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THE IMPACT OF LEAD LEVELS IN BLOOD ON BLOOD PRESSURE, BODY MASS INDEX, AND HAND STRENGTH IN RICE FARMERS

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ABSTRACT
Lead contamination in pesticides poses a serious threat to health due to its bioaccumulative and toxic properties to various organ systems, including the nervous, hormonal, and cardiovascular systems. This study aims to determine the relationship between blood lead levels and blood pressure, body mass index (BMI), and handgrip strength in rice farmers in Tlingsing Village, Cawas District, Klaten Regency. This analytical study used a cross-sectional design with a sample of 24 rice farmers. Venous blood samples were taken using 3 cc EDTA vacuum tubes and examined for lead levels using the Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS) method at BBLK Yogyakarta. Blood pressure was measured using an Omron 7120 digital sphygmomanometer, BMI using a HN 289 digital scale and a GEA SH2A stature meter, and hand strength using a Camry EH101 electronic hand dynamometer. Data analysis was carried out using a bivariate correlation test at a 95% confidence level (p=0.05). The results showed that blood lead levels were significantly associated with blood pressure (p=0.028), with a percentage of stage 1 hypertension of 50.0% and hypertensive crisis of 45.8%. Lead levels were not significantly associated with BMI (p=0.082), with 29.2% of participants classified as overweight and 8.3% as obese. There was no significant association with hand grip strength (p=0.360), with 20.8% of participants classified as having medium strength and 33.3% as having low strength.

Keywords: blood pressure; body mass index; hand strength; lead in blood; rice farmers

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INTRODUCTION

Pesticides are chemical or biological substances used to kill or immobilize pests such as weeds, insects, and rodents in order to increase agricultural productivity. In recent decades, the use of chemical-based pesticides has increased significantly in line with the growing demand for agricultural products due to global population growth (Sharma & Singhvi, 2017). Excessive use of pesticides poses serious problems, especially in developing countries where regulations on pesticide quality and safety are still limited. In addition to the main active ingredient, pesticide formulations often contain heavy metal contaminants such as lead (Pb), cadmium (Cd), and arsenic (As) originating from manufacturing processes, solvents, or non-standardized additives (Li & Sansalone, 2020; Lin et al., 2022)

Lead contamination from pesticides (Rehman et al., 2018) a as well as other sources such as industrial waste and fuel can enter the food chain and ultimately be exposed to the human body (Singh et al., 2010). This poses a serious threat to long-term health because lead is bioaccumulative and toxic to various organ systems (Flora et al., 2012). The main effects of lead exposure are an increased risk of nervous system, hormonal, and cardiovascular disorders. Research over the past two decades has shown a positive correlation between blood lead levels and systolic and diastolic blood pressure in studies conducted by Lanphear et al., (2018) A cohort study of the adult population in the United States (US) showed that even the lowest lead levels (1 µg/dL) can increase systolic blood pressure and the risk of mortality from heart disease (Lanphear et al., 2018). Research by Hara et al., (2015) using data from the National Health and Nutrition Examination

Survey (NHANES) 1999–2016 shows that higher blood lead levels are significantly associated with increased blood pressure and the risk of hypertension. This study involved 39,477 adult respondents with complete data on blood lead levels and blood pressure, consisting of men and women with an average age of 46.5 years, reporting that each doubling of lead levels increased the risk of hypertension by 45%, even after controlling for age, gender, and other factors, and that individuals with the highest lead levels had a higher risk of hypertension than those with the lowest levels (Hara et al., 2015). These results are in line with the findings of Scinicariello et al., (2011) who analyzed NHANES 1999–2006, and Guazzi et al., (2021) with NHANES 2003–2010, both of which also reported a positive association between blood lead levels and increased blood pressure and risk of hypertension in the adult population (Scinicariello et al., 2011; Guazzi et al., 2021). Research in Haiti by Yan et al., (2022), using data from a cohort of Port-au-Prince residents involving 2,504 participants aged ≥ 18 years, found that individuals in the fourth quartile of blood lead levels (≥ 6.5 µg/dL) had an average systolic blood pressure 2.42 mm Hg higher than the group with the lowest lead levels (first quartile, < 3.4 µg/dL). This finding remained significant after controlling for demographic and behavioral variables such as age, gender, obesity, smoking habits, physical activity, and income (Yan et al., 2022).

Lead is known as a chemical that can disrupt the endocrine system, particularly in relation to the function of the hypothalamic-pituitary-adrenal (HPA) axis, thyroid hormones, and bone metabolism (Fan et al., 2024; Wu et al., 2023; Bjørklund et al., 2020). Disruption of the endocrine system has implications for various metabolic processes, including weight regulation. A study conducted by (X. Wang et al., 2018) based on NHANES 2003–2014 data showed a relationship between blood lead levels and increased weight and other indicators of obesity, such as BMI, skinfold thickness, and body fat percentage, as well as the risk of chronic diseases such as hypertension and type 2 diabetes (X. Wang et al., 2018). A number of studies conducted by Fan et al., (2024); Wu et al., (2023); Bjørklund et al., (2020); dan X. Wang et al., (2018) show that exposure to lead as an endocrine disrupting chemical (EDC) also plays a role in metabolic disorders related to obesity (Fan et al., 2024; Wu et al., 2023; Bjørklund et al., 2020; (X. Wang et al., 2018). Lead exposure, especially long-term and from an early age, is suspected to disrupt hormonal regulation and energy metabolism. This condition can then trigger an increase in BMI and contribute to high rates of overweight globally (N. Wang et al., 2015). This is reinforced by data from the NHANES in the United States, which shows a significant relationship between blood lead levels and increased weight and other indicators of obesity (Lanphear et al., 2018).

Lead is a heavy metal that is neurotoxic, causing damage to the central and peripheral nervous systems and affecting cognitive and motor function (Flora et al., 2012) Neurotoxicity resulting from exposure to chemicals can damage the structure or function of the nervous system, affecting sensory, motor (including neuromotor), and cognitive functions (Sarkar & Schmued, 2012). One indicator widely used to assess muscle status and functional health of the nervous system is handgrip strength (Putrawan & Kuswardhani, 2011). Research conducted by (Reymond et al., 2023) found that individuals with high blood lead levels had lower handgrip strength compared to those with low lead levels, indicating a relationship between lead neurotoxicity and decreased muscle function. Similar results were also reported by (Gbemavo & Bouchard, 2019) who found that high blood lead levels were significantly associated with decreased handgrip strength. Thus, handgrip strength can be used as a functional parameter to detect the effects of lead exposure on the nervous and muscular systems, as well as an early indicator of neuromotor disorders caused by heavy metal neurotoxicity.

Rice farmers are a high-risk group for lead exposure from pesticides, especially through inhalation and skin contact during spraying without personal protective equipment. Research in Indonesia, such as by Wijayanti et al., (2019) on vegetable farmers in Semarang and Pradana Sulistiyono Putra et al., (2025) on horticultural farmers in Bandungan District, shows a relationship between pesticide exposure and increased blood pressure, BMI, and cognitive impairment (Wijayanti et al.,

2019); (Pradana Sulistiyono Putra et al., 2025). However, neither study assessed blood lead levels or their relationship with handgrip strength. On the other hand, international studies such as Lanphear et al., (2018); X. Wang et al., (2018); and Gbemavo & Bouchard, (2019) prove the relationship between blood lead levels and hypertension, obesity, and decreased neuromuscular function, but have not specifically highlighted farmers who are directly exposed to pesticides as a high-risk population (Lanphear et al., 2018; X. Wang et al., 2018; and Gbemavo & Bouchard, 2019). Based on the background information presented, an in-depth study is needed on the relationship between blood lead levels and blood pressure, BMI, and handgrip strength in rice farmers. In addition, this study also aims to provide a deeper understanding of the impact of lead exposure on farmers' health, thereby enriching the literature on environmental toxicology and occupational health, particularly among agricultural workers in Indonesia. Thus, the results of this study are expected to form the basis for more appropriate prevention and intervention efforts to protect farmers' health from the risks of lead exposure.

METHOD

This study is an analytical study with a cross-sectional approach. The population of this study are rice farmers in Tlingsing Village, Cawas District, Klaten Regency who have been actively working for at least 2 years. The sample size in this study is 24 rice farmer respondents, selected using purposive sampling technique. This study has obtained ethical approval from Muhammadiyah University Purwokerto with registration number KEPK/UMP/125/VIII/2025. The data used in this study were primary health examination data in the form of blood lead levels, hand strength, BMI, and blood pressure, as well as questionnaire data on respondent demographics. Three cc of rice farmers' venous blood using EDTA vacuum tubes were used for blood lead level examination using the GFAAS method conducted at the Balai Besar Laboratorium Kesehatan (BBLK). Blood pressure was measured using an Omron 7120 digital sphygmomanometer, BMI was measured using an Hn 289 digital scale and a GEA SH2A stature meter, and hand strength was measured using a Camry EH101 electronic hand dynamometer. Hand strength, BMI, and blood pressure tests were conducted in Tlingsing Village, Cawas District, Klaten Regency after respondents completed the questionnaire and before venous blood was drawn for blood lead level testing. Data on blood lead levels, blood pressure, BMI, and hand strength were tested for bivariate correlation using with a 95% confidence interval (p= 0.05).

RESULT

The characteristics of the respondents in this study are presented in Table 1. Most respondents were male (87.5%) with more than five years of work experience (91.67%). The majority of respondents worked 6–8 hours per day (62.5%) and sprayed pesticides for one hour (45.83%). The use of personal protective equipment (PPE) varied, but there were still respondents who did not use PPE (4.2%). Laboratory test results and health status are shown in Table 2. All respondents had blood lead levels <10 µg/dL (100%). More than half of the respondents were identified as having hypertension, either stage 1 (50.0%) or hypertensive crisis (45.8%), while only 4.2% were in the normal blood pressure category. Based on BMI, the majority of respondents had normal nutritional status (54.2%), followed by overweight (29.2%), obese (8.3%), and underweight (8.3%). In the handgrip strength test, most respondents were in the normal category (45.8%), followed by the low category (33.3%) and moderate category (20.8%).

Table 1.
Characteristics Respondents

Identification	f	%
Gender		
Woman	3	12.5
Man	21	87.5
Length of work		
2-5 years	2	8.33
>5 years	22	91.67

Identification	f	%
Working Hours (daily)		
<6 hours	5	20.83
6-8 hours	15	62.5
>8 hours	4	16.67
Duration Spraying		
Without spraying	1	4.17
30 minutes	2	8.33
1 hour	11	45.83
1.5 hours	2	8.33
2 hours	8	33.33
Using EPP (Equipment Personal Protection)		
Face mask	7	29.2
Masks, gloves hand	5	20.8
Masks, gloves hands , both	4	16.7
Masks, gloves hands , apron	1	4.2
Masks, gloves hands , apron, both	2	8.3
Masks, both	1	4.2
No	4	16.7

Table 2.
Result of respondent Examination

Characteristics	f	%	Signification
Leas levels in blood			
Normal (<10µg/dL)	24	100	-
High (≥10µg/dL)	0	0	
Blood Pressure Categories			
Normal syistolic/diastolic values (<120/<80 mmHg)	1	4,2	
Systolic/diastolic blood pressure (120-129/<80 mmHg)	0	0	
Stage 1 hypertension systolic/diastolic value (130-139/80-89 mmHg)	12	50,0	0,028*
Stage 2 hypertension systolic/diastolic value (430-179/90-120 mmHg)	0	0	
Stage 1 hypertension systolic/diastolic value (≥180/>120 mmHg)	11	45,8	
Body Mass index Categories			
Thin value (<18,5 kg/m^2)	2	8,3	
Normal value (18,5-24,9 kg/m2)	13	54,2	0,082
Overweight value (25,0-29,9 kg/m2)	7	29,2	
Obesity value (>30,0 kg/m2)	2	8,3	
Hand strength category			
Low value (<26 kg)	8	33,3	
Medium value (26-31,9 kg)	5	20,8	0,360
Normal value (>32 kg)	11	45,8	

Note: * Blood pressure was measured using the SPSS ETA correlation test, hand strength and BMI were measured using the Spearman's rho correlation test, and blood lead levels, blood pressure, BMI, and hand strength values were taken from the Centers for Disease Control and Prevention (CDC) website. Normal blood lead levels (CDC, 2024), normal blood pressure (Rachael, Zimlich,2023), normal BMI (Samuel D. Emmerich, 2024)values , and normal hand strength values (Anne C. Looker, 2015).

To see based on demographic characteristics, see Table 1. This shows that spraying activities are mostly carried out by men who are generally directly involved in field work. Most respondents have worked for more than five years, namely 22 (91.67%). The longer they have worked as rice farmers, the longer their exposure to pesticides. The respondents' daily working hours were also relatively long, with the majority (15 or 62.5%) working 6–8 hours per day. These conditions have the potential to increase fatigue and the frequency of contact with lead. Research shows that the longer the duration of spraying per hour, the greater the exposure to chemicals in the body (Fajriani, 2019), especially heavy metals that have cumulative properties. Annual exposure with the length of time working as a pesticide sprayer also carries the risk of higher lead exposure, which in the future will cause health problems (Tawakkalni & Winarko, 2019).

Laboratory test results indicate that the lead levels in the respondents' blood are still within safe limits according to standards (CDC, 2024). Bivariate tests show no significant relationship between blood lead levels and blood pressure, BMI, or handgrip strength.

DISCUSSION

Blood lead levels in rice farmers exposed to pesticides had an impact on blood pressure (p=0.028), with a percentage of stage 1 hypertension of 50.0% and hypertensive crisis of 45.8%. The results of this correlation test show a significant relationship between blood lead levels and the incidence of hypertension in the study respondents, but these results do not have a significant impact on BMI (p=0.082) and hand strength (p=0.360). The underlying mechanism of blood lead levels affecting blood pressure is related to increased oxidative stress triggered by increased blood lead levels. Increased oxidative stress will have an impact on endothelial function damage. Lead can increase the production of free radicals and decrease the bioavailability of nitric oxide (NO), causing vasoconstriction and increased peripheral resistance, which leads to hypertension. (Navas-Acien et al., 2007). Although the results of statistical tests of blood lead levels did not have a significant impact on BMI, considering that 29.2% of BMI values fell into the overweight category and 8.3% into the obese category, and the cumulative nature of lead in the body, it will have a disruptive effect on energy metabolism through increased oxidative stress, damage to mitochondrial function, inhibition of metabolic enzymes, and endocrine dysfunction leading to insulin resistance. (Okoroiwu & Iwara, 2018; You et al., 2018) This disorder affects hormonal balance, one of which is increasing excess cholesterol synthesis that triggers a tendency toward obesity (Wattigney et al., 2019). Obesity accompanied by increased total cholesterol, elevated High-Density Lipoprotein (HDL) levels, and decreased Low-Density Lipoprotein (LDL) levels increases the risk of hypertension due to long-term lead exposure (Lanphear et al., 2018).

The results of the hand strength statistical test did not show a significant relationship with lead levels in pesticides, although based on the percentage values, there were respondents with a medium hand strength category of 20.8% and a low category of 33.3%. This condition may reflect the physical effects of neurotoxins, considering that lead accumulation can affect muscle contractility through mitochondrial damage and an increase in free radicals. A study by Gbemavo & Bouchard, (2019) showed that individuals with blood lead levels exceeding the normal threshold had lower hand grip strength than individuals with low lead levels (Gbemavo & Bouchard, 2019). Research by Qu et al., (2019) also found that workers exposed to lead had higher malondialdehyde (MDA) levels and higher blood pressure compared to the non-exposed group, indicating oxidative stress due to heavy metals. (Qu et al., 2019).

At low to moderate levels, lead more often causes kidney dysfunction and high blood pressure than peripheral muscle weakness (Lanphear et al., 2018). The results of the study show that there is no significant relationship between blood lead (Pb) levels and hand muscle strength in rice farmers. Decreased muscle strength is not only influenced by exposure to heavy metals, but also by age, nutritional status, health conditions, and long-term workload. Based on the questionnaire results, the majority of respondents had worked for more than 5 years with a daily duration of 6–8 hours, where plowing, planting, and harvesting are included as heavy manual work that requires repeated physical strength. This is in line with research Walker-Bone et al., (2016) which states that heavy physical work over a long period of time does not increase, but rather tends to decrease hand grip strength in old age due to the monotonous and repetitive nature of the work (Walker-Bone et al., 2016). Thus, although lead levels were not found to be significantly related, age, length of exposure to work, and high work intensity are more likely to affect the neuromuscular function of respondents. These findings confirm that the decline in muscle strength among rice farmers is more influenced by long-term workload and the aging process than by blood lead levels.

Blood lead level test results in 24 respondents showed Pb levels below the normal threshold of <10 µg/dL according to the (CDC, 2024). Heavy metals can enter the human body through various routes, two of which are most important in pesticide chemical toxicity: inhalation and skin contact.

Through inhalation, airborne metal particles are deposited in the respiratory tract according to their size; large particles tend to be retained in the upper respiratory tract, while fine particles can reach the alveoli and then diffuse into the bloodstream (Oberdörster & Elder, 2007). his condition makes inhalation one of the main routes of exposure that contributes to the accumulation of heavy metals in lung tissue and other target organs (Clarà et al., 2023).

The use of personal protective equipment (PPE) such as masks, gloves, aprons, and protective clothing is an important step in reducing exposure to pesticides and heavy metals such as lead among rice farmers. However, the reality in the field shows that the level of PPE use is still low. A study in Rwanda reported that less than 11% of rice farmers use complete PPE, while most rely only on everyday clothing without adequate protection (Ndayambaje et al., 2019). The results of an intervention study in India also show that providing PPE such as coveralls, masks, gloves, boots, and goggles free of charge can significantly reduce pesticide exposure to skin contact in agricultural workers (Lari et al., 2023). Similar conditions were found among vegetable farmers in Indonesia, where the use of PPE was more often limited to hats, long-sleeved shirts, and long pants, while the use of masks, gloves, and aprons was still very rare (Febriana et al., 2023). onsistent use of PPE is very important to prevent the entry of toxic substances, including lead, through both the respiratory tract and skin contact.

The timing of pesticide spraying is an important factor that affects the amount of pesticide exposure to rice farmers. Research in Malaysia reports that wind speeds are lowest in the morning, increasing towards the afternoon, while the highest temperatures are recorded at midday with humidity decreasing over time. These conditions cause higher pesticide volatilization during the day and afternoon, thereby increasing the risk of exposure through inhalation for rice farmers who do not use adequate PPE (Gómez-Redondo et al., 2022) In addition, research in Thailand highlights that standing downwind during spraying with a sprayer increases pesticide concentrations in the breathing zone, while standing upwind significantly reduces inhalation exposure (Konthonbut et al., 2020). A survey of farmers in Brazil also showed that the majority of farmers chose to spray in the morning or late afternoon when temperatures were lower, and paid attention to wind direction before starting spraying to reduce direct exposure of pesticides to the body (Minayo et al., 2012). Thus, spraying in the morning when temperatures are cooler, humidity is higher, and paying attention to wind direction and correct body position can minimize pesticide exposure, including the potential for heavy metals such as lead. This study has limitations because it does not consider the timing of spraying. In addition to the use of PPE, the timing of spraying is an important variable that can affect the amount of pesticide exposure..

The duration of pesticide spraying is an important factor that determines the level of lead exposure in rice farmers' bodies. Studies show that rice farmers in Malaysia spray pesticides for an average of 4 hours per day, 169 days per year, with a working period of less than 17 years, and chronic exposure has been shown to leave pesticide residues and heavy metals in blood serum (Rudzi et al., 2022). This indicates that according to the (CDC, 2024), blood lead levels in adults are considered Elevated Blood Lead Levels (EBLL) when they reach ≥5 µg/dL, which can increase the risk of hypertension, kidney disorders, and cardiovascular disease. Blood lead levels actually only reflect short-term or acute lead exposure, usually within a range of several weeks to two months, so they do not fully describe the chronic accumulation experienced by workers with long periods of high exposure, such as rice farmers (Yu et al., 2023). Research should use protein-containing samples such as hair or nails to represent long-term accumulated lead levels. Since hair is not affected by internal metabolic processes after it grows beyond the skin, the levels of elements in hair indicate long-term exposure depending on hair length, while levels in blood and urine are only a measure of temporary exposure (Harini et al., 2025).

The impact of blood lead levels on blood pressure, hand strength, and BMI parameters shows that these parameters have the potential to be used for monitoring and preventing health risks in rice

farmers. The results of this study indicate that exposure to heavy metals in pesticides has the potential to cause health problems. This is related to the nature of heavy metals, which easily accumulate in the body, making prevention and control of health risks very important.

CONCLUSION

The results of the correlation test analysis show that blood lead levels have a significant effect on blood pressure (p=0.028), but do not have a significant effect on BMI (p=0.082) and hand strength (p=0.360). This study was conducted to determine the impact of blood lead levels on blood pressure, BMI, and hand strength in rice farmers.

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