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Vulnerability to Stress and Depression Risk Related to Occupational Exposure to Aluminum

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Abstract

Occupational exposure to aluminum was reported to be associated with various neurotoxic effects including cognitive impairment, depression, anxiety, and also Alzheimer's disease. The purpose of the present study was to evaluate the level of vulnerability to stress in workers exposed to aluminum. The correlation between vulnerability to stress and depression was also investigated. This was a retrospective study that included 135 participants, 99 were exposed to aluminum, and 36 were not exposed to aluminum. Vulnerability to stress and depression was assessed using a self-rating scale developed in-house. Vulnerability to stress was reported in various degrees in a total of 84 participants, 69 (69.70%) participants from the exposed group and 15 (41.67%) participants from the control group. Out of the 84 participants with vulnerability to stress, 51 had depression also. Excellent resistance to stress was reported in 51 out of 135 participants, 30 (30.30%) in the exposed group and 21 (58.33%) in the control group. Out of the 51 participants with excellent resistance to stress, only 2 participants had depression. The results of the present study suggested that exposure to aluminum is correlated with vulnerability to stress. The level of vulnerability to stress is increasing with the level of exposure to aluminum. Furthermore, since vulnerability to stress is correlated with depression, higher exposure to aluminum might be a risk factor for depression.

Keywords

Aluminum, Vulnerability to Stress, Depression

1. Introduction

Aluminum constitutes approximately 8% of the surface layer of the earth's crust [1] and is spread in the environment as a result of natural processes and also different activities done by human beings. The general population is exposed to aluminum from various sources that include water, food, air, cosmetics, drugs, and vaccines [2]. Given that the use of aluminum is increasing due to its applications in a broad range of fields [3], professional exposure to aluminum and its compounds can represent an important risk factor for workers in the metal refining processes and secondary industries [1]. Several studies have shown increased concentrations of aluminum in the serum and urine of aluminum occupationally exposed workers, probably because aluminum is better absorbed through the respiratory tract than the digestive tract, the most common way of entering the body under non-professional exposure conditions [4] [5]. Aluminum toxicity is a result of multiple mechanisms because the Al(III) ion has increased biological reactivity and causes changes in biological systems [6]. Aluminum crosses the blood-brain barrier and interferes with the cellular homeostasis of iron, thus influencing iron-dependent processes. It influences certain neurotransmitters such as serotonin, glutamate, and gamma-aminobutyric acid (GABA) [7] [8].

Various studies showed that occupational exposure to aluminum can cause neurotoxic effects that include cognitive impairment, depression, anxiety, memory impairment, and personality change [9] [10] [11]. Furthermore, aluminum neurotoxicity involvement in the development of Alzheimer's disease was studied intensively and more information became available in the last two decades regarding the association between exposure to aluminum from various sources and Alzheimer's disease [12] [13].

Psychiatric disorders, especially depression and anxiety, represent one of the most important causes that affect work capacity and lead to absenteeism and loss of productivity, with high economic costs. In the USA, annual losses of over 44 billion dollars due to workers diagnosed with depression have been estimated by Battams *et al.* (2014) [14]. Stress represents a mechanism or a physiological process through which the body responds to various challenges that occur daily during both personal and professional activities. The ability to maintain a balance between the effects of different stress factors and the response of the human body to these stress effects characterizes homeostasis and assures survival. The balance is maintained by hormones (cortisol) and neurotransmitters, cytokines, and growth factors. But prolonged and uncontrolled exposure to various stress factors can cause long-term neurobiological changes that are closely related to depression [15]. Stress has an important subjective component in the sense that the same stress factor can be considered as a challenge or something easy to manage by one person while at the same time it can be considered as a threat to another person [16]. Individual differences in response to stress have a genetic component but these are also influenced by personal life experiences. There are individuals who have an increased sensitivity to common, minor stress factors

which makes them much more vulnerable to stress. This sensitivity was called "vulnerability to stress" [17].

2. Aim of the Study

The aim of this retrospective, observational study was to evaluate the vulnerability to stress and depression rate in workers exposed to aluminum.

3. Material and Methods

3.1. Subjects

The study included 135 patients hospitalized in Colentina Clinical Hospital Bucharest, Occupational Medicine Clinic due to respiratory and musculoskeletal disorders. The study included all patients working in the same aluminum processing company that were hospitalized in the clinic. The patients were selected based on predefined inclusion and exclusion criteria as follows. The main inclusion criteria included: age range from 20 and 65 years; working in the aluminum industry; at least 1-year experience of work in the aluminum industry; subjects with musculoskeletal and respiratory pathology. The main exclusion criteria included: age over 65 years; interruption of professional activity in the aluminum industry for more than one year at the date of evaluation; major mental illnesses; Parkinson's or Alzheimer's disease; history of stroke; excessive alcohol consumption; the presence in the last 6 months in the subject's life of some highly stressful events (death of a family member or close friend, divorce, accident or diagnosis of a severe pathology); Parkinson's or Alzheimer's disease.

This study was conducted in accordance with the ethical principles that have their origin in the Declaration of Helsinki and that are consistent with Good Clinical Practice. Informed consent was obtained from all study subjects, and the study was approved by the appropriate ethics committee.

3.2. Evaluation of Vulnerability to Stress and Depression

Vulnerability to stress and depression was assessed using a self-rating scale developed in-house. The self-rating scale consisted of a questionnaire addressing health status, smoking, alcohol consumption, coffee consumption, eating disorders, sleeping disorders, weight issues, headache, irritability, asthenia, apathy, fatigue, palpitations, precordial pain, blood pressure, joint pain, sexual activity disorders, dyspeptic syndrome, dyspnea, cough, intake of medication, work issues, stress factors. Each subject received and completed the self-rating scale by selecting for each item the appropriate option (1 (always), 2 (frequently), 3 (neutral), 4 (sometimes) and 5 (never)) depending on how much of the time the statement was applicable to the subject. The results were interpreted as follows:

- For vulnerability, score below 50: excellent resistance to stress; score above 50: vulnerable to stress which was further depicted as score 50 - 69: some vulnerability to stress; score 70 - 95: serious vulnerability to stress; score over 95: extreme vulnerability to stress.

- For depression, a score of 0 - 9 was considered to be within the normal range.

3.3. Data Analysis

Data obtained was presented in tabular format and descriptive statistic is provided.

4. Results

Out of the 135 patients included in the study, 99 were exposed to aluminum and 36 were not exposed. From the exposed group, 38 patients were electrometallurgists, 49 locksmiths, and 12 smelters. Of these professional categories, the most exposed to aluminum was the category of smelters, followed by electrometallurgists and locksmiths. The patients not exposed to aluminum worked in the aluminum industry, but they had office-based jobs carrying out different administrative tasks. The subjects not exposed to aluminum were treated as a control group.

4.1. Vulnerability to Stress Levels in the Study Population

Out of 135 subjects, 51 (37%) reported excellent resistance to stress. There were 30 (30.30%) subjects out of 99 in the exposed group and 21 (58.33%) subjects out of 36 in the control group. The distribution of the vulnerability to stress results in the study population is provided in Table 1.

In the exposed group, out of the 49 locksmiths, 16 (32.65%) had excellent resistance to stress, 14 (28.57%) had some vulnerability to stress, 7 (14.28%) had serious vulnerability to stress, and 12 (24.48%) had extreme vulnerability to stress.

In electrometallurgist group, out of 38 electrometallurgists, 11 (28.94%) had excellent resistance to stress, 6 (15.78%) had some vulnerability to stress, 11 (28.94%) had serious vulnerability to stress while 10 (26.31%) had extreme vulnerability to stress.

In the smelter group, out of 12 electrometallurgists, 3 (25%) had excellent resistance to stress, 5 (41.66%) had some vulnerability to stress, none had serious vulnerability to stress, and 4 (33.33%) had extreme vulnerability to stress.

The distribution of the vulnerability to stress results in the exposed group is provided in Table 2.

Table 1. Vulnerability to stress results in the study population.

Group	Excellent resistance to stress	Some vulnerability to stress	Serious vulnerability to stress	Extreme vulnerability to stress
Exposed group (n = 99)	30 (30.30%)	25 (25.25%)	18 (18.18%)	26 (26.26%)
Control group (n = 36)	21 (58.33%)	11 (30.55%)	3 (8.33%)	1 (2.77%)

Table 2. Vulnerability to stress results in the exposed group.

Group	Excellent resistance to stress	Some vulnerability to stress	Serious vulnerability to stress	Extreme vulnerability to stress
Locksmith (n = 49)	16 (32.65%)	14 (28.57%)	7 (14.28%)	12 (24.48%)
Electrometallurgist (n = 38)	11 (28.94%)	6 (15.78%)	11 (28.94%)	10 (26.31%)
Smelter (n = 12)	3 (25%)	5 (41.66%)	0 0%	4 (33.33%)

4.2. Distribution of Depression Cases Depending on the Presence and Level of Vulnerability to Stress

In total, there were 53 (39.25%) cases of depression identified in the total study population.

The presence of depression was investigated in correlation with the level of vulnerability to stress. Out of the total of 51 subjects with excellent resistance to stress reported in the whole study population, only 2 (3.92%) cases of depression were identified. Whereas, out of the total 84 cases with various levels of vulnerability to stress, 51 (60.71%) cases of depression were identified. The distribution of depression cases depending on the presence of vulnerability to stress is presented in Table 3.

Furthermore, the presence of depression was evaluated depending on the level of vulnerability to stress. From the total of 135 subjects, 36 (26.66%) had some vulnerability to stress, 21 (15%) subjects had a serious vulnerability to stress and 27 (20%) subjects had an extreme vulnerability to stress.

Out of 36 subjects with some vulnerability to stress, 8 (22.22%) had depression. Out of 21 subjects with serious vulnerability to stress, 18 (85.71%) had depression and 25 (92.59%) subjects out of the 27 subjects with extreme vulnerability to stress, had depression. The distribution of depression cases depending on the level of vulnerability to stress is presented in Table 4.

5. Discussions

In this retrospective observational study, the vulnerability to stress and depression rate in workers exposed to aluminum was evaluated using a self-rating scale developed in-house. The study included 135 subjects, 99 with professional exposure to aluminum and 36 non-exposed subjects.

The results of this study showed that the controlled group had higher rate for excellent resistance to stress (85%) as compared to the group exposed to aluminum. For the interpretation of the results, it should be considered that the professional activity of subjects not exposed to aluminum took place in better working conditions with fewer risk factors (office activity, administrative tasks). In addition, the subjects in the control group might be better educated and could

Table 3. The distribution of depression cases depending on the presence of vulnerability to stress in the study population.

Study population	Vulnerability to stress level	Depression cases	Absence of depression
n = 135	Excellent resistance to stress (n = 51)	2 (3.92%)	49 (96.07%)
	Vulnerability to stress (n = 84)	51 (60.71%)	33 (39.28%)

Table 4. Distribution of depression depending on the level of vulnerability to stress.

Vulnerability to stress group	Level of Vulnerability to stress	Depression cases
N = 84	some vulnerability to stress (n = 36)	8 (22.22%)
	serious vulnerability to stress (n = 21)	18 (85.71%)
	extreme vulnerability to stress (n = 27)	25 (92.59%)

belong to the category of people that is more resilient or persons with increased resistance to stress who are able to face high intensity stress factors without developing stress related symptoms. The people who were exposed to aluminum worked in a more difficult environment (including noise, intense physical effort, and unfavorable microclimate) and were most frequently affected by restructuring and organizational changes, aspects that could constitute additional stress factors [14].

In the exposed group, the rate for excellent resistance to stress was getting lower with the higher exposure to aluminum. The highest rate of excellent resistance to stress was recorded in case of the locksmiths (less exposed subjects), while the lowest rate was in the smelter group (the most exposed subjects). The highest rate for extreme vulnerability to stress was recorded in the smelter group, while the lowest rate was recorder in the locksmith group.

Literature data showed the concordance between increased exposure to aluminum and the presence of neuropsychic manifestations [18] [19], but the previous studies did not consider an assessment of vulnerability to stress in exposed workers. The increased vulnerability to stress could cause a psychological imbalance even in the conditions of challenges in everyday life.

There were 53 (39.25%) cases of depression identified in the total study population. The results are in agreement with other studies that evaluated the presence of depression in workers professionally exposed to aluminum, with statistically significant differences compared to the control group [11] [20] [21]. The mechanisms of depression are related to the dysfunction of the serotoninergic system, and aluminum inhibits serotonin, an aspect supported by experimental studies carried out on rats, which have showed a significant decrease in the level

of serotonin in the cortex, hippocampus, striatum and spinal cord, a decrease that was maintained even after 60 days of exposure [7].

As expected, a higher rate of depression was identified in the subjects with various levels of vulnerability to stress as 60.71% of the subjects with vulnerability to stress had also depression; depression was identified in only 3.92% of the subjects with excellent resistance to stress. Furthermore, a higher rate of depression (92.59%) was identified in the group of subjects with extreme vulnerability to stress. The results of the present study suggest that the presence of vulnerability to stress is correlated with the presence of depression. The data obtained are consistent with the study of Hankin *et al.* (2010) which supports the link between individual vulnerability to stress and symptoms of depression [22].

The study has some limitations apart from the classical limitations of an observational study. For example, the assessment of vulnerability and depression was done based on an in-house self-rating scale. In addition, there was no sample size calculation and there was no statistical technique applied to consider the imbalance of confounders in the exposure group. Further research is therefore needed.

6. Conclusion

Prolonged and uncontrolled exposure to various stress factors such as aluminum can cause long-term neurobiological changes that are closely related to depression or anxiety. Individual differences in response to stress have a genetic component, but these are also influenced by personal life experiences including occupational and environmental factors. The results of the present study suggested that exposure to aluminum is correlated with vulnerability to stress. The level of vulnerability to stress is increasing with the level of exposure to aluminum. Furthermore, since vulnerability to stress is correlated with depression, higher exposure to aluminum might be a risk factor for depression.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Health Council of the Netherlands (2010) Aluminium and Aluminium Compounds-Health-Based Recommended Occupational Exposure Limit. Health Council of the Netherlands, The Hague.

[2] Skalny, A., Aschner, M., Jiang, Y., Gluhcheva, Y., Tizabi, Y., *et al.* (2021) Molecular Mechanisms of Aluminum Neurotoxicity: Update on Adverse Effects and Therapeutic Strategies. *Advances in Neurotoxicology*, **5**, 1-34. https://doi.org/10.1016/bs.ant.2020.12.001

[3] Inan-Eroglu, E. and Ayaz, A. (2018) Is Aluminum Exposure a Risk Factor for Neurological Disorders? *Journal of Research in Medical Sciences*, **23**, Article No. 51. https://doi.org/10.4103/jrms.JRMS_921_17

[4] Willhite, C., Karyakina, N., Yokel, R., Yenugadhati, N., Wisniewski, T., Arnold, I., Momoli, F. and Krewski, D. (2014) Systematic Review of Potential Health Risks Posed by Pharmaceutical, Occupational and Consumer Exposures to Metallic and Nanoscale Aluminum, Aluminum Oxides, Aluminum Hydroxide and Its Soluble Salts. *Critical Reviews in Toxicology*, **44**, 1-80. https://doi.org/10.3109/10408444.2014.934439

[5] Bast-Pettersen, R. (2022) Neuropsychological Function among Workers Exposed to Aluminum—A Mini-Review. *Industrial Health*, **60**, 97-105. https://doi.org/10.2486/indhealth.2021-0131

[6] Exley, C. (2017) Aluminum Should Now Be Considered a Primary Etiological Factor in Alzheimer's Disease. *Journal of Alzheimer's Disease Reports*, **1**, 23-25. https://doi.org/10.3233/ADR-170010

[7] Zghari, O., Rez-Qaoui, A., Ouakki, S., Lamtai, M., Chaibat, J., Mesfioui, A., El Hessni, A., Rifi, E.-H., Essamri, A. and Ouichou, A. (2018) Effect of Chronic Aluminum Administration on Affective and Cognitive Behavior in Male and Female Rats. *Journal of Behavioral and Brain Science*, **8**, 179-196. https://doi.org/10.4236/jbbs.2018.84012

[8] Nayak, P. and Chatterjee, A.K. (2001) Effects of Aluminium Exposure on Brain Glutamate and GABA Systems: An Experimental Study in Rats. *Food and Chemical Toxicology*, **39**, 1285-1289. https://doi.org/10.1016/S0278-6915(01)00077-1

[9] Shang, N., Zhang, P., Wang, S., Chen, J., Fan, R., Chen, J., Huang, T., Wang, Y., Duncan, J., Zhang, L., Niu, Q. and Zhang, Q. (2020) Aluminum-Induced Cognitive Impairment and *PI3K/Akt/mTOR* Signaling Pathway Involvement in Occupational Aluminum Workers. *Neurotoxicity Research*, **38**, 344-358. https://doi.org/10.1007/s12640-020-00230-z

[10] Giorgianni, C.M., D'Arrigo, G., Brecciaroli, R., Abbate, A., Spatari, G., Tringali, M.A., Gangemi, S., De Luca, A. (2014) Neurocognitive Effects in Welders Exposed to Aluminium. *Toxicology and Industrial Health*, **30**, 347-356. https://doi.org/10.1177/0748233712456062

[11] Elser, H., Rehkopf, D.H., Meausoone, V., Jewell, N.P., Eisen, E.A. and Cullen, M.R. (2019) Gender, Depression, and Blue-Collar Work: A Retrospective Cohort Study of US Aluminum Manufacturers. *Epidemiology*, **30**, 435-444. https://doi.org/10.1097/EDE.0000000000000993

[12] Frisardi, V., Solfrizzi, V., Capurso, C., Kehoe, P.G., Imbimbo, B.P., Santamato, A., Dellegrazie, F., Seripa, D., Pilotto, A., Capurso, A. and Panza, F. (2010) Aluminum in the Diet and Alzheimer's Disease: From Current Epidemiology to Possible Disease-Modifying Treatment. *Journal of Alzheimer's Disease*, **20**, 17-30. https://doi.org/10.3233/JAD-2010-1340

[13] Rondeau, V., Jacqmin-Gadda, H., Commenges, D., Helmer, C. and Dartigues, J.F. (2009) Aluminum and Silica in Drinking Water and the Risk of Alzheimer's Disease or Cognitive Decline: Findings from 15-Year Follow-Up of the PAQUID Cohort. *American Journal of Epidemiology*, **169**, 489-496. https://doi.org/10.1093/aje/kwn348

[14] Battams, S., Roche, A., Fischer, J., Lee, N., Cameron, J. and Kostadinov, V. (2014) Workplace Risk Factors for Anxiety and Depression in Male-Dominated Industries: A Systematic Review. *Health Psychology and Behavioral Medicine*, **2**, 983-1008. https://doi.org/10.1080/21642850.2014.954579

[15] Sharpley, C. (2009) Neurobiological Pathways between Chronic Stress and Depression: Dysregulated Adaptive Mechanisms? *Clinical Medicine*: *Psychiatry*, **2**, 33-45. https://doi.org/10.4137/CMPsy.S3658

[16] Roesch, S., Weiner, B. and Vaughn, A. (2002) Cognitive Approaches to Stress and

Coping. *Current Opinion in Psychiatry*, **15**, 627-632.
https://doi.org/10.1097/00001504-200211000-00012

[17] Zubin, J. and Spring, B. (1977).Vulnerability—A New View of Schizophrenia. *Journal of Abnormal Psychology*, **86**, 103-126.
https://doi.org/10.1037/0021-843X.86.2.103

[18] Irengren, A., Sjögren, B., Gustafsson, K., Hagman, M., Nylén, L., Frech, W., Andersson, M., Ljunggren, K.G. and Wennberg, A. (2001) Effects on the Nervous System in Different Groups of Workers Exposed to Aluminium. *Occupational & Environmental Medicine*, **58**, 453-460. https://doi.org/10.1136/oem.58.7.453

[19] Zhang, T., He, F., Lin, S., Wang, X., Li, F., Zhai, Y., *et al.* (2021) Does Aluminum Exposure Affect Cognitive Function? A Comparative Cross-Sectional Study. *PLOS ONE*, **16**, e0246560. https://doi.org/10.1371/journal.pone.0246560

[20] DeSanto Iennaco, J., Cullen, M.R., Cantley, L., Slade, M., Fiellin, M. and Kasl, S.V. (2009) Effects of Externally Rated Job Demand and Control on Depression Diagnosis Claims in an Industrial Cohort. *American Journal of Epidemiology*, **171**, 303-311.
https://doi.org/10.1093/aje/kwp359

[21] Moussa, F., Moustafa, A., Zyada, F. and El Hamid, D.A. (2013) Psihiatric Evaluation of a Group of Workers in the Aluminium Industry. *Egyptian Journal of Psychiatry*, **34**, 1-9.

[22] Hankin, B. (2010) Personality and Depressive Symptoms: Stress Generation and Cognitive Vulnerabilities to Depression in a Prospective Daily Diary Study. *Journal of Social and Clinical Psychology*, **29**, 369-401.
https://doi.org/10.1521/jscp.2010.29.4.369