DOI: 10.17816/KMJ2021-474

Analysis of microcirculatory disorders in men with more than 10 years' experience on night work

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Abstract

Aim. To study the nature and extent of the effects of long-term sleep and wake phase disorders (working at night for more than 10 years) on the characteristics of microcirculation in men.

Methods. Laser Doppler flowmetry and spectophotometry, optical tissue oximetry, and laser-induced fluorescence spectroscopy were performed in 34 male patients with a mean age of 40.3±0.9 years and more than 10 years' experience of night work to assess the effectiveness of microcirculation. 25 men with a mean age of 40.2±1.2 without night work experience were used as a control group. Microcirculation was studied on the laser diagnostic complex LAKK-M (LAZMA, Russian Federation). The measurement was carried out on the skin of the palmar surface of the terminal phalanx of the second finger of the hand. The following indicators were analyzed in automatic mode: the mean perfusion value, the index of specific oxygen consumption in the tissue, capillary blood saturation, the relative volume of the red blood cell fraction, arterial blood oxygen saturation, the index of perfusion oxygen saturation in the microcirculation, the efficiency of oxygen exchange and the fluorescent indicator of oxygen consumption. Statistical processing of the results was carried out using the Student's t-test for independent samples.

Results. In patients working at night for more than 10 years, a decrease in microcirculation efficiency was revealed. The index of specific oxygen consumption in the tissue was lower than that of healthy volunteers by 34.1% ($p=0.000255$), and the index of oxygen exchange efficiency by 56.3% ($p <0.001$). Long-term night work (>10 years) can lead to violations of microcirculation parameters and an irreversible decrease in the efficiency of oxygen exchange compared with the control group by an average of 56.3% (18.0±0.5 for the group with night work experience, 41.2±0.6 for the group of healthy volunteers, $p <0.001$), the index of specific oxygen consumption in the tissue by an average of 34.1% (1.53±0.03 for the group with night work experience, 2.32±0.2 for the group of healthy volunteers, $p=0.000255$) and an increase in the index of perfusion oxygen saturation in the microcirculation by 2 times compared with the control group (6.2±0.05 for the group with night work experience, 3.67±0.09 for the group of healthy volunteers, $p <0.001$), which is accompanied by an increase in the saturation of mixed (and venous) blood.

Conclusion. The nature of the revealed violations of microcirculatory parameters in the long-term night work suggests their significance in the development of diseases that are currently attributable to the so-called group of "diseases of civilization".

Keywords: microcirculation, oxygen exchange, night work.

For citation: Gribanov I.A., Zarubina E.G. Analysis of microcirculatory disorders in men with more than 10 years' experience on night work. *Kazan Medical Journal.* 2021; 102 (4): 474–478. DOI: 10.17816/KMJ2021-474.

Background. Epidemiological studies have shown a link between frequent stress exposure and the development of cardiovascular and dysmetabolic diseases [1–5]. Exposure to stress increases the risk of death from these conditions [5]. In the modern world, stressors include a high rhythm of life, a change in the natural nature and rhythm of nutrition, and an increase in the number of people working in unusual conditions, i.e., a change in the climatic zone, work in polar day and night conditions, and work at night. The biological effects of such a working rhythm are not fully characterized, but it is known that these effects include autonomic dysfunction and neuroendocrine activation, are associated with disturbances in the circadian rhythm, and are associated with microinflammation and endothelial dysfunction [4]. In addition, accumulated data indicate a link between night work and increased risk of developing or progression of coronary heart disease [6, 7].

In addition, working in night shifts leads to failure of the phase architectonics of the human

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circadian system. Night wakefulness cannot be replenished with either additional daytime sleep, additional nutrition, or medications [8, 9]. In the Russian Federation, European countries and the United States, the proportion of individuals working in various forms of shift work (night or shift work) is 20% of the total number of employees, including employees of the Ministry of Internal Affairs and medical workers employed in trade [10, 11].

Zuraikat et al. have indicated that variability in nocturnal sleep patterns leads to changes in the circadian rhythm and, apparently, increases cardiometabolic risk [12]. The authors reviewed the literature from 2015 to 2020 on indicators of nocturnal sleep variability associated with metabolic syndrome, type 2 diabetes mellitus, and their risk factors. They found that an irregular sleep regimen leads to negative cardiometabolic outcomes.

Microcirculation plays the leading role in ensuring tissue trophism and maintaining nutritive hemostasis in general. Reportedly, night work has a complex negative effect on the body, disrupting the function of several organs and systems [5].

In the modern literature, data on microcirculation in this category of patients cannot be considered exhaustive and ambiguous.

The aim of this work is to study the nature and degree of influence of prolonged disturbances in the phases of sleep and wakefulness (work at night for over 10 years) on the characteristics of microcirculation in men.

Materials and methods. The study involved 34 male patients with an average age of 40.3 ± 0.9 years (first group) and work experience at night for >10 years. In addition, the study enrolled 25 male patients with an average age of 40.2 ± 1.2 years, who were categorized in the control group (second group) without work experience at night. The study included taxi and ambulance drivers who worked only in the night shift. The control group also comprised drivers who regularly work the day shift.

Before enrollment in the study, all participants were examined for their somatic status to exclude chronic diseases present before starting work in the night shift that could affect the state of microcirculation.

Microcirculation was studied using a multifunctional non-invasive laser diagnostic complex LAKK-M (LAZMA, RF) on the skin of the palmar surface of the terminal phalanx of the second hand finger. The study was conducted at the Reaviz multidisciplinary clinic from September to November 2020.

We analyzed indicators such as the average perfusion value (M, perf. units), the index of specific oxygen consumption in the tissue ($U = SpO_2/SO_2$, conventional units), capillary blood saturation (SO_2, %), relative volume of erythrocyte fraction (%), arterial blood saturation (SpO_2, %), perfusion oxygen saturation index in the microcirculation ($SO_m = SO_2/M$, standard units). In addition, during the course of the study, hemoglobin content in the blood and the average hemoglobin content in the erythrocyte were determined.

All measurements were conducted at room temperature (22 ± 2°C) in an isolated room. The participants abstained from taking pharmaceutical products as well as alcoholic and caffeine-containing beverages. The instrument was calibrated before each use.

By combining laser Doppler flowmetry and spectrophotometry; optical tissue oximetry; and laser fluorescence spectroscopy, we calculated integrative indicators of microcirculation such as the efficiency of oxygen exchange (EOE) and the fluorescence parameter of oxygen consumption in relative units, as follows [13]:

$$EOE = M \times U \times FOC$$
$$FPK = ANADN/A_{flavins}$$

where FOC is the fluorescent parameter of oxygen consumption; ANADH is the amplitude of fluorescence emission of the reduced coenzyme nicotinamide adenine dinucleotide; $A_{flavins}$ is the amplitude of fluorescence emission of oxidized flavoproteins at wavelengths of 480–490 and 520 nm.

Results were statistically analyzed using the licensed software package Statistica for Windows 7.0. The Student's test was used for assessing independent samples with a preliminary estimate of normal data distribution [14].

The study was approved by the Ethics Committee of the Reaviz Medical University (minutes of the meeting No. 24 dated November 19, 2018).

Results. Analysis blood hemoglobin concentration and the average hemoglobin level in erythrocytes did not reveal any deviations beyond the reference values (Table 1). There were no statistically significant differences between the groups.

There were significant changes ($p < 0.001$) in the nature of the microcirculation of people working at night compared with that of control participants (Table 2).

Despite the preservation of quantitative indicators, such as the index of microcirculation and arterial blood saturation, in the first group, capillary blood saturation was almost two times higher ($p < 0.001$) than that in the control group. This was confirmed by a comparable increase in the index of perfusion oxygen saturation in the microcirculation ($p < 0.001$) and indicated a deterioration in the oxygen supply to tissues.

Table 1. Comparative indicators of hemoglobin concentration in blood and average hemoglobin level in erythrocytes in drivers of the studied groups

Parameter	First group, n = 34	Second group, n = 25	P-value
Blood hemoglobin concentration, g/l	143.3 ± 6.3	142.6 ± 7.1	0.941476
Mean cell hemoglobin, pg	27.1 ± 1.6	28.2 ± 1.9	0.659585

Such changes inevitably affected the state of metabolic processes in tissues and led to activation of peroxidation processes. However, the fluorescent indicator of oxygen consumption in tissues in the study group decreased by 31.7% compared with that in the control group ($p < 0.001$).

In all patients working at night, both the index of specific oxygen consumption in the tissue and EOE decreased compared with those in the control group. The difference between groups for specific oxygen consumption in the tissue was 34.1% and for EOE – 56.3% (Table 3). Such changes, in our opinion, may reflect a decrease in cellular metabolism and the overall efficiency of microcirculation.

Discussion. The decrease in the efficiency of microcirculation, observed in this study, can be associated with a number of factors. As established by a previous study [7], prolonged changes in the periods of sleep and wakefulness in humans leads to dysregulation of the cardiovascular system and increased level of sympathetic influences, which is inevitably accompanied by increased blood flow velocity. This, in turn, shortens the period of gas exchange in tissues, leading to an increase in the perfusion oxygen saturation index in the microcirculation and is expressed in an increase in the saturation of mixed (and venous) blood.

The lack of oxygen supply to tissues triggers the processes of lipid peroxidation and leads to further disruption of tissue metabolism, impairment of the synthesis of intracellular enzymes, and a further decrease in oxygen consumption by cells [15]. It is possible that hypoxia developing against this background can damage erythrocyte membranes, contributing to the formation of irreversible aggregates from them owing to the "crosslinking" of membranes, which begin to block the microvasculature

Table 2. Comparative indicators of microcirculation in drivers enrolled in study groups

Parameter	First group, n = 34	Second group, n = 25	P-value
Microcirculation parameter, perfusion unit	10.3 ± 0.3	10.3 ± 0.3	>0.001
Capillary blood saturation, %	65.1 ± 0.6	38.0 ± 1.1	<0.001
Arterial blood saturation, %	98.1 ± 0.3	98.9 ± 0.02	0.010153
Relative volume of RBC fraction, mm^3	9.8 ± 0.2	11.4 ± 0.3	0.000043
Index of perfusion oxygen saturation in microcirculation, conventional units	6.2 ± 0.05	3.67 ± 0.09	<0.001

with the formation of plasma capillaries. An indirect reflection of this process can be the decreased number of erythrocytes in the scanned tissue volume, as indicated in the present study, but normal count in the general blood tests of patients of the study group.

Deterioration of oxygen supply to tissues can initiate a number of changes, from metabolic disorders (metabolic syndrome and diabetes mellitus) of tissues and organs as well as disorders of organ and system functions (arterial hypertension or coronary heart disease) to a compensatory increase in dystrophic processes in tissues, which in the future, in our opinion, will further reduce the efficiency of the microvasculature and the efficiency of oxygen exchange.

CONCLUSIONS

1. Compared with healthy participants, participants who did prolonged work in the night shift (for >10 years) had disturbances in microcirculation parameters and an irreversible decrease in the efficiency of oxygen metabolism by an average of 56.3% ($p < 0.001$), of specific oxygen consumption index by an average 34.1% ($p=0.000255$) on the background of an increase in the perfusion oxygen saturation index. Microcirculation was two times higher in the first group than in the control group

Table 3. Comparative efficiency of oxygen metabolism in drivers enrolled in study groups

Groups	Fluorescence parameter of oxygen consumption	Specific oxygen consumption index in tissue, conventional units	Efficacy of oxygen exchange
First group, n = 34	1.1 ± 0.04	1.53 ± 0.03	18.0 ± 0.5
Second group, n = 25	1.61 ± 0.06	2.32 ± 0.2	41.2 ± 0.6
p	<0.001	0.000255	<0.001

($p < 0.001$), which was accompanied by an increase in the saturation of mixed (and venous) blood.

2. The nature of the observed changes in microcirculatory parameters, against the background of prolonged work at night, suggests their importance in the development of diseases, which are currently referred to as "the diseases of civilization."

Author contributions. I.A.G. — conducted research and was responsible for data collection and analysis of results; E.G.Z. — work manager.

Funding. The study had no external funding.

Conflict of interest. The authors declare no conflict of interest.

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