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Scientific literature on welding apprentices and preventive medicine: An integrative literature review

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ABSTRACT

Welding apprentices invest in their professional and technological education. The welding work, and before that, the welding apprenticeship, exposes the apprentices to several risk factors, such as a physical, chemical and physiological. Exposure to these factors can trigger various health disorders and accidents. Among some of the health disorders that may be triggered by welding activity are skin, lung and stomach cancer, coronary heart disease, noise-induced hearing loss and work-related musculoskeletal disorders. This paper is an integrative review of how studies are developing with welding apprentices. Of 638 articles, ten met the search criteria. The publications cover genetic, respiratory and neuropsychological health disorders and improved welding techniques. It is considered that the identification of a low number of publications on welding apprentices constitutes a need for knowledge construction in the areas of occupational and public health.

Keywords: Welding Apprentices; Technological Education; Risk Factors

1. INTRODUCTION

Education is within a process of qualification for a job. Specifically vocational and technological education integrates the dimensions of labour, science and technology [1], leading to ongoing skills development for a productive life [2]. The development of skills for life aims at training a productive workforce. In teaching activities, this training has the objective of increasing productivity and/or meets a social demand of access to culture [3].

Falling into this branch of education, the courses offered by institutions of vocational and technological education seek to promote the development and improvement of the national industry. Of particular interest for this study are welding courses, which enable individuals to undertake work in this specificity. Such individuals will go on to work as welding apprentices.

Welding apprentices invest in their professional and technological education by undertaking the course and this investment integrates the future work force, not only just classifying the same, in that it converts into a job, but that it also fulfills a need which is socially shared and recognized [3].

The welding work, for which these individuals are trained, is an operation which involves a localized coalescence produced by heating to an appropriate temperature, with or without the application of pressure and weld metal [4]. In different countries, such as Nigeria [5], Sri Lanka [6], France [7], Denmark [8], Turkey [9] and Brazil [10], the issue involving the health and safety of welders is being studied.

During the work, welders are exposed to several risk factors, which are, among others, physical, chemical and physiological [11]. Exposure to these factors can trigger various health disorders and accidents. Among some of the health disorders that may be triggered by welding activity are skin [12], lung [13] and stomach cancer [14], coronary heart disease [15], noise-induced hearing loss [16] and work-related musculoskeletal disorders [17].

Concerning accidents at work, this study [18] describes the occurrence of accidents, such as thermal, electrical and chemical burns in workers performing electrical activities. The study indicates that welders have higher age-adjusted rates for burn injuries (61.57 per 10,000 employee/year) and thermal burns (40.87 per 10,000 employee/year). In the case of welding activities, thermal burns can be characterized as chemical burns because the contact with the chemical compounds present in the metal which causes thermal burns may result in chemical burns.

It is understood that exposure to these risk factors, and consequently, potential illness, can occur during post-apprenticeship activity or start during welding apprenticeship. Faced with such factors, the study has aimed to synthesize scientific knowledge generated by research conducted with welding apprentices.

2. METHODS

To achieve this goal, an integrative review method has been chosen, which allows for complete synthesized research and to obtain conclusions from a given theme.

In the production of this review, the following six steps were used: defining the guiding questions; establishing criteria for inclusion/exclusion (selection of articles); definition of information to be extracted from selected articles; analysis of the included studies and interpretations of results and presentation of the integrative review [19]. The question was defined as: How are studies developing with welding apprentices?

The literature review was conducted online in the period from 2002 to 2012. Data collection was conducted in the first half of 2012. The search was based on the keywords: Apprenticeship and Welding, Welding and Apprentice, Trainee and Welding, Trainee and Welders, Welders and Apprentice, Apprenticeship and Welders. The primary search was made using the following electronic databases: CINAHL, LILACS, Medline and Scielo. This search resulted in eleven publications in MEDLINE. In the second search, this was expanded to other databases: Gale—Academic OneFile, Web of Science (Thomson Scientific/ISI Web Services), ScienceDirect (Elsevier), National Science Digital Library: NSDL, Emerald Fulltext (Emerald), MEDLINE/PubMed (via National Library of Medicine), Oxford Journals (Oxford University Press), BMJ, SpringerLink (MetaPress). 197 publications were obtained with the combination of the first keywords, the second, 183, the third, 95, the fourth, 50, the fifth, 99 and the sixth, 113 publications.

The criteria used for selecting the sample were: complete articles published and available online, open access, papers discussing the learning of welding; articles with resume for initial assessment; studies written in English, Spanish or Portuguese. Studies repeated in more than one database were considered only once.

The completion of the searches made on the databases resulted in a total of 882 publications and the database that showed more publications was Gale—Academic OneFile, with 576 results. After identification of the results, the next procedure was the removal of duplicate articles, eliminating 244 publications. In order to determine the sample according to the criteria of inclusion and exclusion, the titles and abstracts of 638 publications were read. After this initial analysis, 627 records were excluded, the reason for this exclusion being the approach to the subject of welding work not being about learning welding but just treating learning as a topic. Of these, eleven were used as inputs in the introduction and discussion of this study. Eleven articles were considered as inclusion criteria: four were identified that addressed the topic of welding work and learning quoted above. They were excluded, stipulating seven articles for analysis. To finalize the search, three additional reading texts were added to assist in understanding the subject. Thus, 10 publications were included in the review (**Figure 1**).

3. RESULTS

In this integrative review 10 articles were analyzed, according to the inclusion criteria previously established. Among the selected articles, five (50%) were produced in the United States [20-24], three (30%) in Canada [25-27], one (10%) in the UK [28] and one (10%) in Romania [29], demonstrating that there is greater concern with the issue in developed countries.

The majority (70%) of the reports analyzed were developed in welding schools. One publication described coping strategies for the inability of welders in private enterprises [28] and two publications did not identify research scenario [20,29]. **Table 1**, shown below, shows an overview of the article analyzed.

Among the 10 papers presented, five publications (50%) [21,22,24-26] presented medical writers, three mechanical engineers (30%) [20,23,29], a teacher (10%) [27] and a journalist (10%) [28].

Regarding the type of journal, five were published in medical journals, two were published in an occupational health journal [22,25], one article in a journal of respiratory medicine [26], and one article were published in a journal specializing in an interdisciplinary journal which addresses public health, environmental and occupational health [21]. Two papers were also published in engineering journals [20,29], two in regular education journals [27,28] and one in a specific journal of welding [23].

The population studied in the articles selected a total sum of 701 subjects, according to inclusion criteria proposed by studies. However, not all the articles specify their inclusion criteria.

Of the articles used in this review, one (10%) was developed in 2003 [26], four (40%) in 2005 [21-23,25], one (10%) in 2008 [29], one (10%) in 2010 [20] and three (30%) [24,27,28] in 2011. In 2012 there were no articles found on the topic.

Regarding the variables studied in the articles, three studied the relationship between exposure to welding fumes and respiratory disorders [22,25,26]; in one paper the authors studied the relationship between exposure to

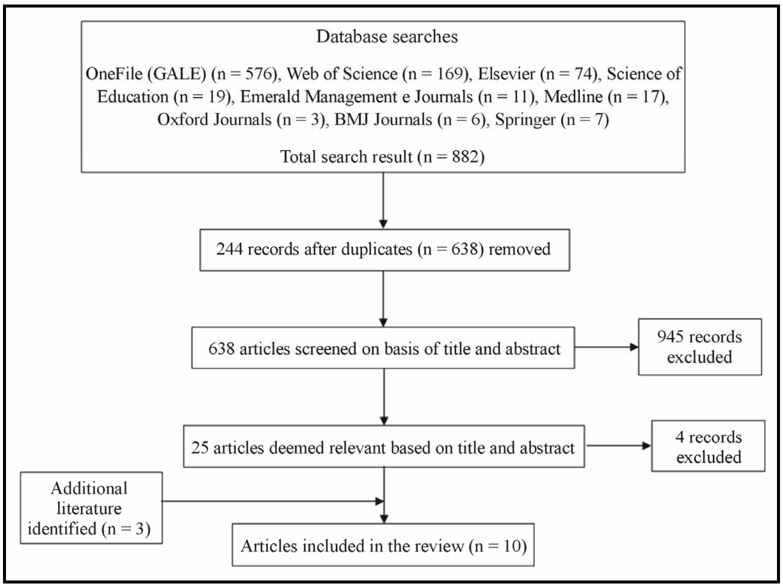

Figure 1. Summary of search strategies and identification of the articles included in the review.

welding fumes and genetic disorders [21]; another the relationship between manganese exposure and neuropsychological disorders [24]; one approached an online learning of weld theory [27]; two described tools to assist in the teaching of welding [23,29]; one showed strategies to combat lack of skill of welders [28] and one presented the need for training to deal with the automation of welding [20].

With regard to the method used in the reviewed articles, it should be noted that the six publications that dealt with this item were all quantitative. Of these, two existing questionnaires were used to measure the variables in studies. One used the "Union Against Tuberculosis and Lung Diseases" [25] and one used the "Student instructional report" [27]. Neither of these are specific questionnaires for learning welding.

4. DISCUSSION

A conducted review which showed publications about welding apprentices, focuses on exposure to chemical hazards and consequent disease and on improving the learning process of welding.

None of the analyzed studies used specific questionnaires covering the process of welding work. Specific questionnaires need to be built, to grasp the risks, accidents and diseases specific to this work. However, none of the publications have the participation of nurses, which illustrates this absence, which is the theme within this subject.

All texts related to health expressed concern over exposure of welding apprentices to risk factors related to chemical fumes from these metals and the relationship with respiratory disorders [22,25,26], neuropsychological [24] and genetic [21].

The literature relating to the welder at work also identifies such concerns. A major respiratory disease studied is occupational asthma. Different studies [30-35] have shown that welders constitute a risk group for developing this disease, which was also demonstrated in the studies analyzed with welding apprentices [22,25,26].

Other diseases identified the harmfulness of welding fumes to the respiratory system. This is because the welding fumes consist of a wide range of metal particles which may be deposited throughout the respiratory tract. The pulmonary effects of welding smoke include bronchitis, fever, cancer and lung functional disorders [6,36]. An example of a harmful compound is stainless steel, the smoke of which can cause acute lung injury. The size of the inhaled particles and exposure time are significant factors in welding, which must be considered in the development of protective strategies [37].

The genetic disorders associated with work in welding are related to exposure to lead, chromium and nickel. Studies with welders exposed to these metals have sought to identify chromosomal damage in individuals who used personal protective equipment and individuals who did not. The analysis showed that workers who did not use personal protective equipment had a higher frequency of chromosomal damage than the group that did [38].

Exposure to manganese, analyzed in a study of welding apprentices, was under investigation [39] and it sought to relate metal exposure with Parkinson's disease but found no direct relationship. However, a study of welders exposed to manganese, identified with the use of MRI, changes to fine motor skills [40].

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Table 1. Identification of articles, in a randomized, objective, methodological procedure with outcomes.

Title	Authors	Objectives	Population	Study design	Methodological procedures	Outcomes
Incidence of probable occupational asthma and changes in airway calibre and responsiveness in apprentice welders	M. El-Zein, J.-L. Malo, C. Infante-Rivard, D. Gautrin	To determine the incidence of probable occupational asthma (OA), bronchial obstruction and hyper-responsiveness among students entering an apprenticeship programme in the welding profession.	286 welding apprentices	Cohort	The apprentices answered a questionnaire about symptoms related to occupational asthma and underwent spirometry and methacholine bronchoprovocati-on in two stages: firstly, apprentices before being exposed to welding fumes and secondly, at the end of the study (after 15 months).	The incidence of occupational asthma was approximately 3%. The bronchial hyper-responsiveness decreased after exposure to welding fumes, representing a 20% decrease in forced expiratory volume of apprentices.
Global gene expression Profiling in whole-Blood samples from individuals exposed to metal Fumes	Zhaoxi Wang, Donna Neuburg, Cheng Li, Li Su, Jee Young Kim, Jiu Chiuan Chen, David C. Christiani	To develop a method for application of micro array technology in whole blood RNA.	15 welding apprentices (case) and 7 office workers welding school (control)	Self-controlled study	Collecting blood for red blood cell count, platelets, hemoglobin, hematocrit and red blood cells.	All subjects' cell counts were within normal ranges. The difference was in relation to welding apprentice smokers, who had higher numbers of leukocytes and neutrophils than non-smokers throughout the study population. There were no genetic changes in the groups. The results suggest that the actual signal changes in the profile of gene expression in response to occupational exposure to metals are small.
Is metal fume fever a determinant of welding related respiratory symptoms and/or increased bronchial responsiveness? A longitudinal study	M. El-Zein, C. Infante-Rivard, J.-L. Malo, D. Gautrin	Investigate the hypothesis of metal fume fever (MFF) being a predictor for the development of respiratory symptoms and functional abnormalities.	286 welding apprentices	Cohort	The apprentices answered a questionnaire about symptoms related to occupational asthma and underwent spirometry, methacholine bronchoprovocati-on and skin tests to determine allergic reactions in two stages: firstly, apprentices before being exposed to welding fumes and secondly, at the end of the study (after 15 months).	The metal fume fever was reported by 39.2% of the apprentices, through the following symptoms: fever, feeling of general malaise, chills, dry cough, metallic taste in mouth and shortness of breath; 13.8% reported at least one suggestive symptom of asthma (coughing, wheezing or chest tightness); skin test showed that 11.8% of the apprentices developed immunological sensitization with at least one metal solution throughout the study, and the main metals were copper, aluminum, zinc, manganese. The fever was significantly associated with respiratory symptoms, thus the metal fume fever may be a predictor for the development of respiratory symptoms.
Neuropsychological effects of low-level manganese exposure in welders	Wisanti Laohaudomchok, Xihong Lin, Robert F. Herrick, Shona C. Fang, Jennifer M. Cavallari, Ruth Shrairman, Alexander Landau, David C. Christiani, Marc G. Weisskopf	Investigate the neuropsychological effects of lower level occupational manganese exposure in male welding apprentices.	46 welding apprentices	Quantitative	Exposure of apprentices based on measurements of manganese in the air and work histories of welding was considered. The subjects also underwent testing domain of attention, motor performance and mood.	The results indicate that the presence of manganese in the air in days of classroom practice welding increases 10 times more than in days when there is no class. Concerning manganese exposure, the authors state that, based on the results, even low exposure to the metal can cause neuropsychological symptoms.
Training system for welding operators	Gabriela Ionescu; Octavian Ionescu	Describe a system to implement virtual learning welding.	The number of apprentices who used the system was not specified	System of virtual learning welding	To develop the system, the following parameters to be monitored during training are considered: trajectory, velocities, accelerations and tilt in a three axe torch, welding current and shielding gas volume. In the solder laboratory stations equipped with a computer and monitor and several welding machines were created. Each apprentice received a different type of solder to run and a random welding instructor oversaw the records of the work done. On the monitor there was no information about the position and inclination of the soldering gun and records variations of speed and acceleration. Whenever the learner manipulated the gun the wrong way, the instructor received a report on the monitor and could correct it in real time.	Using classical methods of training, an instructor was able to supervise up to eight apprentices and a minimum of three weeks of training were required to achieve good results. Using the virtual training system, an instructor can supervise up to 20 apprentices in a week and it was possible to detect and correct typical errors made by each.
As national welder shortage looms, adequate training becomes a critical asset	Ernest A. Benway	Reflecting on the need for adequate training of welding apprentices and increasing automation of this branch.	-	Learning automation in welding	Reflection on learning automation in welding.	The automation of the weld does not diminish the need for training the workforce. Workers are needed to properly handle the machinery. Thus, automation requires more staff training, not less. Apprentices need to have welding knowledge about the composition of the material used, gases used for welding, power and voltage welding machine and electrode sizes. They also need to understand how to operate the welding automation system. Good training programmes will cover such knowledge.

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Continued

Apprenticeship students learning on-line: opportunities and challenges for polytechnic institutions	Martha Burkle	Analyze the expectations of students about online learning; explore the impact of mobile content in student learning; learn about the efficiency of the online course and the ability to engage in the course.	17 electrical apprentices and 7 welding apprentices.	Quantitative and qualitative	Subjects were interviewed using a questionnaire with 23 questions on a Likert scale. The interviews were conducted online. After the interviews were conducted there were focus groups with the apprentices. The information obtained in the focus group was compared with the information obtained during the interviews. And lastly, interviews with instructors were conducted.	Qualitative results show that the theoretical content of online courses showed motivation of apprentices due to availability of the latter at any time. Moreover, the instructors encouraged learning anywhere, breaking the limits of the classroom. Moreover, according to the learners, the time spent by them in practical activities is better used after the theoretical content online. Quantitative data showed that the theoretical content available online helps apprentices to study within work time. Regarding the age of the apprentices, the youngest showed more ease in dealing with the online system.
Apprentices prove their worth at TIS Cumbria	David Pollitt	Describe coping strategies for the inability of welders in a private company.	-	-	-	To combat the lack of ability of welders, a private company opted to train apprentices with solder powder. A training area was created for training within the company, a full-time instructor was recruited and scale systems were used to identify skill levels, costs and efficiency. In the company, tests were performed industrial radiography, ultrasound, weld inspection and evaluation in a specifically designed 3D studio. Apprentices who participate in the training programme of the company are selected after already having some experience in soldering. Furthermore, they should participate in community activities (sports, for example). At the final stage of selection, the interview should include the presence of the parents of the candidate. The approximate cost of an apprentice to the company is £13.450. A portion of that cost, £2.666, is funded by the Nuclear Skills Academy. Initially, the company thought of recovering the value in 2 years but in fact the recovery took seven months. The work that learners perform with the rest of the workforce team makes them feel part of the team and contributes to the costs of their training, making them feel proud of their work. With the support of the Nuclear Skills Academy it is possible to have a young workforce with skills and practice.
How am I doing? System with real-time, heads-up helmet-display monitors performance of trainee welders	James Benes	Describe a learning tool for use in welding apprenticeship.	-	-	-	The tool described is a helmet that provides visual information about how apprentices are performing the weld and how to improve it. The system reduces the workload of an instructor, working as a teaching assistant while collecting data about the performance of learners.
Exposure to welding fumes is associated with acute systemic inflammatory responses	J. Y. Kim, J.-C. Chen, P. D. Boyce, D. C. Christiani	To investigate the acute systemic inflammatory response to welding fumes exposure.	24 welding apprentices (case) and 13 individuals who worked in a welding school (considered not exposed to tobacco-control)	Case-control	For data collection, the following methods were used: deployment of equipment for measurement of particle exposure on the lapel of subjects, blood sampling of the subjects before the start of the activity and immediately after welding. In the control subjects, blood was collected 24 hours after the first collection of cases; collection of urine before and after exposure to welding fumes.	The subjects (cases and controls) remained about six hours in welding school. The average result of exposure to particles indicated greater exposure with the welding apprentices. There was no significant difference between the cases and controls. Regarding the biomarkers in the blood and urine identified in subjects, systemic acute inflammatory response was significantly different when related to the smoker and non-smoker factor, with a higher response for smokers. Concerning the difference between before and after exposure to welding fumes, the only difference was for the subjects who were exposed, but no-smokers.

Other publications [20,23,27-29] have covered the technical preparation of welding apprentices for the work. Such preparation is focused on strategies to improve the quality and skill of apprentices as future workers. Among these can be cited a preference for individuals with previous experience in welding [28], which is similar to that found in another study that considered it more productive to use learners who have prior experience as workers in the civil construction [41].

The enhancement technique overcomes the barriers of "doing" and includes "know you're doing". Employers need workers who have excellent technical skills which reflect in the work, not only representing means of production, *i.e*. labour force for the product but knowledge of the subject, exerting physical and mental strength [42]. Therefore, attention should be paid to carry out interventions and discussions about work in welding and the risk factors that these future workers are/will be exposed to during the learning process. Welding apprentices should be informed about these advantages and occupational hazards within their work. This differentiation of the welding apprentice and future worker generates profits

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for contracting companies, as publications analyzed in this review [28] show there was an expected financial return on investment in apprentices for two years, but the same was achieved in seven months.

Moreover, the improvement of welding techniques helps welding apprentices to minimize the risk factors present in the learning environment. Reports on the development of tools to facilitate the learning of the welder [23,29] minimize the exposure time of apprentices to risk factors. The exposure is less because the time that welding apprentices need to achieve the same results is smaller. Consequently, health disorders and accidents linked to risk factors will be reduced.

In this context, observation is made of the relationship between the apprentice's own qualification of welding, with regard to technique and learning technology, as a process that is by itself characteristic of the work and requires concern for the health of the worker and which should be included as an essential topic in the very process of developing this skill.

It is considered that the number of analyzed texts reflects the limit of the study; however, it underlines the importance of this review and, therefore, encourages the inclusion of new studies on the subject in specific reference to technological and professional course apprentices, as an area of occupational and public focus.

5. CONCLUSIONS

Although a few articles were found on the theme, and it should be noted that most studies were performed in developed countries, they show concerns about respiratory health, genetics and neuropsychology and for the improvement of welding techniques prior to placement of apprentices in the labour market. The synthesis of scientific knowledge to infer poses a methodological profile that enhances the work and the process of welding apprenticeship.

It is felt that the objectives of this study have been achieved and that the identification of only a few publications on welding apprentices constitutes a need for knowledge construction in the occupational and public health area for assistance, especially regarding the health of the welder, supported even in their own acquired knowledge about what is an apprentice welder. Examples of this are the work of welding, occupational hazards, working conditions and even the technology involved in this work. Using these elements, a solid theoretical and methodological base for developing occupational health interventions can be built.

REFERENCES

[1] (1996) Law No. 9.394 of December 20, 1996. Ministry of Education, Brazil.

[2] (2004) Decree No. 5.154 of July 23, 2004. Brazil.

[3] Enguita, M.F. (1993) Work, school and ideology. Artes Médicas, Porto Alegre.

[4] Modenesi, P.J. and Marques, P.V. (2006) Welding I. Introduction to welding processes. Federal University of Minas Gerais.

[5] Sabitu, K., Iliyasy, Z. and Dauda, M.M. (2009) Awareness of occupational hazards and utilization of safety measures among welders in Kaduna Metropolis, Northern Nigeria. *Annals of African Medicine*, **8**, 46-51. http://dx.doi.org/10.4103/1596-3519.55764

[6] Jayawardana, P. and Abeysena, C. (2009) Respiratory health of welders in a container yard, Sri Lanka. *Occupational Medicine*, **59**, 226-229. http://dx.doi.org/10.1093/occmed/kqn166

[7] Rolland, P., Gramond, C., Lacourt, A., Astoul, P., Chamming's, S., Ducamp, S. Frenay, C., Galateau-Salle, F., Ilg, A.G., Imbernon, E., Le Stang, N., Pairon, J.C., Goldberg, M. and Brochard, P. (2010) Occupations and industries in France at high risk for pleural mesothelioma: A population-based case-control study (1998-2002). *American Journal of Industrial Medicine*, **53**, 1207-1219. http://dx.doi.org/10.1002/ajim.20895

[8] Ibfelt, E., Bonde, J.P. and Jansen, J. (2010) Exposure to metal welding fume particles and risk for cardiovascular disease in Denmark: A prospective cohort study. *Occupational and Environmental Medicine*, **69**, 651-657.

[9] Sardas, S., Omurtag, G.Z., Tozan, A., Gül, H. and Beyoglu, D. (2010) Evalution of DNA damage in construction-site workers occupationally exposed to welding fumes and solvent-based paints in Turkey. *Toxicology and Industrial Health*, **26**, 601-608. http://dx.doi.org/10.1177/0748233710374463

[10] Simon, D.P., Gutierrez, L.L.P., Macedo, S.M.D. and Manfredini, V. (2009) Alterações hematológicas e morfocitológicas em fluidos biológicos de trabalhadores do distrito industrial de Erechim, RS. *Revista Brasileira de Análises Clinícas*, **41**, 55-59.

[11] ILO (1999) Occupational safety and health act of 16 June 1999. International Labour Organization (ILO), Geneva.

[12] Andreassi, L. (2011) UV exposure as a risk factor for skin cancer. *Expert Review of Dermatology Expert Reviews*, **6**, 445-454.

[13] Sorensen, A.R., Thulstrup, A.M., Hansen, J., Ramlau-Hansen, C.H., Meersohn, A., Skytthe, A. and Bonde, J.P. (2007) Risk of lung cancer according to mild steel and stainless steel welding. *Scandinavian Journal of Work, Environment and Health*, **33**, 379-386. http://dx.doi.org/10.5271/sjweh.1157

[14] Aragonés, N., Pollán, M. and Gustavsson, P. (2002) Stomach cancer and occupation in Sweden: 1971-89. *Occupational and Environmental Medicine*, **59**, 329-337. http://dx.doi.org/10.1136/oem.59.5.329

[15] Cavallari, J.C., Fang, S.C., Dobson, C.B. and Christiani, D.C. (2007) 161 ventricular arrhythmia events in boilermaker construction workers exposed to metal-rich fine particles. *Occupational and Environmental Medicine*, **64**, e31.

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[16] Guerra, M.R., Lourenço, P.M.C., Bustamante-Teixeira, M.T. and Alves, M.J.M. (2005) Prevalência de perda auditiva induzida por ruído em empresa metalúrgica. *Revista de Saúde Pública*, **39**, 238-244. http://dx.doi.org/10.1590/S0034-89102005000200015

[17] Picoloto, D. and Silveira, E. (2008) Prevalência de sintomas osteomusculares e fatores associados em trabalhadores de uma indústria metalúrgica de Canoas—RS. *Ciência & Saúde Coletiva*, **13**, 507-516. http://dx.doi.org/10.1590/S1413-81232008000200026

[18] Fordyce, T.A., Kelsh, M., Lu, E.T., Sahl, J.D. and Yager, J.W. (2007) Thermal burn and electrical injuries among electric utility workers, 1995-2004. *Burns*, **33**, 209-220. http://dx.doi.org/10.1016/j.burns.2006.06.017

[19] Whittemore, R. and Knafl, K. (2005) The integrative review: Updated methodology. *Journal of Advanced Nursing*, **52**, 546-553. http://dx.doi.org/10.1111/j.1365-2648.2005.03621.x

[20] Benway, E.A. (2010) As national welder shortage looms, proper training becomes a critical asset. *Plant Engineering*, **64**, 43.

[21] Wang, Z., Neuburg, D., Li, C., Su, L., Kim, J.Y., Chen, J.C. and Christiani, D.C. (2005) Global gene expression profiling in whole-blood samples from individuals exposed to metal fumes. *Environmental Health Perspectives*, **113**, 233-241. http://dx.doi.org/10.1289/txg.7273

[22] Kim, J.Y., Chen, J.-C., Boyce, P.D. and Christiani, D.C. (2005) Exposure to welding fumes is associated with acute systemic inflammatory responses. *Occupational and Environmental Medicine*, **62**, 157-163. http://dx.doi.org/10.1136/oem.2004.014795

[23] Benes, J. (2005) How am I doing? Welding Design & Fabrication, Largo.

[24] Laohadomchok, W., Lin, X., Herrick, R.F., Fang, S.C., Cavallari, J.M., Shrairman, R., Landau, A., Christiani, D.C. and Weisskopf, M.G. (2011) Neuropsychological effects of low-level manganeses exposure in welders. *NeuroToxicology*, **32**, 171-179. http://dx.doi.org/10.1016/j.neuro.2010.12.014

[25] El-Zein, M., Infante-Rivard, C., Malo, J.-L. and Gautrin, D. (2005) Is metal fume fever a determinant of welding related respiratory symptoms and/or increased bronchial responsiveness? A longitudinal study. *Occupational and Environmental Medicine*, **62**, 688-694. http://dx.doi.org/10.1136/oem.2004.018796

[26] El-Zein, M., Infante-Rivard, C., Malo, J.-L. and Gautrin, D. (2003) Incidence of probable occupational asthma and changes in airway caliber and responsiveness in apprentice welders. *The European Respiratory Journal*, **22**, 513-518. http://dx.doi.org/10.1183/09031936.03.00000903

[27] Burkle, M. (2011) Apprenticeship students learning online: Opportunities and challenges for polytechnic institutions. *Comunicar*, **37**, 45-53. http://dx.doi.org/10.3916/C37-2011-02-04

[28] Pollitt, D. (2011) Apprentices prove their worth at TIS Cumbria. *Human Resource Management International Digest*, **19**, 15-17. http://dx.doi.org/10.1108/09670731111153285

[29] Ionescu, G. and Ionescu, O. (2008) Training system for welding operators. *Annals of DAAAM & Proceedings*, **1**, 1-2.

[30] Jaakkola, J.J.K., Piipari, R. and Jaakkola, M.S. (2003) Occupation and asthma: A population-based incident case-control study. *American Journal of Epidemiology*, **158**, 981-987.

[31] Hannu, T., Piipari, R., Tuppurainen, M., Nordman, H. and Tuomi, T. (2007) Occupational asthma caused by stainless steel welding fumes: A clinical study. *The European Respiratory Journal*, **29**, 85-90. http://dx.doi.org/10.1183/09031936.00058106

[32] Li, X., Sundquist, J. and Sundquist, K. (2008) Socioeconomic and occupational groups and risk of asthma in Sweden. *Occupational Medicine*, **58**, 161-168. http://dx.doi.org/10.1093/occmed/kqn009

[33] Bakerly, N.D., Moore, V.C., Vellore, A.D., Jaakkla, M.S., Robertson, A.S. and Burge, P.S. (2008) Fifteen-year trends in occupational asthma: data from the Shield surveillance scheme. *Occupational Medicine*, **58**, 169-174. http://dx.doi.org/10.1093/occmed/kqn007

[34] Temel, O., Sakar, C.A., Yaman, N., Sarioglu, N., Alkaç, C., Konyar, I., Ozgen Alpaydin, A., Celik, P., Cengiz Ozyurt, B., Keskin, E. and Yorgancioglu, A. (2010) Occupational asthma in welders and painters. *Tüberküloz ve Toraks Dergisi*, **58**, 64-70.

[35] Eng, A., Mannetje, A.T., Douwes, J., Cheng, S., McLean, D., Ellison-Loschmann, L. and Pearce, N. (2010) The New Zealand workforce survey II: Occupational risk factors for asthma. *The Annals of Occupational Hygiene*, **54**, 154-164. http://dx.doi.org/10.1093/annhyg/mep098

[36] El-Zein, M., Infante-Rivard, C., Malo, J.-L. and Gautrin, D. (2003) Prevalence and association of welding related systemic and respiratory symptoms in welders. *Occupational and Environmental Medicine*, **60**, 655-661. http://dx.doi.org/10.1136/oem.60.9.655

[37] Leonard, S.S., Chen, B.T., Stone, S.G., Schwegler-Berry, D., Kenyon, A.J., Frazer, D. and Antonini, J.M. (2010) Comparison of stainless and mild steel welding fumes in generation of reactive oxygen species. *Particle and Fibre Toxicology*, **7**, 1-13. http://dx.doi.org/10.1186/1743-8977-7-32

[38] Iarmarcovai, G., Sari-Minodier, I., Orsière, T., De Méo, M., Gallice, P., Bideau, C., Iniesta, D., Pompili, J., Bergé-Lefranc, J.L. and Botta, A. (2006) A combined analysis of XRCC1, XRCC3, GSTM1 and GSTT1 polymorphisms and centromere content of micronuclei in welders. *Mutagenesis*, **21**, 159-165. http://dx.doi.org/10.1093/mutage/gel010

[39] Criswell, S.R., Perlmutter, J.S., Videen, T.O., Moerlein, S.M., Flores, H.P., Birke, A.M. and Racette, B.A. (2011) Reduced uptake of [18F]FDOPA PET in asymptomatic welders with occupational manganese exposure. *Neurology*, **76**, 1296-1301. http://dx.doi.org/10.1212/WNL.0b013e3182152830

[40] Fang, J.Y., Phibbs, F.T. and Davis, T.L. (2009) Spectrum of movement disorders in professional welders. *Bratislavské Lekárske Listy*, **110**, 35-60.

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[41] Sparks, A., Ingram, H. and Phillips, S. (2009) Advanced entry adult apprenticeship training scheme: A case study. *Education + Training*, **51**, 190-202.

[42] Cutshall, S. (2005) Practical applications: Building the future in and beyond the classroom. *Technique*, **76**, 1-2.

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