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Mitigating Heat Exposure: Exploring the Role of Knowledge, Risk Perception, and Precautionary Behavior

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ABSTRACT

Increasing ambient temperatures due to climate change have significantly impacted workers' physical and mental workloads, affecting their health and safety. Promoting precautionary behaviors, especially among outdoor workers, is an effective strategy widely recommended for addressing these challenges. Precautionary behavior represents an essential protective mechanism that can be adopted at the individual level. This study explores the connections among Occupational Safety and Health (OSH), risk perception, and precautionary behavior. Descriptive statistics and Structural Equation Modeling with the Partial Least Squares approach were used to analyze the data. This study was conducted at two forest management units in Central Java and East Java, Indonesia, where daily air temperatures are relatively high. The research involved 100 respondents, comprising 50 indoor and 50 outdoor workers. The findings of this investigation reveal that OSH-related knowledge among indoor workers predicts their precautionary behavior. Nevertheless, according to the model, attempts to improve precautionary behavior through knowledge enhancement are estimated to be unsuccessful among outdoor workers. Nonetheless, OSH-related knowledge can facilitate workers in developing a more realistic perception, especially regarding the "dread risk factor" among forestry workers, which can positively impact their precautionary behavior.

1. Introduction

Climate change has resulted in tangible consequences across various aspects of life. The issues of climate change and its adverse effects have emerged as crucial global concerns and have become subjects of serious discussions in numerous countries (IPCC 2014). The escalating occurrence of extreme weather events, altered seasonal patterns, and changes in harvest seasons (all are consequences of climate change) diminish agricultural crop quality (Greenough et al. 2001; Malhi et al. 2020). Climate change has intensified health and safety challenges, exacerbating the severity of the risks faced by workers at their workplaces. The increase in air temperatures has led to heightened physical and mental workload, particularly for outdoor workers.

Given that forestry work carries significant Occupational Safety and Health (OSH) risks, heat exposure adds additional physical and mental strain to the pressures that outdoor workers already face (Yovi et al. 2019). The combination of strenuous physical activities and hot environments poses risks such as heat exhaustion, heat stress, muscular tissue damage (rhabdomyolysis), and even fatalities (NIOSH 2016). Various studies have demonstrated that extreme heat exposure increases the risk of diseases and injuries for workers, particularly those without adequate protection (Xiang et al. 2014). Besides OSH-related issues, several studies also indicate that hot air temperatures lead to a decline in work productivity (Ioannou et al. 2017; Krishnamurthy et al. 2017; Sahu et al. 2013). Working at air temperatures of 33–34°C may cause a worker to lose 50% of their work capacity (ILO 2019; Ioannou et al. 2017). For forestry workers in Indonesia, the heat exposure triggered by climate change is likely to worsen their already low work performance (productivity) levels (Yovi et al. 2021).

To avoid the negative impacts of heat exposure, efforts in risk management need to be implemented. Knowledge plays a vital role in effective risk management practices (Anthonj et al. 2022). Interaction and integration of implicit and explicit information, either between individuals or between individuals and their environments, are essential for forming knowledge (Chou and Tsai 2004). Strong knowledge is required to identify potential impactful risks, analyze their magnitude and likelihood of occurrence, and subsequently devise strategies for risk mitigation and management. Knowledge also aids in risk monitoring and decision-making related to necessary adjustments.

Another crucial factor in this context is the willingness to implement protective measures, which is evident in human behavior, known as precautionary behavior. Several theories suggest that risk perception also contributes in shaping precautionary behavior. Risk perception is associated with knowledge, wherein risk perception employs logic, while risk awareness is linked to information and knowledge of risk information (Iorfa et al. 2020; Ivčević et al. 2020; Riccò et al. 2020; Yovi et al. 2023). Risk perception is the process by which individuals interpret information about risks they encounter. It is of utmost importance since a person's perception can influence their behavior; negative risk perceptions may lead to the neglect of risk exposure (Riccò et al. 2020; Skagerlund et al. 2020; Yovi et al. 2022). This tendency implies that risk perception, reflecting the intuitive or subjective risk assessment of workers based on their knowledge, influences workers' cautious attitudes towards coping with high air temperature. Success in perceiving an event is likely to result in safe behavior, while failure in this perception phase can lead to unsafe actions. Workers' safety attitudes are related to accident occurrences. Workers exhibiting high precautionary behavior tend to have lower accident probabilities. Conversely, when workers' precautionary behavior is low, the risk of accidents increases (Oswald et al. 2014).

The impacts resulting from heat exposure can largely be mitigated through various regulations, work-related policies, and implementable technical strategies. However, workers' knowledge, awareness, and comprehension of the risks of heat exposure limit the effectiveness of such programs. Meanwhile, research on climate change has primarily focused on environmental impacts, with social impacts (e.g., health, lifestyle, quality of life) arising from heat exposure rarely being a central topic of discussion and climate change mitigation programs (Kiefer et al. 2014).

The aim of this research is to explore the relationship among the variables of knowledge, risk perception, and precautionary behavior among indoor and outdoor forestry workers in responding to the impact of climate change, specifically extreme heat exposure. The information obtained will provide insights for formulating appropriate climate change mitigation strategies tailored to both categories of forestry workers operating in distinct workplace conditions. This study posits several hypotheses regarding the relationships among occupational health and safety knowledge, individual risk perception, and cautious behavior in forestry workers. Specifically, it is hypothesized that higher levels of OSH knowledge will lead to increased precautionary behavior (H1), that OSH knowledge will predict how an individual perceives risk (H2), that risk perception will predict precautionary behavior (H3), and that risk perception will mediate the relationship between OSH knowledge and precautionary behavior in a positive direction (H4).

2. Materials and Methods

2.1. Research Sites and Participants

This study was conducted in the operational area of Perum Perhutani, specifically in the Cepu Forest Management Unit, located in Blora District, Central Java Province, and the Bojonegoro Forest Management Unit in East Java Province, Indonesia (**Fig.1**), during July 2022. Encompassing a total of 100 participants, evenly divided into two groups: 50 indoor workers and 50 outdoor workers, this study was designed as a cross-sectional study. This balanced representation aimed to capture the potential diversity within the workforce. Indoor workers were defined as those working in protected environments to avoid direct sunlight exposure, while outdoor workers were those working in open spaces (fields) with direct exposure to sunlight. It is pertinent to note that, for the purpose of this research, two key considerations were made: firstly, Bojonegoro and Cepu were selected as neighboring locations, assuming similar climatic characteristics, and secondly, local cultural factors were not considered as differentiating variables within this study.

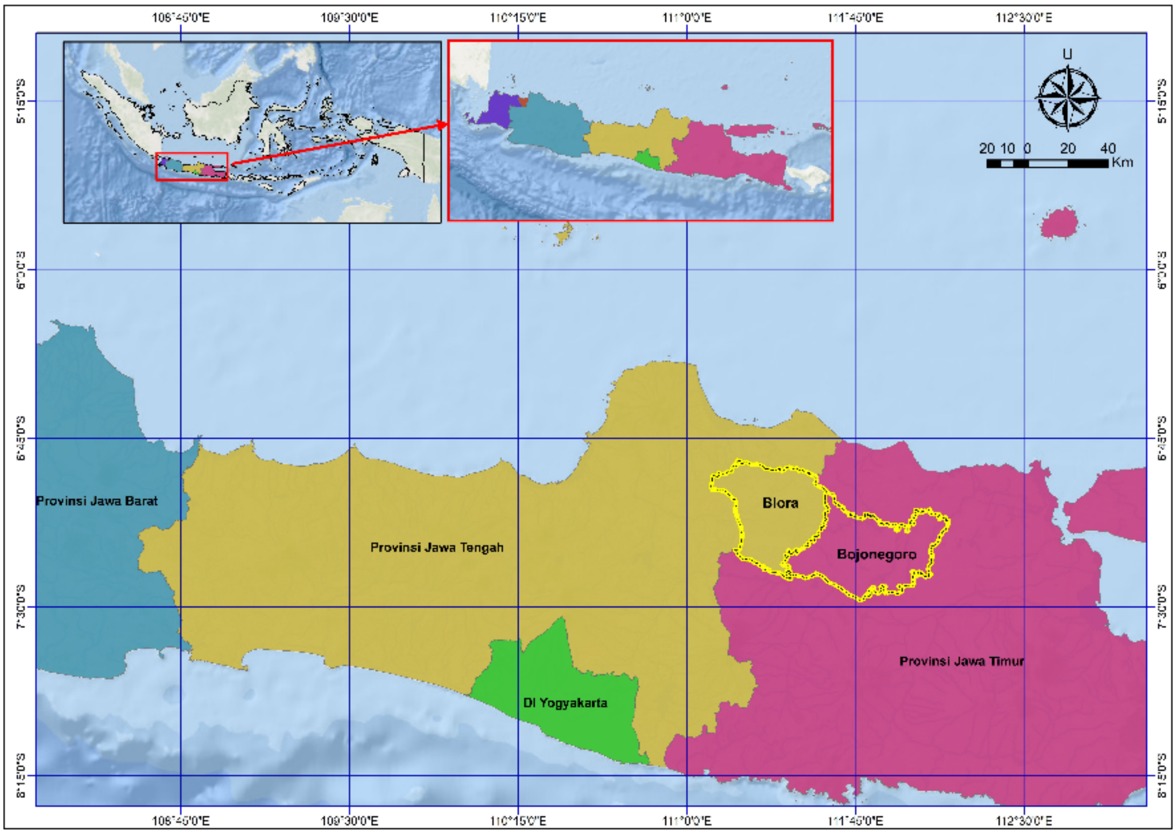


Fig. 1. Map of the study areas.

2.2. Data Collection

Data collection for outdoor workers involved direct interviews due to low literacy levels (Yovi et al. 2023), while indoor workers were surveyed using a questionnaire platform. The study utilized 42 statement items from previous research (Kjellstrom 2016; Riccò et al. 2020; Yovi et al. 2023). Before collecting data, participants were briefed on the research objectives and the publication of the collected data, and provided with informed consent.

2.2.1. Heat-related knowledge

In this research, respondents were asked to assess statements presented as "True" or "False". Correct answers were awarded a score of +1, while incorrect responses received no score. The total points accumulated reflect the respondents' knowledge level concerning aspects related to heat exposure. The measurement variables within the knowledge construct are: general knowledge of heat exposure (K1), symptoms caused by heat exposure in the workplace (K2), prevention and first aid (K3), and the impact of heat exposure on performance (K4). Respondents' knowledge of heat exposure is evaluated by summing up the correct responses. All items were following the work of Riccò et al. (2020).

2.2.2. Risk perception

In this research, respondents were requested to delineate their risk perceptions. Understanding how individuals perceive risks is a complex matter. The psychometric paradigm (Slovic 1987), on which this study's methodology is based, contends that the dread risk factor (DF) and the unknown risk factor (UF) are the two main factors that affect a person's perception of risk. For the DF variable, six elements were queried, encompassing risk controllability (controllable/uncontrollable; DF1), gut reaction to risk (non-dread/dread; DF2), severity of consequences (low/high; DF3), fatality (non-fatal consequences/fatal consequences; DF4), risk to future generations (low risk to future generations/high risk to future generations; DF5), and voluntariness (voluntary/involuntary; DF6). For the UF variable, several questions were asked, such as whether or not the effects of heat exposure on their health at work could be seen (observable/not observable; UF1), newness (old/new; UF2), whether or not science knew about it (known/not known; UF3), and effect immediacy (immediate effect/delayed effect; UF4). The entire construction used in this study on risk perception utilized a questionnaire that has been demonstrated to provide accurate portrayals of responses (Yovi et al. 2023).

2.2.3. Precautionary behavior

The level of precautionary behavior was assessed using a 7-item scale comprising statements addressing proactive measures to protect against occupational health related to heat exposure in the workplace. These actions collectively represent the fourth latent variable known as precautionary behavior (PB). The PB construct comprises 16 measurement variables, which are as follows: working early in the morning (PB1), sharing work shifts with coworkers (PB2), adjusting work hours but increasing work days (PB3), involving more coworkers in tasks (PB4), working intermittently (PB5), taking short breaks during hot periods (PB6), wearing work attire that absorbs sweat easily (PB7), using dark-color outerwear (PB8), donning whole-body layered clothing/trousers (PB9), wearing a hat or similar head protection (PB10), staying hydrated by drinking ample water during work (PB11), refraining from consuming coffee on hot days (PB12), seeking shade when it's hot (PB13), wearing sunglasses to reduce glare on hot-sunny days (PB14), providing medication or a first aid kit (PB15), implementing emergency protocols (PB16), seeking and obtaining health protection information (PB17), and undergoing self-examination at the health center (PB18). All items followed the work of Yovi et al. (2023) and adopted the work of Kjellstrom et al. (2016).

2.3. Data Analysis

Descriptive statistics and the Structural Equation Model (SEM) method with the Partial Least Square (PLS) approach (using Smart PLS Version 3.2.9 software) were employed in the analysis. PLS-SEM was utilized to test the predictive relationships among constructs by assessing the presence and influence of these relationships. There are two stages in PLS-SEM: the outer model and the inner model evaluations, respectively.

The outer model evaluation consists of convergent validity, discriminant validity, and reliability tests. Convergent validity refers to the principle that measures of a construct should have high correlations with the accepted criteria, which is loading factor values of > 0.5. In the discriminant validity test, the cross-loading values of each indicator with its respective latent variable should be greater than the cross-loading values with other latent variables. For reliability testing, Cronbach's alpha > 0.60 and composite reliability > 0.70 were used as criteria (Hair et al. 2017). Only indicators that pass the outer model evaluation test were used in the inner model evaluation.

The components considered in the inner model evaluation are the inner variance inflation factor (VIF), coefficient of determination (R^2), predictive relevance (Q^2), and model fit (Hair et al. 2017). The correlation values (VIF) between observed variables should not exceed 10 (Hair et al. 2018). The R^2 value serves to quantify the extent to which the independent variables may explain the variability observed in the dependent variables. A strong model was indicated by an R^2 value higher than 0.75. The predictive relevance (Q^2) is used to assess the Goodness of Fit of the structural model in the inner model. A Q^2 value greater than 0 indicates good predictive relevance of the model.

In this study, Standardized Root Mean Square Residual (SRMR) and Normal Fit Index (NFI) were used to evaluate model fit. The accepted SRMR criterion was below 0.10 (Ramayah et al. 2017). Another index for model fit in the inner model evaluation is the percent Normed Fit Index (NFI) > 0.5 (50%) (Bentler and Bonett 1980). The bootstrapping procedure is then carried out to enhance the statistical power of the model and reduce bias in parameter estimation. Path coefficient values closer to + 1 indicate stronger relationships between the variables. In this study, the criterion for significance is a T-statistic > 1.96. After passing the inner model evaluation, the next step is hypothesis testing.

3. Results and Discussion

3.1. Demographic Characteristics

The indoor worker cohort exclusively consisted of administrative-related staff working within office settings, while the outdoor worker group comprised individuals involved in various field forestry works, encompassing chainsaw operators and log loading/unloading workers, as well as truck drivers and helpers. The detailed demographic characteristics of the participants encompass nine categories, which are gender, age, formal education, job position, average working hours, employment status, and experience in OSH training (**Table 1**).

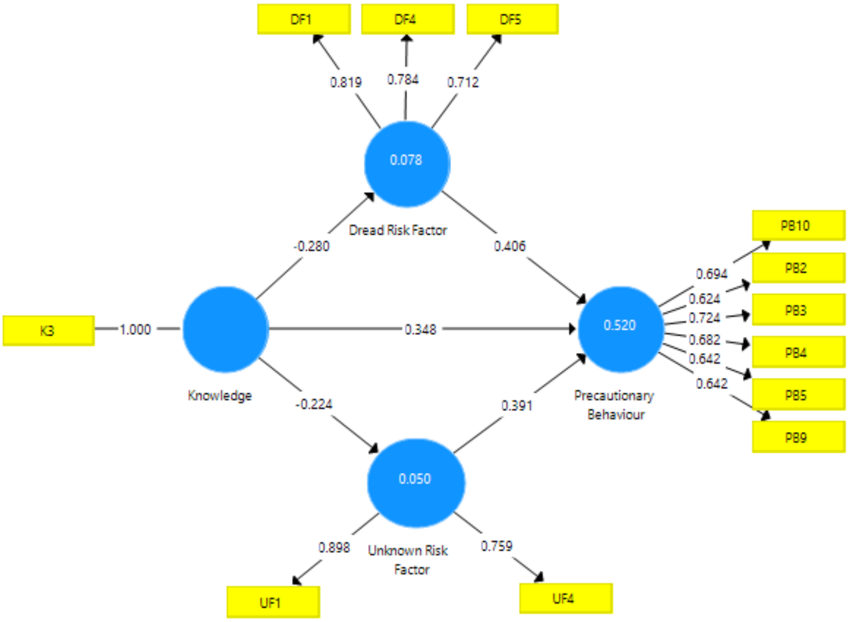
Table 1. Demographic characteristics of the participants in this study

Characteristic		Indoor			Outdoor		
		Number	%	Position	Number	%	Position
Gender	Male	16	32	Head of administration	20	40	Loading/ unloading worker
		9	18	Head of agroforestry and ecotourism subsection	9	18	Chainsaw operator
		11	22	HR staff	4	8	Truck driver
		8	16	Production staff	17	34	Helper
	Female	3	6	Financial and accounting staff	0	0	
		3	6	Administration staff	0	0	
Age (year)	15–24	0	0		2	4	
	25–34	2	4		11	22	
	35–44	12	24		23	46	
	45–54	34	68		11	22	
	55–64	2	4		3	6	
Formal Education	Elementary	0	0		22	44	
	Junior high	1	2		17	34	
	Senior high	32	64		11	22	
	College	17	34		0	0	
Average working hours	3–7 hours	1	2		28	56	
	8–12 hours	49	98		22	44	
Employment status	Permanent	50	100		0	0	
	Temporary contract	0	0		50	100	
OSH training	Yes	14	28		0	0	
	Never	36	72		50	100	

3.2. Results of SEM-PLS Analysis

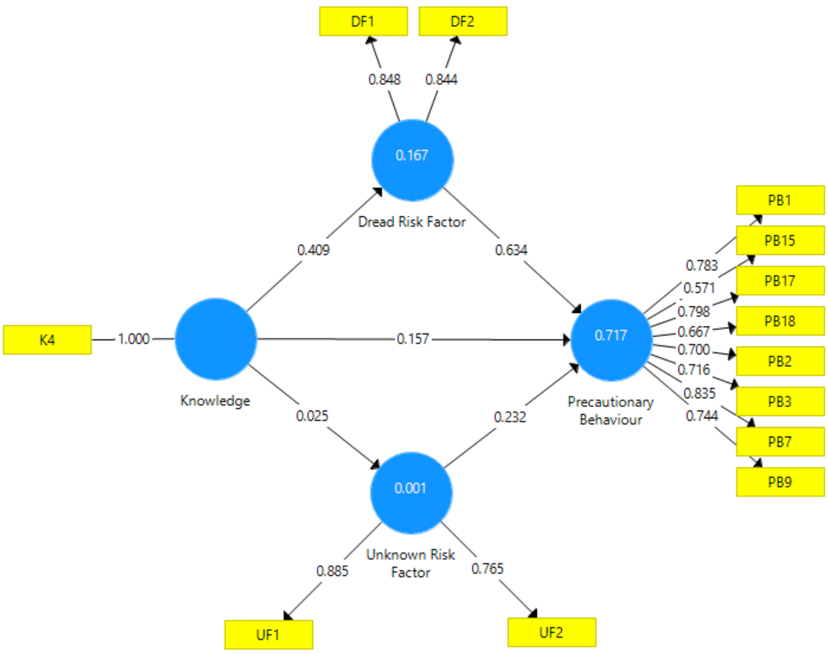
3.2.1. Outer model evaluation

In this phase, selected indicators are used for inner model evaluation. **Fig. 2** and **Fig. 3** represent the selected indicators as a result of convergent validity testing. Based on the reflective measurement model, for the indoor worker group, measurement variables K3, DF1, DF4, DF5, UF1, UF4, PB2, PB3, PB4, PB5, PB9, and PB10 have loading factors > 0.50 or p-value < 0.05. Meanwhile, for the outdoor worker group, measurement variables K4, DF1, DF2, UF1, UF2, PB1, PB2, PB3, PB7, PB9, PB15, PB17, and PB18 have loading factors > 0.50 or p-value < 0.05. **Table 2** and **Table 3** present the cross-loading values as the result of discriminant validity testing, respectively. The cross-loading values for each indicator and its latent variable meet the discriminant validity criteria, indicating that the constructs are empirically distinct from each other and that each indicator effectively explains the characteristics of the latent variables (Hair 2018).



Notes:
K3 = prevention and first aid;
DF1 = risk controllability;
DF4 = fatality;
DF5 = risk to future generations;
UF1 = observability;
UF4 = effect immediacy;
PB2 = sharing work shifts with coworkers;
PB3 = adjusting work hours but increasing work days;
PB4 = involving more coworkers in tasks,
PB5 = working intermittently,
PB9 = donning whole-body layered clothing/trousers,
PB10 = wearing a hat or similar head protection.

Fig. 2. The results of the evaluation of the selected reflective indicator measurement model for forestry workers working indoors.



Notes:
K4 = impact of heat exposure on work performance;
DF1 = risk controllability;
DF4 = fatality;
DF5 = risk to future generations;
UF1 = observability;
UF2 = newness;
PB1 = working early in the morning;
PB2 = sharing work shifts with coworkers;
PB3 = adjusting work hours but increasing work days;
PB7 = wearing work attire that absorbs sweat easily;
PB9 = donning whole-body layered clothing/trousers;
PB15 = providing medication/ a first aid kit;
PB17 = seeking and obtaining health protection information;
PB18 = undergoing self-examination at the health center.

Fig. 3. The results of the evaluation of the selected reflective indicator measurement model for forestry workers working outdoors.

The reliability test for each selected indicator shows that the reliability test for both indoor and outdoor workers for each construct meets the criteria (Cronbach's alpha > 0.60; composite reliability > 0.70) (**Table 4**). The multicollinearity test (VIF) results show that the VIF values are less than 10, indicating no serious multicollinearity between constructs (**Table 5**).

Table 2. The cross-loading values for indoor workers

Variable	Dread risk factor	Knowledge	Precautionary behavior	Unknown risk factor
DF1	0.81	-0.24	0.51	0.61
DF4	0.78	-0.18	0.44	0.55
DF5	0.71	-0.21	0.37	0.42
K3	-0.28	1	0.14	-0.22
PB2	0.35	-0.05	0.62	0.41
PB3	0.39	0.15	0.72	0.50
PB4	0.36	0.09	0.68	0.30
PB5	0.38	-0.00	0.64	0.39
PB9	0.38	0.11	0.64	0.22
PB10	0.43	0.22	0.69	0.47
UF1	0.72	-0.26	0.56	0.89
UF4	0.38	-0.08	0.41	0.75

Notes: K3 = prevention and first aid; DF1 = risk controllability; DF4 = fatality; DF5 = risk to future generations; UF1 = observability; UF4 = effect immediacy; PB2 = sharing work shifts with coworkers; PB3 = adjusting work hours but increasing work days; PB4 = involving more coworkers in tasks, PB5 = working intermittently, PB9 = donning whole-body layered clothing/trousers, PB10 = wearing a hat or similar head protection.

Table 3. The cross-loading values for outdoor workers

Variable	Dread risk factor	Knowledge	Precautionary behavior	Unknown risk factor
DF1	0.84	0.33	0.70	0.52
DF2	0.84	0.36	0.68	0.35
K4	0.40	1	0.42	0.02
PB1	0.68	0.35	0.78	0.58
PB2	0.60	0.27	0.7	0.35
PB3	0.63	0.29	0.71	0.36
PB7	0.68	0.31	0.83	0.60
PB9	0.56	0.30	0.74	0.47
PB15	0.50	0.29	0.57	0.20
PB17	0.63	0.24	0.79	0.37
PB18	0.40	0.44	0.66	0.22
UF1	0.52	-0.02	0.53	0.88

Notes: K4 = impact of heat exposure on work performance; DF1 = risk controllability; DF4 = fatality; DF5 = risk to future generations; UF1 = observability; UF2 = newness; PB1 = working early in the morning; PB2 = sharing work shifts with coworkers; PB3 = adjusting work hours but increasing work days; PB7 = wearing work attire that absorbs sweat easily; PB9 = donning whole-body layered clothing/trousers; PB15 = providing medication; PB17 = seeking and obtaining health protection information; PB18 = undergoing self-examination at the health center.

Table 4. The results of the reliability test for each construct in the indoor and outdoor worker groups

Variable	Indoor worker		Outdoor worker	
	Cronbach's alpha	Composite reliability	Cronbach's alpha	Composite reliability
Dread risk factor (DF)	0.66	0.81	0.60	0.83
Knowledge (K)	1	1	1	1
Precautionary behavior (PB)	0.75	0.82	0.87	0.90
Unknown risk factor (UF)	0.56	0.81	0.54	0.81

Table 5. Variance Inflation Factor (VIF) values for indoor and outdoor worker

Indoor worker		Outdoor worker	
Variable	**VIF**	**Variable**	**VIF**
DF1	1.32	DF1	1.23
DF4	1.34	DF2	1.23
DF5	1.23	K4	1
K3	1	PB1	2.26
PB2	1.30	PB2	2.31
PB3	1.40	PB3	2.39
PB4	1.50	PB7	3.82
PB5	1.30	PB9	1.96
PB9	1.51	PB15	1.34
PB10	1.34	PB17	2.35
UF1	1.18	PB18	2.10
UF4	1.18	UF1	1.16
		UF2	1.16

Notes: K3 = prevention and first aid; K4 = impact of heat exposure on work performance; DF1 = risk controllability; DF4 = fatality; DF5 = risk to future generations; UF1 = observability; UF2 = newness; UF4 = effect immediacy; PB1 = working early in the morning; PB2 = sharing work shifts with coworkers; PB3 = adjusting work hours but increasing work days; PB4 = involving more coworkers in tasks, PB5 = working intermittently; PB9 = donning whole-body layered clothing/trousers, PB10 = wearing a hat or similar head protection; PB9 = donning whole-body layered clothing/trousers; PB15 = providing medication; PB17 = seeking and obtaining health protection information; PB18 = undergoing self-examination at the health center.

3.2.2. Inner model evaluation

For indoor workers, the R^2 value for the latent variable of cautious behavior is the highest at 0.52 (**Table 6**). This value indicates that cautious behavior accounts for 52% of the variability, with other variables not included in the model explaining the remaining 48%. For the outdoor worker group, the highest R^2 value is for the latent variable of cautious behavior, which is 0.717. This means that the cautious behavior variable can relatively strongly explain the DF and UF in the model. However, the relationship between DF and UF is relatively weak. **Table 7** shows the values of SRMR and NFI for the model. The analysis results indicate that the model in this study meets the good fit criteria.

Table 6. R-square values for indoor and outdoor workers

Variable	Indoor worker		Outdoor worker	
	R^2	R^2 adjusted	R^2	R^2 adjusted
Dread risk factor (DF)	0.07	0.05	0.16	0.15
Precautionary behavior (PB)	0.52	0.48	0.71	0.69
Unknown risk factor (UF)	0.05	0.03	0.001	-0.02

Table 7. Model fit for indoor and outdoor workers

Variable	Indoor worker		Outdoor worker	
	Saturated model	**Estimated model**	**Saturated model**	**Estimated model**
SRMR	0.10	0.16	0.10	0.14
d_ULS	0.85	2.11	0.91	1.94
d_G	0.34	0.52	0.60	0.75
Chi-Square	95.23	120.28	151.50	168.72
NFI	0.55	0.44	0.59	0.54

3.3. Hypotheses Testing and Analysis

The T-statistic values, which resulted from data processing using the bootstrapping procedure for both the indoor and outdoor worker groups, respectively, directly and indirectly, indicate the strength of the relationships between latent variables (**Table 8**, **Table 9**, **Table 10**, and **Table 11**). The T-test values are observed from the computed T-statistic and are compared to the critical T-table value used in research with a two-tailed hypothesis and a significance level of 95% (alpha 5%), which is 1.96.

Table 8. The results of testing the direct relationships between latent variables in the indoor worker group

Variable	(O)	(M)	STDEV	|O/STDEV|	P Values	Significancy
DF -> PB	0.40	0.41	0.13	3.00	0.003	*
K -> DF	-0.28	-0.27	0.14	2.01	0.044	*
K -> PB	0.34	0.35	0.14	2.42	0.016	*
K -> UF	-0.22	-0.21	0.13	1.71	0.087	Not significant
UF -> PB	0.39	0.39	0.14	2.85	0.004	*

Notes: O = original sample; M = sample mean; STDEV = standard deviation; |O/STDEV| = T Statistics K = knowledge, DF = dread risk factor, PB = precautionary behavior, UF = unknown risk factor.

Table 9. The results of testing the direct relationships between latent variables in the outdoor worker group

Variable	(O)	(M)	STDEV	|O/STDEV|	P Values	Significancy
DF -> PB	0.63	0.63	0.09	6.88	0.000	**
K -> DF	0.41	0.41	0.12	3.28	0.001	**
K -> PB	0.16	0.16	0.09	1.80	0.07	Not significant
K -> UF	0.02	0.03	0.15	0.16	0.87	Not significant

Notes: O = original sample; M = sample mean; STDEV = standard deviation; |O/STDEV| = T Statistics K = knowledge, DF = dread risk factor, PB = precautionary behavior, UF = unknown risk factor.

Table 10. The results of testing the indirect relationships between latent variables in the indoor worker group

Variable	(O)	(M)	STDEV	|O/STDEV|	P Values	Significancy
K -> DF -> PB	-0.11	-0.11	0.07	1.59	0.11	Not Significant
K -> UF -> PB	-0.08	-0.08	0.06	1.35	0.17	Not Significant

Notes: O = original sample; M = sample mean; STDEV = standard deviation; |O/STDEV| = T Statistics K = knowledge, DF = dread risk factor, PB = precautionary behavior, UF = unknown risk factor.

Table 11. The results of testing the indirect relationships between latent variables in the outdoor worker group

Variable	(O)	(M)	STDEV	|O/STDEV|	P Values	Significancy
K -> DF -> PB	0,26	0,26	0,09	2,92	0,003	*
K -> UF -> PB	0,006	0,003	0,04	0,14	0,88	Not Significant

Notes: O = original sample; M = sample mean; STDEV = standard deviation; |O/STDEV| = T Statistics K = knowledge, DF = dread risk factor, PB = precautionary behavior, UF = unknown risk factor.

3.4. Discussion

The gender ratio of forestry workers indicates a male-dominated workforce, not only in outdoor activities but also in indoor tasks. Indoor workers are mainly above 45 years old, while outdoor workers are generally younger. This age difference might correlate with the risk levels in both worker groups. Younger workers are more prone to OSH issues, especially in outdoor tasks like logging and heavy physical labor, predominantly performed by males. Almost all respondents have families, suggesting they are the main breadwinners. This data, when correlated with the time spent working, indicates a significant dependence on forestry work for their livelihoods. Additionally, the data shows that outdoor workers are typically temporary employees. Considering that health issues from heat exposure are slow-onset disasters, the vulnerability of contract workers is higher, as they might experience the negative effects later, even after leaving forestry employment. This vulnerability is amplified by the lack of OSH training for outdoor workers. Overall, this study indicates that outdoor forestry workers face higher OSH risks compared to indoor workers.

3.4.1. Heat-related knowledge versus precautionary behavior

Knowledge and cautious behavior towards heat exposure differ between indoor and outdoor worker groups. In the indoor worker group, OSH knowledge positively correlates with cautious behavior. However, in the outdoor worker group, OSH knowledge does not show any correlation with cautious behavior.

Taking that knowledge is of paramount importance in shaping an individual's actions, several explanations may account for these differences. Firstly, outdoor workers face higher daily risks in their workplace, leading them to overlook the risks of heat exposure, considering them less serious compared to other hazards. Secondly, outdoor workers may not have equal access to information and resources on protecting themselves from heat exposure (Geana 2020). This is relevant with information theory, underlining that precautionary behaviors and acceptance based on knowledge tend to be more enduring than those without knowledge as a foundation (Ning et al. 2020).

This study highlights the need for diversified strategies to enhance cautious behavior toward heat exposure among indoor and outdoor workers. Strategies for indoor workers may involve raising awareness about heat exposure risks and providing training on self-protection (Iorfa et al. 2020). For outdoor workers, strategies may entail improving access to information (Yovi et al. 2016) and resources regarding OHS protection and creating a safer work environment.

3.4.2. Heat-related knowledge versus risk perception

As mentioned earlier, risk perception is approached through two primary modulating elements, namely the dread risk factor (DF) and the unknown risk factor (UF) (Slovic 1987). In the group of indoor workers, it was found that knowledge significantly predicts DF (T-statistic 2.016; p-value 0.044; **Table 8**). However, K has no significant predictive effect on UF (T-statistic 1.714; p-value 0.087; **Table 8**). Similar patterns were also observed in the group of outdoor workers. The results indicate a significant connection between K and DF (T-statistic 3.28; p-value 0.001; **Table 9**), while there is no significant relationship between K and UF (T-statistic 0.161; p-value 0.872; **Table 9**).

These findings are consistent with the work of previous studies (Fadel et al. 2021; Lu et al. 2021; Yovi et al. 2023). These studies observed a strong association between knowledge and risk perception. Knowledge, which can be obtained either through education or experience, can encourage a person to have a more realistic perception of risk, encourage individuals to provide an appropriate assessment of the losses that may be obtained, and formulate strategies to avoid or mitigate negative impacts that may arise (Iorfa et al. 2020; Ning et al. 2020).

Another interesting aspect of this research is the similar trend observed in Yovi et al. (2023) study, indicating that the "dread" factor appears to be an effective approach for the outdoor worker group. Dread risks trigger an individual's emotional early warning system, causing an increase in our heart rate and a feeling of discomfort. This can be attributed to the feeling of a lack of control over exposure to severe consequences (Weber 2006). In cultural contexts where outdoor workers respect and listen to their field supervisors, using "fear language" when delivering messages about cautious behavior may be considered an alternative communication strategy to enhance cautious behavior (Harper et al. 2020; Ning et al. 2020; Yovi et al. 2023). However, the use of fear-based language is not universally effective, and its application should be done cautiously (Whitmer and Sims 2021).

3.4.3. Risk perception versus precautionary behavior

This study confirms prior findings that risk perception and precautionary behavior are positively correlated (Liu et al. 2013; Li et al. 2016; Yovi et al. 2023). This relationship was strong and significant in both indoor worker groups for DF (T-statistic 3.007; p-value 0.003; **Table 8**) and outdoor worker groups for DF (T-statistic 6.886; p-value 0.000; **Table 9**).

Perception becomes highly crucial as it can shape an individual's behavior. It influences how one responds to hazards and risks in their environment. Several researchers agree that various factors influence risk perception within and outside the workplace. These factors encompass individual, external, and situational factors (Slovic et al. 2000; Yovi et al. 2022). However, in general, it can be said that most individuals will alter their behavior once they become aware of the presence of danger (Harper et al. 2020; Li et al. 2016; Liu et al. 2013; Ning et al. 2020). The higher the risk perception, the greater the likelihood that individuals will act to mitigate those risks.

3.4.4. Risk perception as a mediator between OSH-related knowledge and precautionary behavior

Risk perception is a complex issue. Understanding the effects of heat exposure on workers poses a challenge due to individual variations in perceived temperatures and overall exposure levels. Nonetheless, the psychometric paradigm approach employed in this study provides insights into aspects of risk perception. Risk perception is a process through which workers interpret information regarding OSH risks they encounter (Slovic 1987; Slovic et al. 2000). If workers perceive risks negatively, they are more likely to overlook risk exposures (Ning et al. 2020; Yovi et al. 2022). Risk exposures related to heat can largely be prevented, and it is crucial for workers to be aware of the potential health effects of working in hot conditions. Implementation of preventive programs and workplace responses to heat-related illnesses are essential to ensuring workers remain safe from the adverse effects of extreme heat exposure.

This study demonstrates that, for the outdoor worker group, understanding the context of "loss" and "fear" regarding the negative impacts of heat exposure improves a realistic perception of the risks of occupational health disorders that workers may experience, ultimately enhancing their willingness to adopt precautionary behaviors. Overall, the findings of this study match earlier researches on outdoor forestry workers (Harper 2020; Ning et al. 2020; Yovi et al. 2023).

A realistic perception of heat exposure risks in the workplace is necessary for developing heat prevention strategies and minimizing the negative impacts of extremely high temperatures on health and occupational safety (Bonafede et al. 2022). The formulation of strategies for protection and mitigation against heat exposure and minimizing potential negative impact requires workers to possess a realistic perception of risks (Uejio et al. 2018).

4. Conclusions

This mediation-moderation investigation shows that higher levels of OSH-related knowledge among indoor workers are associated with increased precautionary behavior. However, merely enhancing knowledge may not effectively improve precautionary behavior among outdoor workers. For the outdoor worker group, improving knowledge may lead to more realistic risk perceptions, particularly regarding "dread risk factors", which can positively influence precautionary behavior. Strengthening the aspect of "dread" in forestry workers has been shown to boost precautionary behavior, reflecting the importance of realistic risk perception in promoting safe practices. Furthermore, it is crucial to recognize that outdoor workers are more vulnerable compared to indoor workers. Therefore, urgent and comprehensive efforts should be undertaken to address and improve the occupational safety and health of outdoor forestry workers.

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