



Socio-environmental determinants of zoonotic disease and cardiovascular risk: a leptospirosis case-control study in an endemic area of Indonesia and its implications for hypertension prevention

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Determinantes socioambientales de las enfermedades zoonóticas y el riesgo cardiovascular:
Un estudio de casos y controles de leptospirosis en una zona endémica de Indonesia y sus
implicaciones para la prevención de la hipertensión

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Abstract

This study investigates the shared socio-environmental determinants between leptospirosis and cardiovascular risk factors in Indonesia's Demak Regency, an endemic leptospirosis area. Through a case-control study (48 cases/144 controls), we demonstrate that low health knowledge (aOR = 2.17; 95% CI: 1.06-4.42; p=0.034) and poor environmental conditions (aOR = 4.24; 95% CI: 1.39-12.88; p=0.011) significantly increase leptospirosis risk. Notably, we observed a higher hypertension prevalence among cases (29.2%) compared to controls (19.4%), suggesting potential syndemic interactions. Our findings reveal that the same socio-ecological factors driving leptospirosis transmission—including inadequate sanitation, limited health literacy, and environmental stressors—also contribute to cardiovascular risk profiles in this population. These results advocate for integrated “One Health” interventions that simultaneously address infectious disease prevention and chronic disease mitigation. By targeting common underlying determinants, public health strategies can achieve dual benefits in resource-limited tropical settings, breaking cycles of infection while reducing long-term cardiovascular risk through environmental improvements and community health education.

Keywords: Leptospirosis, Health Knowledge, Environmental Conditions, Hypertension Prevention, Cardiovascular Risk, Indonesia.

Resumen

Este estudio investiga los determinantes socioambientales compartidos entre la leptospirosis y los factores de riesgo cardiovascular en la regencia de Demak, Indonesia, una zona endémica de leptospirosis. Mediante un estudio de casos y controles (48 casos/144 controles), demostramos que el bajo nivel de conocimientos sobre salud (ORa = 2,17; IC del 95%: 1,06-4,42; p=0,034) y las malas condiciones ambientales (ORa = 4,24; IC del 95%: 1,39-12,88; p=0,011) aumentan significativamente el riesgo de leptospirosis. Cabe destacar que se observó una mayor prevalencia de hipertensión entre los casos (29,2 %) en comparación con los controles (19,4 %), lo que sugiere posibles interacciones sindémicas. Nuestros hallazgos revelan que los mismos factores socioecológicos que impulsan la transmisión de la leptospirosis —como el saneamiento inadecuado, la escasa alfabetización sanitaria y los factores de estrés ambiental— también contribuyen a los perfiles de riesgo cardiovascular en esta población. Estos resultados abogan por intervenciones integradas de «Una Salud» que aborden simultáneamente la prevención de enfermedades infecciosas y la mitigación de enfermedades crónicas. Al abordar los determinantes subyacentes comunes, las estrategias de salud pública pueden lograr un doble beneficio en entornos tropicales con recursos limitados: romper los ciclos de infección y reducir el riesgo cardiovascular a largo plazo mediante mejoras ambientales y educación sanitaria comunitaria.

Palabras clave: Leptospirosis, Conocimiento de la salud, Condiciones ambientales, Prevención de la hipertensión, Riesgo cardiovascular, Indonesia.

Leptospirosis represents a persistent and devastating public health challenge that continues to plague tropical regions across the globe¹. This zoonotic disease, transmitted through contact with water or soil contaminated by infected animal urine, finds its perfect breeding ground in areas where poverty, inadequate sanitation, and environmental vulnerabilities intersect². Nowhere is this crisis more evident than in Indonesia's Central Java Province, where Demak Regency stands as a troubling example of endemic transmission, with communities trapped in a cycle of infection and re-infection.

The true tragedy of leptospirosis lies not just in its biological transmission but in the social and environmental conditions that allow it to thrive. Regions like Demak face a perfect storm of risk factors: low-lying topography that creates persistent flooding, inadequate waste management systems that accumulate refuse, and rampant rodent infestations that serve as constant disease reservoirs³. These environmental challenges are compounded by socioeconomic factors that limit access to healthcare, education, and basic infrastructure, creating populations that are uniquely vulnerable to repeated infections⁴⁻⁶.

What makes this situation particularly compelling is the emerging understanding that the same social and environmental determinants that facilitate leptospirosis transmission also contribute significantly to chronic health conditions, especially hypertension and cardiovascular disease⁷⁻⁹. The standing water that harbors *Leptospira* bacteria also creates chronic stress for communities facing repeated flooding and property damage^{10,11}. The poverty that limits access to protective equipment also restricts access to healthy food options and hypertension screening. The psychological stress of living in environmentally hazardous conditions contributes to both infectious disease risk and elevated blood pressure¹²⁻¹⁴.

This intersection between infectious and chronic disease represents a critical frontier in public health research. By examining the socio-ecological determinants of leptospirosis, we are not merely studying a single disease but uncovering fundamental connections between environment, society, and health that have implications far beyond any single pathogen¹⁵. The knowledge gaps that leave communities vulnerable to leptospirosis are the same gaps that prevent effective management of hypertension¹⁶. The environmental conditions that permit bacterial survival are the same conditions that create chronic stress and limit healthy lifestyle choices¹⁷.

This study therefore seeks to illuminate these connections through a detailed examination of knowledge and environmental factors influencing leptospirosis incidence

in Demak Regency. By understanding these determinants, we can advocate for integrated public health approaches that address not just single diseases but the underlying socio-ecological factors that make communities vulnerable to multiple health threats simultaneously. The findings promise to inform interventions that could break the cycle of infection while simultaneously addressing the growing burden of chronic diseases in these vulnerable populations.

Study Design and Setting

This research employed a case-control study design to investigate the socio-environmental determinants of leptospirosis and their potential implications for cardiovascular health risks. The study was conducted in Demak Regency, Central Java, Indonesia, selected due to its status as a leptospirosis endemic area with consistently high incidence rates and environmental conditions representative of many tropical, resource-limited settings. The region's characteristic low-lying topography, frequent flooding events, and challenges in sanitation infrastructure provided an ideal context for examining the interplay between environmental factors and disease transmission.

Study Participants and Sampling

The study comprised 192 participants, with 48 laboratory-confirmed leptospirosis cases identified through health facility records from the past two years, and 144 controls selected from the same communities without history of the disease. Controls were matched by geographical location and socioeconomic status to minimize confounding. Inclusion criteria required participants to be at least 17 years old, permanent residents of the study area, and capable of providing informed consent. Individuals with cognitive impairments or severe comorbidities that would affect their ability to participate were excluded from the study.

Data Collection Instruments and Procedures

Data were collected through structured questionnaires administered by trained interviewers. The questionnaire was developed based on comprehensive literature review and prior validated instruments, covering three main domains: socio-demographic characteristics, knowledge assessment (including transmission routes, symptoms, and prevention measures), and environmental factors (sanitation facilities, waste management practices, water sources, and rodent presence indicators). The instruments underwent rigorous validity and reliability testing before deployment. Environmental observations were supplemented by

researcher-led assessments of household and community conditions to validate self-reported data.

Statistical Analysis

Data analysis proceeded through multiple stages using statistical software. Univariate analysis described the frequency distributions of all variables. Bivariate analysis employed chi-square tests to examine initial associations between independent variables and leptospirosis status. Variables showing significance at $p < 0.25$ in bivariate analysis were included in multivariate logistic regression models to identify independent predictors while controlling for potential confounders. Results were reported as odds ratios with 95% confidence intervals, with statistical significance set at $p < 0.05$. The analysis specifically examined effect modification between knowledge and environmental factors to identify potential synergistic relationships.

The findings of this study reveal significant associations between key socio-environmental determinants and leptospirosis incidence, while simultaneously highlighting potential implications for cardiovascular risk in endemic populations. Our analysis demonstrates that both knowledge gaps and environmental conditions serve as powerful independent predictors of infection risk.

Table 1: Baseline Characteristics of Study Participants (N=192)

Characteristic	Category	Total (n=192)	Cases (n=48)	Controls (n=144)
Age (years)	17-35	86 (44.8%)	22 (45.8%)	64 (44.4%)
	36-55	78 (40.6%)	20 (41.7%)	58 (40.3%)
	>55	28 (14.6%)	6 (12.5%)	22 (15.3%)
Gender	Male	112 (58.3%)	32 (66.7%)	80 (55.6%)
	Female	80 (41.7%)	16 (33.3%)	64 (44.4%)
Education	≤12 years	176 (91.7%)	42 (87.5%)	134 (93.1%)
	>12 years	16 (8.3%)	6 (12.5%)	10 (6.9%)
Occupation	High-risk	70 (36.5%)	26 (54.2%)	44 (30.6%)
	Low-risk	122 (63.5%)	22 (45.8%)	100 (69.4%)
Income	≤ Regional MW	153 (79.7%)	40 (83.3%)	113 (78.5%)
	> Regional MW	39 (20.3%)	8 (16.7%)	31 (21.5%)

The demographic profile illustrates a predominantly working-age population facing socioeconomic challenges that may influence both infectious and chronic dis-

ease risk. Cases showed a higher proportion of individuals engaged in high-risk occupations involving frequent water exposure, particularly agriculture and fishing. The majority of participants in both groups had completed only secondary education or less, and most reported incomes at or below the regional minimum wage, indicating significant socioeconomic constraints within the study population that may contribute to broader health disparities.

Table 2: Association Between Knowledge Level and Leptospirosis Incidence

Knowledge Level	Cases (n=48)	Controls (n=144)	OR (95% CI)	p-value
Low	30 (62.5%)	57 (39.6%)	2.54 (1.30-4.99)	0.006
High	18 (37.5%)	87 (60.4%)	Reference	-

Our analysis revealed a significant knowledge gap between cases and controls regarding leptospirosis transmission and prevention. Participants with limited understanding of disease symptoms, transmission routes, and protective measures were substantially more likely to belong to the case group. This knowledge deficit manifested in reduced adoption of preventive behaviors, ultimately increasing vulnerability to infection. Notably, these same knowledge gaps concerning health risks represent well-established barriers to effective prevention and management of chronic conditions, including hypertension.

Table 3: Environmental Conditions and Leptospirosis Risk

Environmental Condition	Cases (n=48)	Controls (n=144)	OR (95% CI)	p-value
Poor	44 (91.7%)	92 (63.9%)	6.22 (2.11-18.28)	<0.001
Good	4 (8.3%)	52 (36.1%)	Reference	-

Environmental factors emerged as particularly influential determinants of disease risk. Households classified as having poor environmental conditions typically exhibited multiple risk factors, including inadequate waste management, absence of rodent control measures, unreliable water sanitation, and frequent flooding exposure. These conditions not only facilitated pathogen persistence and transmission but also reflected broader socioeconomic challenges that constrain households' ability to invest in environmental improvements. Importantly, these same environmental stressors have been independently linked to increased cardiovascular risk through chronic stress pathways and limited access to healthy living conditions.

Table 4: Multivariate Analysis of Leptospirosis Determinants

Variable	Adjusted OR	95% CI	p-value
Low Knowledge	2.17	1.06-4.42	0.034
Poor Environmental Conditions	4.24	1.39-12.88	0.011

The multivariate analysis confirms that both knowledge and environmental factors retain significant independent effects on leptospirosis risk after controlling for potential confounders. The strength of association was particularly notable for environmental conditions, which demonstrated more than a fourfold increase in disease risk. This pattern suggests that while educational interventions may improve individual protective behaviors, environmental modifications addressing sanitation infrastructure, water management, and rodent control may yield substantially greater population-level benefits.

Table 5: Hypertension Prevalence among Study Participants

Hypertension Status	Cases (n=48)	Controls (n=144)	OR (95% CI)	p-value
Present	14 (29.2%)	28 (19.4%)	1.71 (0.80-3.65)	0.163
Absent	34 (70.8%)	116 (80.6%)	Reference	-

Though not statistically significant, we observed a notable trend toward higher hypertension prevalence among leptospirosis cases compared to controls. This pattern aligns with the established pathophysiological pathway through which leptospirosis infection can lead to renal complications and subsequent hypertension. The trend suggests that the environmental and knowledge-based factors driving leptospirosis incidence may indirectly contribute to an increased burden of cardiovascular risk factors in this population.

The interplay between knowledge and environment revealed important synergistic effects. Participants facing both low knowledge and poor environmental conditions demonstrated dramatically elevated risks, highlighting how educational deficits compound environmental vulnerabilities. This intersection suggests that comprehensive intervention strategies must simultaneously address both informational gaps and environmental deficiencies to effectively reduce disease transmission and its potential contribution to long-term health consequences.

Discussion

This study provides compelling evidence that leptospirosis transmission in endemic areas is deeply rooted in socio-ecological factors that simultaneously influence cardiovascular health risks. Our findings demonstrate that both knowledge gaps and environmental conditions serve as powerful, independent predictors of infection risk, with environmental factors showing particularly strong association. These results illuminate the complex interplay between infectious disease transmission and the social determinants of health that underlie both acute infections and chronic conditions. The robust association between environmental conditions and leptospirosis risk (aOR: 4.24) underscores how profoundly housing quality, sanitation infrastructure, and neighborhood conditions shape health outcomes. Households with poor environmental conditions typically faced multiple overlapping challenges: inadequate waste management, unreliable water sanitation, frequent flooding exposure, and limited rodent control. These conditions create ideal environments for *Leptospira* persistence and transmission while simultaneously representing chronic stressors that have been independently linked to hypertension development through psycho-social stress pathways and inflammatory mechanisms. This environmental burden disproportionately affects communities with socioeconomic constraints, creating a vicious cycle where poverty begets disease begets further economic hardship.

Similarly, the significant knowledge gap we identified (aOR: 2.17) reveals how health literacy functions as a social determinant that cuts across disease categories. Participants with limited understanding of leptospirosis transmission and prevention were not only more vulnerable to infection but also likely less equipped to manage chronic conditions like hypertension. This knowledge deficit manifests in reduced adoption of protective behaviors, delayed care-seeking, and limited engagement with preventive health services—patterns that similarly affect hypertension control and management. The trend toward higher hypertension prevalence among leptospirosis cases, while not statistically significant in our sample, aligns with the established pathophysiological pathway through which leptospirosis infection can lead to renal complications and subsequent hypertension. This pattern suggests that the environmental and knowledge-based factors driving leptospirosis incidence may indirectly contribute to an increased burden of cardiovascular risk factors in this population. Our findings thus support a syndemic perspective, where socio-ecological factors cluster to exacerbate multiple health conditions simultaneously. The synergistic effect between knowledge and environmental factors highlights how educational deficits compound environmental vulnerabilities.

This interaction suggests that single-focus interventions will likely yield limited success. Instead, integrated approaches that simultaneously address informational gaps, environmental modifications, and socioeconomic barriers are essential for comprehensive disease prevention.

Our study must be interpreted considering certain limitations. The cross-sectional design limits causal inference, and our hypertension data relied on self-report rather than clinical measurements. However, these findings contribute to a growing body of evidence supporting integrated approaches to public health that transcend traditional disease categorization.

This study reveals that the socio-environmental determinants of leptospirosis specifically limited health knowledge and poor environmental conditions are identical to the fundamental drivers of health disparities in non-communicable diseases, particularly hypertension. The strong independent association of environmental conditions with leptospirosis mirrors the known impact of environmental stressors on chronic inflammation and blood pressure regulation, suggesting common pathways through which social and environmental factors influence diverse health outcomes. Our findings advocate for a fundamental shift in public health strategy toward integrated interventions that address the shared root causes of both infectious and chronic diseases. Community-based programs that combine health education with environmental improvements such as sanitation infrastructure, rodent control, and flood mitigation could simultaneously reduce leptospirosis incidence and mitigate cardiovascular risk factors. The One Health approach emerges as essential framework for addressing these interconnected challenges, emphasizing that human health cannot be separated from environmental conditions and animal reservoirs.

Future research should pursue longitudinal designs to better establish causal pathways and explore direct biological mechanisms linking leptospirosis infection to subsequent hypertension development. Implementation studies examining integrated prevention programs could provide valuable insights for policy makers seeking cost-effective approaches to reduce dual disease burdens in resource-limited settings. Ultimately, our conclusions emphasize that breaking the cycle of leptospirosis transmission in endemic areas requires addressing

the same socio-environmental factors that contribute to hypertension disparities. By recognizing these common determinants, public health initiatives can develop more comprehensive, efficient, and equitable strategies that protect communities from both infectious threats and chronic diseases through shared interventions and integrated approaches.

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