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A Study on the Prevention of Thermal Diseases in Workers in High Heat Working Environment
- Around the steel mill -

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Abstract

Purpose: This study examined the major risk factors for heat-related illnesses in high-temperature work environments within domestic steel mills and evaluated the effectiveness of current preventive measures. A descriptive analytical approach was used, combining literature review, reported accident cases, and comparison with international guidelines such as ISO 7243 and OSHA heat-stress standards. The analysis showed that heat-related illnesses are influenced by multiple factors, including high WBGT levels, strong radiant heat from furnaces, inadequate acclimatization, limited access to shade or cooling facilities, and the thermal burden caused by personal protective equipment. Quantitative indicators—including heat illness incidence, self-reported symptoms, rest-time compliance, hydration behavior, and WBGT–symptom correlation—were used to assess preventive measures. Results indicated that the "water–shade–rest" protocol and improved rest environments helped reduce symptoms, although effectiveness remained limited under high work intensity, insufficient acclimatization, and differences in job tasks. Key implications include the need to reinforce heat acclimatization programs, expand cooling and shaded rest areas, establish standardized rest schedules based on WBGT levels, and strengthen employer and worker awareness. This study is limited by its reliance on literature and case-based data; future research should incorporate real-time exposure measurements and worker-level physiological indicators to develop more tailored heat-stress management strategies.

Keywords : Aheat-related illness, steel mill workers, WBGT, heat acclimatization, heat-stress prevention, occupational safety

JEL Classification Code : I118, L60, L740, O14, O25, Q54

1. Introduction

Workers working in a high-temperature working environment are constantly exposed to high temperatures and humidity and face a lot of physical burden. In a continuous high-temperature environment, it is difficult to control body temperature, and as a result, the risk of thermal diseases (thermal death, heat exhaustion, etc.) can be greatly increased. In serious cases, thermal diseases can lead to central dysfunction of body temperature control, leading to death, so systematic preventive measures are essential to protect workers' health and lives.

Thermal diseases mainly occur in summer or in high-temperature and humid working environments, especially high-temperature working industries such as steel mills and glass factories, construction and road pavement workers are exposed to high risks. The main causes include an increase in body temperature due to excessive heat, an imbalance in moisture and electrolytes, and accumulation of fatigue, which requires the establishment of scientific and management measures to reduce them.

The purpose of this study is to investigate (1) the major risk factors for heat diseases exposed to workers in the high-temperature working environment of domestic steel mills, (2) how effective prevention measures such as water, shade, and rest actually are, and (3) what are the limitations of the current system and management system. To this end, the characteristics and cases of high-temperature work in the steel mill were analyzed, and the implementation status of existing preventive measures and the need for improvement were reviewed. In particular, since steel mills have structural characteristics that are always exposed to very high heat and radiant heat in furnaces and heating and roll pressing processes, it is necessary to consider multidimensional risk factors such as heat acceleration, ventilation and cooling systems, and the adequacy of protective equipment.

Therefore, this study aims to improve the level of safety management in the field by systematically examining the types and causes of heat diseases that appear in the steel mill's high-temperature workplaces and suggesting effective preventive measures. Through this, it is intended to reduce heat diseases that repeatedly occur in steel mill sites, and to provide basic data for protecting workers' health and creating a safe working environment.

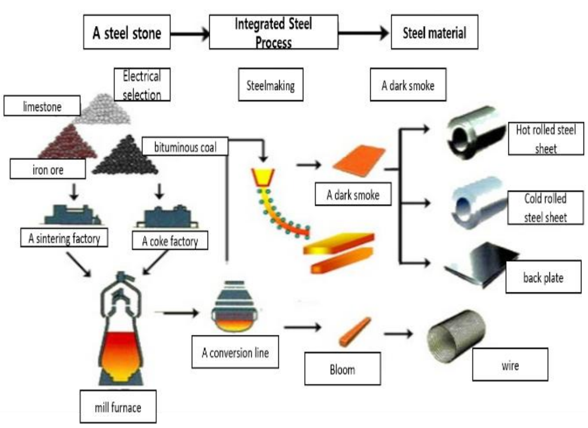

Figure 1: The main process of a steel mill
Source: wiki.hash.kr

2. Literature Review

Recently, as the summer heat wave caused by climate change intensifies, heat stroke deaths have occurred repeatedly at the steel mill's high-temperature workplaces. Hankyoreh (2020.6) and Oh My News (2023.9) pointed out the seriousness of the steel mill's high-temperature exposure by reporting a case in which a worker working in a high-temperature environment died of heat stroke.

As a result, some steel mills are implementing various measures, including the operation of a "special emphasis week on warm diseases," on-site tour treatment, support for preventive goods, and strengthening water, shade, and rest rules. However, these measures have a strong short-term and auxiliary nature, so there is a limit to fundamentally lowering structural risk factors in high-temperature working environments.

2.1. Method of Research

This study conducted a descriptive analysis study combining literature research, field case review, and analysis of related systems and guidelines to analyze the effectiveness of major risk factors and preventive measures for heat diseases occurring in the high-temperature working environment of steel mills in Korea. The purpose of this study is to structurally understand the characteristics of the steelworks' high-temperature exposure environment and to systematically organize the effectiveness and limitations of the current preventive measures.

2.1.1. Research Subjects and Scope of Analysis

The subjects of the study include high-temperature work processes (melting furnaces, heating furnaces, rolling processes, etc.) of major steel mills in Korea, related industrial accidents, and guidelines for high-temperature work presented by the government and industrial safety-related organizations. The scope of the analysis includes cases of heat diseases in steel mills reported at home and abroad in the past decade, related laws and systems in Korea (Industrial Safety and Health Act, standards for high-temperature work), guidelines for responding to heat waves and prevention policies of overseas steel mills.

2.1.2. Analysis Method

The collected data were classified into four categories: the characteristics of the high-temperature work environment, the factors of occurrence of heat diseases, the risk factors of the steel mill's work process, and the effectiveness of preventive measures, and the content analysis technique was applied. In addition, domestic and foreign cases presented in this study were compared and reviewed focusing on the cause of occurrence, working environment conditions (WBGT, work intensity, exposure time), worker characteristics (compliance, whether or not protective equipment is worn), and whether preventive measures are implemented. Through this, the conditions and limitations in which preventive measures actually work in a high-temperature work environment were structurally derived.

2.1.3. Ethical Considerations (IRB)

Since this study is a literature and case-based study that does not collect specific personal information or pose a risk to the study subject, it is a non-risk group study under Article 33 (2) of the Bioethics and Safety Act, and is subject to exemption from the Institutional Bioethics Review Committee (IRB).

2.2. Relevant Regulations according to the High-Temperature Working Environment

2.2.1 Domestic related offenders and regulations

Table 1 summarizes the Occupational Safety and Health Act and the laws and regulations on high-temperature work.

Table 1: Laws and regulations related to heat diseases in Korea

category	content
law	Article 24 (Health Measures) of the Occupational Safety and Health Act and Chapter 7 of the Rules on Occupational Safety and Health Standards (Prevention of Health Disorders by Temperature and Humidity)
High Heat Operation Definition (Article 559)	High-temperature work means work that can cause heat cramps, heat exhaustion, heat stroke, etc. to workers by heat. Based on the place where high-temperature work is performed.
High-temperature work place	① Smelting/refining work in furnaces, plain furnaces, furnaces, furnaces, and electric furnaces ② Melting metal/glass in a furnace ③ Metal/glass heating in a heating furnace ④ Metal/glass heating in a heating furnace ⑤ Ceramic, tile firing ⑥ Mineral roasting/sintering ⑦ Metal transport, rolling, and processing ⑧ Molten metal ⑨ Glass molding ⑩ Heat source use drying ⑪ Heat generating ⑬ In a pit, repair ⑫ And other places recognized by the Minister of Labor
Preventive Measures for High Heat Work (Article 560)	Mandatory installation of temperature and humidity control devices for cooling and ventilation when high-temperature work indoors
Improvement of high-temperature working environment (Article 561)	Measures such as installation of ventilation system, isolation from heat source, and blocking of radiant heat are required
Prevention of Outdoor High Heat Work (Article 566)	Appropriate rest and worker health protection measures are required for high-temperature work outdoors
Establishment of rest facilities (Article 567)	Obligations to prepare rest facilities isolated from high-temperature work
Temperature of high-temperature operation in the shaft (Article 568)	Keep the temperature below 37 degrees Celsius during high-temperature work in the shaft

2.2.2 Foreign-related laws and regulations

<Table 1> shows the integrated comparison of the heat wave measures of each overseas country and the Occupational Safety and Security Agency's high-temperature work environment management guidelines to identify problems and improve safety management systems for heat wave disaster prevention, and <Table 2> shows the countermeasures against heat waves.

A. Measures to prevent heat diseases in major steel mills by country

· United States – United Steel

United Steel of the United States has introduced a heat wave warning system as the risk of developing heat diseases increases when workers work for a long time in high-temperature environments. The system ensures the safety of workers by adjusting the rest time and work intensity according to temperature, humidity and work intensity. dehydration. To prevent this, education and

Among the past cases, some of the workers who worked without sufficient rest in high-temperature environments in summer fell from heat stroke or showed water supply for preventing heat diseases were strengthened, and improvements were made so that workers could rest more often.

· Australia – Bluescope Steel

Bluescorp Steel Works in Australia has introduced a "heat wave warning system" to prevent heat diseases and is adjusting the intensity of work according to temperature and humidity. Bluescorp has set up a "cooling zone" to prevent heat diseases so that workers can get out of the heat and relax in a cool environment.

In addition, water and electrolyte drinks are supplied to workers working in high-temperature environments to prevent dehydration, and in the event of a heat wave, a method of shortening working hours or adjusting working conditions is used.

· United Kingdom – Ticely Steel

Ticely Steel Mill in the UK is implementing a number of programs to prevent thermal diseases for workers working in high-temperature environments. In particular, during the period when the high temperature persists in summer, work was distributed, and working hours were divided so that workers could take regular breaks so that they were not exposed to high temperatures for a long time. In addition, we are protecting the safety of workers by strengthening education on thermal diseases and taking measures such as stopping or changing specific tasks in accordance with heat wave warnings.

Table 2: Overseas Heat Wave Standards and Integrated Comparison

Sortation	operation Period	Related agencies	Temperature standard	The heat wave stage
United States	5.1~9.30	the Meteorological Administration, Disaster Management Center, a federal disaster Management Office	heat index, (Heat Index)	(A total of four steps) ExcessiveHeatOutlook, ExcessiveHeatWatch, HeatAdvisory, ExcessiveHeatWarning
United Kingdom	6.1~9.15	the Meteorological Administration, Health Protection Agency, national health insurance	the best/ the lowest temperature	(A total of four steps) Awareness,Alert, Heatwave,Emergency
France	6.1~9.30	The Meteorological Administration, the Health Administration, Ministry of Industry	the best/ the lowest temperature	(A total of four steps) Vigilance,Alert, Intervention,Requisition
Japan	6.1~10.31	Meteorological Agency, Ministry of Environment, Ministry of Internal Affairs and Communications, Ministry of Health, Labor and Welfare	Wet ball, black ball Temperature (WBGT)	(A total of five steps) safety, caution, vigilance, danger, Very dangerous

Table 3: Heat Wave Measures by Country

Sortation	Heatwave measures
United States Heatwave policy	-Obtain a weather forecast that can fully predict the possibility of EHE4) 1 to 5 days in advance -Development of a model for estimating heat waves and deaths, securing information on the vulnerable groups of heat waves, and securing information on the evacuation sites of the vulnerable groups of heat waves -Whether information on the use of cooling centers is broadcasted or whether information on heat waves has been delivered to the public -Whether efforts are made to reduce the urban heat island phenomenon
United Kingdom Heatwave policy	-Prepare for summer and establish long-term measures -act quickly and prepare for harm reduction -Special preparations for heat wave vulnerable groups -preparation for the whole nation
France Heatwave policy	-Conduct public relations and general seasonal surveys for prevention during the summer -Starting from the regional level, a national service system is operated -Medical and social measures are taken -Take special measures if the heat wave is extended or sustained
Japan Heatwave policy	-need to rehydrate -Accidents caused by heat stroke are likely to occur, sufficient water intake -Increased risk of heat stroke. Hydration replenishment. Rest for intense exercise every 30 minutes -Risk of heat stroke Avoid heavy exercise or walking for a long time, get proper rest and hydrate during exercise -Temperature higher than skin temperature, stop exercising

· India – JSW Steel

JSW Steel Works in India has introduced safety protocols in high-temperature work environments to prevent thermal diseases. In summer, they adjust the intensity of work and rest time through real-time monitoring of heat waves, and provide periodic hydration and drinks to prevent workers from being excessively dehydrated in high-temperature environments. In addition, when the risk of thermal diseases is high, they are actively responding by delaying dangerous work or moving external work indoors.

· Brazil – Gordau Steel

Brazil's Gordau Steel Mill is updating its heat wave response protocols every year during the high-temperature summer to prevent heat diseases. The steel mill adjusts working hours, strictly manages water supply and breaks, and periodically provides training to prevent heat diseases to workers in the field to minimize exposure to heat. In high-temperature environments in summer, workers gradually increase their workload so that they can adapt to high temperatures, and when the risk of high temperatures is high, immediate action is taken.

Each country includes various measures to ensure the safety of workers in order to prevent heat diseases that may occur in steel mills. Each country and company is strengthening preventive measures tailored to local climate conditions, and monitoring temperature and humidity in real time, especially in preparation for summer heat waves.

2.3. Risk Factors for High Temperature Work Environment

2.3.1. Risk Factors for Heat Diseases

A. One of the biggest risks arising in the steel mill is thermal diseases, and the working environment of the steel mill may cause thermal diseases to workers due to high temperature, high humidity, and flames. The types of thermal diseases that can occur in a high-temperature working environment are as follows.

① Heat Stroke: Because a steel mill is a high-temperature environment that melts iron, there is a high risk of heat stroke if the worker's body temperature rises excessively. Heat stroke occurs when the body temperature rises rapidly by more than 40 degrees Celsius, and it can be life-threatening if proper first aid is not provided.

② Heat exhaustion: Working at high temperatures can lead to insufficient moisture in the body and electrolyte imbalance. Heat exhaustion occurs as symptoms of excessive sweat secretion and dehydration, and workers can no longer perform work while dehydrated.

③ Heat Cramps: Heat cramps caused by excessive sweating in high-temperature environments in steel mills can cause muscle cramps, which make it very difficult for workers to continue their work.

B. Risk of fire and explosion

Steel mills use high-temperature furnaces in the process of manufacturing steel, and sparks are generated in the process of heat treatment, which poses a high risk of fire or explosion accidents.

The high temperature of the furnace: a high temperature of 1,500°C or higher is required to melt iron ore in the furnace of the steel mill. Heat and sparks generated at such a high temperature cause a risk of occurrence of thermal diseases, fire, and explosion in the working environment and workers. In addition, if the heat generated in the furnace is not properly controlled, there is a possibility that it may lead to a fire. Combustible substances and gases: Since steel mills deal with various combustible substances and gases, they may cause an explosive reaction, for example, gas leaks or combustible chemicals occurring at high temperatures may cause explosions.

C. Exposure to toxic gases and chemicals

In steel mills, chemicals that generate toxic gases are used during the production of steel. Typical examples include carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), and ozone (O_3). Carbon monoxide (CO): Carbon monoxide is a colorless, odorless gas that can cause poisoning when inhaled by workers at high concentrations, and carbon monoxide poisoning can lead to headaches, dizziness, loss of consciousness, and even death. Sulfur dioxide (SO2): Sulfur dioxide generated in steel mills stimulates the respiratory tract and can cause lung or respiratory diseases when exposed to long-term exposure.

D. Risk of complaint work

High-temperature work is often performed in the high-temperature environment of a steel mill. High-temperature work is a risk that can occur in the process of performing work at a high place and can lead to accidents such as falling, slipping, and bumping. Working at high temperature and high location: When high temperature work is carried out in a steel mill, high temperature and strong heat directly affect workers, and high temperature can accumulate sweat and fatigue, resulting in loss of balance in the body, and falling or bumping accidents.

E. Dangers of noise and vibration

In addition to high temperatures, steel mills are also noisy and vibrating environments. In addition to high-temperature work, they are exposed to continuous noise and vibration due to the operation of mechanical facilities and compressed air systems. These noises and vibrations can cause hearing damage or stress in workers. Continuous noise in steel mills can cause hearing loss over time and can lead to hearing loss. For this reason, noise management is necessary to protect workers' hearing, and musculoskeletal disease management due to vibration is also necessary.

F. Other Risk Factors

In addition to the high-temperature environment, there are various risk factors in steel mills, such as physical injuries, mechanical accidents, and accidents in the process of transportation. For example, accidents such as injury in the process of handling heavy objects or damage to parts during machine operation may occur.

2.3.2. Risk Factors for Heat Diseases

A. Excessive external heat burden: High temperature and humidity work in combination, making it easy for the human body to overheat. You can control your body temperature through sweat while working in a high-temperature environment, but if the humidity is high, the sweat does not evaporate, making it difficult to control your body temperature.

B. Physical fitness and health status: Workers' age, gender, physical condition, physical strength, etc. have an important influence on the occurrence of thermal diseases. In particular, among high-temperature workers, obesity, cardiovascular abnormalities, skin diseases or recovering workers, and elderly workers may be directly affected by work restrictions.

C. Work intensity and duration: If you continue to work with high intensity for a long time, the temperature in the body continues to rise, and there is a high risk of developing thermal diseases. In addition, lack of rest time and lack of water intake are also major causes.

D. Characteristics of the working environment: Closed spaces or workplaces with insufficient ventilation are environments that cause heat diseases, and if air circulation is not smooth, high temperatures continue to accumulate and increase the risk.

bad luck. Contract Practice Structure: If an outsourcing company that performs certain tasks such as equipment repair at a steel mill works as a daily worker for a short period of time whenever the task occurs, it is highly likely that they have not gone through an appropriate high-temperature purification process, and unlike regular workers, they have not received related training through safety and health education.

2.4. Measures to prevent heat diseases in a high-temperature working environment

In order to prevent thermal diseases in a high-temperature working environment, systematic preventive measures are needed for the health protection and safety of workers through related laws. For this, various preventive strategies are needed in consideration of environmental and personal factors. Regulations on Occupational Safety and Health Standards delegated pursuant to Article 32 (2) (Health Measures) of the Related Regulations for the Protection of Workers (Prevention of Health Disorders by Temperature and Humidity in Chapter 6)

Table 4: Health measures to protect workers

	Sortation	Details of health measures
Key content	Heatwave exposure place	❶ Provision of adequate rest (Article 566) <Rest> ❷ Installation of rest facilities (Article 567) <Shade> ❸ Provision of salt and clean beverages (Article 571) <Water>
	High-temperature work place	Above❶~❸a measure of ❹ Installation of temperature and humidity control devices (Article 560) ❺ Necessary measures, such as the installation of ventilation systems (Article 561) ❻ Installation of temperature and hygrometer (Article 562) *(Others) Prohibition of external shaft penetration (Article 569), payment of heat gloves and heat dissipation clothing (Article 572)

* Appropriate rest is 10 minutes per hour, ▲ warnings and hazards for each heat wave risk stage Guide for 15 minutes of rest every hour during the phase

<Source: Ministry of Employment and Labor >

2.5. Improvement of Working Environment in High Temperature Work Environment

2.5.1. Ventilation and cooling system improvement

In a high-temperature working environment, an appropriate ventilation system should be installed and the temperature of the working environment should be controlled by using cooling equipment or air conditioner. You should actively utilize natural ventilation or install a ventilation fan to circulate indoor air.

Adjusting Working Hours and Ensuring Rest Time: During summertime, work hours should be adjusted to avoid work during times when the temperature is highest (usually between 12 and 4 o'clock). In addition, regular breaks should be provided so that workers can lower their body temperatures.

Improving work clothes and protective equipment: Wearing clothes with heat protection or cool, breathable work clothes should help reduce workers' body temperature. In addition, when wearing personal protective equipment, you should use equipment that is designed to minimize the generation of excessive heat.

2.5.2. Workers' education and training

Education on the risk of thermal diseases: Workers should be regularly educated on symptoms, prevention methods, and first aid methods of thermal diseases. Through this, workers should be able to recognize early signs of thermal diseases and respond immediately.

Water Intake and Salinity Supplement Education: Water and electrolyte balance is fragile in high-temperature environments, so workers should be educated about the importance of sufficient water intake and salt supplementation. It is essential to drink water regularly during work and consume electrolyte drinks if necessary.

2.5.3. Personal protective equipment and rules

Introduction of Hydration System: Each workplace should be equipped with a hydration system, and workers should be able to easily drink water. It is also useful to introduce a portable hydration system that can continuously hydrate

during work.
Wearing Heat Prevention Equipment: Wearing cooling equipment, such as cooling vests or cooling vests, to help keep workers' body temperatures constant can also be an effective precaution.

2.5.4 Measurement and evaluation of the work environment for high-temperature work

When a business owner engages workers in high-temperature work, he/she shall evaluate the risk of high-temperature work in order to prevent health disorders such as heat cramps and heat exhaustion, and shall consider the following matters when evaluating.
(1) Types and sources of high-temperature work
(2) Properties of high-temperature operation (characteristics and strength, etc.)
(3) Thermal characteristics (temperature, surprise, airflow, radiant heat, etc.)
(4) Work activities of workers and the form of clothing worn
(5) High-temperature related injury and disease occurrence status
(6) Installation and Appropriateness of Industrial Ventilation Facilities, etc
(7) the degree of thermal adaptation of a worker
(8) Other matters necessary for improving the high-temperature environment
In the measurement cycle, when an employer engages a worker in high-temperature work, he/she shall regularly measure the wet-bulb temperature index at least once every six months pursuant to Article 42 of the Act. Provided, That where a worker complains of symptoms such as heat cramps and heat exhaustion or is concerned about health problems due to high-temperature work, he/she may conduct measurements from time to time as necessary.

Table 5: Exposure criteria for high-temperature work

Work break time cost	work strength		
	light work	secon dary work	heavy work
Continue working	30.0℃	26.7℃	25.0℃
75% work every hour, 25% rest	30.6℃	28.0℃	25.9℃
50% work every hour, 50% rest	31.4℃	29.4℃	27.9℃
25% work every hour, 75% rest	32.2℃	31.1℃	30.0℃

Here, light work : It refers to work that requires up to 200 kcal/hr of heat, such as light use of hands or arms to adjust the machine while sitting or standing
secondary work : It refers to work that requires heat from 200 to 350 kcal/hrIt means walking around while lifting or pushing.
heavy work : Picking works that require heat from 350 to 500 kcal/hr Or shoveling, etc.

2.5.5. Payment of protective equipment

Protective equipment such as heat dissipation suits, heat dissipation gloves, heat dissipation helmets, and heat dissipation shoes must be provided to workers working in high-temperature environments. Work clothes should be made of materials with good hygroscopicity and breathability so that heat does not accumulate. Outdoor workers should be provided with a highly ventilated hat and cooling vest so that their body temperature can be controlled.
The correction values of different WBGT exposure standards for worn clothes are as follows.

Table 6: Correction value of WBGT exposure standard according to wearing clothes

the form of one's dress	CAF*
summer work clothes	0℃
cotton work clothes with top and bottom	+2℃
winter work clothes	+4℃
waterproofs suit	+6℃

* CAF : Clothing Adjustment Factors

When working for a long time in a high-temperature working environment, it is very important to provide certified products for protective equipment. During the suppression of the fire in Uiseong-gun in March 2025, the equipment received from contract workers in their 60s belonging to Changnyeong-gun County Office, who died, was a construction helmet that had no body protection function, and the temperature of the helmet rose due to the hot heat and took it off. Therefore, when selecting or using a heat suit, it is necessary to select a heat suit suitable for the user's working environment and physical conditions, and to adjust and use it to suit the user. In particular, the KCs certification mark must be checked.
In the case of a heat dissipation headscarf, the head fixing table and chin strap of the outfit are adjusted to suit the user's head size, the upper part is a structure capable of discharging air, and the lower part is used after checking whether there is a protective cloth to prevent the intrusion of hot air. In addition, select a light blocking level appropriate for the work purpose.

3. Effectiveness and Limitations of Heat Disease Prevention Measures

Currently, measures to prevent heat diseases in large steel mills are showing a certain level of effectiveness, but there are structural limitations such as inconvenience in wearing protective gear, non-compliance with the high-temperature purification process, lack of rest facilities, and lack of awareness of safety investment by managers.

First of all, in terms of personal protective equipment, it is difficult to use it for a long time due to the large physical burden and work inconvenience when wearing it in a high-temperature environment, and the impermeable material of the protective equipment can rather increase heat stress, which needs to be improved. In addition, in the case of newly deployed workers or those who return after vacation or sick leave, the heat acceleration process is not sufficiently implemented, increasing the risk of heat disease. The OSHA guidelines also suggest that unskilled workers have a high risk of heat disease when the WBGT is above 25°C (Table 7), so adjustment of working hours is required depending on compliance.

Table 7: Comparison between skilled and unskilled workers

valid WBGT(℃)	an unskilled worker	an adapted worker
70°F(21℃) less than	a low risk of heat-related diseases	a low risk of heat-related diseases
70~77°F(21~25℃)	Violent operations may not be safe	a low risk of heat-related diseases
77°F(25℃) More than	High risk of developing heat illness due to hard work	Violent operations may not be safe

Source: OSHA National Emphasis Program "Outdoor and Indoor Thermal Related Hazards“

In terms of the environment, government support and facility improvement are needed for workplaces with poor cooling and ventilation facilities, and since simple water supply alone is not enough, sufficient moisture and electrolyte management such as providing electrolyte drinks and water intake every 20 minutes should be carried out in parallel. In addition, a system to adjust rest time and location (shade and cooling space) according to high temperature exposure level (WBGT), work intensity, and personal risk factors is also needed. In some shipbuilding and steelmaking workplaces, the break time is extended according to the temperature standards of hot weather (Table 8), but this is inconsistent because there are large variations and is not institutionalized.

In order to evaluate the practical effectiveness of preventive measures, this study focused on quantitative indicators such as the incidence of heat diseases (number of occurrences per 100 people per month), the reporting rate of subjective symptoms (the frequency of dizziness, cramps, and dehydration), the rate of compliance with rest and moisture intake, and the use rate of cooling and shade. In addition, by analyzing the correlation between the WBGT index of the workplace and the incidence of symptoms, it was confirmed whether high-temperature exposure led to an increase in actual symptoms. As a result, the higher the use of basic preventive rules (water, shade, and rest), the lower the symptom reporting rate, but several factors, such as wearing protective gear, heat adaptation, and differences in occupational and work intensity, have a limited effect on the effectiveness of preventive measures. Finally, the success or failure of preventive measures also depends on the consciousness of employers and workers. If the employer does not actively promote the improvement of the high-temperature working environment and facility investment, preventive measures remain in short-term measures, and the practice of rest and moisture intake varies greatly depending on whether workers comply. Therefore, in order to increase the effectiveness of preventive measures, not only physical measures but also management and educational approaches must be taken in parallel, and institutional measures that guarantee hourly rest are needed if the heat exposure standard is exceeded.

Table 8: Comparison of break times by company

company	Regulations on break time during hot weather
Daewoo Shipbuilding & Marine Engineering Co., Ltd	If the noon measurement temperature is above 28℃, the rest time is extended by 30 minutes (paid), and the rest is extended by 1 hour over 32℃ (paid)
Sungdong Shipbuilding Co., Ltd	Summer season (June to September): Temperature measurement at 11:40 a.m. Extend 30 minutes over 29℃ and extend 60 minutes over 31℃
K Shipbuilding	Hot weather: The average temperature of the four companies is 29° or higher, and one hour paid break time
HJ Heavy Industries Co., Ltd	Criteria for announcement by the Korea Meteorological Administration: Recognition of 1 hour paid break time of 30℃ or higher in summer and -7℃ or lower in winter
Hyundai Samho	During the hot weather (7.10 to 8.31) at 12:00 a.m., the 28℃ lunch was extended by 30 minutes, and paid break time was recognized (excluding rainy days) (including nighttime workers)
Samsung Heavy Industries Co., Ltd	On the 95th day of the hot season (the starting point is selected by the council) at 11:50 p.m. white leaf image measurement 28.5℃ → 30 minutes, 32.5℃ → 1 hour rest
Hyundai Mipo Dockyard	7.10. ~ 8.17. 39 days of hot weather. 30 minutes of Chinese meal extension (same night time) 11:50 before and after hot weather, 28℃ of white leaf temperature extension for 20 minutes of Chinese meal
Hyundai Heavy Industries Co., Ltd	30 minutes extension of Chinese meal during hot weather (7.20 to 8.24); 20 minutes extension of Chinese meal at least 28℃ of white leaf temperature at 11:50 p.m. (excluding rain)

Source: "11. Working Hours" in the Korean Metal Industry Union's Shipbuilding Division (2020), the comparative data collection of the wage and collection association.

5. Conclusions

This study attempted to analyze the main factors of heat diseases and the effectiveness of preventive measures in the high-temperature working environment of steel mills in Korea, and to derive improvement measures applicable in the field. As a result of the study, it was found that the occurrence of heat diseases in high-temperature workplaces was affected by a combination of factors such as work process characteristics (high-temperature heat sources such as furnaces and heating furnaces), long exposure, burden of wearing protective equipment, non-compliance with heat, and lack of access to rest facilities. In addition, basic preventive rules centered on water, shade, and rest have a certain level of effect, but the limitations of limiting the effect due to work strength, WBGT level, and personal risk factors have been confirmed.

Through quantitative index analysis, the incidence of heat diseases and the reporting rate of subjective symptoms were closely related to the utilization rate of cooling, shade, and rest facilities and compliance with breaks, and the higher the WBGT index, the higher the heat stress and symptom incidence of workers tended to increase. On the other hand, the discomfort of protective equipment, lack of heat acclimatization, and differences in work intensity acted as factors that weakened the effectiveness of preventive measures.

Implications in terms of policy and management were also derived. First, it is necessary to apply the high-temperature purification process in stages and strengthen the systematic health management program for new and returned workers. Second, it is necessary to institutionalize the improvement of the physical environment such as cooling, shade, and rest facilities, and to prepare a support system according to the size of the workplace. Third, preventive measures centered on work management are needed, such as the introduction of a WBGT-based real-time risk warning system, standardization of rest time, and reinforcement of electrolyte and moisture management guidelines. Fourth, raising safety awareness of employers and workers and expanding education and participation were identified as key factors to increase the effectiveness of prevention policies.

This study has a limitation of literature and case-oriented analysis, and quantitative verification is limited because exposure and symptom data at the level of individual workers cannot be directly collected. In future studies, empirical investigation and model analysis including detailed variables such as WBGT measurement data, individual biosignals, access to rest facilities, and work intensity are needed. In addition, if a customized thermal stress management model is developed according to the size and type of the workplace, it will be able to make an important contribution to improving the level of safety management in the steel plant's high-temperature work environment.

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