DOI: 10.54538/2707-5265-2026-7-1-155-164

Thermoregulatory responses of miners in high-altitude conditions of Kyrgyzstan: seasonal variations and risk factors

K.O. Dzhusupov[1], Zh.K. Derbishalieva[1], K.K. Toguzbaeva[2]
[1]International Higher School of Medicine, Bishkek, Kyrgyzstan;
[2]Kazakh National Medical University named by S.D. Asfendiyarov, Almaty, Kazakhstan

Objective: To evaluate the thermoregulatory responses of miners in high-altitude quarries in Kyrgyzstan depending on the season, altitude, and the nature of their physical activity.

Materials and Methods: The field study was conducted during the winter and summer seasons at the Kumtor (elevation 4,200 m) and Makmal (elevation 3,000 m) open pit mines. Forty-eight workers participated in the study. The following parameters were measured: body and skin temperature (at seven points), moisture loss, subjective temperature perception, and weather conditions.

Results: It was found that during cold periods, physical exertion leads to a significant decrease in average skin temperature (to 25.16°C) while maintaining a stable body temperature. During the warm season, the differences between these parameters are smoothed out. A regression analysis revealed that the subjective sensation of cold and moisture loss during the winter, particularly at Kumtor, are strongly correlated with air temperature (determination coefficient R^2=0.97), wind speed, and physical exertion level.

Conclusion: High-altitude conditions, especially during the cold season, create significant thermal stress on miners, requiring the development of individual work schedules, acclimatization measures, and thermal protection. The study emphasizes the need to consider climate factors in occupational safety and health in the mining industry. This is especially relevant in the context of global climate change.

Key words:
miners, high altitude, thermoregulation, thermal state, physiological adaptation, thermal sensation, moisture loss, seasonal variation, occupational health

For citation:
Dzhusupov K.O., Derbishalieva Zh.K., Toguzbaeva K.K. Thermoregulatory responses of miners in high-altitude conditions of Kyrgyzstan: seasonal variations and risk factors. Eurasian Scientific and Medical Journal "Sino". 2026; 7(1): 155-164. https://doi.org/10.54538/2707-5265-2026-7-1-155-164

DOI: 10.54538/2707-5265-2026-7-1-155-164

Терморегуляторные реакции горнорабочих в высокогорных условиях Кыргызстана: сезонные различия и факторы риска

К.О. Джусупов[1], Ж.К. Дербишалиева[1], К.К. Тогузбаева[2]
[1] *Международная высшая школа медицины, Бишкек, Кыргызстан;*
[2]*Казахский национальный медицинский университет им. С. Д. Асфендиярова, Алматы, Казахстан*

Цель исследования. Оценить терморегуляторные реакции организма горнорабочих в условиях высокогорных карьеров Кыргызстана в зависимости от сезона, высоты над уровнем моря и характера физической активности работников.

Материалы и методы. Полевое исследование проводилось в зимний и летний сезоны на карьерах Кумтор (высота 4200 м) и Макмал (высота 3000 м). В исследование участвовали 48 работников. Измерялись следующие показатели: температура тела и кожи (в семи точках), уровень влагопотерь, субъективное восприятие температуры, а также погодные условия.

Результаты. Установлено, что в холодный период при физической нагрузке происходит выраженное снижение средневзвешенной температуры кожи (до 25,16°C) при стабильной температуре тела, в тёплый сезон различия между этими показателями сглаживаются. Проведённый регрессионный анализ показал, что субъективное ощущение холода и влагопотери в зимний период, особенно на Кумторе, имеют сильную корреляцию с температурой воздуха (коэффициент детерминации R^2=0,97), скоростью ветра и уровнем физической нагрузки.

Заключение. Высокогорные условия, особенно в холодное время года, создают значительную термическую нагрузку на организм горнорабочих, что требует разработки индивидуальных режимов труда, мер акклиматизации и теплозащиты. Исследование подчёркивает необходимость учитывать климатические факторы при охране труда в горнодобывающей промышленности. Это особенно актуально в условиях глобальных климатических изменений.

Ключевые слова: *горнорабочие, высокогорье, терморегуляция, тепловое состояние, физиологическая адаптация, теплоощущение, влагопотери, сезонные различия, охрана труда*

Для цитирования: *Джусупов К.О., Дербишалиева Ж.К., Тогузбаева К.К. Терморегуляторные реакции горнорабочих в высокогорных условиях Кыргызстана: сезонные различия и факторы риска. Евразийский научно-медицинский журнал «Сино». 2026; 7(1): 155-164. https://doi.org/10.54538/2707-5265-2026-7-1-155-164*

INTRODUCTION

The formation and development of the mining industry in Kyrgyzstan occur under complex natural and climatic conditions. A significant portion of large industrial open-pit mines, including Kumtor, Makmal, Saryjaz, and others, is located at altitudes ranging from 2200 to 4200 meters above sea level. At such altitudes, the climate is characterized by intense solar radiation, low air temperatures, reduced atmospheric pressure, and high wind loads. These features necessitate special attention to occupational safety, hygiene, and human physiology in mountain mining conditions [1, 2].

In recent years, the assessment of the functional state of workers in high-altitude conditions has become particularly relevant due to the increasing industrial development of mountainous regions and climate change. Despite advancements in hygienic standards and technological recommendations, the problem of thermal state and heat balance under combined exposure to cold, hypoxia, and physical exertion remains understudied. The growing number of studies in this field highlights the importance of understanding human adaptation to extreme microclimates, especially during prolonged outdoor work [3, 4].

Existing research shows that, in high-altitude conditions, skin temperature on the extremities is significantly lower than on the torso, indicating blood flow redistribution and activation of thermoregulation mechanisms. Concurrently, shifts in oxygen consumption, increased heat production via shivering thermogenesis, and reduced heat loss due to vasoconstriction have been observed [5, 6]. This underscores the need for a comprehensive assessment of thermal state, accounting for real meteorological conditions, labor specifics, and altitude adaptation.

RESEARCH OBJECTIVE

To assess changes in the thermal state and structure of the heat balance among miners in various quarries of Kyrgyzstan depending on the season, altitude and working conditions.

PARTICIPANTS AND METHODS

Study design: A prospective field study with comparative analysis elements was conducted to assess thermoregulatory responses in real production conditions.

Location: The study was carried out at the Kumtor (4200 m) and Makmal (3000 m) mines during two seasonal periods: winter (December–February) and summer (July–August).

Participants: The study included 48 miners aged 25–55 years. Anthropometric data are presented in Table 1. Inclusion criteria: ≥3 years of work experience, absence of chronic diseases, participation in regular production cycles. Exclusion criteria: acute infectious diseases, cardiovascular insufficiency, acclimatization disorders.

Methods: Measurements included:

- Skin temperature at body sites (forehead, chest, shoulder, hand, thigh, calf, foot);
- Average body temperature (ABT);
- Mean weighted skin temperature (MWST);
- Thermal sensation using a subjective perception scale (1–5 points);
- Moisture loss (g/h) via body weight changes and evaporation assessment;
- Physical workload via energy expenditure calculations and oxygen consumption using metabolic equivalents (METs).

Protocol: Measurements were taken under standard conditions: at rest and during moderate-intensity work (road and drilling operations). Weather parameters (air temperature, humidity, wind speed) were recorded using certified meteo-

Table 1. General Characteristics of Participants

Indicators	Altitude above sea level, m	
	2800	4200
Number of participants	24	24
Age , years	25-40	25-40
Weight body , kg	69±0.96	70±1.05
Height , cm	168±0.68	168±0.9

rological instruments.

Mean weighted skin temperature (MWST) was calculated using Hardy and Dubois' formula (1938) [7], based on skin temperature measurements at seven body sites (forehead, chest, shoulder, hand, thigh, calf, foot) weighted by their surface area proportions:

$$MWST = 0.0886 \cdot t_{forehead} + 0.34 \cdot t_{chest} + 0.134 \cdot t_{shoulder} + 0.045 \cdot t_{hand} + 0.23 \cdot t_{hip} + 0.125 \cdot t_{lower\ leg} + 0.0644 \cdot t_{foot} \quad [1]$$

Measurements were conducted indoors (after 30 minutes of rest) and outdoors (during work). Seasonal measurements were taken in winter (December-January) and summer (June-July).

Clothing insulation (clo units) was assessed using the I.S. Kandror scale (1974) [8]. For this purpose, the quantity and quality of clothing were recorded. Thermal sensation during the studies was studied using the Bedford scale, which contains 7 gradations [9]: very cold (l point), cold (2 points), cool (3 points), comfortable (4 points), warm (5 points), hot (6 points), very hot (7 points).

The amount of moisture loss was calculated based on the data on heat loss by evaporation from the body surface using the formula:

$$E\ (g/hour) = 17000 \cdot 60 \cdot L / 0.577, \quad [3]$$

where 17000 is the average surface area of the human body, cm^2; 60 is the coefficient for converting minutes to hours; L is the amount of heat loss due to evaporation from the body surface, cal/min cm^2; 0.577 is the caloric equivalent of evaporation of 1g of sweat; E is the amount of moisture loss, g/hour.

Thermoregulatory strain was classified per Kandror's physiological scale (1974) [8], distinguishing nine types of thermal load (heating: 1-T to 4-T; cooling: 1-C to 4-C; comfort: N).

Statistical Analysis: Data were processed using SPSS 26.0. Descriptive statistics, ANOVA, paired t-tests for comparing values under different conditions, and linear regression analysis were were applied to establish the dependence of indicators on weather conditions.

Ethics: The study was approved by the local ethics committee of the International Higher School of Medicine (Protocol No. 3 dated 23/11/2015). Participants provided informed consent. All bioethical standards were observed, including anonymity and voluntary participation.

RESULTS AND DISCUSSION

The results of measuring the heat balance of miners are presented in Tables 2 and 3.

The analysis of the data revealed clear differences in the thermal state of mine workers depending on the season, altitude, and the nature of the work performed. During the cold period, especially under physical exertion, a significant decrease in the mean weighted skin temperature (MWST) was observed, while the average body temperature (ABT) remained relatively stable. At the Kumtor mine, during work performed in the cold season, the MWST dropped to 25.16°C, which is 7-8°C lower than in a state of rest.

In the warm season, the differences between the mines and physiological states were less pronounced. ABT remained within the range of 35.2-36.7°C, and MWST – within 32.4-33.2°C. Figure 1 illustrates the comparison of MWST and ABT by season (cold and warm) and by mine (Kumtor and Makmal), under both rest and physical work conditions. It is evident that in the cold season, MWST sharply decreases during physical work, especially at Kumtor. In the warm season, the differences level off, and the values of MWST and ABT stabilize. ABT is less variable compared to MWST, especially among adapted workers.

The obtained data on mean weighted skin temperature (MWST) and average body temperature (ABT) confirm a reduction in climatic stress during the summer period and better stabilization of the body's thermal state.

Water loss and subjective thermal sensation provide additional means of assessing the level of physiological strain. Figure 2 presents the water loss of mine workers by season and working conditions. As shown in the figure, water loss indicators also varied depending on the season and the nature of the work. The highest values were recorded during work at Kumtor in the cold period (46.02 g/h), and the lowest – during rest at Makmal in summer (17.70 g/h).

This may reflect both increased evaporation and intensified thermoregulatory effort. These findings highlight the impact of climate and physical workload on evaporative loss.

At high temperatures and low humidity in mountainous regions during the summer, active evaporative losses occur, whereas in cold con-

Table 2. Thermal State of Miners in Quarries of Kyrgyzstan in Cold Season

Quarries	Kumtor (H=4200 m)				Makmal (H=3000 m)	
State of body	Rest	Road works			Rest	Road works
Parameters	t=+18 °C v=0.1m/s f=1.6g/l	t=-18 °C v=0.1m/s f=1.6g/l	t=-27 °C v=2.4m/s f=0.6g/l	t=-27 °C v=4.5m/s f=0.6g/l	t=+19.5 °C v=0.1m/s f=2.1g/l	t=-18.5 °C v=1.2m/s f=1.0g/l
1. $t_{forehead}$ (°C)	31.12±0.03	14.48±0.06	14.50±0.06	14.22±0.01	31.88±0.01	14.88±0.03
2. t_{chest} (°C)	33.15±0.05	28.10±0.03	28.88±0.05	26.56±0.01	33.42±0.08	29.16±0.03
3. $t_{core\ body}$ (°C)	36.35±0.01	36.79±0.01	36.26±0.01	35.71±0.01	36.26±0.01	36.36±0.01
4. $t_{shoulder}$ (°C)	32.63±0.06	28.67±0.06	28.82±0.08	26.52±0.01	32.60±0.01	28.43±0.03
5. t_{hand} (°C)	28.95±0.01	17.04±0.03	14.01±0.09	12.96±0.01	29.11±0.02	17.38±0.05
6. t_{thigh} (°C)	32.05±0.04	30.75±0.05	30.34±0.12	27.48±0.14	32.71±0.04	30.75±0.09
7. t_{calf} (°C)	32.63±0.07	30.14±0.04	29.35±0.04	27.18±0.01	32.42±0.07	30.27±0.13
8. t_{feet} (°C)	28.76±0.06	20.57±0.09	17.86±0.01	15.86±0.01	29.09±0.05	20.76±0.15
9. t_{2-5} (°C)	4.20±0.03	11.32±0.01	14.86±0.14	13.6±0.01	4.31±0.06	11.78±0.02
10. t_{2-8} (°C)	4.39±0.02	7.59±0.16	11.02±0.06	10.7±0.01	4.33±0.06	8.39±0.12
11. MWST (°C)	33.02±0.04	27.62±0.07	27.38±0.07	25.16±0.03	33.28±0.05	28.01±0.07
12. ABT (°C)	35.57±0.05	33.62±0.04	33.54±0.02	32.84±0.04	35.66±0.05	33.76±0.04
13. Thermal sensation (score)	3.90±0.06	3.10±0.005	2.80±0.02	1.00±0.02	3.91±0.01	3.20±0.01
14. Moisture loss (g/h)	23.01±0.01	46.02±0.01	17.70±0.03	21.24±0.01	24.78±0.01	30.09±0.04
15. Thermoregulation strain	“N” minimal	“2x” moderate	“3x” big	“2x-4x” significant	“N” minimal	“2x” moderate

Table 3. Thermal State of Miners in Quarries of Kyrgyzstan Warm Season

Quarries	Kumtor (H=4200 m)			Makmal (H=3000 m)	
State of body	Rest	Road works		Reast	Road works
Parameters	t=+18 °C v=0.2m/s f=6.3g/l	t=+14 °C v=0.7m/s f=6.0g/l	t=+12 °C v=0.9m/s f=6.0g/l	t=+18,0 °C v=0.2m/s f=5.3g/l	t=+16.0 °C v=1.0m/s f=6.6g/l
1. $t_{forehead}$ (°C)	31.21±0.02	27.07±0.06	27.73±0.02	31.70±0.05	28.21±0.01
2. t_{chest} (°C)	33.07±0.04	32.67±0.09	31.68±0.01	33.44±0.04	32.60±0.02
3. $t_{core\ body}$ (°C)	36.25±0.01	36.72±0.02	36.64±0.01	36.25±0.01	36.62±0.01
4. $t_{shoulder}$ (°C)	32.68±0.02	32.02±0.08	31.57±0.04	32.60±0.02	31.86±0.01
5. t_{hand} (°C)	29.53±0.05	26.90±0.11	25.23±0.02	29.91±0.11	25.45±0.01
6. t_{thigh} (°C)	32.71±0.06	32,91±0,09	33.13±0.01	31.51±0.08	33.31±0.07
7. t_{calf} (°C)	32.53±0.05	32.23±0.03	31.72±0.04	31.08±0.08	32.24±0.02
8. t_{feet} (°C)	29.63±0.05	28.01±0.06	27.16±0.06	29.71±0.03	27.90±0.02
9. t_{2-5} (°C)	3.54±0.01	5.77±0.02	6.45±0.02	3.52±0.07	7.15±0.02
10. t_{2-8} (°C)	3.43±0.01	4.65±0.03	4.52±0.01	3.73±0.07	4.70±0.01
11. MWST (°C)	33.19±0.04	32.46±0.04	31.90±0.01	32.89±0.02	32.46±0.01
12. ABT (°C)	35.63±0.04	35.37±0.04	35.16±0.05	35.52±0.04	35.57±0.04
13. Thermal sensation (score)	4.00±0.00	4.53±0.03	4.20±0.02	4.00±0.00	4.25±0.02
14. Moisture loss (g/h)	33.63±0.04	24.78±0.03	28.32±0.03	17.70±0.02	26.55±0.04
15. Thermoregulation strain	“N” minimal	“N” minimal	“1x” weak	“N” minimal	“N” minimal

ditions, thermoregulation is primarily achieved through changes in skin temperature.

The thermal sensations of miners under various conditions throughout different periods of the year are presented in Figure 3.

The analysis of thermal sensation revealed that during the cold season, while working at Kumtor, the subjective assessment of thermal comfort decreased to 1.0 point, whereas in the warm season all values exceeded 4.0, indicating an overall feeling of thermal comfort.

The results of one-way analysis of variance (ANOVA) showed statistically significant differences in MWST and moisture loss between seasons

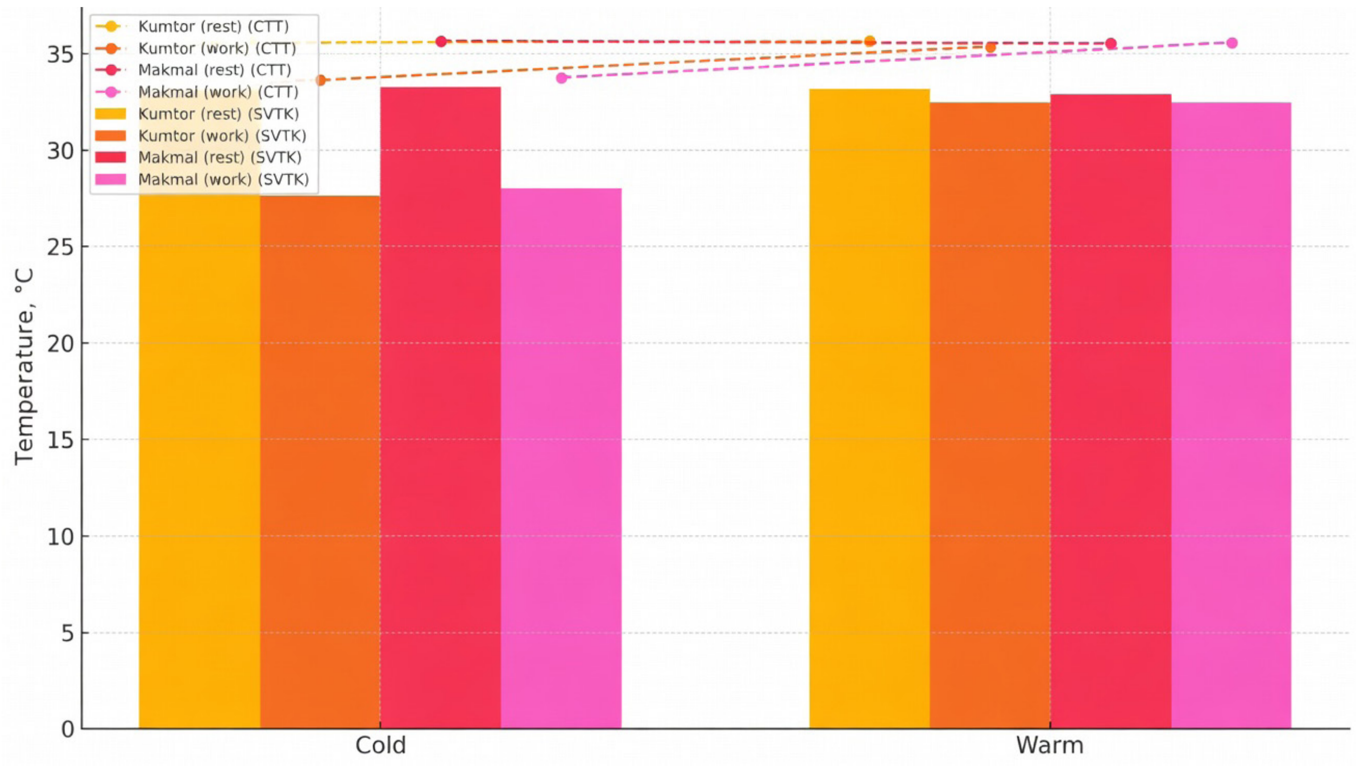

Fig. 1. Comparison of MWST and ABT of mine workers by season and mining site

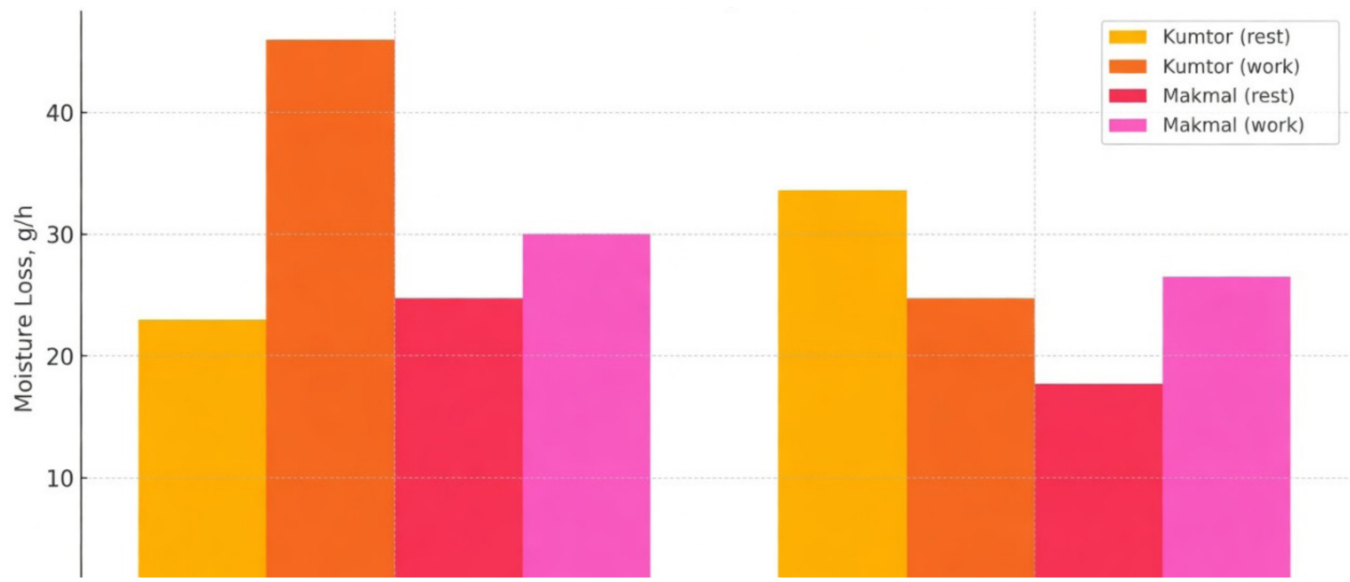

Fig. 2. Moisture losses of miners by season and mining site

($p<0.001$), as well as between work sites ($p<0.05$). However, ANOVA across four working conditions (rest/work during the summer and winter seasons at Kumtor and Makmal) showed no statistically significant differences ($F=1.08$; $p=0.45$).

Regression analysis confirmed a strong dependence of MWST on ambient air temperature ($R^2=0.97$), wind speed ($R^2=0.82$), and physical workload ($R^2=0.88$), with air temperature identified as the primary predictor.

The obtained results indicate a high sensitivity of skin thermoregulation to temperature and wind speed, especially in high-altitude environments. The pronounced decrease in MWST, while maintaining stable ABT, likely reflects effective adaptation of miners' bodies, achieved through peripheral vasoconstriction and activation of physical thermoregulatory mechanisms.

These findings confirmed the dominant influence of air temperature and physical workload on MWST, underscoring the need to consider these factors when developing work-rest schedules and individual protective measures.

This study aims to analyze the impact of high-altitude climatic factors on the thermal state of miners under real working conditions. These data are of significant importance to the fields of occupational physiology, hygiene, and the organization of health protection in the mining industry.

The key findings of the study include: a significant decrease in mean weighted skin temperature (MWST) under cold conditions and physical exertion; stable average body temperature (ABT) values even in unfavorable weather conditions; and a marked deterioration in subjective thermal sensation and an increase in moisture loss among workers during the cold season. These findings indicate a high level of physiological adaptation, achieved through the activation of physical thermoregulation – vasoconstriction, changes in skin temperature, and increased heat production.

The statistical data obtained complement the physiological observations: although differences between experimental groups did not reach statistical significance according to ANOVA results ($p>0.05$), the observed trend of decreasing MWST under cold and strenuous conditions is supported by regression analysis, which demonstrated a negative correlation between ambient temperature and MWST. This underscores the importance of expanding sample sizes and conducting detailed monitoring of microclimatic conditions in future studies of this kind.

These findings are consistent with a number of studies investigating the physiological responses of the human body under high-altitude and extreme microclimatic conditions. For example, Young A.J. and Sawka M.N. (2000 and 2002) emphasized that cold exposure under reduced atmospheric pressure leads to significantly restricted skin perfusion and

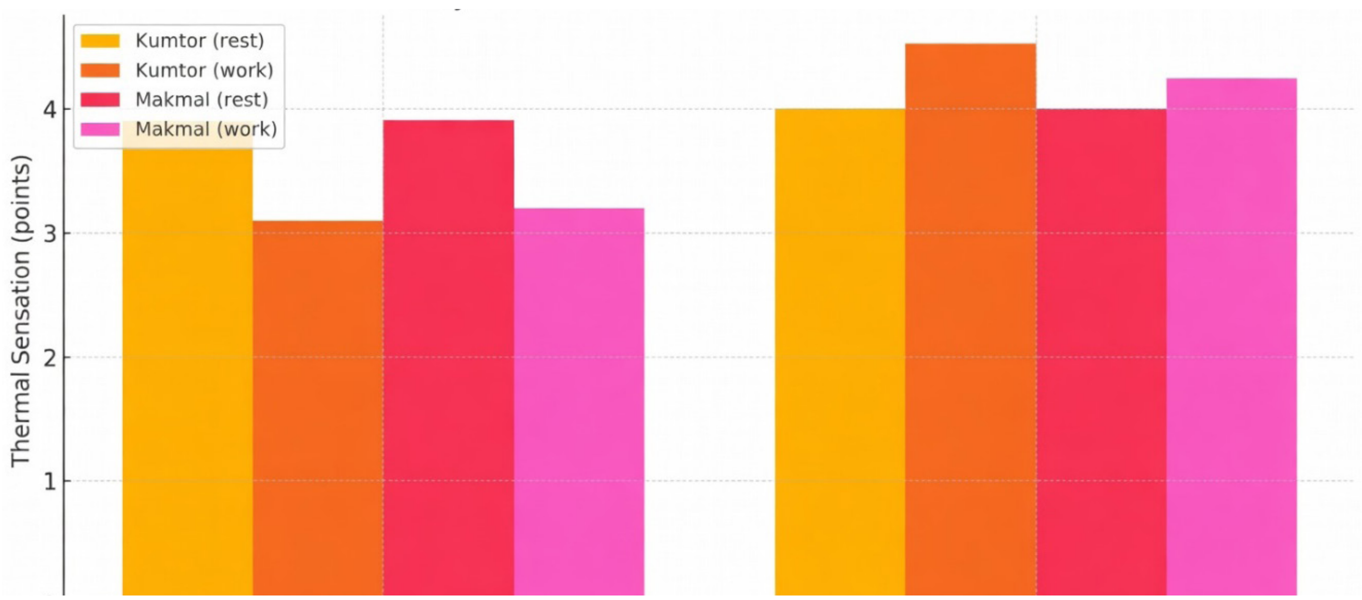

Fig. 3. Subjective thermal sensation of miners by season and mining site

reduced extremity temperature [10, 11]. Similar conclusions were drawn by Castellani J.W. et al. (2001), who found that even with adequate clothing insulation, thermoregulation among climbers and mountain workers requires high energy expenditure [12].

Studies by Mäkinen (2006) and Wiggen et al. (2011) highlight the impact of combined cold and physical exertion on the development of physiological fatigue and reduced cognitive performance [13, 14]. This directly corresponds with our observations of impaired thermal sensation and increased moisture loss during the cold period.

Moreover, our observations align with the conclusions of Schlader Z.J. et al. (2011), who investigated the role of local and central vasoconstriction in regulating heat exchange and maintaining thermal homeostasis during cold exposure [15].

More recent research also supports and expands upon our findings. For instance, Wang S. et al. (2025) demonstrated significant changes in physiological parameters (skin temperature, heart rate) and cognitive functions – especially during complex tasks – in workers performing physical labor under high heat and humidity conditions [16]. Habibi P. et al. (2024), in a systematic review, highlighted the increasing burden of heat stress and declining work capacity amid climate change, emphasizing the need for acclimatization and protective measures [17]. Zhang Y. and colleagues (2024) reported impaired attention and memory in operators exposed to extreme microclimates, reinforcing our conclusion regarding the importance of adaptation in high-altitude environments [18].

Thus, our findings are supported by both classical and contemporary field and experimental studies conducted in various countries and contexts, contributing to the global understanding of thermoregulation in occupational settings at high altitudes.

Our data can be explained by the interaction of several factors: reduced atmospheric pressure, low humidity, enhanced heat loss due to increased air movement, and the necessity of performing physical labor. The fact that MWST dropped by 7-8°C while ABT remained stable suggests heat conservation through peripheral vasoconstriction, helping to maintain internal temperature despite increased energy expenditure for heat production.

Among the strengths of the present study are its field-based design in real production conditions, the use of objective physiological and climatic parameters, and comprehensive statistical data analysis. Nonetheless, certain limitations include the lack of data on cardiovascular and respiratory parameters, the small cohort size limiting generalizability to other climatic regions, and the inability to conduct long-term dynamic monitoring of adaptation processes.

The practical significance of these results lies in their potential application for developing individualized work-rest regimes, substantiating requirements for thermal protection, dietary recommendations, and acclimatization protocols for workers in high-altitude areas. These findings can also inform the development of remote monitoring systems for workers' physiological status.

In the future, it is advisable to conduct more in-depth physiological studies focusing on heart rate variability, blood oxygen saturation, stress hormone levels, and nutritional specifics, as well as modeling heat exchange using bioengineering methods.

In conclusion, the present study demonstrated that the high physiological burden associated with cold and altitude requires continuous monitoring of workers' thermal status. The identified correlations and risk factors should be taken into account when developing occupational standards and preventive programs against hypothermia and fatigue in open-pit mining operations at high elevations.

CONCLUSION

The present study confirmed the high sensitivity of miners' thermal state to the extreme conditions of high-altitude environments. It was established that working in open-pit mines during the cold season leads to a marked decrease in skin temperature, while core body temperature remains relatively stable. These changes are accompanied by an increased subjective sensation of cold and elevated moisture loss, particularly at high-altitude sites.

The conducted analysis revealed a strong dependence of thermoregulatory parameters on ambient air temperature, wind speed, and the nature of physical workload.

The obtained data can serve as a basis for optimizing working conditions, developing individualized work schedules, and implementing protective systems aimed at reducing thermal strain and the risk of hypothermia.

Incorporation of recent research highlights the relevance of this topic in the context of global climate change and the growing need for adaptive strategies.

REFERENCES

1. Muratov Zh. K. Influence of High-Altitude Factors on the Human Body. In A New Word in Science: Prospects for Development – Proceedings of the VII International Scientific and Practical Conference, Cheboksary. 2016; 1(1 (7)): 129–133. Cheboksary: Center for Scientific Cooperation "Interactive Plus," 2016. ISSN 2411-8133. [In Russian]
2. Rajabzoda M.E., Odinaev F.I., Fayzulloev H.T., Tursunov R.A. Main indicators of the lipid spectrum in patients with coronary heart disease living at different mountain altitudes. Bulletin of the Smolensk State Medical Academy. 2019; 18(4): 67-73.
3. MUK 4.3.1895-04. Methodical Guidelines: Assessment of the Thermal State of Humans for the Prevention of Hypothermia and Overheating. Ministry of Health of the Russian Federation, 2004. [In Russian]
4. Liskova M.Yu., Vishnevskaya N.L., Plakhova L.V. Influence of Microclimatic Conditions on Miners Working in Deep Horizons of Potash Mines. Mining Information and Analytical Bulletin. 2019; 9: 219–230.
5. Irgashev T.A., Shabunova B.K., Kosilov V.I. Physiological Characteristics of Different Gender and Age Groups of the Murgab Population of the Pamir Yak Ecotype. Izvestiya of OGAU. 2017; 2 (64): 223–227.
6. Protsiv M., Ley C., Lankester J., Hastie T., Parsonnet J. Deccreasing human body temperature in the United States since the Industrial Revolution eLife. 2020; 9: e 49555. https://doi.org/10.7554/eLife.49555
7. Hardy J.D. and DuBois E.F. The Technique of Measuring Radiation and Convection. Journal of Nutrition. 1938; 15: 461-475. https://doi.org/10.1093/jn/15.5.461
8. Kandror I.S., Demina D.M., Ratner E.M. Physiological principles of sanitary and climatic zoning of the territory of the USSR, M., 1974.
9. Al-Khatri H., Gadi M.B. Investigating the behavior of ASHRAE, Bedford, and Nicol thermal scales when translated into the Arabic language. Building and Environment. 2019;151:348-355. https://doi.org/10.1016/j.buildenv.2019.01.051.
10. Young A.J., Sawka M.N. Physical exercise and human thermoregulation in cold environments. International Journal of Sports Medicine. 2002;23(02):85–96.
11. Sawka M.N., Young A.J. Physical exercise in hot and cold climates. Exercise and Sport Science, WE Garrett and DT Kirkendall (Eds.). Philadelphia: Lippincott Williams & Wilkins. 2000; 26: 385-400.
12. Castellani J.W., Young A.J., Degroot D.W. et al. Thermoregulation during cold exposure after several days of exhaustive exercise. J Appl Physiol (1985). 2001;90(3):939-946. https://doi.org/10.1152/jappl.2001.90.3.939
13. Mäkinen T. Human cold exposure, adaptation and performance in a northern climate. International Journal of Circumpolar Health. 2006; 65(4): 369–370. https://doi.org/10.3402/ijch.v65i4.18118
14. Wiggen Ø.N., Heen S., Færevik H., Reinertsen R.E. Effect of Cold Conditions on Manual Performance while Wearing Petroleum Industry Protective Clothing. Industrial Health. 2011; 49(4):443-451, https://doi.org/10.2486/indhealth.MS1236
15. Schlader Z.J., Stannard S.R., Mündel T. Human thermoregulatory behavior during rest and exercise - a prospective review. Physiology & behavior. 2010; 99 (3): 269–275. https://doi.org/10.1016/j.physbeh.2009.12.003 .
16. Wang S., Gui X., Ding L. Thermophysiology and Cognitive Performance of Live-Line Workers in High-Temperature and High-Humidity Environments. International Journal of Environmental Research and Public Health. 2025; 22(3):387. https://doi.org/10.3390/ijerph22030387
17. Habibi P., Razmjouei J., Moradi A. et al. Climate change and heat stress resilient outdoor workers: findings from systematic literature review. BMC Public Health. 2024; 24: 1711.

https://doi.org/10.1186/s12889-024-19212-3 .
18. Zhang Y., Jia M., Li M., Wang J., Hu X., Xu Zh and Chen T. Operators' cognitive performance under extreme hot-humid exposure and its physiological-psychological mechanism based on ECG, fNIRS, and Eye Tracking. arXiv. 2024;2403:00020. https://arxiv.org/abs/2403.00020

ФИНАНСИРОВАНИЕ

Финансовой поддержки не было.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют об отсутствии конфликта интересов.

ИНФОРМАЦИЯ ОБ АВТОРАХ:

***Джусупов Кенеш Осконбаевич** – кандидат медицинских наук, заведующий кафедрой общественного здравоохранения, Международная высшая школа медицины, Бишкек, Кыргызстан.
Researcher ID: N-8490-2019
E-mail: k.dzhusupov@ism.edu.kg
https://orcid.org/0000-0002-2213-1373
Scopus ID: 55363030800

Дербишалиева Жыпар Какиловна – преподаватель кафедры общественного здравоохранения, Международная высшая школа медицины, Бишкек, Кыргызстан.
E-mail: j.derbishalieva@gmail.com
https://orcid.org/0009-0005-3706-2066

Тогузбаева Карлыгаш Кабдешевна – доктор медицинских наук, профессор, профессор кафедры общественного здравоохранения, Казахский национальный медицинский университет им. С.Д. Асфендиярова, директор Центра инновации в образовании и исследовании в области гигиены труда и окружающей среды, Алматы, Казахстан.
E-mail: toguzbaeva@gmail.com
https://orcid.org/ 0009-0000-2063-8114

***Автор для корреспонденции**

FINANCING

There was no financial support.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

INFORMATION ABOUT AUTHORS:

***Dzhusupov Kenesh Oskonbaevich** – Candidate of Medical Sciences, Head of the Department of Public Health, International Higher School of Medicine, Bishkek, Kyrgyzstan.
Researcher ID: N-8490-2019
E-mail: k.dzhusupov@ism.edu.kg
https://orcid.org/0000-0002-2213-1373
Scopus ID: 55363030800

Derbishalieva Zhypar Kakilovna – Lecturer Department of Public Health, International Higher School of Medicine, Bishkek, Kyrgyzstan.
E-mail: j.derbishalieva@gmail.com
https://orcid.org/0009-0005-3706-2066

Toguzbaeva Karlygash Kabdeshevna – Doctor of Medical Sciences, Professor, Professor of the Department of Public Health, S.D. Asfendiyarov Kazakh National Medical University, Director of the Center for Innovation in Education and Research in Occupational and Environmental Health, Almaty, Kazakhstan.
E-mail: toguzbaeva@gmail.com
https://orcid.org/0009-0000-2063-8114

***Author for correspondence**