</td>
<td>4 (13.3)</td>
<td>0.076</td>
</tr>
</tbody>
</table>

* Fisher’s exact test
these symptoms. For example, a headache is a common symptom of hypertension as well as a number of other illnesses. It has been reported that there is a connection between EHS and other idiopathic environmental illnesses.\textsuperscript{13} Ergonomic factors in the workplace could also play a role in the development of some symptoms. Welders and fitters spend much time lifting objects, standing, and bending their bodies. This may cause them to experience muscular symptoms such as back pain, and pain in their arms, hands and necks. Office workers spend many hours sitting in front of computers in static position and this could also account for musculoskeletal symptoms.

Skin burning sensation was observed more commonly among the exposed than the unexposed group. The human skin is a highly sensitive organ with receptors that detect various stimuli. Many workers (exposed and unexposed) also reported other dermatological symptoms, such as skin redness, numbness, swelling and rash. These symptoms may occur due to viral infections, allergies, insect bites, chronic skin conditions (such as acne), and extremely hot and cold temperatures. Welders and fitters were also exposed to ultraviolet radiation from welding which may contribute to the development of skin and visual-ocular symptoms. Welding produces a full spectrum of ultraviolet wavelengths and welders are therefore at a high risk of developing dermatological symptoms.\textsuperscript{21} Ultraviolet radiation causes damage to all skin types, but the effects are more severe in lightly pigmented skin. Dermatological symptoms have been shown to not be associated with cell phone use and VDU exposure in some studies. For example, skin problems were not observed among subjects who were using GSM mobile phones for 60 minutes at a distance of 4 cm from the ear for 60 minutes.\textsuperscript{22} Reduction of electric fields from VDU by electric-conducting screen filters did not reduce the prevalence of skin symptoms among study subjects in Norway.\textsuperscript{23}

A review of 46 studies by Rubin et al. in 2010, and a study conducted in 2008 by Röösli, did not support the hypothesis that exposure to EMFs causes EHS.\textsuperscript{24,25} A systematic review of 31 experimental studies testing whether EHS can be caused by exposure to EMFs also found no correlation.\textsuperscript{26}

Respiratory symptoms such as coughing, chest pain, wheezing, irritation of the respiratory tract and chest tightness/dyspnea were very common among fitters and welders. Exposure to ultraviolet radiation and EHS may trigger these symptoms. The symptoms could also be triggered by other hazards such as fumes and gases produced during welding and fitting,\textsuperscript{27} as well as smoking. However, respiratory symptoms among welders have been reported in previous studies conducted in the welding industry.\textsuperscript{28–30}

CONCLUSION
In South Africa, information regarding prevalence of health symptoms among employees in the welding industry is lacking. This study provides some preliminary data. The overall prevalence of health symptoms was high among the study participants, with exposed workers experiencing a higher prevalence of some symptoms than unexposed workers. However, there is no clear relationship between EMF exposure and the development of the reported symptoms. It is, nevertheless, necessary to implement safety measures in the workplace and to provide medical treatment to alleviate the symptoms that workers are experiencing.

RECOMMENDATIONS
It is recommended that subjects who are experiencing health symptoms seek medical help. This should be done in consultation with the medical personnel and occupational hygienist in the company. All contributing factors should be identified and appropriate control measures should be implemented. Thorough medical examinations of the subjects should be conducted to identify and treat any underlying conditions that may be responsible for the symptoms. A psychological assessment should also be done to determine if there are any psychiatric or psychological conditions related to the symptoms. Subjects who experience these symptoms should try to reduce their exposure to EMFs; complete avoidance is a major challenge in modern society. Methods that can be used are:
• Avoiding close contact with sources of exposure, such as welding cables.
• Disconnecting electrical devices not in use.
• Using screens or shields against EMFs.

An assessment of the workplace for other factors contributing to the development of the symptoms should be conducted by the occupational hygienist. All employees in the welding industry should be informed and educated about the potential health hazards of EMFs.

A larger study should be undertaken to determine if these health symptoms are specific to EMF exposure, using a larger sample of welders and fitters, and taking potential confounders into account, such as smoking and other exposures.

ACKNOWLEDGEMENTS

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CONFlict of interest

The authors declare no conflict of interest.

LESSONS LEARNED

1. The prevalence of some symptoms was high among the exposed and unexposed groups in the welding industry.
2. It is important to identify other possible reasons for the cause of these symptoms before definitively linking them with exposure to electromagnetic fields.

REFERENCES