



RESEARCH ARTICLE

Behavioral and occupational factors associated with *Schistosoma japonicum* egg excretion in Napu Valley, an elimination-phase setting in Indonesia

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ABSTRACT

Despite substantial reductions in schistosomiasis prevalence following repeated praziquantel administration, *Schistosoma japonicum* infection remains a concern in agricultural communities in Indonesia. This study aims to examine the relationship between behavioral and occupational factors and *S. japonicum* egg shedding as an indicator of parasite burden among farmers in the Napu Valley, Central Sulawesi, Indonesia. The study evaluates whether the use of personal protective equipment (PPE) and post-exposure hygiene practices are associated with lower egg counts in the context of this elimination phase. A community based cross sectional study was conducted among 132 farmers selected through proportional random sampling. Data on occupational exposure, water contact behavior, PPE use, and hygiene practices were collected using interviewer administered questionnaires. Stool samples were examined using the Kato Katz method, and infection intensity was quantified as eggs per gram of feces / egg density (EPG). Associations with egg counts were assessed using bivariate and multivariable linear regression analyses. Detectable *S. japonicum* egg excretion was identified in 30 participants (22.7%). Longer duration of farming work was associated with higher egg counts ($\rho = 0.188$; $P = 0.031$). Farmers who used boots and gloves had significantly lower egg counts ($P = 0.006$). In multivariable analysis, PPE use remained independently associated with lower egg counts ($\beta = -0.452$; 95% CI: $-0.870 - -0.034$; $P = 0.034$). Detectable *S. japonicum* egg excretion remains present among farmers in Napu Valley despite declining endemicity. Longer farming duration was associated with higher *S. japonicum* egg density, whereas consistent use of personal protective equipment was independently associated with lower parasite burden in this elimination phase setting.

Keywords: *Schistosoma japonicum*; schistosomiasis; behavioral risk factors; occupational exposure; personal protective equipment.

INTRODUCTION

Schistosomiasis transmission is strongly influenced by environmental exposure and human behavior. Agricultural communities in endemic regions frequently experience occupational water contact, particularly in irrigated rice fields and freshwater bodies harboring *Oncomelania hupensis lindoensis* snails. Behavioral risk factors such as prolonged water exposure, inconsistent use of protective equipment, and inadequate hygiene practices have been linked to infection risk.

In Indonesia, mass praziquantel administration has reduced prevalence; however, persistent transmission in agricultural zones suggests that behavioral and occupational factors continue to sustain infection. Repeated mass drug administration with praziquantel has significantly reduced the prevalence and intensity of schistosomiasis. Praziquantel is highly effective against adult schistosomes by triggering calcium influx, which causes paralysis of the parasite and damage to its tegument, thereby reducing the worm burden and egg shedding. However, because praziquantel has limited activity against immature schistosomes and does not prevent reinfection

after exposure to cercariae, persistent transmission can continue in agricultural communities where occupational contact with water is still common (Colley *et al.*, 2014; Vale *et al.*, 2017; WHO, 2022).

Transmission of schistosomiasis is closely shaped by environmental conditions and human behavioral patterns that determine exposure to cercariae infested water. In endemic agricultural settings, particularly irrigated rice fields and freshwater ecosystems, routine occupational activities such as planting, harvesting, irrigation management, and livestock handling frequently require direct and prolonged contact with water bodies that harbor the intermediate host snail, *O. hupensis lindoensis*. Numerous epidemiological studies have demonstrated that frequency and duration of water contact are strong predictors of *S. japonicum* infection, as cercarial penetration occurs during skin exposure to contaminated water (Colley *et al.*, 2014; Gryseels *et al.*, 2006). Occupational exposure, particularly among farmers, has repeatedly been identified as a key determinant of infection risk in endemic Asian settings (Huang *et al.*, 2025; Li *et al.*, 2000; Wang *et al.*, 2009; Zhou *et al.*, 2012).

Behavioral factors further modulate transmission dynamics. Inconsistent use of personal protective equipment (e.g., boots or gloves), inadequate post exposure hygiene practices, and limited access to safe water and sanitation have been associated with higher infection risk in multiple field based studies (Ross *et al.*, 2002; WHO, 2022). Inconsistent use of personal protective equipment and unsafe water contact behaviors have been associated with increased infection risk in several endemic settings (Kloos *et al.*, 2006; McManus *et al.*, 2018; Wang *et al.*, 2013).

Although large scale praziquantel administration in Indonesia has substantially reduced overall prevalence and intensity of infection, persistent transmission in agricultural zones such as Central Sulawesi suggests that chemotherapy alone may not fully interrupt exposure related reinfection (Satrija *et al.*, 2015). Continued occupational water contact and suboptimal protective practices likely sustain low level transmission despite repeated treatment cycles, highlighting the need to better understand behavioral and occupational determinants in elimination phase settings (WHO, 2022; Zhou *et al.*, 2012).

Despite declining prevalence, transmission continues in Napu Valley. Standard control strategies focus primarily on chemotherapy, with limited emphasis on behavioral risk reduction. Although the prevalence of schistosomiasis has declined substantially following repeated mass drug administration with praziquantel, transmission persists in localized foci such as Napu Valley in Central Sulawesi. This pattern reflects a well-recognized challenge in elimination phase settings, where chemotherapy effectively reduces worm burden and morbidity but does not prevent reinfection in communities with ongoing environmental exposure. In agricultural landscapes characterized by irrigated rice fields and freshwater habitats supporting the intermediate snail host, continued occupational water contact maintains opportunities for cercarial exposure despite regular treatment cycles (Colley *et al.*, 2014; Wang *et al.*, 2009).

Standard control strategies in many endemic regions have historically prioritized preventive chemotherapy as the primary intervention, given its demonstrated effectiveness in reducing infection intensity and morbidity at the population level. However, growing evidence suggests that chemotherapy alone is insufficient to interrupt transmission in areas where behavioral and occupational exposure remains frequent (Gray *et al.*, 2010; Ross *et al.*, 2013; Wang *et al.*, 2021). Limited emphasis on behavioral risk reduction such as consistent use of protective equipment, improved hygiene practices, and reduction of unsafe water contact may allow persistent low-level transmission to continue. As endemic areas transition toward elimination targets, understanding and addressing these behavioral determinants becomes increasingly critical to achieving sustainable transmission interruption.

Frequent occupational contact with freshwater environments remains a major driver of schistosomiasis transmission in agricultural communities. Cercariae released from infected intermediate host snails actively penetrate intact human skin during water exposure, making both the frequency and duration of water contact important determinants of infection risk (Colley *et al.*, 2014; Gryseels *et al.*, 2006). Epidemiological studies have consistently shown that farmers working in irrigated agricultural systems and other freshwater environments experience increased risk of infection because of repeated occupational exposure to cercariae-infested water (Gordon *et al.*, 2019; Grimes *et al.*, 2015; Sady *et al.*, 2013; Steinmann *et al.*, 2006). Conversely, protective measures such as boots and gloves may reduce direct skin contact with infective larvae and have been associated with lower infection risk in endemic farming populations (Gordon *et al.*, 2019; Grimes *et al.*, 2015). However, the effectiveness of these behaviors may vary across epidemiological settings, and evidence regarding their protective value in low-endemic areas approaching elimination remains limited (Bergquist *et al.*, 2017).

Most epidemiological studies of schistosomiasis have evaluated behavioral risk factors using infection prevalence as the primary outcome. However, parasite burden, commonly measured as eggs per gram of feces, may provide additional insights into transmission dynamics because it reflects infection intensity and potential contribution to environmental contamination. In low-endemic settings approaching elimination, where infection prevalence is often low and focal, examining factors associated with egg excretion may be more informative than assessing infection status alone. Nevertheless, evidence regarding behavioral and occupational determinants of *S. japonicum* egg excretion remains limited.

Although behavioral risk factors for schistosomiasis are well established in moderate- and high-endemic settings, it remains unclear which factors continue to influence transmission in low-endemic areas approaching elimination. As prevalence and infection intensity decline, transmission often becomes more focal, and infection may be concentrated within specific occupational or behavioral groups rather than the general community (Bergquist *et al.*, 2017; Gray *et al.*, 2010). However, evidence quantifying the contribution of individual behaviors, including water contact, use of personal protective equipment (PPE), and hygiene practices, remains limited in low-transmission settings.

The effectiveness of behavioral interventions under declining transmission conditions is also not well understood. While consistent use of boots, gloves, and other protective measures has been associated with reduced infection risk in higher-endemic areas, their protective value in low-endemic settings has rarely been evaluated. Furthermore, the relationship between occupational exposure intensity and parasite burden remains insufficiently characterized in elimination-phase contexts. Improved understanding of these factors is important for designing targeted interventions that complement preventive chemotherapy and support sustainable transmission interruption.

Therefore, this study aimed to identify behavioral and occupational factors associated with *S. japonicum* egg excretion, a measure of parasite burden, among farmers in Napu Valley, Central Sulawesi, Indonesia. The study further evaluated whether PPE use and post-exposure hygiene practices were associated with lower egg counts in this elimination-phase setting.

MATERIALS AND METHODS

Study design

A community based cross sectional analytical study was conducted in Napu Valley, Central Sulawesi, Indonesia, a low endemic area historically affected by *S. japonicum*. Napu Valley is an inland intermontane agricultural basin located in Central Sulawesi, Indonesia (Figure 1) (approximately 1°23'56.6" S, 120°20'02.1" E). The study aimed to examine behavioral and occupational factors associated with *S. japonicum* egg excretion among farmers living in agricultural areas where *O. hupensis lindoensis* habitats remain present. Data collection was performed during the peak agricultural season to capture routine occupational exposure to wet environments.

Study population

The study population consisted of adult farmers residing in endemic villages in Napu Valley, Central Sulawesi, Indonesia. Participants were routinely engaged in agricultural activities involving exposure to wet environments, including rice farming, plantation work, and irrigation-related activities. Eligible participants were individuals aged ≥15 years who had lived in the study area for at least one year, were actively cultivating agricultural land located within or near habitats of *O. hupensis lindoensis*, and had not received praziquantel treatment within the previous 6–8 weeks prior to data collection.

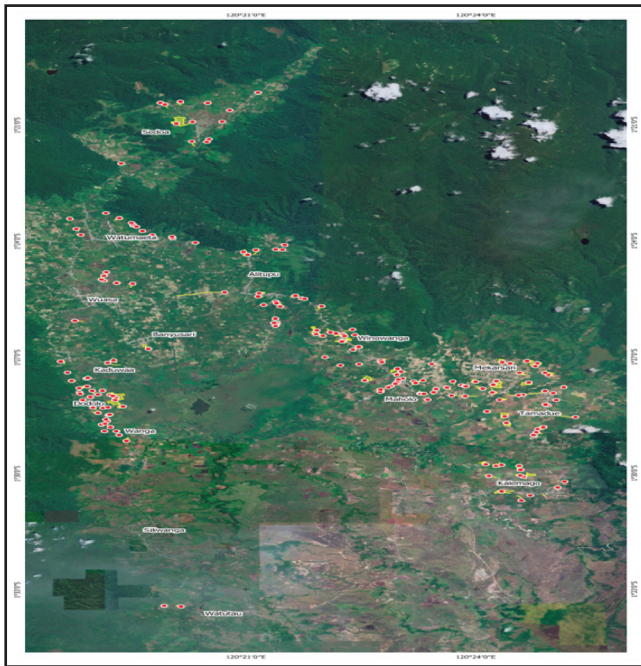


Figure 1. Map of schistosomiasis distribution in Napu Valley, Central Sulawesi, Indonesia (Widayati *et al.*, 2021).

All participants provided informed consent before enrollment. Individuals who were severely ill or unable to complete interviews or stool sample collection were excluded from the study.

A total of 132 participants were included in the final analysis. The sample size was determined based on feasibility within the identified transmission foci and was considered sufficient for multivariable regression analyses. Participants were selected using a stratified random sampling approach from villages with confirmed *O. hupensis lindensis* habitats in the Napu Valley area. Stratification was based on village-level schistosomiasis prevalence obtained from the 2023 schistosomiasis control program records of the Poso District Health Office. Villages were categorized into three endemicity strata: low prevalence (<1%; $n = 7$), moderate prevalence (1% to <2%; $n = 4$), and high prevalence ($\geq 2\%$; $n = 5$). Sample allocation was distributed proportionally according to transmission risk, with 15% of participants selected from low prevalence villages, 35% from moderate prevalence villages, and 50% from high prevalence villages. Within each stratum, eligible farmers were selected through simple random sampling using village population lists. We used this sampling strategy to capture variation in transmission intensity across endemic villages and to improve the representativeness of occupational and behavioral exposure patterns.

Data collection

Data collection was performed using standardized field and laboratory procedures to ensure consistency across participants. Sociodemographic characteristics, occupational exposure, and behavioral information were obtained through structured interviewer administered questionnaires. Approximately 2 g of stool was collected from each participant and processed using the Kato Katz thick smear technique for detection and quantification of *S. japonicum* eggs. Three Kato Katz thick smears were prepared from each stool sample and examined microscopically by trained laboratory personnel. Egg counts were expressed as eggs EPG and used as an indicator of parasite burden. All laboratory procedures followed standard WHO protocols. To ensure diagnostic quality and consistency, a subset of slides was re-examined as part of quality control procedures.

The primary outcome variable was *S. japonicum* egg excretion, measured as EPG using the Kato Katz method. Behavioral and Occupational exposure variables included duration of farming

(years), history of water contact, daily working duration (hours/day), use of personal protective equipment (boots and gloves), and post-exposure hygiene practices, including hand and foot washing with soap after farming activities. Sociodemographic variables included age and sex.

Data analysis

Data were analyzed using IBM SPSS Statistics version 29.0.2.0. Descriptive statistics were used to summarize participant characteristics and study variables. Continuous variables were presented as mean and standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Egg counts expressed as EPG were log-transformed prior to analysis to reduce skewness and improve data distribution. Bivariate associations between continuous exposure variables and log-transformed egg counts were assessed using Spearman correlation analysis. Differences in egg counts between categorical exposure groups were evaluated using the Mann–Whitney U test. Variables with $P < 0.20$ in bivariate analyses were entered into the multivariable linear regression model to avoid excluding potentially important predictors. Regression coefficients (β), 95% confidence intervals (CI), and p -values were reported. Statistical significance was defined as $P < 0.05$. Variables with $P < 0.20$ in bivariate analyses were entered into the multivariable linear regression model to avoid excluding potentially important predictors.

RESULTS

The study included 132 farmers from Napu Valley, with participants predominantly male (65.9%) and a mean age of 41.81 ± 12 years (Table 1). Participants had worked in agricultural activities for an average of 16.98 ± 10.93 years and spent approximately 6.80 ± 1.58 hours per day in farming areas. The use of complete personal protective equipment was relatively low, with only 38.6% reporting

Table 1. Characteristics of study participants

Variable	n (%)	Mean $\pm$ SD
Age (years)		41.81 $\pm$ 12
Male	87 (65.9)	–
Female	45 (34.1)	–
Duration of farming work (years)	–	16.98 $\pm$ 10.93
Daily working duration (hours/day)	–	6.80 $\pm$ 1.58
Use of boots and gloves during farming		
Yes	51 (38.6)	–
No	81 (61.4)	–
Use of boots during farming		
Yes	31 (23.5)	–
No	131 (76.5)	–
Use of gloves during farming		
Yes	57 (43.2)	–
No	75 (56.8)	–
Foot and hand washing after farming with soap		
Yes	45 (34.1)	–
No	87 (65.9)	–
Foot washing after farming with soap		
Yes	47 (35.6)	–
No	85 (64.4)	–
Hand washing after farming with soap		
Yes	68 (51.5)	–
No	64 (48.5)	–
Water contact		
Yes	104 (78.8)	–
No	28 (21.2)	–
Detectable <i>S. japonicum</i> eggs	30 (22.7)	–
Egg counts (EPG)	–	5.52 $\pm$ 20.53

DISCUSSION

the combined use of boots and gloves during farming activities. Similarly, post exposure hygiene practices were limited, as only 34.1% reported washing both hands and feet with soap after work. Most participants (78.8%) reported regular contact with water bodies in agricultural environments. Detectable *S. japonicum* egg excretion was found in 22.7% of participants, and the mean egg count was 5.52 ± 20.53 EPG.

The distribution of *S. japonicum* egg count was markedly right skewed. Among the 132 participants, 102 (77.3%) had no detectable egg excretion, whereas 30 (22.7%) had detectable eggs. Egg counts ranged from 0 to 164 EPG, with a mean of 5.52 ± 20.53 EPG. Most participants had no detectable eggs, whereas only two participants (1.5%) exhibited egg densities ≥ 100 EPG, indicating that infection intensity was concentrated in a limited subset of the study population.

According to the WHO classification, 28 of the 30 infected participants (93.3%) had light-intensity infection (World Health Organization, 2024), whereas only two (6.7% of infected participants; 1.5% of the total study population) had moderate-intensity infection, and no heavy-intensity infections were detected.

As shown in Table 2, longer duration of farming work was significantly correlated with higher egg counts. Daily working duration also demonstrated a weak positive correlation with egg counts, although the association did not reach statistical significance. Farmers who reported using boots and gloves together during agricultural activities had significantly lower egg counts compared with those who did not use complete personal protective equipment. In contrast, no significant associations were observed between egg counts and reported water contact or post-exposure hand and foot washing with soap.

In the multivariable linear regression model (Table 3), consistent use of boots and gloves during farming activities remained independently associated with lower log-transformed *S. japonicum* egg counts. Daily working duration showed a positive but non-significant association with egg counts after adjustment. Similarly, duration of farming work was not significantly associated with egg counts in the adjusted model.

Table 2. Behavioral and occupational factors associated with *S. japonicum* egg counts / egg density

Variable	Statistic	p-value
Continuous variables		
Duration of farming work (years)	$\rho = 0.188$	0.031
Daily working duration (hours/day)	$\rho = 0.163$	0.061
Categorical variables		
Water contact (Yes/No)	$U = 1345.0$	0.400
Use of boots and gloves together (Yes/No)	$U = 1630.0$	0.006
Use of boots (Yes/No)	$U = 1414.5$	0.269
Use of gloves (Yes/No)	$U = 1748.5$	0.015
Foot and hand washing after farming with soap (Yes/No)	$U = 1955.0$	0.987
Foot washing (Yes/No)	$U = 2125.0$	0.752
Hand washing (Yes/No)	$U = 1965.0$	0.833

ρ = Spearman correlation coefficient.

U = Mann–Whitney U .

Table 3. Multivariable linear regression analysis of factors associated with log-transformed *S. japonicum* egg counts

Variable	β	95% CI	p-value
Use of boots and gloves together	-0.452	-0.870 – -0.034	0.034
Duration of farming work (years)	0.012	-0.0007 – 0.031	0.208
Daily working duration (hours/day)	0.112	-0.017 – 0.242	0.089

This study identified several behavioral and occupational factors associated with *S. japonicum* egg excretion among farmers in Napu Valley, a historically endemic but currently low endemic area of Central Sulawesi, Indonesia. Detectable egg excretion remained present in nearly one quarter of participants, indicating that residual transmission continues despite long-standing schistosomiasis control efforts (Wang et al., 2021). The findings suggest that occupational exposure related to agricultural activities remains an important determinant of parasite exposure in this setting.

The many low-intensity infections observed in this study are consistent with the epidemiological characteristics of regions that are close to eliminating schistosomiasis, where repeated preventive chemotherapy significantly reduces the parasite burden and severe infections become rare (Colley et al., 2014). Nevertheless, the continued detection of egg shedding, even at low intensity, indicates that transmission has not yet been completely halted and that occupational exposure continues to occur among farmers.

The continued detection of egg excretion, despite the generally mild nature of the infection, indicates that transmission is continuing though not spreading in the study area. During the elimination phase, repeated administration of praziquantel is expected to reduce infection intensity and morbidity; however, this does not prevent reinfection in individuals who remain exposed to freshwater infested with cercariae during routine agricultural activities. Consequently, even low-intensity infections can contribute to sustaining the parasite's life cycle if infected individuals continue to contaminate the environment where the snail intermediate hosts are present. These findings highlight the importance of complementing preventive chemotherapy with interventions that reduce workplace exposure and interrupt ongoing transmission in remaining endemic foci.

A significant positive association was observed between duration of farming work and log-transformed egg counts. This finding suggests that cumulative occupational exposure over time may increase opportunities for repeated contact with cercariae infested water or wet agricultural environments. Similar observations have been reported in endemic agricultural communities where long-term farming activities contribute to sustained schistosomiasis transmission through repeated environmental exposure (Li et al., 2000; Wang et al., 2009; Zhou et al., 2005). In Napu Valley, agricultural activities are commonly conducted in wet rice fields and irrigation systems located near habitats of *O. hupensis lindoesis*, creating continuous opportunities for parasite transmission. In addition to rice cultivation, farmers in Napu Valley commonly engage in cocoa, coffee, and corn farming, as well as fish farming activities, many of which involve routine contact with moist soils, irrigation channels, or freshwater environments that may facilitate exposure to cercariae.

In Napu Valley, agricultural activities are conducted in irrigated rice fields, irrigation canals, fish ponds, and plantations of cocoa, coffee, maize, and horticultural crops that are frequently located near habitats of *O. hupensis lindoesis*. Farmers often move repeatedly between these environments during land preparation, planting, irrigation management, harvesting, and routine field maintenance. These activities require frequent contact with wet soil and shallow freshwater, creating repeated opportunities for exposure to cercariae released from infected intermediate host snails. Similar occupational exposure patterns have been identified as important determinants of *S. japonicum* infection in endemic agricultural regions of China and the Philippines, where long-term farming activities and repeated water contact contribute to sustained transmission (Li et al., 2000; Tabilin et al., 2025).

Although self-reported contact with water was not independently associated with egg count, the duration of farming work remained a significant predictor. These findings suggest that the duration of

farming may better represent cumulative occupational exposure than the binary measure of contact with water. Farmers who have worked for many years experience repeated exposure over multiple growing seasons, whereas the contact with water variable used in this study does not distinguish between the frequency, duration, or location of exposure. Furthermore, not all contact with freshwater occurs in habitats containing infected *O. hupensis lindoensis*, which may also explain the absence of a statistically significant association between reported water contact and egg count. A limitation is that the assessment of water exposure is based on self-reported measurements and does not measure the frequency, duration, or specific location of that exposure.

The study also demonstrated that the combined use of boots and gloves during farming activities was independently associated with lower egg counts. This finding supports the protective role of PPE in reducing skin exposure to cercariae during agricultural work. Although the use of gloves was associated with a significantly lower egg counts in the bivariate analysis, the use of boots alone was not. It is important to note, however, that the simultaneous use of boots and gloves was still independently associated with a lower egg counts, suggesting that the comprehensive use of PPE rather than individual components may provide more effective protection against workplace exposure. Importantly, the combined use of boots and gloves was associated with lower egg counts, suggesting that comprehensive PPE use, rather than reliance on a single protective measure, may be more effective in reducing occupational exposure to *S. japonicum* in agricultural settings.

Previous observational studies have demonstrated that the frequency and nature of water-contact activities are important determinants of schistosomiasis transmission, supporting the value of behavioral and protective measures aimed at reducing skin exposure to contaminated water. (Fulford et al., 1996; Grimes et al., 2015; Reitzug et al., 2023). The present findings highlight that behavioral intervention remain relevant even in low-endemic settings where transmission intensity has substantially declined. Promotion of consistent PPE use may therefore represent a practical and low-cost complementary strategy alongside preventive chemotherapy. Recent evidence suggests that behavioral interventions and exposure reduction strategies remain important components of schistosomiasis elimination programs, particularly in settings approaching transmission interruption (Torres-Vitolas et al., 2023; WHO, 2022).

The protective association observed for PPE in this study may have been reduced due to inconsistent use of boots and gloves during farming activities. Although PPE was associated with lower egg density, many farmers may not wear personal protective equipment consistently during activities involving contact with water, leaving them vulnerable to exposure to cercariae. These findings are supported by previous research that found an association between the use of boots and a lower risk of detecting *S. japonicum* eggs in feces (Rosmini et al., 2016). The proper use of PPE to protect body parts that come into contact with water has been shown to be effective in reducing the risk of exposure to cercariae; however, many farmers still do not use PPE because they find it cumbersome and hinders their ability to perform farming activities. Similar barriers to PPE adoption have also been reported among agricultural workers, where discomfort, reduced work flexibility, and limited risk perception contribute to inconsistent use of protective equipment.

The proper use of PPE to protect body parts that come into contact with water has been shown to be effective in reducing the risk of exposure to cercariae; however, many farmers still do not use PPE because they find it cumbersome and difficult to perform their farming activities. Similar barriers to PPE adoption have been reported among agricultural workers, where discomfort, reduced work flexibility, and limited risk perception contribute to inconsistent use of protective equipment (Owusu Ansah & Skevas, 2024).

In contrast, post-exposure hygiene practices, including hand and foot washing with soap after farming activities, were not significantly associated with egg counts. Several explanations may account for this finding. First, self-reported hygiene practices may not accurately reflect actual behavior frequency or quality. Second, cercarial penetration likely occurs during water exposure itself, limiting the protective effect of washing after exposure has already occurred. Similar inconsistencies regarding hygiene related protective effects have been reported in schistosomiasis behavioral studies conducted in other endemic settings (Grimes et al., 2015; Haas & Haeberlein, 2009; Kloos et al., 2006).

Although occupational factors and PPE use were evaluated in the present study, other determinants may also have influenced the observed egg density. In particular, differences in participation and adherence to repeated praziquantel administration could have contributed to variation in parasite burden among farmers. Praziquantel is highly effective against adult schistosomes but does not prevent reinfection following subsequent exposure to cercariae. Therefore, individuals with inconsistent participation in mass drug administration or irregular treatment may remain at greater risk of maintaining low-intensity infections, especially in endemic agricultural settings. Because individual treatment history and adherence were not assessed in the present study, their contribution could not be evaluated and should be investigated in future studies.

The absence of a significant association between post-exposure washing practices and egg counts may be explained by the rapid skin penetration of schistosome cercariae. Experimental studies have demonstrated that cercarial penetration can occur within minutes after water contact, with complete skin invasion commonly occurring within approximately 3–10 minutes following exposure. Consequently, washing hands or feet after agricultural activities may occur after cercarial (Clegg & Smithers, 1968; Haas & Haeberlein, 2009).

In this study, washing hands and feet after exposure to water showed no significant association with the number of *S. japonicum* eggs. One possible explanation is that these practices are generally performed after farmers return home, rather than immediately after exposure to freshwater. Cercariae actively penetrate human skin within minutes of contact with contaminated water. Consequently, washing hands or feet after agricultural activities is unlikely to prevent infection if skin penetration has already occurred. In contrast, personal protective equipment such as boots and gloves acts as a physical barrier that reduces direct skin exposure during contact with water, which may explain their association with lower egg counts in this study. Similar observations have been reported in previous studies, which show that hygiene after exposure alone provides limited protection against schistosomiasis once exposure has occurred, whereas interventions that prevent skin contact with cercariae are more effective in reducing the risk of infection.

Although daily working duration showed a positive association with egg counts, the relationship was not statistically significant after multivariable adjustment. This finding suggests that cumulative occupational exposure accumulated over many years may be more important in determining parasite burden than the number of hours worked per day. In endemic agricultural settings, infection risk is influenced not only by the duration of work but also by the frequency and location of contact with cercariae infested environments. Consequently, brief exposure in areas containing infected *O. hupensis lindoensis* may pose a greater risk than longer periods of work in non-infested locations. Previous studies have shown that occupational exposure associated with farming activities and contact with snail infested habitats are important determinants of *S. japonicum* infection, whereas exposure intensity is strongly influenced by ecological and behavioral factors rather than time spent working alone (Li et al., 2000; Yi-Xin & Manderson, 2005). Moreover, the relatively low prevalence and low egg counts observed in this population may have limited the ability to detect

weaker associations between daily working duration and parasite burden.

The persistence of detectable *S. japonicum* egg excretion among farmers in this low endemic setting has important implications for schistosomiasis elimination efforts in Indonesia. Although repeated praziquantel administration has substantially reduced prevalence, residual transmission appears to persist within specific occupational and ecological contexts. These findings support integrated control strategies that combine preventive chemotherapy with behavioral risk reduction, environmental surveillance, and promotion of occupational protection measures, particularly among farmers living near snail habitats.

Individuals living for prolonged periods in endemic areas may develop partial acquired immunity following repeated exposure to schistosome antigens through natural infection and reinfection, which may influence parasite burden and egg excretion (Hambrook & Hanington, 2021). However, immunological responses were not evaluated in the present study. The relatively long farming history observed in this population (mean approximately 17 years) suggests that cumulative exposure over many years may have contributed to parasite burden. Nevertheless, the present findings also indicate that modifiable behavioral factors, particularly consistent PPE use, remain associated with lower egg density despite prolonged occupational exposure. These findings suggest that cumulative exposure and current protective behaviors are likely to interact in determining infection intensity.

Several limitations should be considered. The cross-sectional design precludes causal inference, while the Kato Katz method may underestimate low intensity infections because of its limited sensitivity in low endemic settings. In addition, behavioral variables were self-reported and may be subject to recall or social desirability bias. Despite these limitations, the study provides valuable evidence on behavioral and occupational determinants of residual schistosomiasis transmission in one of Indonesia's remaining endemic areas.

Future study should identify specific agricultural activities and environmental conditions associated with cercarial exposure, as well as investigate the factors that influence consistent use of PPE. This information can support targeted behavioral interventions in areas currently in the elimination phase. In addition, prospective longitudinal studies are needed to better characterize the impact of chronic occupational exposure on parasite burden, as well as to investigate long-term host responses, including acquired immunity and other immunological adaptations, in populations living in endemic areas. Understanding the interactions between cumulative exposure, host immune responses, and repeated praziquantel administration can provide important insights for optimizing schistosomiasis elimination strategies. Overall, workplace exposure remains relevant to *S. japonicum* transmission, while the consistent use of boots and gloves appears to provide protection, underscoring the importance of integrating workplace risk reduction into schistosomiasis elimination programs.

CONCLUSION

Detectable *S. japonicum* egg excretion was identified in 22.7% of farmers, with most infections being of light intensity. Longer farming duration was positively associated with higher egg density ($p = 0.031$), whereas consistent use of boots and gloves remained independently associated with lower egg density ($p = 0.034$). These findings indicate that cumulative occupational exposure and modifiable protective behaviors continue to influence parasite burden in elimination-phase agricultural settings. Integrating occupational risk reduction with ongoing preventive chemotherapy may strengthen schistosomiasis elimination efforts in Indonesia.

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Conflict of Interest

The author declares that they have no conflict of interests

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