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Lead Levels in Blood and Urine, Blood Pressure, and Hemoglobin Levels in Online Motorcycle Taxi Workers in Denpasar

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Abstract: This study aimed to analyze the relationship between blood lead (Pb) level, urine Pb level, blood pressure, and hemoglobin level among online motorcycle taxi workers in Denpasar. A quantitative cross-sectional design was used involving 96 drivers selected by purposive sampling. Data were collected through questionnaires, direct physical measurements, and laboratory examinations of blood Pb, urine Pb, and hemoglobin. Normality was tested using the Kolmogorov–Smirnov test. Because several variables were not normally distributed, the data were analyzed using Spearman rank correlation, Mann–Whitney U test, and linear regression. Blood Pb level was not significantly associated with systolic blood pressure, diastolic blood pressure, or hemoglobin level. Urine Pb level was not significantly associated with systolic or diastolic blood pressure, but showed a significant weak negative correlation with hemoglobin level. Blood Pb and urine Pb levels were not significantly correlated. Work duration was not significantly associated with Pb levels, whereas daily working hours showed a marginal association with blood Pb. These findings indicate limited hematological effects and support routine biomonitoring and preventive occupational health measures in traffic-exposed workers.

Keywords: Blood Pressure; Hemoglobin; Lead Exposure; Occupational Health; Online Motorcycle Taxi Workers

Introduction

Lead (Pb) exposure remains an important environmental and occupational health problem, particularly in urban areas with high traffic density and persistent outdoor air pollution. The World Health Organization has stated that lead exposure can cause long-term adverse effects in adults, including increased risk of high blood pressure, cardiovascular problems, kidney damage, and anemia, indicating that Pb is still a relevant public health concern in both environmental and occupational settings (Flora et al., 2012; Needleman, 2004; World Health Organization, 2024b). A recent study by Alayyannur and Arini (2024) further emphasizes the growing concerns of occupational health and safety in various sectors, particularly in high-risk environments such as urban areas.

In addition, ambient air pollution is a major contributor to cardiovascular morbidity and mortality, with the World Health Organization reporting that ischemic heart disease and stroke account for most outdoor air-pollution-related premature deaths worldwide (World Health Organization, 2024a). These conditions make urban workers who spend long hours on the road a particularly vulnerable population. Kementerian Lingkungan Hidup dan Kehutanan (2021) has also highlighted the growing impact of environmental pollution in urban settings, which exacerbates the risks faced by informal workers in these areas.

In Indonesia, this issue is especially relevant because a large proportion of the workforce is employed in the informal sector. Statistics Indonesia reported that the proportion of informal workers increased from

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59.17% in February 2024 to 59.40% in February 2025, showing that more than half of Indonesian workers remain in occupations with limited formal occupational health protection (Badan Pusat Statistik, 2024). Kurniadi et al. (2017) also pointed out that informal workers, particularly in remote areas, face significant health risks due to limited access to proper healthcare and occupational safety regulations. Online motorcycle taxi workers are part of this group and play an essential role in urban mobility and local economic activity, yet they are continuously exposed to traffic emissions, roadside dust, and outdoor pollutants during prolonged working hours. This occupational pattern provides a strong practical reason for investigating environmental exposure among online motorcycle taxi workers as a vulnerable informal-worker population (Badan Pusat Statistik, 2024; Fujishiro, 2019).

From a toxicological perspective, Pb may enter the body through inhalation of polluted air, ingestion of contaminated food or water, and contact with Pb-containing materials, after which it circulates in the blood and may accumulate in soft tissues and bone (Flora et al., 2012; Needleman, 2004; Tchounwou et al., 2012). This toxicokinetic pathway provides an important theoretical basis for biomonitoring studies because internal Pb burden cannot be adequately assessed only from environmental measurements. Hair et al. (2021) also provide valuable insights into the use of advanced statistical methods for evaluating complex exposure–health relationships, which is useful for understanding how Pb exposure correlates with health outcomes in informal workers.

Blood Pb level is widely used as a biomarker of internal exposure, while urinary Pb level may complement blood measurements by reflecting excretion processes and more recent exposure patterns. This combined biomarker approach is important because measuring both blood and urine Pb can provide a more comprehensive picture of absorption, body burden, and elimination of lead in exposed individuals (Mandal et al., 2023; Rahimpoor et al., 2020). The use of both biomarkers is therefore theoretically relevant in workers with repeated and chronic contact with urban pollution sources.

The theoretical basis for linking Pb exposure with blood pressure is also well established. Lead exposure may induce oxidative stress, endothelial dysfunction, autonomic imbalance, and vascular injury, all of which may contribute to elevated blood pressure and hypertension (Brook et al., 2010; Flora et al., 2012). Ishtiaq (2019) reviews several quantitative research approaches that may support the systematic investigation of exposure and health outcomes in urban workers. More recent evidence continues to support this relationship. A systematic review and dose-response meta-analysis published in 2025 concluded that lead exposure is a risk factor for hypertension and demonstrated a clear dose-response pattern across environmental and occupational exposure settings (Yang et al., 2025). Likewise, recent epidemiological work has shown that blood lead remains relevant to blood-pressure abnormalities even at present-day exposure levels, reinforcing the biological plausibility of investigating blood pressure as a cardiovascular outcome in Pb-exposed populations (Wang et al., 2024; Yu et al., 2023).

Hemoglobin level is also a relevant outcome because Pb can interfere with heme biosynthesis and erythrocyte function. Previous studies have shown that Pb inhibits enzymes involved in heme formation, including delta-aminolevulinic acid dehydratase, and may reduce hemoglobin concentration, thereby increasing the risk of anemia or subclinical hematological disturbance (Ebrahimi et al., 2020; Flora et al., 2012; Patrick, 2006). Khosla (2021) also reviews contemporary approaches in social and health research that are useful for understanding complex occupational health outcomes. The World Health Organization also recognizes anemia as one of the adverse effects associated with lead exposure, further supporting the inclusion of hemoglobin as a relevant hematological indicator in this study (World Health Organization, 2024b).

In urban settings, traffic-related pollution remains one of the major exposure pathways for outdoor workers. Denpasar and other urban areas in Bali face air-quality concerns, and online motorcycle taxi workers are highly vulnerable because of prolonged outdoor exposure to vehicle emissions and airborne pollutants during daily work activities (Gong et al., 2024; Hoffmann et al., 2021; Rahmasari et al., 2022). These environmental and occupational conditions provide both a theoretical and practical basis for examining Pb exposure in this worker population.

Although a number of studies have discussed the general health effects of lead exposure, evidence specifically linking blood Pb level and urine Pb level with blood pressure and hemoglobin level among informal urban workers in Indonesia remains limited. Previous studies have linked lead exposure with hypertension and other adverse health effects, but data specifically correlating blood and urine lead biomarkers with blood pressure and hemoglobin in online motorcycle taxi workers are still scarce (Flora et al., 2012; Gong et al., 2024; Were et al., 2014). This gap is important because online motorcycle taxi workers represent a high-exposure occupational group, while biomarker-based evidence is needed to support stronger worker protection, routine biomonitoring, and environmental health policy.

Therefore, this study was conducted for several important reasons. First, online motorcycle taxi workers are routinely exposed to urban air pollution for long working hours, making them a high-risk population for chronic low-level Pb exposure. Second, informal workers constitute a large proportion of the Indonesian workforce, yet their occupational health risks are often overlooked in surveillance and prevention programs (Badan Pusat Statistik, 2024). Third, the simultaneous measurement of blood and urine Pb levels offers complementary information on lead absorption and excretion, which may improve the assessment of exposure status (Mandal et al., 2023; Rahimpoor et al., 2020). Fourth, blood pressure and hemoglobin are clinically meaningful indicators for evaluating possible cardiovascular and hematological consequences of Pb exposure (Brook et al., 2010; Patrick, 2006; Yang et al., 2025). Based on these considerations, this study aimed to analyze the relationship between lead levels in blood and urine and blood pressure and hemoglobin levels among online motorcycle taxi workers in Denpasar, Bali.

Method

Time and place of the research

This study was conducted in Denpasar, Bali, Indonesia, among online motorcycle taxi workers working in urban traffic areas. Field data collection and biological specimen collection were carried out in Denpasar, while laboratory examinations were conducted using standardized laboratory procedures. Based on the research report, the estimated duration of the study was 3–5 months. Ethical approval was obtained from the Health Research Ethics Committee of STIKES Wira Medika Bali with approval number 426/E1.STIKESWIKA/EC/III/2025. Kementerian Lingkungan Hidup dan Kehutanan (2021) also provides important information on environmental quality in Bali, which supports the contextual background of pollution exposure in the study area.

Research design

This study employed a quantitative cross-sectional design with a correlational approach to examine the relationship between blood lead (Pb) level, urine Pb level, blood pressure, and hemoglobin level among online motorcycle taxi workers in Denpasar, Bali. A cross-sectional observational design is appropriate for measuring exposure and outcome variables at the same point in time and is commonly reported using the STROBE guideline framework, while Khosla (2021) provides a useful discussion of research designs for examining exposure–health relationships. The population consisted of active online motorcycle taxi workers in Denpasar, and the sample comprised 96 respondents selected using purposive sampling. Purposive sampling was used to ensure that all respondents met the eligibility criteria and were relevant to the objectives of the study (Polit & Beck, 2018; Sugiyono, 2006).

The inclusion criteria were online motorcycle taxi workers who had worked for at least six months, were willing to participate in all study procedures, and agreed to blood and urine specimen collection, whereas respondents who were unable to complete the data collection procedures were excluded. Ishtiaq (2019), in the review of Creswell's research design, also supports the use of structured instruments to strengthen the rigor and validity of data collection procedures. The independent variables were blood Pb level and urine Pb level, whereas the dependent variables were systolic blood pressure, diastolic blood pressure, and hemoglobin level. Additional variables included age, sex, work duration, daily working hours, smoking habit, work location exposure, and personal protective equipment (PPE) use. Data were collected through structured questionnaires, direct physical measurements, laboratory examinations, and field observations. The tools and materials used in this study included a structured questionnaire, a calibrated digital sphygmomanometer, blood collection equipment, urine specimen containers, Atomic Absorption Spectrophotometry (AAS) for measuring blood and urine Pb levels, and an automated hematology analyzer for measuring hemoglobin level. Blood and urine Pb levels were measured using AAS, which is widely used for metal determination in biological specimens (Skoog et al., 2017). Blood pressure was measured using a calibrated digital sphygmomanometer following standard measurement recommendations (Pickering et al., 2005), while hemoglobin level was measured using an automated hematology analyzer (Cintia Risqi et al., 2022). The use of blood and urine as complementary biomonitoring matrices is supported by recent literature because both matrices provide important information on internal exposure and excretion patterns (Mandal et al., 2023; Tobia et al., 2025).

Research procedure

The study was conducted in several stages. *First*, the researchers prepared the research proposal, research instruments, laboratory coordination, and ethical documents. *Second*, respondents were screened according to the inclusion and exclusion criteria, and eligible participants were recruited using purposive sampling. *Third*, each respondent was informed about the objectives, procedures, risks, and benefits of the study, and written informed consent was obtained prior to data collection. Tang et al. (2022) emphasizes policy recommendations for reducing lead exposure and provides relevant support for ethical awareness in studies involving populations vulnerable to environmental exposure, including informal urban workers. *Fourth*, demographic and occupational data were collected using a structured questionnaire covering age, sex, work duration, daily working hours, smoking habit, and PPE use, followed by field observations to document work environment characteristics, including traffic exposure and PPE use. Fifth, blood pressure was measured directly using a digital sphygmomanometer. Sixth, blood and urine specimens were collected from each respondent using standard specimen collection procedures. *Seventh*, blood and urine Pb levels were analyzed using AAS, while hemoglobin level was measured using an automated hematology analyzer. Eighth, all collected data were checked, coded, tabulated, and prepared for statistical analysis. Respondent confidentiality was maintained throughout the study, and all procedures were conducted in accordance with research ethics principles. Hair et al. (2021) also discusses model evaluation techniques and statistical procedures that are useful for guiding the analysis of relationships between Pb exposure biomarkers and health indicators. The overall research workflow of lead exposure assessment and health indicator analysis is presented in Figure 1.

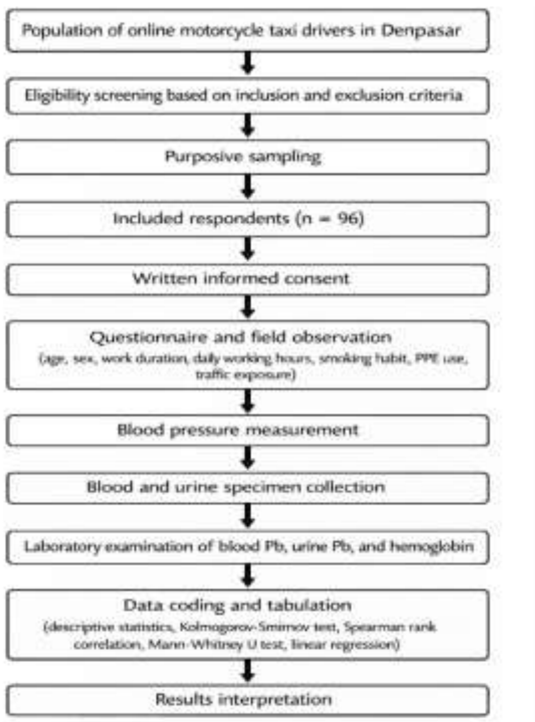

Figure 1. Research flow chart of lead exposure assessment and health indicator analysis among online motorcycle taxi workers in Denpasar, Bali.

Research data analysis

Data were analyzed using statistical software. Descriptive statistics were used to summarize respondent characteristics and the distribution of blood Pb level, urine Pb level, blood pressure, and hemoglobin level. Prior to inferential analysis, normality testing was performed for all continuous variables using the Kolmogorov–Smirnov test. Because several variables did not meet the normality assumption, bivariate correlation analysis was conducted using Spearman rank correlation rather than Pearson correlation (Field, 2013). Erdfelder et al. (2009) also provides an important foundation for understanding statistical power and the interpretation of associations between biomarkers and health outcomes. Linear regression analysis was used to examine the association of work duration and daily working hours with Pb levels. Because the continuous variables were not normally distributed, differences in blood Pb level and urine Pb level according to smoking status and PPE use were analyzed using the Mann–Whitney U test rather than the independent samples t-test (Field, 2013; Pallant, 2017). A significance level of $p < 0.05$ was applied in all analyses (Erdfelder et al., 2009; Pallant, 2017). In addition, Elm et al. (2007), through the STROBE guidelines, supports transparent and rigorous reporting of observational studies, thereby strengthening the reproducibility and clarity of the present study.

Result and Discussion

Results

Respondent Characteristics

The study involved 96 online motorcycle taxi workers in the urban area of Denpasar. The demographic characteristics of the respondents are presented in Table 1.

The study involved 96 in Online motorcycle taxi workers in Denpasar. Most respondents were male (75.0%) and were predominantly aged 36–45 years (25.0%). In terms of work profile, 27.1% had worked for more than 6 years and 27.1% worked more than 8 hours per day. Smoking habit was reported by 51.0% of respondents, while 62.5% did not use PPE and only 37.5% used a standard mask. Most respondents were male, aged 36–45 years, had worked for more than 6 years, and a considerable proportion worked more than 8 hours per day, smoked, and did not use PPE.

Table 1. Distribution of Online Motorcycle Taxi Driver Characteristics

Characteristic	Category	Frequency (n)	Percentage (%)
Age	< 25 years	20	20.8
	26–35 years	18	18.8
	36–45 years	24	25.0
	46–55 years	11	11.5
	> 55 years	23	24.0
Gender	Male	72	75.0
	Female	24	25.0
Work Experience	< 1 years	19	19.8
	1–3 years	28	29.2
	4–6 years	23	24.0
	> 6 years	26	27.1
Work Hours per Day	< 4 hours	20	20.8
	4–6 hours	30	31.3
	6–8 hours	20	20.8
	> 8 hours	26	27.1
Smoking Habit	Yes	49	51.0
	No	47	49.0
PPE Usage	None	60	62.5
	Standard Mask	36	37.5

Lead Levels, Blood Pressure, and Hemoglobin

The descriptive analysis results for blood and urine lead levels, blood pressure, and hemoglobin are presented in Table 2.

Table 2. Descriptive Analysis Results for Lead Levels, Blood Pressure, and Hemoglobin

Parameter	Mean	Standard Deviation	Minimum	Maximum
Blood Pb level (µg/dL)	4.21	0.70	0.87	5.72
Urine Pb level (µg/dL)	4.26	0.79	2.06	7.79
Systolic blood pressure (mmHg)	123.6	13.59	100	149
Diastolic blood pressure (mmHg)	79.9	12.27	60	98
Hemoglobin (g/dL)	13.88	1.10	12.1	16.0

Descriptive analysis showed that the mean blood Pb level was 4.21 µg/dL (SD 0.70; range 0.87–5.72), while the mean urine Pb level was 4.26 µg/dL (SD 0.79; range 2.06–7.79). The mean systolic blood pressure was 123.6 mmHg, the mean diastolic blood pressure was 79.9 mmHg, and the mean hemoglobin level was 13.88 g/dL.

Normality Test

Prior to inferential analysis, a normality test was performed for all continuous variables using the Kolmogorov–Smirnov test. The results showed that systolic blood pressure ($p = 0.011$), diastolic blood pressure ($p = 0.014$), hemoglobin level ($p = 0.009$), and blood Pb level ($p = 0.017$) were not normally distributed, whereas urine Pb level was normally distributed ($p = 0.078$). Therefore, because several key study variables did not meet the normality assumption, the data were analyzed using nonparametric methods for correlation and two-group comparisons.

Table 3. Normality Test of Study Variables

Variable	Kolmogorov–Smirnov Statistic	p-value	Interpretation
Systolic blood pressure	0.105	0.011	Not normal
Diastolic blood pressure	0.103	0.014	Not normal
Hemoglobin level	0.107	0.009	Not normal
Urine Pb level	0.086	0.078	Normal
Blood Pb level	0.101	0.017	Not normal

Correlation of Lead Levels with Blood Pressure and Hemoglobin

Because the data were not normally distributed, the relationship between Pb biomarkers and health indicators was analyzed using Spearman rank correlation.

Table 4. Spearman Rank Correlation between Lead Levels and Health Variables in In Online motorcycle taxi workers in Denpasar

Relationship	ρ-value	p-value	Interpretation
Blood Pb vs. Systolic	-0.011	0.916	Not significant, very weak negative relationship
Urine Pb vs. Systolic	-0.058	0.576	Not significant, very weak negative relationship
Blood Pb vs. Diastolic	-0.180	0.078	Not significant, very weak negative relationship
Urine Pb vs. Diastolic	-0.145	0.160	Not significant, very weak negative relationship
Blood Pb vs. Hemoglobin	-0.058	0.575	Not significant, very weak negative relationship
Urine Pb vs. Hemoglobin	-0.213	0.037*	Significant, weak negative relationship

Spearman rank correlation analysis showed no significant relationship between blood Pb level and systolic blood pressure, diastolic blood pressure, or hemoglobin level. Urine Pb level was also not significantly correlated with systolic or diastolic blood pressure. However, a significant weak negative correlation was found between urine Pb level and hemoglobin level (ρ = -0.213; p = 0.037), indicating that respondents with higher urine Pb levels tended to have lower hemoglobin levels.

Correlation between Blood and Urine Lead Levels

Table 5. Spearman Rank Correlation between Blood Pb and Urine Pb Levels

Relationship	ρ-value	p-value	Interpretation
Blood Pb vs. Urine Pb	0.112	0.278	Not significant, very weak positive relationship

A very weak positive correlation was found between blood Pb and urine Pb levels (ρ = 0.112; p = 0.278), but the relationship was not statistically significant. This indicates that blood Pb level and urine Pb level did not show a significant monotonic relationship in this sample.

Effect of Work Duration and Working Hours on Lead Level

Table 6. Regression Test for Work Duration and Working Hours with Lead Levels

Variable	Blood Pb (µg/dL)	Urine Pb (µg/dL)
Duration of Work	p = 0.234	p = 0.841
Working Hours per Day	p = 0.055*	p = 0.900

Note: Working hours showed a marginal effect on blood lead levels.

Regression analysis showed that work duration was not significantly associated with blood Pb (p = 0.234) or urine Pb (p = 0.841). Daily working hours also did not significantly affect urine Pb (p = 0.900), but showed a marginal association with blood Pb (p = 0.055). These findings suggest that daily exposure intensity may be more relevant than total years of work in relation to blood Pb level.

Effect of Smoking Habit and PPE Usage on Lead Levels

Because the data were not normally distributed, differences in Pb levels according to smoking habit and PPE usage were analyzed using the Mann–Whitney U test.

Table 7. Mann–Whitney U Test for Smoking Habit and PPE Usage with Blood Pb and Urine Pb Levels

Comparison	Group sizes	U	p-value	Result
Blood Pb by smoking habit	49 vs 47	1068.000	0.541	Not significant
Urine Pb by smoking habit	49 vs 47	1075.000	0.575	Not significant
Blood Pb by PPE usage	60 vs 36	748.000	0.688	Not significant
Urine Pb by PPE usage	60 vs 36	617.000	0.110	Not significant

Because the data were not normally distributed, group differences in blood Pb and urine Pb levels according to smoking habit and PPE usage were assessed using the Mann–Whitney U test. The results showed no significant difference in blood Pb level or urine Pb level between smokers and non-smokers (p > 0.05). Similarly, no significant difference was observed in blood Pb level or urine Pb level according to PPE usage (p > 0.05). Overall, these results suggest that smoking habit and PPE usage were not significantly associated with Pb levels among in Online motorcycle taxi workers in Denpasar.

Discussion

Correlation between Lead Levels and Blood Pressure and Hemoglobin

This study found no significant correlation between blood Pb level and systolic blood pressure, diastolic blood pressure, or hemoglobin level among in Online motorcycle taxi workers in Denpasar. Urine Pb level was also not significantly correlated with systolic or diastolic blood pressure. However, urine Pb level showed a significant weak negative correlation with hemoglobin level. These findings indicate that, in this study population, Pb exposure measured through blood and urine biomarkers was not statistically associated with the observed cardiovascular indicators, while a limited hematological association was identified for urine Pb.

This finding should be interpreted cautiously because the absence of statistical significance does not necessarily indicate the absence of biological effect. Flora et al. (2012) explained that lead exposure may induce oxidative stress and disrupt multiple physiological systems, while Brook et al. (2010) described mechanisms linking pollutant exposure with vascular dysfunction, inflammation, endothelial injury, and autonomic imbalance. More recent evidence also supports the biological plausibility of a Pb–blood pressure relationship. Yang et al. (2025), in a systematic review and dose–response meta-analysis, concluded that lead exposure is a risk factor for hypertension and reported a clear dose–response relationship between lead exposure and hypertension risk. Gong et al. (2024) similarly reported that blood lead had a negative impact on blood pressure and hypertension prevalence, particularly under certain occupational and air-pollution conditions. Compared with those studies, the present study did not demonstrate a statistically significant relationship between Pb biomarkers and blood pressure. This difference may be related to variation in exposure level, population characteristics, sample size, and the multifactorial nature of blood pressure regulation.

The non-significant association observed in this study may therefore be related to several factors. First, the average Pb exposure in this sample may reflect chronic low-to-moderate exposure that had not yet produced measurable changes in blood pressure at the time of assessment. Second, the cross-sectional design measured exposure and outcome at one point in time, which limits the ability to detect cumulative physiological effects. Third, blood pressure is influenced by many factors other than Pb exposure, including nutritional status, hydration, stress, medication use, and other individual characteristics that were not fully controlled in this study. Flora et al. (2012) and Patrick (2006) have noted that lead may interfere with heme synthesis and erythrocyte metabolism, while He et al. (2024) also reported that blood lead levels were associated with hematological and biochemical indices in a multifactorial manner rather than through a single simple pathway.

A different pattern was found for hemoglobin. Although blood Pb level was not significantly correlated with hemoglobin, urine Pb level showed a significant weak negative correlation with hemoglobin. This suggests that respondents with higher urine Pb levels tended to have lower hemoglobin levels. From a biological perspective, this result is plausible because Pb may interfere with heme synthesis, erythrocyte metabolism, and hematopoietic function (Flora et al., 2012; Patrick, 2006). This finding is also in line with the broader evidence summarized by He et al. (2024), who showed that lead exposure may be associated with hematological indices through complex biological pathways. Nevertheless, the magnitude of the relationship in this study was weak, and hemoglobin concentration may also have been influenced by many other factors, including nutritional intake, hydration, inflammation, renal function, and host susceptibility (He et al., 2024). Therefore, the present finding should be interpreted as evidence of a limited hematological association rather than a strong clinical effect.

Overall, the present findings do not negate the toxicological importance of lead exposure, but suggest that in this particular sample, the association of Pb with blood pressure was not statistically demonstrated, whereas a weak inverse association was observed between urine Pb level and hemoglobin. This interpretation is more appropriate than concluding that lead has no effect, because broader toxicological and epidemiological evidence continues to show that lead remains relevant to cardiovascular and hematological health.

Correlation between Blood and Urine Lead Levels

This study found a very weak positive correlation between blood Pb level and urine Pb level, but the relationship was not statistically significant. This indicates that respondents with higher blood Pb levels did not necessarily have higher urine Pb levels in a statistically meaningful monotonic pattern.

Rahimpoor et al. (2020) and Tchounwou et al. (2012) support the use of biological matrices to evaluate internal exposure, while more recent evidence by Tobia et al. (2025) reaffirmed that blood remains the standard biomarker for occupational inorganic lead exposure and that comparison with other biological matrices can strengthen interpretation of exposure patterns. Mandal et al. (2023) also emphasized that biomonitoring of lead using multiple biological indicators may provide a more comprehensive understanding of body burden and elimination. In several biomonitoring studies, blood and urine measurements have been used as complementary indicators because they may represent different phases of internal exposure and excretion rather than identical biological processes (Mandal et al., 2023; Rahimpoor et al., 2020; Tobia et al., 2025). Therefore, the absence of a significant correlation between blood and urine Pb levels in this study should not be interpreted as reducing the relevance of either biomarker, but rather as indicating that these two matrices may reflect different physiological aspects of lead exposure and excretion.

Effect of Work Duration and Working Hours on Lead Levels

The regression analysis showed that work duration was not significantly associated with blood Pb level or urine Pb level, while daily working hours showed a marginal association with blood Pb level. This suggests that the intensity of daily exposure may be more relevant than total years of work in explaining Pb burden among online motorcycle taxi workers.

This interpretation is reasonable because workers who spend longer hours in traffic may experience greater short-term inhalation exposure to roadside pollutants, even if their total years of work are not exceptionally long. Fujishiro (2019) has emphasized the occupational vulnerability of informal workers, while Rahimpoor et al. (2020) reported that exposure duration may influence blood lead levels. At the same time, He et al. (2024) showed that blood lead levels are influenced by several factors, indicating that cumulative years of work alone may not directly predict lead burden. Thus, the present result suggests that exposure intensity, traffic conditions, route variation, and workplace behavior may modify the relationship between working time and Pb exposure. Compared with previous studies that reported a positive relationship between duration of exposure and Pb burden, the present study suggests that the number of working hours per day may be more relevant than total years of employment in this occupational setting.

Effect of Smoking Habit and PPE Usage on Lead Levels

This study found that smoking habit and PPE usage were not significantly associated with blood Pb level or urine Pb level among in Online motorcycle taxi workers in Denpasar. Thus, although group comparisons showed some variation in Pb levels, these differences were not statistically significant in this sample.

These findings should be interpreted carefully. Chen et al. (2022) showed that smoking-related exposure was associated with multiple heavy metal concentrations, and Ho et al. (2021) reported that smoking interacted with lead exposure and oxidative stress-related susceptibility. He et al. (2024) likewise identified smoking as one of the factors associated with blood lead levels. Together, these studies support the biological plausibility that cigarette smoke may serve as an additional source of Pb exposure and may increase biological burden in traffic-exposed workers. However, in the present study, smoking habit was not statistically demonstrated to be associated with blood Pb level or urine Pb level. This difference from previous studies may reflect the influence of other environmental exposures shared by most respondents, as well as the lack of more detailed measurement of smoking intensity, duration, and frequency.

A similarly cautious interpretation is needed for PPE usage. Duncan et al. (2021) showed that mask types differ in filtration performance and total inward leakage, indicating that protective barriers can reduce inhalation of airborne particles to varying degrees. Therefore, although regular mask use may theoretically help reduce inhalation exposure to traffic-related particles, including Pb-containing particulates, the present study did not find a statistically significant difference in blood Pb level or urine Pb level according to PPE usage. This interpretation is more appropriate than attributing PPE effectiveness directly to Flora et al. (2012), because Flora primarily discusses lead toxicity rather than mask performance. At the same time, Flora et al. (2012) remains relevant in explaining the broader biological importance of limiting Pb exposure. The discrepancy between previous studies and the present results may also be related to differences in mask type, consistency of use, duration of use, and the relatively limited protection provided by standard masks in open-road traffic environments.

Policy Implications and Statistical Recommendations

The findings of this study indicate that Pb exposure among online motorcycle taxi workers remains an important occupational and environmental health issue. Although Pb biomarkers were not significantly associated with blood pressure, and blood Pb was not significantly associated with hemoglobin, urine Pb level showed a significant weak negative correlation with hemoglobin. These findings suggest that routine biomonitoring remains important, particularly for informal workers with prolonged exposure to traffic-related pollution. Hematological monitoring may also be relevant in workers with chronic roadside exposure.

This study has several limitations. The cross-sectional design does not permit causal inference between Pb exposure and health outcomes. In addition, purposive sampling limited the sample to in Online motorcycle taxi workers in Denpasar, which may reduce the generalizability of the findings to other informal worker groups. Future studies are recommended to use longitudinal designs, larger and more representative samples, and additional variables such as nutritional status, body mass index, medication use, smoking intensity, and genetic susceptibility in order to better explain individual differences in response to Pb exposure.

Conclusion

This study showed that blood Pb level was not significantly associated with systolic blood pressure, diastolic blood pressure, or hemoglobin level among in Online motorcycle taxi workers in Denpasar. Urine Pb level was also not significantly associated with systolic or diastolic blood pressure, but it showed a significant weak negative correlation with hemoglobin level. Blood Pb level and urine Pb level were not significantly correlated with each other. Work duration was not significantly related to Pb levels, while daily working hours showed a borderline association with blood Pb level. In addition, smoking habit and PPE usage were not significantly associated with either blood Pb level or urine Pb level. Overall, these findings suggest that the cardiovascular effects of Pb exposure were not statistically demonstrated in this study, although the inverse association between urine Pb and hemoglobin may indicate a limited hematological effect. Therefore, online motorcycle taxi workers may still represent a potentially exposed occupational group, and routine biomonitoring as well as preventive occupational health measures may be considered to minimize possible long-term health risks.

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Author Contributions
All authors contributed to the writing and revision of the article. The tasks of individual authors. e.g., D.P contributed to data collection by conducting research; P.A.P contributed to data analysis and interpretation; A.A.A.E.C contributed to data curation and formal analysis; all authors have approved the final version.

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Conflicts of Interest
The authors declare no conflict of interest. in the publication of this scientific article.

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