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The Effect of Carboxyhemoglobin on Subjective Complaints of Fish Smoking Workers in Penatarsewu Village, Sidoarjo

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ABSTRACT Fish smoking activities generate substantial amounts of smoke from incomplete combustion, exposing workers to various air pollutants, including carbon monoxide (CO), which may lead to adverse respiratory health effects. Prolonged inhalation of CO can result in the formation of carboxyhemoglobin (COHb), reducing oxygen transport in the blood and potentially causing subjective health complaints such as cough, dizziness, nausea, and shortness of breath. In Penatarsewu Village, Sidoarjo, a major center of traditional fish smoking, a high prevalence of respiratory complaints among workers has been reported, yet evidence regarding the role of COHb in these complaints remains limited. Therefore, this study aimed to analyze the effect of carboxyhemoglobin levels on subjective complaints among fish smoking workers in Penatarsewu Village, Sidoarjo. This study employed an observational analytic design with a cross-sectional approach. The study population consisted of 57 fish smoking workers, from which 25 female workers were selected using purposive sampling. COHb levels were measured through laboratory blood analysis, while data on subjective complaints, age, duration of daily exposure, and tenure were collected through structured interviews. Data were analyzed using simple linear regression to assess the influence of COHb and other related factors on subjective complaints. The results showed that all respondents had COHb levels within normal limits (≤3.5%), with values ranging from 0.40% to 1.72%. Despite this, 92% of workers reported experiencing subjective respiratory complaints. Statistical analysis revealed that COHb levels and tenure did not significantly affect subjective complaints ($p>0.05$). In contrast, age ($p<0.001$) and duration of daily exposure ($p=0.003$) showed a significant association with subjective complaints. In conclusion, subjective respiratory complaints among fish smoking workers were significantly influenced by age and length of exposure rather than COHb levels. These findings highlight the importance of regulating working hours and considering workers' age to reduce health risks associated with fish smoking activities.

INDEX TERMS Carboxyhemoglobin, Subjective Complaints, Fish Smoking Workers, Carbon Monoxide Exposure, Occupational Health

I. INTRODUCTION

Traditional fish smoking is widely practiced in coastal and rural communities as a method of food preservation and income generation. Despite its socio-economic benefits, this activity exposes workers to substantial levels of smoke generated from incomplete combustion of biomass fuels such as wood and coconut shells. The resulting emissions contain hazardous pollutants, including carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds, which pose significant occupational health risks when inhaled chronically [1]–[3]. Among these pollutants, CO is of particular concern due to its high affinity for hemoglobin, forming carboxyhemoglobin (COHb) and reducing oxygen delivery to body tissues, potentially leading to respiratory and neurological complaints [4], [5].

Recent epidemiological studies have reported a high prevalence of subjective respiratory symptoms such as cough, dyspnea, dizziness, and headache among workers exposed to biomass smoke in informal occupational settings [6], [7]. Fish smoking workers are particularly vulnerable due to prolonged daily exposure, inadequate ventilation, and limited use of personal protective equipment [8]. However, while subjective complaints are frequently documented, the physiological mechanisms underlying these symptoms, especially the role of COHb as an internal exposure biomarker, remain insufficiently explored in traditional fish smoking environments [9].

State-of-the-art occupational health research increasingly employs biomarker-based exposure assessment, integrating blood COHb measurements with environmental monitoring and self-reported health outcomes to improve exposure characterization [10], [11]. This approach has been successfully applied in studies involving traffic police, charcoal workers, and indoor

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biomass users, demonstrating its value in linking CO exposure to adverse health effects [12]–[14]. Nevertheless, most existing studies on fish smoking workers focus on ambient air pollutant concentrations or symptom prevalence alone, without incorporating biochemical indicators such as COHb [15], [16]. Additionally, demographic and occupational factors including age, duration of daily exposure, and work tenure are often inadequately controlled, limiting causal interpretation [17].

This evidences a clear research gap: the lack of empirical studies that simultaneously assess COHb levels, subjective complaints, and individual work-related characteristics among fish smoking workers, particularly in Southeast Asian contexts. Understanding whether normal or low COHb levels can still be associated with high symptom prevalence is critical for refining occupational exposure limits and health protection strategies [18].

Accordingly, the aim of this study is to analyze the effect of carboxyhemoglobin levels on subjective complaints among fish smoking workers in Penatarsewu Village, Sidoarjo, while accounting for age, length of exposure, and tenure as potential confounding variables.

This study offers several key contributions. First, it provides a comprehensive assessment of CO exposure by integrating biological monitoring (COHb) with self-reported health outcomes in a traditional food-processing occupation. Second, it identifies non-chemical determinants, such as age and daily exposure duration, that significantly influence subjective complaints, thereby enriching occupational risk assessment models. Third, the findings contribute evidence-based recommendations for exposure control, worker selection, and the use of personal protective equipment in small-scale fish smoking industries.

The remainder of this article is organized as follows. Section II describes the materials and methods, including study design, sampling, and analytical procedures. Section III presents the results of COHb measurements and statistical analyses. Section IV discusses the findings in relation to existing literature. Finally, Section V concludes the study and outlines practical implications and directions for future research.

II. METHODS

A. STUDY DESIGN AND METHODS

This study employed an observational analytic design with a cross-sectional approach, in which exposure and outcome variables were measured simultaneously within a defined population. A cross-sectional design was selected to assess the relationship between carboxyhemoglobin (COHb) levels and subjective health complaints under real-world occupational conditions without experimental manipulation [21], [22]. The study was conducted in Penatarsewu Village, Sidoarjo Regency, Indonesia, a well-known center of traditional fish smoking activities where workers are routinely exposed to biomass smoke generated from incomplete combustion. Data collection was carried out over a single study period to minimize temporal variability in exposure conditions.

B. STUDY POPULATION AND SAMPLING TECHNIQUE

The study population consisted of 57 fish smoking workers actively engaged in traditional smoking activities in Penatarsewu Village. The study sample was determined using a purposive sampling technique, based on predefined inclusion and exclusion criteria to ensure population homogeneity and control confounding factors [23]. A total of 25 female workers were included in the final analysis. Inclusion criteria were: (1) active involvement in fish smoking activities for at least one year, (2) daily exposure to smoke during working hours, (3) non-smokers, and (4) willingness to participate and provide blood samples. Exclusion criteria included: (1) active cigarette smoking, (2) known chronic respiratory or cardiovascular diseases diagnosed by a physician, and (3) recent acute illness at the time of data collection. Restricting the sample to non-smoking female workers was intended to reduce bias from tobacco-related CO exposure and physiological variability associated with sex differences [24].

C. STUDY VARIABLES

The independent variable was carboxyhemoglobin (COHb) level, expressed as a percentage of total hemoglobin. The dependent variable was subjective health complaints, particularly respiratory and neurological symptoms associated with smoke exposure. Confounding variables included age, daily duration of exposure, and work tenure, which have been shown to influence susceptibility to air pollution-related health effects [25], [26].

D. DATA COLLECTION PROCEDURES

1) Measurement of Carboxyhemoglobin (COHb)

COHb levels were measured through laboratory blood analysis using the Hinsberg–Lang method, a spectrophotometric technique widely used for occupational CO exposure assessment [27]. Venous blood samples were collected by trained laboratory personnel following standard biosafety procedures. The method involves measuring the absorbance of blood samples treated with ammonium hydroxide (NH_4OH) and sodium dithionite ($Na_2S_2O_4$), allowing quantification of COHb concentration relative to a reference standard. COHb values were expressed as percentages and interpreted using the American Conference of Governmental Industrial Hygienists (ACGIH) threshold, where values $\leq$3.5% are considered within normal limits for non-smokers [28].

2) Assessment of Subjective Complaints

Data on subjective complaints were collected using a structured interview questionnaire, administered immediately after blood sampling to reduce recall bias. The questionnaire covered commonly reported symptoms related to smoke exposure, including cough, shortness of breath, runny nose, headache, dizziness, nausea, and fatigue. Responses were recorded in a dichotomous format (presence or absence of symptoms). The questionnaire was adapted from previously validated occupational health instruments used in biomass smoke exposure studies [29].

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3) Demographic and Occupational Data

Demographic variables (age) and occupational characteristics (daily exposure duration in hours and work tenure in years) were obtained through direct interviews. Daily exposure duration was defined as the average number of hours per day spent actively smoking fish, while tenure represented the total number of years working in fish smoking activities.

E. STATISTICAL ANALYSIS

Data were processed and analyzed using statistical software. Descriptive statistics were used to summarize COHb levels, demographic characteristics, and the prevalence of subjective complaints. Continuous variables were presented as means, minimums, and maximums, while categorical variables were expressed as frequencies and percentages.

To evaluate the relationship between COHb levels and subjective complaints, simple linear regression analysis was applied. Separate regression analyses were also conducted to assess the effects of age, exposure duration, and tenure on subjective complaints. A p-value < 0.05 was considered statistically significant. Linear regression was selected due to its suitability for examining associations between continuous predictors and health outcomes in cross-sectional occupational studies [30].

F. ETHICAL CONSIDERATIONS

Ethical approval for the study was obtained from the institutional ethics committee prior to data collection. All participants received a clear explanation of the study objectives, procedures, potential risks, and benefits. Written informed consent was obtained from each participant. Confidentiality of personal data was maintained throughout the study, and blood sampling was performed by qualified personnel following ethical and safety guidelines for human research.

III. RESULT

A. MEASUREMENT OF CARBOXYHEMOGLOBIN LEVEL

Measurement of COHb levels on this study used the Hinsberg-Lang method, which measures the absorbance of reagents from blood samples with CO and NH4OH, and the absorbance of standards from blood samples with CO, NH4OH, and $Na_2S_2O_4$. COHb concentration is obtained from the calculation of reagent absorbance divided by standard absorbance, multiplied by the conversion factor [9].

TABLE 1
Data of Respondents Based on Cohb Levels of Fish Smoking Workers in Penatarsewu Village Sidoarjo

Average	0.99%
Maximum	1.72%
Minimum	0.40%
Normal limit	<3.5%

TABLE 1 showed that the COHb levels of fish smoking workers in Penatarewu Village Sidoarjo were still in the normal category (≤ 3.5%), with the lowest level of 0.40% and the highest of 1.72%. This study is not in line with Cahyani & Pramana (2022), who found 59.5% of workers experienced abnormal CO exposure, because the study sample was limited to women who did not smoke [8]. However, the results of this study were related with Pamukti (2021), who have found that COHb levels of roof tile workers were still below the ACGIH standard (3.5%) [10]. Variations in COHb levels can be caused by differences in endurance, lifestyle, physical activity, diet, and rest habits. Other factors that affect COHb levels include CO in the air, length of exposure, age, and smoking habits.

B. IDENTIFICATION OF SUBJECTIVE COMPLAINTS OF FISH SMOKING WORKERS IN PENATARSEWU VILLAGE SIDOARJO

Subjective complaints are complaints felt by a person due to smoke from smoking fish, such as coughing, phlegm, shortness of breath, flu, runny nose, nausea, and headache [11]. In addition to exposure to carbon monoxide gas, respiratory complaints are also influenced by length of exposure and smoking habits [12]. Data on subjective complaints from fish smoking workers in Penatarsewu Village, Sidoarjo were obtained through interviews conducted after blood sampling, using an interview sheet the record results

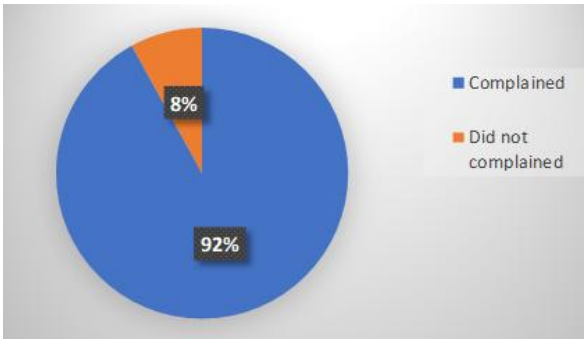

FIGURE 1. **Percentage of Subjective Complaints of Fish Smoking Workers in Penatarsewu Village, Sidoarjo**

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FIGURE 1 showed that the 25 respondents, 23 people (92%) experienced subjective complaints, while 2 people (8%) did not. These results differ from Idrus' (2022) study on satay sellers in Palembang, which found 24 out of 58 respondents (41.4%) experienced respiratory complaints [12]. This difference may be due to different methods or populations in the two studies.

Physiological adaptation occurs as an adjustment to the environment. Frequent exposure to charcoal smoke makes workers' bodies develop immunity to upper respiratory tract infections, so they do not feel subjective respiratory complaints. This adaptation allows them to better withstand repeated exposure to smoke.

C. THE EFFECT OF CARBOXYHEMOGLOBIN ON SUBJECTIVE COMPLAINTS OF FISH SMOKING WORKERS IN PENATARSEWU VILLAGE SIDOARJO

High levels of COHb in a person's blood can occur due to exposure to carbon monoxide (CO) gas, which has a stronger binding force to hemoglobin than oxygen. The

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bond between hemoglobin and CO forms COHb in the blood. Abnormal COHb levels (>3.5%) can increase a person's risk of experiencing subjective complaints [13].

Based on the simple linear regression test, the effect of carboxyhemoglobin on subjective complaints in fish smoking workers in the village has a significance value of 0.372, which is greater than 0.05. This means there was no significant influence between COHb levels and subjective complaints in these workers.

Research by Rezki Wijaya (2022) states that there is a strong correlation between exposure to carbon monoxide gas and subjective complaints [7]. The difference in results was caused by differences in research variables; Wijaya used the concentration of CO gas in the air, while this study used COHb variables to determine CO gas exposure. This shows that the methods and variables used can affect the results of research related to carbon monoxide gas exposure and subjective complaints [7].

D. THE EFFECT OF AGE ON SUBJECTIVE COMPLAINTS OF FISH SMOKING WORKERS IN PENATARSEWU VILLAGE, SIDOARJO

Human age is measured in years, and with age, the function of the lung organs tends to decrease, so individuals are more easily exposed to harmful pollutant gases such as carbon monoxide (CO). Exposure to carbon monoxyde can increase COHb levels, which has the potential to cause subjective complaints for individuals exposed to the gas [14].

TABLE 2
Data of Respondents Based on Age of Fish Smoking Workers in Penatarsewu Village Sidoarjo

Average	48 years old
Maximum	68 years old
Minimum	20 years old
Statistical Test Result	0,000

According to TABLE 2, the workers' average age was 48 years old, with the oldest being 68 years old and the youngest being 20. The results of statistical tests using the basic linear regression approach indicated a significant relationship between the age of employees and the reported subjective complaints, with a significance value of 0.000. This study is in line with the findings of Anggraeni (2022) who also showed a relationship between age and subjective respiratory complaints [15].

Fish smoking workers in this study have a significant age range, from 20 to 68 years old. As we age, the function of the body's organs, including the lungs, declines, making individuals more susceptible to respiratory disorders due to muscle degeneration and loss of tissue elasticity. The performance of the respiratory muscles also declines, with a decrease of about 20% after the age of 40 [16],

E. THE EFFECT OF LENGTH EXPOSURE ON SUBJECTIVE COMPLAINTS OF FISH SMOKING WORKERS IN PENATARSEWU VILLAGE, SIDOARJO

Length of exposure is a term used to describe a period of time that indicates how long a person is exposed to a pollutant in a day. The longer a person is exposed, the higher the risk of health problems they can experience [17]. Length of exposure takes into account the duration of exposure to risk factors that have the potential to cause health problems.

TABLE 3
Data Of Respondents Based On Length Exposure Of Fish Smoking Workers In Penatarsewu Village Sidoarjo

Average	**3,8 hours**
Maximum	5 hours
Minimum	3 hours
Statistical Test Result	0,003

TABLE 3 revealed that the workers' daily average exposure time was 3.8 hours, with the minimum being 3 hours and the highest being 5 hours. A significance value of 0.003 was obtained using a simple linear regression test, which means there was a significant influence between the length of exposure and subjective complaints in fish smoking workers in Penatarsewu Village Sidoarjo. These findings are consistent with a study by Mutiara Christina (2017), who discovered a strong correlation between the duration of exposure and the officers' subjective reports of severe respiratory deseases in the underground parking lots of Blok M Mall and Poins Square [18].

The length of exposure of fish smoking workers in Penatarsewu Village Sidoarjo varies between 3 to 5 hours per day. This variation in exposure duration affects the subjective complaints felt by workers. The longer the duration of exposure, the greater the likelihood of workers experiencing health complaints, especially related to respiratory disorders.

F. THE EFFECT OF TENURE ON SUBJECTIVE COMPLAINTS OF FISH SMOKING WORKERS IN PENATARSEWU VILLAGE, SIDOARJO

Tenure refers to the duration of time a person has worked since they first entered the workforce. The length of service can affect subjective complaints, because the longer a person is exposed to hazards in the work environment, the higher the risk of health complaints that may arise.

TABLE 4
Data of Respondents Based on Tenure of Fish Smoking Workers in Penatarsewu Village Sidoarjo

Average	**5,7 years**
Maximum	16 years
Minimum	3 years
Statistical Test Result	0,705

TABLE 4 showed that it was found that the average working period of fish smoking workers in Penatarsewu Village Sidoarjo was 5.7 years, with the shortest working period of 3 years and the longest of 16 years. The simple linear regression test showed a significance value of 0.705, which means there is no significant influence between tenure and subjective complaints in fish smoking workers in Penatarsewu Sidoarjo Village. This result is consistent with the research of Fauziah et al. (2020) who found that tenure has no relationship with subjective complaints in the coal stockpile area.

The possible cause of the absence of a relationship in these variables is due to a regular lifestyle, such as getting enough rest, eating nutritious food, and exercising regularly. In addition, the more often a person is exposed

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to occupational hazards each day, the more his or her immunity may increase, so tenure does not have an effect on subjective respiratory complaints.

IV. DISCUSSION

A. Interpretation of the Main Findings

This study examined the relationship between carboxyhemoglobin (COHb) levels and subjective complaints among fish smoking workers in Penatarsewu Village, Sidoarjo, while accounting for age, daily exposure duration, and work tenure. The findings indicate that although the vast majority of respondents (92%) reported experiencing subjective complaints, all measured COHb levels remained within the normal range for non-smokers (≤3.5%). Statistical analysis demonstrated that COHb levels did not have a significant effect on subjective complaints, whereas age and duration of daily exposure were significantly associated with the occurrence of symptoms.

The absence of a significant relationship between COHb levels and subjective complaints suggests that acute physiological CO burden, as reflected by COHb, may not be the primary determinant of perceived health symptoms in this occupational setting. This finding implies that subjective complaints may arise even when COHb levels are relatively low, potentially due to cumulative exposure to other smoke constituents such as particulate matter, aldehydes, and polycyclic aromatic hydrocarbons, which are known respiratory irritants but are not captured by COHb measurement alone [31]. Furthermore, COHb reflects relatively recent exposure and may not adequately represent chronic low-level exposure patterns characteristic of traditional fish smoking activities.

In contrast, age emerged as a significant predictor of subjective complaints. This association is biologically plausible, as advancing age is associated with declining pulmonary function, reduced mucociliary clearance, and diminished physiological reserve, rendering older workers more susceptible to airborne pollutants [32]. Similarly, the significant effect of daily exposure duration highlights the importance of time-intensity of exposure. Workers who spend longer hours in smoke-filled environments are likely to experience greater cumulative inhalation of harmful pollutants, increasing the probability of respiratory and neurological symptoms regardless of COHb concentration at the time of measurement.

Interestingly, work tenure did not demonstrate a significant association with subjective complaints. This may reflect adaptive physiological or behavioral mechanisms, whereby long-term workers develop tolerance or coping strategies that reduce symptom perception. Alternatively, this finding may indicate a "healthy worker effect," in which individuals who experience severe symptoms leave the occupation earlier, leaving behind a relatively healthier long-term workforce [33].

B. Comparison with Previous Studies

The findings of this study partially align with and partially diverge from previous research on occupational exposure to biomass smoke. Several studies conducted among informal workers, including charcoal producers, traffic police, and street food vendors, have reported significant associations between elevated COHb levels and respiratory or neurological symptoms [34], [35]. However, these studies often involved higher ambient CO concentrations, mixed smoking status among participants, or more enclosed working environments, which may explain the discrepancy with the present findings.

Studies specifically focused on fish smoking workers have reported high prevalence of respiratory symptoms, consistent with the current study's observation that over 90% of respondents experienced subjective complaints [36]. However, many of these studies relied solely on self-reported exposure or environmental CO measurements, without incorporating biological markers such as COHb. Research conducted in Ghana and Nigeria demonstrated that fish smokers frequently experience cough, dyspnea, and eye irritation, with symptom severity correlating more strongly with exposure duration and ventilation conditions than with measured CO levels [37]. These findings support the present study's conclusion that exposure duration plays a more critical role than COHb in determining subjective complaints.

The lack of association between tenure and symptoms observed in this study is consistent with findings reported by Chen et al. [38], who noted that long-term exposure duration per day, rather than cumulative years of employment, was a stronger predictor of respiratory complaints among biomass-exposed workers. Conversely, other studies have reported significant associations between tenure and chronic respiratory outcomes, particularly in settings with higher pollutant concentrations or limited environmental controls [39]. These contrasting results suggest that the impact of tenure may be context-specific and influenced by factors such as ventilation, fuel type, and individual susceptibility.

Overall, the comparison with previous studies indicates that while CO exposure is a recognized occupational hazard, subjective complaints among fish smoking workers appear to be multifactorial, with age and daily exposure duration exerting greater influence than COHb levels alone. This underscores the importance of adopting a holistic exposure assessment approach rather than relying on a single biomarker.

C. Limitations, Implications, and Future Directions

Several limitations of this study should be acknowledged. First, the cross-sectional design limits causal inference, as exposure and outcome were assessed simultaneously. As a result, temporal relationships between CO exposure, COHb levels, and subjective complaints cannot be definitively established. Longitudinal or prospective studies would be more suitable for examining causal pathways and long-term health effects [40].

Second, the relatively small sample size and restriction to female non-smoking workers may limit the generalizability of the findings to broader fish smoking populations, including male workers or smokers. However, this restriction was intentionally applied to reduce confounding from tobacco-related CO exposure and sex-related physiological differences. Future studies

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should consider larger, more diverse samples to enhance external validity.

Third, COHb was used as the sole biological marker of exposure. While COHb is a well-established indicator of CO exposure, it does not capture exposure to other harmful components of smoke, such as $PM_{2.5}$ and PAHs, which may independently contribute to subjective complaints. Incorporating multi-pollutant exposure assessments and additional biomarkers would provide a more comprehensive understanding of occupational health risks [41].

Despite these limitations, the findings of this study have important practical implications. The significant influence of age and daily exposure duration suggests that occupational health interventions should prioritize work organization strategies, such as limiting daily exposure hours and implementing shift rotations. Additionally, worker selection and task allocation should consider age-related vulnerability to smoke exposure. The high prevalence of subjective complaints, even in the presence of normal COHb levels, highlights the need for improved ventilation and consistent use of personal protective equipment, such as half-face respirators.

From a policy perspective, the results emphasize the importance of extending occupational health surveillance and risk management programs to informal sectors such as traditional fish smoking. Future research should focus on longitudinal health monitoring, evaluation of engineering controls, and assessment of combined pollutant exposures to develop evidence-based guidelines for protecting the health of fish smoking workers.

V. CONCLUSION

This study was conducted with the aim of analyzing the effect of carboxyhemoglobin (COHb) levels on subjective health complaints among fish smoking workers in Penatarsewu Village, Sidoarjo, while considering age, daily exposure duration, and work tenure as potential influencing factors. The findings demonstrate that all respondents had COHb levels within the normal range for non-smokers (≤3.5%), with measured values ranging from 0.40% to 1.72% and an average of approximately 0.99%. Despite these normal physiological indicators, a very high proportion of workers 23 out of 25 respondents (92%) reported experiencing subjective complaints, predominantly respiratory and neurological symptoms such as cough, runny nose, dizziness, headache, and nausea. Statistical analysis revealed that COHb levels did not have a significant effect on subjective complaints ($p = 0.372$), indicating that current COHb concentrations alone were insufficient to explain the high prevalence of symptoms. Similarly, work tenure showed no significant association with subjective complaints ($p = 0.705$). In contrast, age and duration of daily exposure were found to be significant determinants of subjective complaints, with age showing a strong association ($p < 0.001$) and daily exposure duration also demonstrating a significant effect ($p = 0.003$). These results suggest that individual susceptibility related to aging and the intensity of daily exposure play a more critical role in the occurrence of subjective complaints than short-term physiological CO burden as reflected by COHb levels. Based on these findings, it can be concluded that occupational health risks among fish smoking workers are multifactorial and cannot be adequately assessed using a single biomarker. The results underscore the importance of managing exposure duration, organizing work shifts, and considering age-related vulnerability in this occupational group. For future research, longitudinal or prospective study designs are recommended to better establish causal relationships between chronic smoke exposure and health outcomes. Additionally, future studies should incorporate larger and more diverse samples, include male workers and smokers, and assess multiple exposure indicators such as particulate matter, polycyclic aromatic hydrocarbons, oxygen saturation, or pulmonary function to provide a more comprehensive evaluation of occupational health risks in traditional fish smoking industries.

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DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTION

All authors contributed substantially to this research. E.I.S. conceptualized the study, designed the methodology, and supervised data collection. I.S. contributed to data analysis and interpretation of results. P.A.I. assisted in laboratory analysis and data validation, while R. contributed to manuscript drafting, critical revision, and literature review. All authors reviewed, revised, and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

DECLARATIONS

ETHICAL APPROVAL

This study was approved by the institutional ethics committee of Poltekkes Kemenkes Surabaya. Written informed consent was obtained from all participants prior to data collection.

CONSENT FOR PUBLICATION PARTICIPANTS

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Not applicable.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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