

International Journal of Environmental Health Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/cije20

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To cite this article: Burcu Yuksel, Serap Arsal Yildirim & Fikriye Polat (2022): Erythrocyte morphology and fatigue levels in podologists, International Journal of Environmental Health Research, DOI: 10.1080/09603123.2022.2084515

To link to this article: https://doi.org/10.1080/09603123.2022.2084515

Published online: 01 Jun 2022.

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INTERNATIONAL JOURNAL OF ENVIRONMENTAL HEALTH RESEARCH
https://doi.org/10.1080/09603123.2022.2084515

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Erythrocyte morphology and fatigue levels in podologists

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ABSTRACT

Aesthetic and clinical care of the feet includes reducing nail thickness and removing calluses which are perfomed by high-speed nail drill machines. These micromotors diffuse skin material, nail dust, and pathogenic fungi into the air, some of which are then inhaled and causes an occupational risk to workers. This study examines occupational risks of inhaling organic dust in the working environment of Podologists (PDL) through their erythrocyte morphologies. Chalder Fatigue Scale was used to determine fatigue symptoms of the participants related to occupational exposures. 25 PDL and 26 control subjects were compared. Peripheral smear technique was used to identify erythrocyte morphologies. The results demonstrated that physical, mental, total fatigue levels, and erythrocyte anomaly amounts of the individuals in the PDL group were higher ($p < .05$). Findings also revealed that fatigue effectively formed Hypochromic, Stomatocytes, Dacrocytes, Elliptocytes, Spherocytes, and Ovalocytes. This study aims to increase awareness of podologists' occupational risks..

ARTICLE HISTORY
Received 2 May 2022
Accepted 27 May 2022

KEYWORDS
Erythrocyte; cellular anomaly; occupational health; organic powder; podologists

Introduction

While occupational health and safety problems are generally discussed around the dangers of skin contact with chemicals and bad posture for podologists (PDL), who provide services for the protection and care of people's foot health, studies on the effects on respiratory health are negligible (Gupta and Quinlan 2021). Podologists use micro-milling devices to reduce nail thickness and soften foot calluses. These devices produce a great quantity of dust, some of which is tiny enough to breathe and can accumulate in the deepest parts of the respiratory tract, possibly leading to health problems. Because of this dust, podologists complain of allergies and other respiratory symptoms (Coggins et al. 2012). Continuous inhalation of fine particles (<2.5 μm) by immunocompromised and allergy-prone individuals can cause adverse health effects such as lung inflammation and pneumoconiosis (Yuksel 2021; Yuksel and Yildirim 2021). Allergy, asthma, nasal symptoms, cough, and chest tightness, which are the most cited complaints among podologists, may result from exposure to dead skin dust produced by micro-milling devices or from exposure to toxic substances such as abrasive chemicals used to create and shape false nails (Kieć-Świerczyńska et al. 2013).

Along with the data on respiratory tract diseases, the risk of exposure to fungi in podiatry professions seems to be high, but especially onychomycosis is the most common nail disease affecting 5.5% of the world's population (Gupta and Quinlan 2021). Podologists trained to recognize and treat onychomycosis can be exposed to many types of fungi, including dermatophytes (86%), *Aspergillus* species (spp.), *Candida, Scopulariopsis spp, Trichophyton rubrum*, and non-

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dermatophyte mold (Hainsworth et al. 2015). However, researchers have reported that fungal exposure sources can also come from normal-looking nails and feet (Nowicka et al. 2016). The addition of fungi to inhaled dust, which can reach deep into the lungs, further increases the risk to workers' health (Woodfolk 2005). While most healthy people can endure inhaled fungi, they can react with inflammatory Type 2 T helper cells, causing excessive mucus production, bronchoconstriction, and in severe cases, lung tissue damage (Boonpiyathad et al. 2019). While most healthy, immune-competent podologists do not experience respiratory ailments, those who are prone to allergies or have weakened immune systems experience respiratory diseases due to fungi on the skin, nails, and inhalation of chemical elements (Gupta and Quinlan 2021).

Exposure to bioaerosols and organic dust such as fungi, yeast, and bacterial organisms in occupational exposures leads to adverse health effects such as allergic reactions, cancer, fatigue, muscle/joint pain, rhinitis, sinusitis, neurocognitive dysfunction, and respiratory problems (Tinley et al. 2014; Yuksel and Arsal Yildirim 2021). Considering the significant adverse impact of the exposure to bioaerosols and organic dust and relatively limited research on this topic, this study aimed to determine the morphological changes of red blood cells (RBC) of podologists working in Podology units, increase awareness about their occupational exposure, guide them on safety precautions, and contribute to the literature on this rarely discussed subject.

Materials and methods

Participants

The Podology unit in Kocaeli University Medical Faculty Hospital and four different Podology units serving in Kocaeli were selected as the research sample. A convenience selection method was used in the sampling of the participants. Out of seven potential Podology units, participants from four units accepted to take part in our study. Thus, our research was carried out with 25 podology workers forming the experimental group and a total of 26 teachers/office workers forming the control group. Necessary ethical approval was obtained before starting the data collection.

Sampling considerations

All participants filled in a questionnaire containing contact and some demographic information in person. It was noted that none of the control group members had any daily routines or hobbies with organic dust or had been occupationally exposed to other chemicals. The procedures were explained to all participants of the study, and they volunteered to sign consent forms.

Chalder fatigue scale

To measure the severity of the individual's perceived fatigue, the Chalder fatigue scale was applied to all participants and the data obtained from this scale were compared with the RBC abnormalities. The scale consists of 11 items and assesses physical fatigue with seven items and mental fatigue with four items. The items in the scale are answered on a 4 point scale (better than usual, no worse than usual, worse than usual, and much worse than usual). The total fatigue score is obtained by summing the physical fatigue subsection score and the mental fatigue subsection score of the scale. The physical fatigue subsection score can vary between 0–21; the mental fatigue subsection score can vary between 0–12, and the total fatigue score can vary between 0–33. The normative score of the scale is 12, and an increase in the score indicates an increase in the severity of fatigue (Chalder et al. 1993; Fil Balkan and Adın 2019).

Investigation of the blood samples

Capillary blood was used for blood analysis. The blood samples were stained with May-Grünwald and Giemsa by making a peripheral smear. The smears are made with vein or capillary blood. Vacuum tubes containing the potassium salt of EDTA (ethylene diamine tetraacetic acid) are used as an anticoagulant for vein blood. EDTA prevents coagulation by chelating calcium. Smears should not be made on dirty, dusty, oily slides. Smears made on slides that have not been cleaned and dried well will have gaps that can be seen with the naked eye. In such smears, you may encounter target cells or stomatocytes as artefacts. Even if the slides have been cleaned beforehand, it is useful to wipe them again while spreading. One drop of blood is placed on a clean slide. With the help of another slide, the blood drop was spread on the slide. The prepared preparation was air-dried. After drying, May-Grünwald ($C_{11}H_{15}N_5O$, which contains May-Grünwald's eosin methylene blue and methanol (>85%)) solution, was dripped and left for 3 minutes. The stained slide was washed with distilled water, and then Giemsa solution ($C_{14}H_{14}ClN_3S$) was dripped and left for 10 minutes. Then the preparation was washed under running water for 1–3 minutes. The preparation was then left to dry. RBC morphologies were determined using the Olympus B×51 research-level microscope. Blood samples taken from the experimental and control groups were analyzed twice, with 5000 cells from each preparation. Anomaly types (Microcyte, Macrocyte, Hypochromic, Acanthocytes (Spur Cells), Burr Cells, Stomatocytes, Dacrocytes, Keratocytes, Schistocytes, Spherocytes, Target Cells(codocytes), Sickle cells, Elliptocytes, Ovalocytes, and Heinz body) were investigated by examining RBC cells and analyzed by calculating the mean scores of each participant.

Statistical methods

Statistical analyzes were carried out using SPSS 15 statistical package. Descriptive statistics (e.g. arithmetic mean ± and standard deviations) were used to determine the values of nuclear abnormalities. *T*-test was utilized to estimate the differences between erythroid abnormalities in the PDL group exposed to toenail dust and the control group. To identify any differences between the two groups based on mental, physical, and total fatigue scores, Pearson Correlation coefficients were determined. Statistical significances were set at a p-value <.05. All p-values were two-tailed. In order to determine the effects of mental, physical, and total fatigue score, multifactorial analysis of variance (MANCOVA) were used. Control and experimental group difference were utilized as a covariate in all analyses.

Results

Demographic data obtained from the answers of 25 PDL and 26 control group participants to the questionnaire were presented in Table 1. It was observed that the mean age of the PDL group was not much different from the control group. As shown in Table 1, there was no statistical difference between the prevalence of smoking and the PDL and the control group ($p > .05$).

The Chalder Fatigue Scale, an easy-to-understand, short, fast, and useful fatigue scale, which deals with fatigue with its two dimensions, physical and mental, and consists of items that enable individuals to express their fatigue fully, was used in the PDL and control group (Table 2). According to these results, when the groups were compared in terms of fatigue, the physical and mental fatigue levels of the individuals in the experimental group were higher than the control group ($p < .05$). When the total score of the Chalder Fatigue Scale was analyzed, it was observed that fatigue was higher in the PDL group ($p < .05$).

In Table 3, it was investigated whether the Physical Section Score, Mental Section Score, and Total Score, which were obtained from the Chalder Fatigue Scale of the PDL and control group, had an effect on RBC abnormalities. According to these results, it was determined by MANCOVA

Table 1. Demographic characteristics of the PDL group and control group.

Variables	PDL Group (n = 25)	Control Group (n = 26)	p-value
Age (years)			.234
17–30	12	10	
31–40	6	8	
41–56	7	8	
Mean (± S.D.)	32	34.33	
Smoking	11	10	.487
Non-smoking	14	16	
Gender			.096
Female	22	18	
Male	3	8	
Duration of job (years) Mean	9.87	12.98	.534

Table 2. Chalder fatigue scale of PDL and control group.

	PDL Group (n = 25)	Control Group (n = 26)	p-value
Chalder Physical Section Score (based on a 21-point Likert scale)	11.12	9.65	.025*
Chalder Mental Section Score (based on a 12-point Likert scale)	6.47	4.87	.000*
Chalder Total Score (out of 33 points)	17.59	14.52	.004*

*$p < .05$.

analysis that physical, mental, and total fatigue had an effect on the formation of Hypochromic, Stomatocytes, Dacrocytes, Elliptocytes, and only mental fatigue had an effect on the formation of Spherocytes and Ovalocytes, Heinz body ($p < .05$) (Table 3).

In Table 4, RBC abnormalities were analyzed from blood taken from PDL and the control group. According to these results, a statistically significant difference was determined in all observed abnormalities except Hypochromic (p = .103), Stomatocytes (p = .773), and Heinz body (p = .501) abnormalities. While Target Cells (codocytes) (M = 51.92) were observed the most in the PDL group, the most observed abnormalities were Burr Cells (M = 35.60) and Ovalocytes (M = 28.53), Spherocytes (M = 14.48), respectively. The Heinz body was least observed (M = 1.67) (Table 4).

Some of the abnormalities occurring in RBC cells are shown in Figure 1. The shots were taken by measuring on the 10 µm scale.

Discussion

Podologists are healthcare professionals specializing in treating foot problems and disorders. When performing podiatric treatments, thinning thickened toenails, trimming onychomycosis and calluses produces significant concentrations of organic dust that can pose an occupational hazard. This dust can sometimes contain infectious fungal elements, even on healthy-looking nails. For this reason, nail and podiatrists frequently complain of allergies, rhinitis, conjunctivitis, and respiratory symptoms (Donaldson et al. 2002). In this study, abnormalities in RBC cells of the PDL and control group were investigated. In addition, the Chalder Fatigue Scale, which deals with fatigue with its two dimensions, physical and mental, was applied to both groups. Then, the physical and mental fatigue of the PDL group was compared with the control group. The data obtained from the Chalder fatigue scale examined whether the Physical, Mental, and Total fatigue data of the PDL group affected the RBC abnormalities. The review of the literature showed that there was no study comparing the data of the PDL group with RBC morphological abnormalities before. The present study was the first study with the PDL group in which such a study design had been conducted.

Table 3. Analysis of variance for erythrocyte abnormalities frequencies by taking into chalder fatigue scale.

Erythrocyte Abnormalities	Mean square	F-ratio	*p*-value
Microcyte			
Physical	128.60	5.16	.025*
Mental	195.22	8.11	.005*
Total	161.50	6.59	.012*
Macrocyte			
Physical	3401.69	31.90	.000*
Mental	2726.85	25.37	.000*
Total	3154.27	29.49	.000*
Hypochromic			
Physical	42.18	3.23	.075
Mental	22.66	1.73	.191
Total	36.50	2.78	.098
Acanthocytes (Spur Cells)			
Physical	254.58	28.37	.000*
Mental	257.44	29.07	.000*
Total	254.11	28.51	.000*
Burr Cells			
Physical	19,770.44	26.97	.000*
Mental	18,483.28	25.11	.000*
Total	19,990.86	27.44	.000*
Stomatocytes			
Physical	3.64	.32	.568
Mental	.018	.00	.968
Total	2.78	.24	.619
Dacrocytes			
Physical	44.36	.15	.695
Mental	195.33	.69	.408
Total	144.69	.51	.476
Keratocytes			
Physical	2335.75	33.87	.000*
Mental	1739.87	25.48	.000*
Total	1945.47	28.40	.000*
Schistocytes			
Physical	812.34	38.12	.000*
Mental	770.28	35.91	.000*
Total	739.57	34.56	.000*
Spherocytes			
Physical	520.87	6.46	.013*
Mental	293.89	3.67	.058
Total	421.86	5.23	.024*
Target Cells(codocytes)			
Physical	70,162.62	13.69	.000*
Mental	50,780.07	9.88	.002*
Total	62,856.70	12.24	.001*
Sickle cells			
Physical	2396.81	24.87	.000*
Mental	2148.55	22.00	.000*
Total	2070.07	21.42	.000*
Elliptocytes			
Physical	10.71	.19	.664
Mental	15.10	.27	.602
Total	1.60	.02	.867
Ovalocytes			
Physical	1421.30	5.37	.023*
Mental	852.60	3.18	.077
Total	1299.13	4.88	.030*
Heinz body			
Physical	10.04	1.20	.276
Mental	31.47	4.01	.048*
Total	23.33	2.92	.091

* $p < .05$.

Table 4. Analysis of RBC abnormalities for PDL and control group.

Erythrocyte Abnormalities	Mean (M)	Std. Deviation	F-ratio	*p*-value
Microcyte			6.027	.038*
PDL	6.88	6.06		
Control	4.79	3.66		
Macrocyte			40.864	.000*
PDL	6.17	5.05		
Control	17.96	13.39		
Hypochromic			7.130	.103
PDL	1.88	5.07		
Control	.69	1.00		
Acanthocytes (Spur Cells)			41.933	.000*
PDL	3.17	4.31		
Control	.07	.40		
Burr Cells			57.792	.000*
PDL	35.60	38.22		
Control	9.12	9.30		
Stomatocytes			.096	.773
PDL	1.50	3.67		
Control	1.31	2.94		
Dacrocytes			.100	.927*
PDL	10.21	18.95		
Control	10.52	14.71		
Keratocytes			11.929	.000*
PDL	7.19	6.52		
Control	17.67	9.56		
Schistocytes			.018	.000*
PDL	4.31	4.73		
Control	10.58	4.48		
Spherocytes			.506	.009*
PDL	14.48	9.24		
Control	19.25	8.57		
Target Cells(codocytes)			58.944	.000*
PDL	51.92	102.74		
Control	.13	.74		
Sickle cells			40.746	.000*
PDL	11.02	14.18		
Control	.31	.57		
Elliptocytes			.744	.871
PDL	8.67	7.31		
Control	8.42	7.63		
Ovalocytes			.697	.037*
PDL	28.53	20.30		
Control	21.60	11.46		
Heinz body			4.502	.501
PDL	1.67	3.76		
Control	1.27	1.89		

*$p < .05$.

The Chalder Fatigue Scale is a questionnaire applied to measure the extent and severity of fatigue, both clinically and non-clinically, epidemiologically (Chalder et al. 1993). Tiredness and fatigue affect workers' health, performance, and safety in applied occupational medicine (Jackson 2015). When the Chalder Fatigue Scale was applied to the PDL and control groups, it was determined that the physical, mental, and total fatigue levels of the PDL group were higher than the control group (Table 2). Considering the effect of fatigue on occupational health, it can be said that it causes poor performance, decreased quality of services and products, feelings of professional inadequacy, and accidents (Collewet and Sauermann 2017). It has also been stated that it has devastating effects on private social life, increases the risk of depression, and triggers cardiovascular diseases (Lock et al. 2018). According to the fatigue data obtained in the present study, various strategies to reduce the risk of occupational fatigue should be determined in order to reduce the short and long-term health risks of both the podologists and their patients, like every other group working in the field of health.

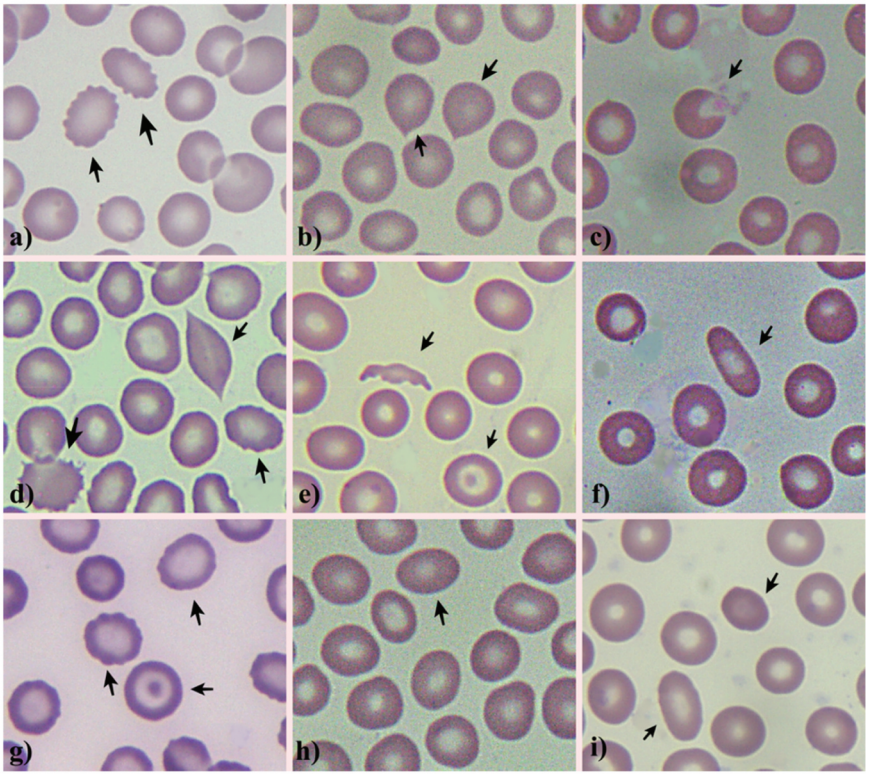


Figure 1. RBC abnormalities observed in PDL: (a.); Burr cell (b); Dacrocytes (c); Keratocytes (d) Sickle cells and Burr cell (e) Schistocytes and Target cell (f); Elliptocytes (g.E); Target cell and burr cell (h) Ovalocytes (i); Macrocyte and spherocytes.

The physical, mental, and total fatigue scores of the PDL group revealed that it affected the formation of Hypochromic, Stomatocytes, Dacrocytes, Elliptocytes, and mental fatigue had an effect on the formation of the Heinz body (Table 3). Many researchers associated deformities in RBCs with fatigue (Balducci 2010; Sakuma et al. 2014; Swift et al. 2016; Prochaska et al. 2018; Saha et al. 2019). Fatigue is the primary symptom of anaemia due to decreased tissue oxygenation (Prochaska et al. 2018). In addition, the change in erythrocytes in people with chronic fatigue may occur due to oxidative radicals. Moreover, it was determined that 2,3-DPG levels and malondialdehyde, which is a product of peroxidation of lipids, increase in people with chronic fatigue (Richards et al. 2007). Researchers have reported that there is a link between ROS molecules that may occur as a result of chronic fatigue and damage to erythrocyte morphology (Kennedy et al. 2005; Gyawali et al. 2015). There are studies indicating that exposure to endotoxin and fungi together with human nail dust during podiatric medical activities can increase ROS molecules in the body (Zughaier et al. 2005; Sabharwal and Schumacker 2014; Yurinskaya et al. 2017). It can be said that there may be reductions in nutrition in people with chronic fatigue symptoms (Kennedy et al. 2005). Especially in dietary nutrition with low magnesium intake, the amount of damage to RBC cells increases (DiNicolantonio et al. 2018). The magnesium amounts of podologists can be evaluated in another study, and the relationship between erythrocyte morphologies can be investigated in future studies. In the light of the present data, it can be said that the work environment they were exposed to may have affected the damage changes in the erythrocyte morphology of PDL, whose fatigue scores were higher than the control group.

In Table 4, when the RBC abnormalities analyzed from the blood taken from the PDL and control group subjects were compared, Microcyte, Macrocyte, Acanthocytes (Spur Cells), Burr Cells, Stomatocytes, Dacrocytes, Keratocytes, Schistocytes, Spherocytes, Target Cells (codocytes), Sickle cells, Elliptocytes, Ovalocytes amounts were found to be statistically significant. It can be concluded that the occupational conditions of the PDL group are an issue that needs attention, as these morphological abnormalities, which occur in various forms, are so common. The micro mills used by podologists for nail treatment produce human nail and skin dust, so most workers are exposed to respiratory tract infections and diseases, including asthma and sinusitis (Kieć-Świerczyńska et al. 2013). During podiatric treatments, workers are exposed to endotoxin, the outer cell wall component of gram-negative bacteria, as well as potentially pathogenic fungi (Tinley et al. 2014). These bacteria, including parasites and fungi, require sufficient iron for metabolism, proliferation, and pathogenicity. Also, as soon as they invade the cell, they can steal iron from iron transport proteins such as transferrin and produce siderophores by expressing iron uptake receptors (Valente de Souza et al. 2021). Since adequate iron availability is required for changes in iron homeostasis for RBC formation during erythropoiesis, it causes the development of anaemia as a result of both its biosynthesis and its effect on red blood cells (Weiss et al. 2019). Because of these infectious effects, typical changes in body iron homeostasis might occur with decreased serum iron levels and decreased transferrin saturation, in which case there may be an increase in RBC abnormalities. Continuously inhaling fine particles found in nail and skin dust can cause adverse health effects such as pneumonia and lead pneumoconiosis (Gupta and Quinlan 2021). The addition of fungi to inhaled dust further complicates the risk to one's health. When inhaled, these fungi can reach deep into the lungs and initiate a cycle of inflammation that can damage lung tissue (Woodfolk 2005). These inflammatory conditions may activate the immune system, causing antibodies to bind to RBCs and deform RBC cells by phagocytosis or complement-mediated destruction (Phillips and Henderson 2018). As stated in the previous paragraph, reactive oxygen species may increase chronic fatigue and an inflammatory condition. The shape and size of RBCs vary significantly with the oxidative response and inflammatory stresses, thus causing hemolysis in RBCs due to excessive oxidative stress (ROS molecules) and decreased energy production (Gyawali et al. 2015; Hoffman et al. 2017; Saha et al. 2019). In addition, toenail dust and endotoxin content are diffused from micro-milling devices can increase lung inflammation and asthma by stimulating the release of interleukin 8 (IL-8) from lung epithelial cells (Donaldson et al. 2002). Researchers have stated that high IL-8 release from lung cells is associated with hemolytic anaemia (Alagbe et al. 2018; Abdul-Hussein et al. 2021). These data may explain the increase in RBC abnormalities in the PDL group. Moreover, the appearance of these abnormalities may be a sign of high exposure to dust and pathogenic microbial activity.

As in many situations that disrupt the metabolic balance, the damage caused by long-term exposure to bioaerosols, dust, microbes, and particle mixtures, can be reflected in haematological parameters and cell morphologies. This study aimed to contribute to the literature on RBC abnormalities due to occupational exposure of podologists. The results of the study showed that the erythrocyte fragility increased in the PDL group compared to the control group and caused hemolysis. This may cause anaemia, lung diseases, deterioration of respiratory functions, and chronic fatigue in the chronic period. Because of this, variations can be observed in hematocrit and red blood cell indices. Considering all these factors, the occupational conditions of the PDL group seriously threaten their health.

Conclusion

Podologists are exposed to toenail dust, endotoxins, pathogenic microorganisms, and various chemicals for fungal and callus treatments during nail or foot treatment. They are also likely to be contaminated with viruses that are transmitted through the blood, primarily hepatitis B, C, or

HIV. Therefore, they are in the high-risk group against various diseases such as respiratory disorders due to inhalation of fungi and chemical elements on nails and skin. To avoid these risks, using personal protection equipment (PPE), using a dust suppression system with water spray on micro mills, and installing air filtration systems can help reduce exposure to nail dust. A combination of water spray suppression and air filtration systems can likely improve indoor air quality and help reduce exposure to nail dust. In addition, hand washing and the use of gloves are some of the most effective ways to reduce infection. With these measures, occupational risks can be reduced, protection against respiratory system diseases can be created, and the transmission of pathogenic fungi can be prevented. This study was carried out to increase the awareness of podology specialists about occupational risks and encourage those working in this field to comply with safety precautions. Furthermore, no other study was found in the literature being studied with the PDL group. Therefore, the present study is the preliminary one in the literature.

Acknowledgement

Thanks to all PDL and control group subjects who volunteered to participate.

Compliance with ethical standards

The Ethics Committee of Kocaeli University approved this study.

Consent to participate

All participants volunteered to participate in the study and signed consent forms.

Consent to publish

All authors agreed to publish their manuscript in this journal and gave consent to publish.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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