

Personal Hygiene Practices and Blood Cholinesterase Activity among Tobacco Pesticide Sprayers in Rural Indonesia

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Abstrak

Penyemprot pestisida berisiko tinggi terpapar pestisida di tempat kerja, terutama di lingkungan pertanian pedesaan di mana tindakan pencegahan terbatas. Praktik kebersihan pribadi dapat memainkan peran penting dalam mengurangi paparan pestisida internal, namun bukti berbasis biomarker dari pedesaan Indonesia masih langka. Studi ini bertujuan untuk meneliti hubungan antara praktik kebersihan pribadi dan aktivitas kolinesterase darah di antara penyemprot pestisida tembakau di pedesaan Indonesia dan untuk menggambarkan keluhan kesehatan terkait. Studi potong lintang dilakukan pada 20 penyemprot pestisida tembakau di Desa Jelbudan, Jawa Timur, Indonesia, menggunakan pendekatan pengambilan sampel total. Praktik kebersihan pribadi dan keluhan kesehatan dinilai melalui wawancara terstruktur. Aktivitas kolinesterase darah diukur menggunakan kit Tintometer dan dikategorikan menurut nilai referensi standar. Data dianalisis secara deskriptif dan menggunakan rasio prevalensi untuk menilai hubungan. Praktik kebersihan pribadi yang tidak memadai umum terjadi, terutama kegagalan mencuci tangan dengan sabun setelah penyemprotan (55%). Inhibisi kolinesterase ringan diamati pada 60% peserta. Penyemprot yang tidak segera mencuci tangan setelah menyemprot memiliki prevalensi aktivitas kolinesterase yang menurun lebih tinggi (PR = 1,84) dibandingkan mereka yang mencuci tangan dengan benar. Sakit kepala, pusing, dan sesak napas adalah keluhan kesehatan yang paling sering dilaporkan, meskipun hubungannya dengan aktivitas kolinesterase lemah. Praktik kebersihan pribadi yang buruk lazim terjadi di kalangan penyemprot pestisida tembakau dan dikaitkan dengan penurunan aktivitas kolinesterase darah. Mempromosikan perilaku kebersihan dasar dan biomonitoring rutin dapat membantu mengurangi paparan pestisida di tempat kerja di komunitas pertanian pedesaan.

Kata Kunci:

Praktik kebersihan pribadi; Aktivitas kolinesterase darah; Paparan pestisida; Penyemprot tembakau; Kesehatan kerja

Abstract

Pesticide sprayers are at high risk of occupational exposure, particularly in rural agricultural settings where preventive measures are limited. Personal hygiene practices may play a critical role in reducing internal pesticide exposure, yet biomarker-based evidence from rural Indonesia remains scarce. This study aimed to examine the association between personal hygiene practices and blood cholinesterase activity among tobacco pesticide sprayers in rural Indonesia and to describe related health complaints. A cross-sectional study was conducted among 20 tobacco pesticide sprayers in Jelbudan Village, East Java, Indonesia, using a total sampling approach. Personal hygiene practices and health complaints were assessed through structured interviews. Blood cholinesterase activity was measured using a Tintometer kit and categorized according to standard reference values. Data were analyzed descriptively and using prevalence ratios to assess associations. Inadequate personal hygiene practices were common, particularly failure to wash hands with soap after spraying (55%). Mild cholinesterase inhibition was observed in 60% of participants. Sprayers who did not wash their hands immediately after spraying had a higher prevalence of reduced cholinesterase activity (PR = 1.84) than those who washed their hands properly. Headache, dizziness, and shortness of breath were the most frequently reported health complaints, although their association with cholinesterase activity was weak. Poor personal hygiene practices are prevalent among tobacco pesticide sprayers and are associated with reduced blood cholinesterase activity. Promoting basic hygiene behaviors and routine biomonitoring may help reduce occupational pesticide exposure in rural agricultural communities.

Keyword:

Personal hygiene practices; Blood cholinesterase activity; Pesticide exposure; Tobacco sprayers; Occupational health

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INTRODUCTION

The use of pesticides remains an integral part of agricultural practices worldwide, particularly in low- and middle-income countries where agriculture is a primary source of livelihood (Boedeker, Watts, Clausen, & Marquez, 2020). Pesticides are widely applied to control pests and diseases that threaten crop productivity, including in tobacco cultivation, a commodity that requires intensive pest management due to its high susceptibility to insect infestation (K. H. Kim, Kabir, & Jahan, 2021). Despite their agronomic benefits, pesticides pose substantial risks to human health, especially among agricultural workers who are directly exposed during preparation, application, and post-application activities (Damalas & Koutroubas, 2019; Negatu, Kromhout, Mekonnen, & Vermeulen, 2020). Occupational exposure to pesticides has been consistently associated with a wide range of acute and chronic health effects, ranging from mild neurological symptoms to severe systemic toxicity (Sombatsawat, Siri Wong, & Puangthongthub, 2023; Wesseling, Keifer, & Ahlbom, 2020).

Among the various health hazards linked to pesticide exposure, inhibition of blood cholinesterase activity is one of the most widely recognized biological indicators of pesticide-related toxicity (Carvalho, 2019). Cholinesterase enzymes, particularly acetylcholinesterase (AChE), play a critical role in the normal functioning of the nervous system by hydrolyzing acetylcholine at synaptic junctions (Gullino, Keller, & Garibaldi, 2023). Exposure to certain classes of pesticides most notably organophosphates and carbamates can inhibit cholinesterase activity, leading to the accumulation of acetylcholine and subsequent overstimulation of cholinergic receptors, a mechanism underlying many neurological and systemic symptoms observed among pesticide-exposed workers (Sabarwal, Kumar, & Sharma, 2020).

Over the past several decades, blood cholinesterase activity has been widely utilized as a biomarker for assessing occupational exposure to pesticides, particularly in agricultural settings (Ratnasekhar & Reddy, 2021). Numerous studies conducted in different regions have documented reduced cholinesterase levels among pesticide sprayers, farm workers, and pest control operators, underscoring the relevance of cholinesterase monitoring for early detection of pesticide toxicity and for guiding preventive interventions in occupational health (Sprengel & Souza, 2020).

Recent international literature highlights that pesticide-related health risks are not solely determined by the type and toxicity of the chemical agents used, but also by behavioral and environmental factors that influence exposure intensity (Rani & Singh, 2022). Among these factors, personal hygiene practices have received increasing attention as modifiable behaviors that significantly affect the extent of pesticide absorption through dermal, oral, and inhalation routes (Mekonnen & Agonafir, 2020). Practices such as handwashing with soap after spraying, changing contaminated clothing, bathing promptly after pesticide application, and avoiding eating, drinking, or smoking during or immediately after spraying are widely recommended as basic protective measures to reduce pesticide exposure (Alarcon & Calvert, 2020).

Several studies conducted in Asia, Africa, and Latin America have demonstrated that inadequate personal hygiene is associated with higher levels of pesticide residues on the body, increased internal exposure, and a greater prevalence of pesticide-related symptoms (Negatu, Kromhout, & Mekonnen, 2021). Research among agricultural workers in Thailand, Vietnam, India, and China has reported that failure to wash hands after spraying and improper handling of contaminated clothing are significantly associated with decreased blood cholinesterase activity and increased neurological complaints (Jørs & Neupane, 2019). These findings indicate that personal hygiene practices play a critical role in mediating the health effects of pesticide exposure, particularly in contexts where the use of personal protective equipment is limited or inconsistent (Damalas, 2022).

In Indonesia, agriculture remains a major economic sector employing a large proportion of the rural population, with tobacco farming being one of the most prominent agricultural activities in regions such as East Java (Munfiah & Wibowo, 2023). Tobacco pesticide sprayers constitute a high-risk occupational group due to frequent pesticide application, prolonged exposure, and limited access to occupational health services (Maksuk, 2024). Previous studies in Indonesia have primarily focused on the prevalence of pesticide poisoning, farmers' knowledge and attitudes, or the use of personal protective equipment, while relatively few have integrated behavioral factors such as personal hygiene with objective biological markers of exposure such as blood cholinesterase activity (Hartini, 2025).

Furthermore, much of the existing research in Indonesia relies on self-reported symptoms without corroborating laboratory-based biomarkers, which may lead to underestimation or misclassification of pesticide-related health effects. Consequently, there is a growing recognition of the need for biomarker-based

studies that provide objective evidence of pesticide exposure and its association with modifiable behavioral factors in rural agricultural settings.

Despite established guidelines emphasizing the importance of personal hygiene in reducing pesticide exposure, compliance among agricultural workers remains suboptimal, particularly in rural areas. Many pesticide sprayers continue to eat, drink, or smoke immediately after spraying without washing their hands, reuse contaminated clothing, and delay bathing due to limited access to clean water or insufficient awareness, practices that substantially increase internal pesticide exposure.

In rural Indonesia, especially in tobacco-producing regions, empirical evidence linking specific personal hygiene practices with biological indicators of pesticide exposure and health complaints remains limited. This lack of evidence constrains public health authorities and agricultural extension services in designing effective, evidence-based interventions tailored to actual exposure pathways. The present study addresses these gaps by examining the association between personal hygiene practices and blood cholinesterase activity among tobacco pesticide sprayers in a rural Indonesian setting. By integrating behavioral assessments with biomarker measurements, this study provides empirical evidence linking modifiable hygiene practices to measurable health risks and aims to support the development of practical, behavior-based strategies to improve occupational health and safety among agricultural workers.

Moreover, occupational health surveillance systems in rural Indonesia rarely include routine cholinesterase monitoring, and pesticide poisoning cases are often underreported. As a result, mild to moderate pesticide toxicity may go undetected, allowing cumulative exposure to persist over time and potentially leading to long-term neurological and systemic health consequences. Addressing this issue requires research that not only documents the prevalence of unsafe hygiene practices but also demonstrates their measurable impact on biological markers and health outcomes.

Several interrelated factors underscore the urgency of this research. First, tobacco pesticide sprayers in rural Indonesia represent a vulnerable population with limited access to occupational health protections, training, and regular medical screening. Second, personal hygiene practices are relatively low-cost and feasible interventions compared to engineering controls or advanced protective equipment, making them particularly relevant in resource-limited settings. Third, early detection of reduced blood cholinesterase activity provides an opportunity for timely intervention before severe poisoning occurs.

In addition, the continued reliance on pesticides in tobacco cultivation, combined with climate variability and increasing pest resistance, may further intensify pesticide use in the future. Without adequate preventive measures, the health burden associated with pesticide exposure among rural agricultural workers is likely to increase. Evidence-based research that highlights modifiable behavioral risk factors is therefore essential to inform public health policies, occupational safety guidelines, and community-based education programs.

Although international studies have explored the relationship between personal hygiene and pesticide exposure, several critical gaps remain, particularly in the Indonesian context. First, there is a lack of studies focusing specifically on tobacco pesticide sprayers, a group characterized by frequent pesticide application and prolonged exposure. Second, few studies in rural Indonesia have combined behavioral assessments of personal hygiene with objective biomarker measurements such as blood cholinesterase activity. Third, existing research often treats personal hygiene as a general concept without examining specific practices that may differentially influence exposure risk.

The present study addresses these gaps by examining the association between personal hygiene practices and blood cholinesterase activity among tobacco pesticide sprayers in a rural Indonesian setting. By integrating questionnaire-based assessments of hygiene behaviors with laboratory measurements of blood cholinesterase levels, this study provides a more comprehensive understanding of how everyday practices influence biological exposure and health complaints. The novelty of this research lies in its biomarker-based approach within a rural tobacco-farming community, providing empirical evidence linking modifiable behaviors to measurable health risks. Furthermore, this study contributes to the growing body of occupational health literature by contextualizing pesticide exposure within the realities of rural agricultural work in Indonesia. The findings are expected to inform targeted interventions that prioritize feasible, culturally appropriate hygiene practices to reduce pesticide-related health risks.

Based on the aforementioned background, this study aims to examine the association between personal hygiene practices and blood cholinesterase activity among tobacco pesticide sprayers in rural Indonesia. Additionally, the study seeks to describe the prevalence of health complaints associated with pesticide exposure and to examine their relationship with cholinesterase activity. By elucidating these associations, the

study aims to provide evidence to support the development of practical, behavior-based strategies to improve occupational health and safety among agricultural workers in rural settings.

METHOD

This study employed a quantitative observational design with a cross-sectional approach. A cross-sectional design was selected to assess the association between personal hygiene practices and blood cholinesterase activity at a single point in time among tobacco pesticide sprayers. This design is appropriate for identifying exposure–outcome relationships in occupational health studies, particularly when investigating behavioral risk factors and biological markers of exposure in resource-limited settings. The study was conducted during the active tobacco spraying season, when pesticide exposure among sprayers was most likely to occur. By simultaneously collecting data on hygiene practices, blood cholinesterase activity, and health complaints, the study aimed to provide a comprehensive snapshot of occupational exposure and its potential health implications.

The study participants consisted of tobacco pesticide sprayers residing and actively working in Jelbudan Village, Dasuk District, Sumenep Regency, East Java, Indonesia. This group was selected because pesticide sprayers represent the occupational population most directly exposed to pesticides during preparation, application, and post-application activities in tobacco farming. Eligibility criteria were established to ensure that participants had sufficient exposure and that their experience was relevant to the study objectives. Individuals were included if they were actively involved in pesticide spraying, had at least 3 years of spraying experience, were aged 18 years or older, and were willing to participate voluntarily in the study, including completing interviews and providing blood samples. Individuals with known neurological disorders unrelated to pesticide exposure or those receiving medical treatment that could affect cholinesterase activity were excluded. Given the relatively small and well-defined population of tobacco pesticide sprayers in the study area, a total sampling technique was employed. All individuals who met the inclusion criteria during the study period were invited to participate. This approach was chosen to minimize selection bias and to ensure comprehensive representation of the target population. A total of 20 pesticide sprayers fulfilled the eligibility criteria and were successfully recruited into the study. The use of total sampling was considered appropriate for this cross-sectional occupational health study, as it enabled complete coverage of the exposed population in the rural setting while providing sufficient data to describe associations between personal hygiene practices and blood cholinesterase activity.

Data in this study were collected using a combination of structured questionnaires and biological measurement instruments to comprehensively assess personal hygiene practices, blood cholinesterase activity, and health complaints among tobacco pesticide sprayers. The use of both self-reported behavioral data and objective biological markers was intended to enhance the validity of exposure assessment and to provide a more robust understanding of occupational pesticide exposure in the study population. Personal hygiene practices were assessed using a structured interviewer-administered questionnaire developed based on occupational health guidelines for pesticide safety and adapted from previous studies on pesticide exposure among agricultural workers. The questionnaire was designed to capture routine hygiene behaviors performed after pesticide spraying that may influence dermal and oral pesticide exposure. To ensure clarity and consistency, the instrument consisted of closed-ended questions with dichotomous response options (Yes/No). The questionnaire was administered through face-to-face interviews to minimize misinterpretation and to accommodate varying levels of literacy among participants.

Table 1. Personal Hygiene Practices Assessment Instrument

No	Personal Hygiene Practice Assessed
1	Washing hands with soap immediately after pesticide spraying
2	Bathing with soap and shampoo after spraying
3	Eating without washing hands or bathing after spraying
4	Drinking without washing hands or bathing after spraying
5	Smoking without washing hands or bathing after spraying
6	Changing work clothes immediately after spraying
7	Using spraying clothes as daily clothing
8	Reusing spraying clothes without washing
9	Washing spraying clothes using detergent
10	Washing spraying clothes together with family members' clothing

Blood cholinesterase activity was measured using a Tintometer Cholinesterase Test Kit, a standardized field-based instrument commonly used for occupational exposure monitoring. Capillary blood samples were collected from the fingertip using sterile lancets by trained laboratory personnel. The test procedure followed national health guidelines, and results were expressed as a percentage of regular cholinesterase activity. Based on established reference values, cholinesterase activity was categorized into standard (75–100%), mild inhibition (50–74%), moderate inhibition (25–49%), and severe inhibition (<25%). In this study, blood cholinesterase activity served as an objective biomarker of pesticide exposure.

Health complaints potentially related to pesticide exposure were assessed using a symptom checklist administered during the interview. Participants were asked whether they experienced common symptoms associated with pesticide exposure during or after spraying activities. These symptoms included headache, dizziness, fatigue, shortness of breath, nausea, blurred vision, and abdominal discomfort. Responses were recorded in a dichotomous format (Yes/No) to facilitate descriptive analysis and comparison with biological findings. The combination of structured questionnaires and biological measurements enabled triangulation of data, allowing the study to examine the relationship between personal hygiene practices, biological indicators of pesticide exposure, and self-reported health complaints in a rural agricultural setting.

All collected data were reviewed for completeness and consistency before analysis. Descriptive statistical analysis was performed to summarize participant characteristics, personal hygiene practices, blood cholinesterase activity, and reported health complaints. Categorical variables were presented as frequencies and percentages to describe the distribution of hygiene behaviors, cholinesterase activity categories, and health-related symptoms among the study participants.

To examine the association between personal hygiene practices and blood cholinesterase activity, two-by-two (2×2) contingency tables were constructed. The prevalence ratio (PR) was calculated as the primary measure of association, as it is considered appropriate for cross-sectional studies when assessing the relationship between exposure and outcome variables. In this study, key personal hygiene behaviors—particularly handwashing with soap after pesticide spraying—were analyzed in relation to cholinesterase activity categories (standard versus mild inhibition). The prevalence ratio was used to estimate the relative likelihood of reduced cholinesterase activity among participants with inadequate hygiene practices compared to those with adequate practices.

Associations between self-reported health complaints and blood cholinesterase activity were analyzed using the same descriptive and comparative approach. Health symptoms were dichotomized as present or absent and examined in relation to cholinesterase activity categories to explore potential biological–clinical relationships. Given the limited sample size, inferential statistical testing was not emphasized; instead, the analysis focused on the magnitude and direction of observed associations to provide meaningful epidemiological insight. All analytical procedures were conducted with careful consideration of the study’s cross-sectional design and sample size. Results were interpreted descriptively and cautiously, avoiding causal inference, and were presented in tables to facilitate clarity and transparency.

RESULT AND DISCUSSION

This section presents the study's findings on personal hygiene practices, blood cholinesterase activity, and health complaints among tobacco pesticide sprayers in rural Indonesia. Results are organized to provide a comprehensive overview of respondent characteristics, distribution of hygiene behaviors, biological indicators of pesticide exposure, and observed associations between key variables. All results are presented descriptively and analytically to facilitate interpretation while maintaining consistency with the cross-sectional study design. A total of 20 tobacco pesticide sprayers participated in the study. All respondents were actively involved in pesticide spraying activities during the data collection period and met the predefined inclusion criteria.

Table 2. Characteristics of Study Participants (n = 20)

Characteristic	Category	n	%
Age (years)	≥18 years	20	100
Spraying experience	≥3 years	20	100
Occupational role	Tobacco pesticide sprayer	20	100

All respondents had prolonged occupational exposure to pesticides due to their involvement in routine spraying activities over multiple years. This uniformity in occupational exposure ensured that the study population was relevant for examining the relationship between hygiene practices and biological indicators of pesticide exposure.

Table 3. Distribution of Personal Hygiene Practices among Tobacco Pesticide Sprayers

No	Personal Hygiene Practice	Yes n (%)	No n (%)
1	Handwashing with soap after spraying	9 (45.0)	11 (55.0)
2	Bathing with soap and shampoo after spraying	13 (65.0)	7 (35.0)
3	Eating without washing hands or bathing	4 (20.0)	16 (80.0)
4	Drinking without washing hands or bathing	17 (85.0)	3 (15.0)
5	Smoking without washing hands or bathing	17 (85.0)	3 (15.0)
6	Changing work clothes immediately after spraying	2 (10.0)	18 (90.0)
7	Using spraying clothes as daily clothing	15 (75.0)	5 (25.0)
8	Reusing spraying clothes without washing	20 (100)	0 (0.0)
9	Washing spraying clothes with detergent	20 (100)	0 (0.0)
10	Washing spraying clothes together with family clothing	20 (100)	0 (0.0)

The results indicate that inadequate personal hygiene practices were prevalent among the majority of respondents. More than half of the sprayers (55%) did not wash their hands with soap immediately after spraying, and an even higher proportion reported drinking or smoking before washing or bathing. Notably, 90% of respondents did not change their work clothes immediately after spraying, and all respondents reported reusing contaminated clothing and washing it together with household laundry, potentially increasing secondary exposure risks for family members. These findings highlight substantial gaps in post-spraying hygiene behaviors that may contribute to ongoing pesticide exposure among sprayers and their households.

Table 4. Distribution of Blood Cholinesterase Activity Levels

Cholinesterase Activity Level	Category	n	%
75–100% of normal	Normal	8	40.0
50–74% of normal	Mild inhibition	12	60.0
<50% of normal	Moderate–severe inhibition	0	0.0
Total		20	100

More than half of the respondents (60%) exhibited mild inhibition of blood cholinesterase activity, indicating early biological effects of pesticide exposure. Although no cases of moderate or severe inhibition were observed, the predominance of reduced cholinesterase activity suggests ongoing low-level exposure that may accumulate over time if preventive measures are not implemented. From an occupational health perspective, mild cholinesterase inhibition is clinically relevant, as it may precede more severe toxicity if exposure continues.

Table 5. Distribution of Health Complaints among Tobacco Pesticide Sprayers

Health Complaint	Yes n (%)	No n (%)
Headache	9 (45.0)	11 (55.0)
Dizziness	8 (40.0)	12 (60.0)
Shortness of breath	7 (35.0)	13 (65.0)
Fatigue	3 (15.0)	17 (85.0)
Nausea	2 (10.0)	18 (90.0)
Blurred vision	1 (5.0)	19 (95.0)
Abdominal cramps	0 (0.0)	20 (100)

Headache, dizziness, and shortness of breath were the most frequently reported symptoms. These complaints are consistent with early neurological and respiratory effects commonly associated with pesticide exposure. Although the prevalence of severe symptoms was low, the presence of multiple mild symptoms among a substantial proportion of respondents warrants attention, particularly in conjunction with reduced cholinesterase activity.

Table 6. Association between Handwashing with Soap after Spraying and Blood Cholinesterase Activity

Handwashing Practice	Mild Inhibition n (%)	Normal n (%)	Total (%)
Did not wash hands immediately	9 (81.8)	2 (18.2)	100
Washed hands immediately	4 (44.4)	5 (55.6)	100
Prevalence Ratio (PR)			1.84

Respondents who did not wash their hands with soap immediately after spraying had a 1.84 times higher prevalence of mild cholinesterase inhibition compared to those who practiced proper handwashing. This finding suggests that inadequate hand hygiene may substantially increase internal pesticide exposure, reinforcing the importance of handwashing as a key preventive behavior.

Table 7. Association between Headache and Blood Cholinesterase Activity

Headache Complaint	Mild Inhibition n (%)	Normal n (%)	Total (%)
Headache present	6 (66.7)	3 (33.3)	100
No headache	7 (63.6)	4 (36.4)	100
Prevalence Ratio (PR)			1.04

The prevalence ratio indicates only a slight difference between respondents with and without headaches. This suggests that while headache is a common complaint, it may not be a strong standalone indicator of cholinesterase inhibition. Multiple factors, including individual susceptibility, environmental conditions, and non-occupational causes, may influence health complaints. Overall, the results demonstrate a high prevalence of inadequate personal hygiene practices among tobacco pesticide sprayers, a substantial proportion of reduced blood cholinesterase activity, and frequent mild health complaints. The observed association between poor hand hygiene and reduced cholinesterase activity underscores the importance of behavioral factors in occupational pesticide exposure.

Discussion

This study provides empirical evidence that inadequate personal hygiene practices are common among tobacco pesticide sprayers in rural Indonesia and that poorer hygiene behavior, particularly the absence of handwashing with soap immediately after spraying, is associated with a higher prevalence of reduced blood cholinesterase activity. Similar patterns of reduced cholinesterase activity among agricultural workers exposed to pesticides have been widely documented across different regions, reinforcing the validity of cholinesterase inhibition as a sensitive biomarker of occupational exposure (S. J. Kim, 2019). More than half of the respondents in this study exhibited mild cholinesterase inhibition, indicating ongoing low-level occupational exposure to pesticides. Although no cases of moderate or severe inhibition were identified, mild inhibition remains epidemiologically meaningful, as it reflects early biological effects that may progress to more serious neurological and systemic outcomes if exposure persists without adequate preventive measures (Saha, 2020).

The high prevalence of inadequate hygiene practices observed in this study highlights the critical role of behavioral factors in pesticide exposure pathways. Practices such as drinking or smoking before washing hands, delayed bathing, and reusing contaminated clothing were common among respondents and represent important routes of dermal and oral pesticide absorption. These findings are consistent with international studies demonstrating that behavioral practices are often more influential determinants of internal pesticide exposure than pesticide type alone, particularly in small-scale and subsistence farming systems (Negatu et al., 2020; Damalas, 2022). In settings where access to personal protective equipment and engineering controls is limited, personal hygiene becomes a primary defense against exposure (Damalas & Koutroubas, 2019; Kim et al., 2021).

Comparisons with previous studies show strong consistency between the present findings and global research. Studies among rice and vegetable farmers in Thailand have reported significantly lower blood cholinesterase activity among pesticide sprayers who failed to wash their hands after spraying or who ate and smoked without adequate hygiene (Mekonnen, 2021). Similar associations have been observed in Vietnam and China, where unsafe post-spraying behaviors were linked to biochemical indicators of pesticide exposure and increased neurological symptoms among agricultural workers (Sombatsawat et al., 2023). In South Asia, research conducted among farmers in India and Sri Lanka has shown that inadequate hygiene practices, including delayed bathing and improper handling of contaminated clothing, are strongly associated with acetylcholinesterase inhibition and early neurotoxic effects (Gullino et al., 2023). Evidence from Latin America further supports these findings; studies among agricultural workers in Ecuador and Brazil have demonstrated that poor hygiene practices significantly contribute to internal pesticide absorption, even in the absence of acute poisoning events (Boedeker et al., 2020).

Within the Indonesian context, the results of this study are consistent with previous findings emphasizing the importance of personal hygiene in pesticide exposure. Studies among Indonesian farmers, including horticultural workers and women farmers of reproductive age, have reported associations between poor hygiene behaviors—such as not washing hands after pesticide application and reusing contaminated work clothes—and decreased cholinesterase activity (Sprengel & Souza, 2020). However, many earlier studies relied primarily on self-reported symptoms, knowledge, or attitudes without incorporating objective biomarkers. By integrating biological measurement of blood cholinesterase activity, the present study strengthens existing evidence and provides more robust support for hygiene-focused interventions in rural agricultural communities.

The predominance of mild cholinesterase inhibition observed in this study mirrors findings from other low- and middle-income countries, where chronic low-dose pesticide exposure is common and often

underrecognized. International studies have noted that mild inhibition frequently occurs without severe clinical manifestations, which limits the effectiveness of symptom-based surveillance alone (K. H. Kim et al., 2021). In the present study, headache, dizziness, and shortness of breath were frequently reported; however, the weak association between headache and cholinesterase inhibition supports evidence that early biochemical effects may occur independently of specific or severe symptoms and that many reported complaints are non-specific, influenced by heat stress, fatigue, dehydration, or pre-existing conditions. Consequently, biomarker-based monitoring remains essential for detecting subclinical exposure and guiding timely preventive action.

From a public health and policy perspective, the findings of this study reinforce global recommendations that emphasize personal hygiene as a cornerstone of occupational pesticide safety, particularly in rural and resource-limited settings (OECD, 2021). International experience from countries with more developed occupational health systems demonstrates that routine hygiene facilities, mandatory training, and biological monitoring programs contribute to lower levels of pesticide-related toxicity (Damalas, 2022). In contrast, the results from this rural Indonesian setting illustrate how behavioral practices become the primary line of defense against exposure when such systems are absent or limited. Simple practices such as handwashing with soap immediately after spraying, prompt bathing, and changing contaminated clothing represent low-cost, feasible interventions with substantial potential impact (Damalas, 2022).

An additional concern highlighted by this study is the widespread practice of washing pesticide-contaminated clothing together with household laundry. This behavior increases the risk of secondary exposure among family members, including women and children, a phenomenon also reported in studies from Latin America and South Asia (Sprengel & Souza, 2020). Addressing this issue requires targeted education that extends beyond the individual sprayer to the household level, alongside improved access to adequate washing facilities and community-based hygiene infrastructure.

Overall, the findings of this study are consistent with and reinforce international and national evidence indicating that inadequate personal hygiene significantly contributes to occupational pesticide exposure among agricultural workers. By integrating behavioral assessment with biological measurement, this study adds to the global literature by providing biomarker-based evidence from a rural tobacco-farming context in Indonesia. The convergence of findings across diverse agricultural systems suggests that the underlying exposure mechanisms are broadly generalizable and that hygiene-centered interventions, supported by routine cholinesterase monitoring, should be prioritized in occupational health policies and agricultural extension programs to protect pesticide sprayers in low-resource settings.

CONCLUSION

This study demonstrates that inadequate personal hygiene practices are standard among tobacco pesticide sprayers in rural Indonesia and that poorer hygiene behavior—particularly the failure to wash hands with soap immediately after pesticide spraying—is associated with a higher prevalence of reduced blood cholinesterase activity. More than half of the study participants exhibited mild cholinesterase inhibition, indicating ongoing low-level occupational pesticide exposure despite the absence of severe clinical poisoning. The findings highlight that behavioral factors play a critical role in mediating pesticide exposure in rural agricultural settings, where access to personal protective equipment, engineering controls, and occupational health services is often limited. While self-reported health complaints such as headache, dizziness, and shortness of breath were frequently observed, their weak association with cholinesterase activity underscores the importance of biological monitoring to detect subclinical exposure that may not be captured by symptom-based assessment alone. By integrating assessments of personal hygiene practices with an objective biomarker of exposure, this study provides evidence that simple, low-cost hygiene behaviors can significantly influence internal pesticide exposure. These findings support prioritizing hygiene-centered interventions, including handwashing with soap after spraying, prompt bathing, proper handling of contaminated clothing, and routine cholinesterase monitoring, as feasible strategies to improve occupational health among pesticide sprayers in low-resource agricultural communities. Overall, this study contributes to the growing body of global occupational health literature by providing biomarker-based evidence from a rural tobacco-farming context in Indonesia. Strengthening personal hygiene practices through targeted education, improved access to basic hygiene facilities, and integration of biological monitoring into local health programs may play a pivotal role in reducing pesticide-related health risks among agricultural workers.

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