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Heat-Resilient Workforce: Unveiling the Relationships Between Heat-related Knowledge, Risk Perception, and Precautionary Behavior in Indonesian Pine Forest Workers

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Abstract

Behavioral changes play a crucial role in protecting the occupational health of outdoor workers, particularly those engaged in physically demanding jobs like forestry, against the adverse effects of rising temperatures–a clear consequence of climate change. Working in an environment with increasing temperature exposure heightens the risk of health disorders from both physiological and psychological perspectives, ultimately resulting in decreased work productivity. Numerous studies emphasize the positive correlation between behavior and knowledge. However, other variables that require thorough exploration are risk perception and work experience. Understanding the interplay among these four variables–behavior, knowledge, risk perception, and work experience–is crucial for formulating precise strategies to foster more cautious behavioral changes. This cross-sectional study, executed through a survey involving 50 pine tappers in the pine forest area of Bogor, Indonesia, utilizes Structural Equation Modelling with the Partial Least Squares approach. The research aims to explore the relationships between heat-related knowledge, risk perception, precautionary behavior, and work experience among outdoor workers, particularly pine oleoresin tappers. Through semi-structured interviews, insight into how to improve the workers' precautionary behavior against the impacts of climate are investigated. The analysis uncovers positive connections between knowledge-risk perception, knowledge-precautionary behavior, and risk-perception-precautionary behavior. Additionally, the study underscores the mediating role of the dread risk factor (one element of risk perception) in shaping workers' precautionary behavior. Another finding is that, with increasing work experience, pine tappers tend to underestimate risks, thereby diminishing their inclination toward precautionary behavior. These findings offer valuable guidance for enhancing the precautionary behavior of outdoor workers who confront the challenges of rising temperatures.

Keywords: Climate change, Health-related illness, Mediation analysis, Occupational health, Pine tappers.

1. Introduction

Climate change is one of the most pressing ecological and socioeconomic problems of the twenty-first century (Dietz et al., 2020). Increased temperatures are a widespread consequence of climate change (Weisheimer and Palmer, 2005; Battisti and Naylor, 2009; Yadav et al., 2015). According to the Intergovernmental Panel on Climate Change (IPCC), from 1880 to 2012, the average global surface temperature increased by around 0.85°C (IPCC, 2013). The tangible impacts of climate change are anticipated to intensify in the future, necessitating the implementation of appropriate measures (Pielke et al., 2008). More than 500 hydro-meteorological or climate-related disasters occurred in Indonesia between 1909 and 2020 (Gan et al., 2021). These disasters have caused widespread damage. Everyone is affected by climate change, but the impacts are not evenly distributed, depending on the level of exposure, personal factors such as age, education, income, health status, and access to health care (Kendrovski and Schmoll, 2019). Elderly persons, kids, those who work outdoors, and people who are homeless are particularly at risk (Paavola, 2017).

Humans are the primary victims of climate change. Extensive research unequivocally has demonstrated the profound impacts of air temperature increases on workers' health and work productivity across diverse sectors. Exposure to working environment temperatures exceeding the threshold value will make workers stressed, angry, depressed, and dehydrated more easily (Lukas et al., 2018). Other studies mentioned health problems, including skin and kidney cancer, reproductive issues, immune dysfunction, and eye problems (Ansah et al., 2021; Abokhasabah et al., 2021). Although reducing workload or taking more frequent

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short breaks can help mitigate the detrimental effects of heat, these actions can also lead to reduced work productivity (Dunne et al., 2013).

Among the vulnerable groups identified by Paavola (2017), outdoor forestry workers have received attention. Workers involved in extended outdoor activities require high levels of physical exertion and face an increased susceptibility to heat stress. This risk is heightened for individuals with low to moderate incomes, particularly in tropical regions (Xiang et al., 2014). Heat stress can also cause workers to work ineffectively when working conditions are unfavorable, thus decreasing work productivity (Kjellstrom et al., 2009; Lundgren et al., 2013). In addition to heat stress, the intensity of exposure to high heat can lead to the potential for heat-related illness (HRI) in workers. HRI is a complaint caused by disturbances in body temperature regulation due to increased heat exposure, which is not matched by heat loss. HRI and its severity may be experienced more by outside workers because they generally work in direct sunlight with high humidity and carry out work activities that can increase body heat too high. Therefore, forestry workers engaged in physically demanding tasks carry a high risk of health disorders (such as musculoskeletal disorders), such as tree felling (Yovi and Prajawati, 2015) or pine oleoresin tapping (Yovi and Wilantara, 2023), oleoresin gathering (Yovi and Fauzi, 2021) and facing low work productivity due to the absence of efficient work systems (Yovi et al., 2021), the impact of HRI represents a substantial added challenge to their occupational health and well-being.

An intriguing phenomenon arises within the context of forestry workers. The impact of rising temperatures on forestry workers, especially those who work outdoors, is evident, as it negatively affects their working conditions, which harms their health and productivity (Yovi et al., 2023; Permatasari et al., 2023). However, many workers tend to accept these risks due to obstacles in rational decision-making (Yovi et al., 2021). Mortada and Elhessewi (2022) stated that knowledge of the risks that arise generally results in someone being able to increase their precautionary behavior compared to if someone did not understand these risks. In addition, various studies have proven that increasing knowledge will enhance the ability of rational decision-making, as manifested through a readiness to engage in precautionary behavior (Iorfa et al., 2020; Arslanca et al., 2021; Fadel et al., 2022; Permatasari et al., 2023; Yovi et al., 2023).

Despite these findings, a critical gap exists in understanding the nuanced impacts on workers operating under tree canopies. An exemplary outdoor activity carried out in shaded areas is to practice tapping pine oleoresin. Pine tapping is vital in Indonesia's forestry sector. The estimated pine plantation spans 1.8 million hectares, with a recorded national export value of USD 84.7 million (Yovi et al., 2021). Despite unknown pine tapper numbers, the extensive pine plantations suggest positive impacts on Indonesia's forestry industry improvement. Therefore, the lack of information on variables that can positively influence precautionary behavior, thus mitigating the adverse effects of heat exposure while working under the canopy, poses challenges in addressing and preempting health issues among forestry workers who work on 1.8 million hectares of pine plantation in Indonesia.

This research aims to address this gap by focusing on pine oleoresin workers who operate in shaded areas, where light intensity and temperature variations may influence their vulnerability differently compared to those working in unshaded environments. Furthermore, considering the tendency of forestry workers in Indonesia towards risk acceptance, we also conducted an analysis to determine whether work experience is one of the triggers for this risk acceptance. Understanding this is intriguing, as the risk acceptance attitude may be related to precautionary behavior.

By delving into this specific aspect, the study contributes to a more comprehensive understanding of the occupational health challenges faced by forestry workers. Furthermore, it emphasizes the need for targeted interventions and risk management strategies tailored to the unique conditions faced by workers engaged in shaded outdoor activities, providing a valuable foundation for policy formulation and program development.

2. Materials and Methods

2.1. Research Sites

This research was conducted in March–June 2023 in a pine forest area in Bogor, West Java Province, Indonesia. This location was chosen because it has a massive annual production of pine oleoresin, reaching 300,000 kilograms. The climate conditions in the research area are pretty warm, with average temperatures throughout the year ranging from 25°C to 26°C. Hidayat and Farihah (2020) stated that temperature conditions in the Bogor area in 2001–2013 could reach 28.5°C but in the last five years, the highest temperature reached 33.72°C (Diskominfo Kabupaten Bogor, 2022). This study is designed as a cross-sectional study involving 50 pine tappers encountered during the research conducted in a pine forest area in Bogor, Indonesia.

The questions discussed in this research are: What variables influence the precautionary behavior of pine oleoresin workers. The research hypotheses are formulated as follows: Hypothesis 1 (H1) perceived risk can predict precautionary behavior, H2: heat-related knowledge can predict risk perception and precautionary behavior, H3: perceived risk can mediate heat-related knowledge with precautionary behavior, and H4: work experience can moderates risk perception with knowledge related to heat exposure.

2.2. Data Collection

2.2.1. Heat-related Knowledge

Knowledge of heat exposure serves as the first variable in this study. Its significance lies in the fact that individuals lacking this variable are at a heightened risk of several adverse outcomes, such as being more likely to miss out on essential health services, increasing their vulnerability to diseases, misunderstandings in the assessment of their conditions, and generally hindering their ability to adopt health-promotion practices (Craig et al., 2017). Adequate knowledge empowers individuals or communities to take proactive measures, facilitating knowledge transformation into actionable strategies to prevent the adverse effects of prolonged sun exposure. On the other hand, individuals with limited knowledge are more likely to reject health services, harbor misconceptions about disease or illnesses, face an elevated risk of disease contraction, and frequently exhibit unfavorable attitudes toward adopting healthy behaviors (Nyasulu et al., 2018; Kazaura, 2020). The assessment of knowledge encompasses four indicators, namely general knowledge (K-1), symptoms due to heat exposure (K-2), prevention and first treatment of heat exposure (K-3), and how heat exposure can impact work productivity (K-4). The four indicators are expressed in statements, and the pine oleoresin tappers are asked whether the reports are true or false. The above indicators follow previous research of Riccò et al. (2020).

2.2.2. Risk Perception

Risk perception is a significant subject in health and risk communication that can influence how people deal with hazards so that a person experiences a behavior change. O'Connor et al. (1999) proved that risk perception played a significant role in explaining the variation in behavioral intentions connected to climate change. People need to understand their current risks to prevent or lessen any undesirable outcomes, such as illness, disease, or virus (Siegrist and Árvai, 2020), reduce the tragedy of disease (Iorfa et al., 2020), and prevent infection or any injuries (Heydari et al., 2021). This research refers to Slovic (1987), who mapped risks into two dimensions, namely dread risk factors (DF) and unknown risk factors (UF). Perceived risk in the form of DF was divided into six indicators and answered on a 7-score Likert scale. These indicators include the ability to control heat (DF-1), the dread of the effects caused by exposure to heat (DF-2), the severity of health problems (DF-3), facilities (DF-4), increased risk (DF-5), and volunteering to bear the consequences of work (DF-6). The second factor in determining the risk perception of pine oleoresin tappers is using an element in the form of UF. These elements were presented in a 7-score Likert scale, consisting of four facets: observability (UF-1; how workers see the harmful effects of heat clearly or not), newness (UF-2; how long workers know that exposure to heat can interfere with health and can lead to death), knowledge of exposure (UF-3; how many effects what they know is the result of exposure to heat), and immediacy (UF-4; how fast the negative impact on human health is due to exposure to sun's heat).

2.2.3. Precautionary Behavior

Precautionary behavior is proactive measures taken by individuals to reduce and avoid situations considered risky, particularly those with adverse implications for health and economic well-being (Sadique et al., 2007). Janz and Becker (1984) proposed four factors influencing precautionary behavior: perceived susceptibility, severity of consequences, perceived benefits, and perceived barriers. Numerous studies have also corroborated a positive correlation between knowledge and risk perception on precautionary behavior (Mortada and Elhessewi, 2022; Yovi et al., 2023; Permatasari et al., 2023). This variable encompasses 18 indicators related to the actions taken by the tappers to protect themselves from occupational health problems from prolonged sun exposure. Each indicator is presented in the form of a statement, offering choices of strategies with both positive and negative information (reverse questions). Tappers are required to rate their responses on a 7-score Likert scale (1 = highly unnecessary → 7 = absolutely essential). These indicators encompass precautionary behavior: working earlier so that work can be completed before noon (PB-1), dividing work shifts with co-workers (PB-2), reducing working hours but increasing working hours at other times (PB-3), inviting more co-workers to finish their task quickly (PB-4), seeking intermittent break (PB-5), persevering despite physical fatigue and hot discomfort (-)(PB-6), wearing clothes that absorb sweat quickly (PB-7), wearing dark outer clothes (PB-8), choosing shirts and shorts (-)(PB-9), wearing a hat (PB-10), staying hydrated during work (PB-11), and drink lots of coffee at work (-)(PB-12). Additionally, protective measures encompass finding shelter (PB-13), wearing sunglasses (PB-14), maintaining access to a first aid kit (PB-15), being aware of emergency procedures (PB-16), ignoring health protection information (-)(PB-17), and conducting health check-up (PB-18). All items followed the work of Yovi et al. (2023).

2.3. Data Analysis

The data was processed using a Structural Equation Model (SEM) with a Partial Least Square (PLS) approach. SEM-PLS is employed to test the relationship between constructs, and it is known for its flexibility, as it does not necessarily require a solid theoretical basis. Instead, it can produce a new theory or refine existing ones. The hypothesis was tested using SmartPLS 4.0 software, a second-generation SEM tool (Vinzi et al., 2010). SmartPLS was chosen due to its suitability for small sample sizes (Vinzi et al., 2010), compatibility with nominal, ordinal, and interval scale variables (Nitzl, 2010), and it does not require distribution assumptions (Ringle et al., 2012).

SEM-PLS analysis was conducted in two sequential steps, as Barclay et al. (1995) recommended. The first stage was testing the validity and reliability of the outer model, and the second was evaluating the model's structural aspect (inner model evaluation). Reliability was evaluated using criteria of Cronbach's Alpha ≥ 0.5 and composite reliability (CR) >0.7 (Dijkstra and Henseler, 2015). The Average Variance Extracted (AVE) was used to measure validity. Confirmatory Factor Analysis (CFA) was employed to test validity, whit outer loading values ≥0.50 considered valid (Henseler et al., 2015).

The next step was the multicollinearity test. Multicollinearity is a phenomenon that occurs when two or more predictors are correlated which increases the standard error of the coefficient (McClendon, 2002). This tests whether the indicators exhibit multicollinearity, as the Varian Inflation Factor (VIF) indicates. VIF measures how much the variance of the regression estimator coefficient increases compared to the orthogonal independent variables in a linear relationship. Numerous tolerable maximum VIF value is 10 (Hair et al., 2018). Following the outer model evaluation, the subsequent phase involves evaluating the structural or inner models. The inner model analysis is an analysis to see the relationship between latent constructs. This analysis focused on determining the relationship between latent constructs. Key evaluation metrics included R^2 (R-Square), quantifying how many endogenous variables can be explained by exogenous variables; Q^2 (Q-Square), a test measuring the quality of observed value generated by the model; and the Goodness of Fit Index test (GoF). The R^2 determines how well the model is produced, while the Q^2 value assesses how well the observed values are generated in the model. The GoF test is a non-parametric test measures how closely observed data aligns with expected data. The GoF can be calculated through reflective measurements, especially the roots of the geometric mean commonality with an average R^2 (Vinzi et al., 2010). Baseline GoF values are 0.1 (small category), 0.25 (medium category), and 0.36 (large category) (Wetzels et al., 2009).

3. Results and Discussion

3.1. Demographics data of Respondents Involved

This study enlisted the participation of 50 pine sap tappers actively engaged in daily tapping activities within the designated research area. Pine sap collection is a physically demanding task typically performed by men. The workers are mostly between the ages of 21 and 60, and most have less than eight years of work experience. The demographics of the research participants are categorized into four groups: gender, age, formal education, and work experience (Table 1).

Table 1. Demographic characteristics of respondents.

No	Characteristics		Frequency	Percentage
1	Gender	Male	48	96%
		Female	2	4%
2	Age	0–20	1	2%
		21–40	22	44%
		41–60	23	46%
		61–80	4	8%
3	Formal Education	No School	9	18%
		Elementary	29	58%
		Junior High	10	20%
		Senior High	2	4%
4	Work Experience	0–8 years	31	62%
		8–16 years	10	20%
		16–24 years	4	8%
		24–32 years	4	8%
		32–40 years	1	2%

3.2. Outer Model Evaluation

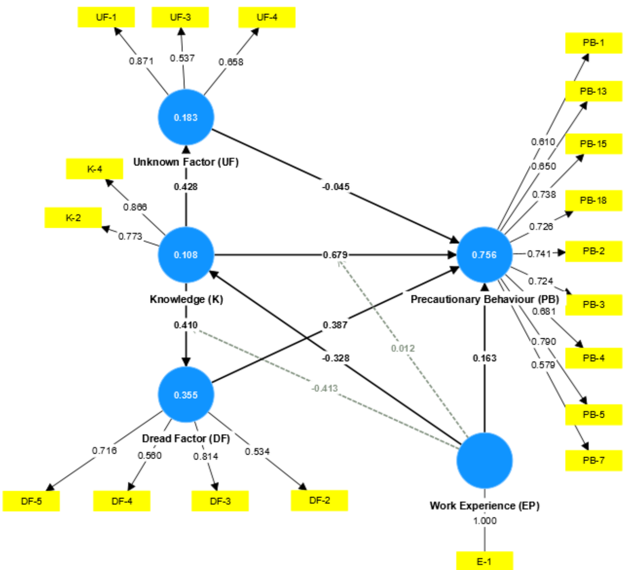
Based on Henseler et al.'s (2015) criteria, only two indicators (K-2 and K-4) of the knowledge latent variable passed the validation test with outer loading values > 0.5 (Table 2). The concurrent validity test on the knowledge variable was successful with an AVE > 0.5. Reliability tests, assessed by CA and CR values, indicated the knowledge latent variable's reliability, meeting criteria (CA ≥ 0.5, CR > 0.7). The risk perception latent variable (DF) has four indicators (DF-2, DF-3, DF-4, DF-5) passing the validation test, but its AVE value < 0.5 suggests a failure in the convergent validity test. However, DF's reliability test is successful, with CR at 0.894 and CA at 0.583. Another risk perception variable (UF) with three indicators passed the validation (UF-1, UF-3, UF-4), while UF-2 did not due to an outer loading < 0.5. Despite this, UF passed the reliability test (CR = 0.756, CA = 0.553).

Table 2. The results of the validity and reliability test for each variable.

Variable	Indicator	Outer Loading	AVE	Cronbach's Alpha	Composite Reliability
K	K-2	0.773	0.674	0.521	0.805
	K-4	0.866			
DF	DF-2	0.534	0.443	0.583	0.894
	DF-3	0.814			
	DF-4	0.560			
	DF-5	0.716			
UF	UF-1	0.871	0.494	0.553	0.756
	UF-3	0.537			
	UF-4	0.658			
PB	PB-1	0.610	0.485	0.865	0.738
	PB-2	0.741			
	PB-3	0.724			
	PB-4	0.681			
	PB-5	0.790			
	PB-7	0.579			
	PB-13	0.650			
	PB-15	0.738			
	PB-18	0.726			

Note: K = Heat-related knowledge, DF = Dread risk factor, UF = Unknown risk factor, PB = Precautionary behavior, DF-2 = The dread of the effects caused by exposure to heat, DF-3 = The severity of health problems, DF-4 = Facilities, DF-5 = Increased risk, E-1 = Work experience, K-2 = Symptoms due to heat exposure, K-4 = How heat exposure can affect work productivity, PB-1 = Working earlier so that work is completed before noon, PB-2 = Dividing work shifts with friends, PB-3 = Reducing working hours but increasing working hours at other times, PB-4 = Inviting more friends to finish quickly, PB-5 = Entering intermittent work, PB-7 = Wears clothes that absorb sweat quickly, PB-13 = Find shade, PB-15 = Provide first aid kit, PB-18 = Checked himself into the health centre, UF-1 = Observability, UF-3 = Knowledge of exposure, UF-4 = Immediacy.

The precautionary behavior latent variable was further scrutinized, revealing that only nine out of the eighteen indicators in the research questionnaire passed the validation test. Although these nine indicators displayed varying outer loading values, the precautionary behavior latent variable failed the convergent validity test due to an AVE value below 0.5. Despite this, the variable demonstrated reliability by surpassing the threshold values for CR (more than 0.7) and CA (more than 0.5). Despite risk perception variables (DF and UF) and precautionary behavior having an AVE value below 0.5, which is acceptable by Fornell and Lacker (1981), the concurrent validity test necessitates a CR value greater than 0.6. Consequently, all variables in the model successfully passed both validity and reliability tests. After these evaluations, a multicollinearity test (Table 3) was done. All VIF values were below ten, meaning that none of the indicators showed multicollinearity. This test is vital, as indicators failing it could lead to invalid significance and coefficient values that contradict the underlying theory (Figure 1).



Note: DF-2 = The dread of the effects caused by exposure to heat, DF-3 = The severity of health problems, DF-4 = Facilities, DF-5 = Increased risk, E-1 = Work experience, K-2 = Symptoms due to heat exposure, K-4 = How heat exposure can affect work productivity, PB-1 = Working earlier so that work is completed before noon, PB-2 = Dividing work shifts with friends, PB-3 = Reducing working hours but increasing working hours at other times, PB-4 = Inviting more friends to finish quickly, PB-5 = Entering intermittent work, PB-7 = Wears clothes that absorb sweat quickly, PB-13 = Find shade, PB-15 = Provide first aid kit, PB-18 = Checked himself into the health centre, UF-1 = Observability, UF-3 = Knowledge of exposure, UF-4 = Immediacy.

Figure 1. The results of the evaluation of the selected reflective indicator measurement model for the pine oleoresin tapper.

Table 3. Collinearity assessment results between heat-related knowledge, risk perception (DF and UF), and precautionary behavior (PB).

Variable	VIF
DF-2 (The dread of the effects caused by exposure to heat)	1.185
DF-3 (The severity of health problems)	1.389
DF-4 (Facilities)	1.144
DF-5 (Increased risk)	1.438
E-1 (Work experience)	1.000
K-2 (Symptoms due to heat exposure)	1.142
K-4 (How heat exposure can affect work productivity)	1.142
PB-1 (Working earlier so that work is completed before noon)	1.685
PB-2 (Dividing work shifts with friends)	2.496
PB-3 (Reducing working hours but increasing working hours at other times)	2.169
PB-4 (Inviting more friends to finish quickly)	2.088
PB-5 (Entering intermittent work)	2.339
PB-7 (Wears clothes that absorb sweat quickly)	1.401
PB-13 (Find shade)	1.557
PB-15 (Provide first aid kit)	1.881
PB-18 (Checked himself into the health centre)	1.942
UF-1 (Observability)	1.093
UF-3 (Knowledge of exposure)	1.204
UF-4 (Immediacy)	1.245

Note: EP = Work experience, K = Heat-related knowledge, DF = Dread risk factor, UF = Unknown risk factor, PB = Precautionary behavior.

3.3. Inner Model Evaluation

The structural model (inner model) was evaluated by examining the percentage variance represented by R^2 for each latent variable, as well as Q^2 and GoF. R^2 is a numerical indicator that signifies the degree of contribution or influence exerted by an exogenous latent variable on its endogenous variable. R^2 values range from zero to one, with values approaching one suggesting that independent variables provide valuable information for predicting endogenous variables and vice versa. Chin (1998) categorizes R^2 values into three levels: good (0.67), medium (0.33), and weak (0.19), and if the value exceeds 0.7, it can be inferred that the model is robust. R^2 values can be calculated using various methods, including SEM-PLS. The R^2 values produced varying results for each latent variable (Table 4). The highest R^2 was observed for the latent variable PB, indicating that the exogenous variables can explain 75.6% of the variation in the endogenous variable PB. On the other hand, the latent variable DF is categorized into the medium/moderate category, with only 35.5% of the endogenous variables explained by the exogenous variables. The adjusted R^2 value addresses issues within the R^2 metric, particularly when additional exogenous variables are introduced into the model.

Table 4. Coefficient of determination (R^2) calculation results.

Variable	R-square	R-square adjusted
Dread risk factor (DF)	0.355	0.312
Heat-related knowledge (K)	0.108	0.089
Precautionary behavior (PB)	0.756	0.728
Unknown risk factor (UF)	0.183	0.166

The inner model's structure was evaluated by examining the Q^2 value. A Q^2 value greater than zero suggests the model has a good observation value. Q^2 values range from 0 to 1 ($0<Q^2<1$) and are akin to the coefficient of determination in path analysis. Q^2 was calculated based on the R^2 value using the following formula:

$$Q^2 = 1 - \{(1 - R_1^2)(1 - R_2^2)(1 - R_3^2)(1 - R_n^2)\} \tag{1}$$

$$Q^2 = 1 - \{(1 - 0.355)(1 - 0.108)(1 - 0.756)(1 - 0.183)\}$$

$$Q^2 = 1 - \{(0.645)(0.892)(0.244)(0.817)\}$$

$$Q^2 = 1 - 0.114 = 0.886 = 88.6\%$$

Based on the calculation of the Q^2 value, it is evident that the predictive relevance value was 0.886. It indicates that the research model's accuracy and precision can explain 88.6% of the variation between latent variables, leaving only 11.4% that can be explained by other variables not included in the model. The Q^2 value is categorized into three levels: 0.02 (weak model), 0.15 (medium model), and 0.35 (strong model). Therefore, based on these categories, it can be concluded that the model used falls into the strong and good category, close to a value of one. Another test within the inner model for GoF involves validating the overall structural model using calculations by Tenenhaus (2005). The GoF is an index that validates a combination of measurement and structural models. The GoF value is derived from the square root of the communalities index multiplied by the average R^2 of the model. GoF values range from 0 to 1, with categories such as 0.1 (small category), 0.25

(medium category), and 0.36 (large category), according to Wetzels et al. (2009).

$$GoF = \sqrt{AVE\ Average\ x\ R^2\ Average} \quad (2)$$

$$GoF = \sqrt{0.524\ x\ 0.350} = \sqrt{0.1834} = 0.428$$

Based on the calculation above, the GoF value was 0.428, which falls into the large category. This indicates that the model is highly capable of explaining empirical data as a whole, and as a result, it is considered valid for use in hypothesis testing.

4. Hypothesis Testing

Hypothesis testing was performed using the bootstrap resampling method with 5000 bootstraps. The acceptance or rejection of each hypothesis depends on the p-value associated with each latent variable. This study used a significance level of 5% (0.05). Therefore, if the p-value for the relationship between latent variables is less than 0.05, it is considered a significant relationship. Table 5 shows the results of the structural model evaluation for hypothesis testing using the PLS method.

Table 5. Results of testing the direct relationship between latent variables.

Variable	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EP-> K	-0.328	-0.329	0.106	3.089	0.002*
EP -> PB	0.163	0.165	0.079	2.062	0.039*
EP -> DF	-0.217	-0.187	0.187	1.158	0.247
K -> PB	0.679	0.674	0.103	6.605	0.000*
K -> DF	0.410	0.431	0.152	2.689	0.007*
K -> UF	0.428	0.450	0.103	4.162	0.000*
DF -> PB	0.387	0.382	0.103	3.747	0.000*
UF -> PB	-0.045	-0.017	0.116	0.391	0.696

Note: EP = Work experience, K = Heat-related knowledge, DF = Dread risk factor, UF = Unknown risk factor, PB = Precautionary behavior, *has a significant effect (p-value <0.05).

The relationship between perceived risk and precautionary behavior showed significant results (Table 5). This means that an increase in rational risk perceived by the tappers will directly lead to a strong precautionary behavior. Therefore, Hypothesis 1, which states that perceived risk can predict precautionary behavior, is accepted. The results of this study align with the research conducted by Yovi et al. (2023) and Permatasari et al. (2023), which suggest that rational risk perception tends to lead to stronger precautionary behavior (Chaswa et al., 2020) in work settings. Of the two risk perception elements, only the dread risk factor shows a significant and positive connection with precautionary behavior. Another risk factor, the unknown element, seems not to have effect on precautionary behavior. One possible reason for this finding is that workers might not fully comprehend the future and lasting consequences they could face. On the other hand, this pattern could be related to the natural traits of the workers, as highlighted in a study by Yovi et al. (2021). This research noted that "pride" can impede logical decision-making, and the willingness to take risks is viewed as a choice. The findings indicate that pine oleoresin tappers may enhance their safety measures by cultivating a perception that evokes a sense of apprehension (dread risk factor).

Hypothesis 2, which proposes that heat-related knowledge can predict risk perception and precautionary behavior, is also accepted (Table 5). Several studies have also explained that having accurate knowledge will motivate individuals to change their behavior to reduce the impact or risk associated with their work (Rimal and Real, 2003; Yovi et al., 2023; Permatasari et al., 2023). The findings of this research are consistent with the studies carried out by Lee et al. (2022) and Alsoghair et al. (2021). These studies indicate that enhanced knowledge is associated with a propensity for precautionary behavior and increased risk perception in occupational settings, as Chaswa et al. (2020) noted. Acquiring knowledge can stem from experiences, the surrounding environment, and informal education sources (Olaimat et al., 2022). Conversely, research indicates that individuals with advanced formal education levels generally exhibit higher knowledge levels (Bates et al., 2021; Kirac et al., 2021). Elevated levels of formal education facilitate the accessibility to information and the ease of gaining experience (Carter, 2008). Based on these findings, particularly within the context of forestry workers at the operational level, such as the tappers investigated in this study, it is imperative to prioritize knowledge reinforcement. This is crucial because these individuals often perceive themselves as possessing an adequate level of knowledge even though, in reality, they may not (Yovi et al., 2012; Yovi et al., 2016).

Nevertheless, it is important to note that an insignificant relationship between knowledge and precautionary behavior could occur (Alsoghair et al., 2021; Rayani et al., 2021). These findings suggest that the relationship between knowledge, risk perception, and precautionary behavior is not always directly correlated and may involve other variables that mediate these connections. Therefore, an analysis testing was also carried out using a mediating variable where perceived risk was used as a mediator (Table 6). Among the indirect effects of the three significant variables, the perception of risk in the form of the dread risk factor served as the mediating variable between knowledge and precautionary behavior with a positive relationship (O = 0.158). This implies that knowledge instilling a sense of fear (dread risk factor) will indirectly lead to greater precautionary behavior, particularly among the pine oleoresin tappers in this particular study. Several prior studies have also explored how perceived risk can mediate the relationship between knowledge and precautionary behavior (Iorfa et al., 2020; Yovi et al., 2023).

Table 6. Results of testing the indirect relationship between latent variables.

Variable	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EP -> K -> UF	-0.140	-0.143	0.047	2.979	0.003*
EP -> K -> PB	-0.223	-0.221	0.080	2.801	0.005*
EP -> K -> DF	-0.134	-0.146	0.078	1.730	0.084
K -> DF -> PB	0.158	0.164	0.074	2.128	0.033*
EP -> DF -> PB	-0.084	-0.074	0.077	1.083	0.279
K -> UF -> PB	-0.019	-0.011	0.053	0.366	0.366

Note: EP = Work experience, K = Heat-related knowledge, DF = Dread risk factor, UF = Unknown risk factor, PB = Precautionary behavior, *has a significant effect (p-value <0.05).

In addition to examining the mediating effect, this study investigated work experience as a variable expected to moderate risk perception with heat-related knowledge. In this study, gender and age were not included as variables for moderation, as both gender and age were initially tested in the model but did not indicate significant results. It aligns with the findings of numerous studies that suggest that gender and age do not significantly explain the relationships under investigation, as seen in research conducted by Yovi et al. (2023) and Lee et al. (2022). However, it is important to note that this conclusion may not always hold, given the research findings of Olaimat et al. (2020), suggesting a significant relationship between gender and knowledge, with age potentially playing a less significant role. Work experience moderates the relationship between knowledge and risk perception, and this relationship is statistically significant (Table 7). However, both variables exhibited a negative direction when EP was used as the moderator variable. The role of work experience in shaping workers' knowledge has been supported by various studies, including Olaimat et al. (2022), which suggests that work experience can impact the knowledge levels of workers. Work experience was employed here to understand risk perception and risk-taking behavior, recognizing that individuals have varying environmental conditions, accident records, work experiences, and exposure to risks, which are not evenly distributed across society. Work experience can also vary significantly among individuals, influenced by factors such as ignorance, disinterest, and a lack of motivation to adopt safe behaviors in the workplace (Yovi et al., 2021).

Table 7. Results of the direct effect between latent variables and moderator variables.

Variable	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
EPxK-> PB	0.012	0.027	0.113	0.105	0.917
EPxK -> DF	-0.413	-0.416	0.187	2.212	0.027*

Note: EP = Work experience, K = Heat-related knowledge, DF = Dread risk factor, PB = Precautionary behavior, *has a significant effect (p-value <0.05).

Workers with more experience are less likely to view tapping pine as a health risk due to the dread factor (DF) element in risk perception. Extended work experience does not consistently lead to improved precautionary behavior compared to individuals with less experience. One possible explanation is that workers demonstrate a significant degree of voluntariness to accept risks, a key aspect of the dread risk factor (Slovic, 1987). It is consistent with Barnett and Breakwell's (2001) research, which delves into the impact of experience on understanding variations in risk evaluation. The correlation between experience and risk perception varies based on whether the encounter with the risk is voluntary or involuntary. Aside from voluntariness, workers may perceive certain preventive measures as obstacles to their work productivity. This belief stems from the correlation between their earnings and the quantity of resin they are able to tap. Extended working hours have a negative impact on tappers. One significant observation during the study was the discomfort reported by workers while wearing visors or glasses while performing their tasks. Feeling uncomfortable, they decided to forgo safety glasses or visors to work faster and earn more, risking potential eye irritation from acid used to prevent resin solidification. Individuals are inclined to perceive the possible health hazards as acceptable risks. This character is consistent with the traits of other individuals in the forestry industry, like tree fellers (Yovi et al., 2019; Yovi et al., 2021).

5. Conclusion

Risk perception is a variable that can directly positively influence the precautionary behavior of pine tappers, protecting their occupational health from the threats of climate change effects. This study also emphasizes that pine oleoresin tappers could enhance their readiness to engage in proper precautionary behavior by acquiring good knowledge. Simultaneously, possessing knowledge enables the tappers to develop the ability for rational decision-making. Furthermore, this study suggests that knowledge that instills a sense of "fearness" (dread risk factor) will indirectly lead to greater precautionary behavior. Moreover, work experience is identified as a moderator influencing the link between knowledge and risk perception (dread factor) in a negative direction. Experienced workers often underestimate the risk. As work hours increase, employees tend to view health risks from heat exposure as unavoidable and accept them as part of the job.

Ethics Committee Approval: This research adheres to the principles of integrity, transparency, and respect for all participants involved, as underlined in the Helsinki Declaration (1964). Informed consent was obtained from each participant, and their confidentiality was strictly maintained. The study follows ethical guidelines set by the Ethical Commission of IPB University Document No. 882/IT3.KEPMSM-IPB/SK/2023. Any potential conflicts of interest have been disclosed. The aim of this research is to contribute valuable insights while prioritizing the well-being and rights of all individuals involved.

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