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Risk Factors for Tuberculosis Among Livestock Farmers in Geyer and Toroh Districts, Grobogan Regency

Aisyah Purnomosari[1], Martini Martini[2]

[1]Master of Epidemiology Study Program, Faculty of Public Health, Diponegoro University
[2]Department of Epidemiology and Tropical Disease, Faculty of Public Health, Diponegoro University

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ABSTRACT

Background: Tuberculosis (TB) remains a major global public health problem. The World Health Organization (WHO) estimated 10.8 million new TB cases and 1.2 million deaths worldwide in 2023. Indonesia is among the countries with the highest TB burden. Livestock farmers may face additional occupational exposure risks due to prolonged exposure to enclosed barn environments characterized by high humidity, organic dust, ammonia accumulation, and limited ventilation. However, evidence regarding TB risk factors in livestock farming communities remains limited.
Methods: A *retrospective case–control* study was conducted among 156 livestock farmers in Geyer and Toroh Districts, Grobogan Regency (78 TB cases and 78 controls matched by village). Cases were individuals aged ≥18 years with confirmed TB diagnoses documented in medical records. Controls were farmers without TB history from the same communities. Data were collected using structured interviews and environmental observation checklists. Associations were examined using *chi-square* tests and multivariable *logistic regression*, with adjusted odds ratios (AORs) and 95% confidence intervals (CIs).
Results: Eight variables were associated with TB in bivariate analysis. After adjustment, age remained the only independent predictor. Farmers aged >50 years demonstrated a 3.6-fold higher likelihood of TB compared with younger farmers (AOR=3.612; 95% CI: 1.689–7.684). The final model accounted for 23.6% of variance (Nagelkerke R^2=0.236).
Conclusion: Age >50 years is the dominant risk factor for TB among livestock farmers. Targeted TB screening and occupational health integration are urgently needed in rural farming communities.

Keywords: tuberculosis; livestock farmers; case–control study; Grobogan

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*Corresponding author, e-mail:, aisyahpurnomosari@gmail.com

Introduction

Tuberculosis (TB) continues to pose a major global public health challenge. In 2023, an estimated 10.8 million individuals developed TB worldwide, with approximately 1.2 million deaths attributed to the disease1. Indonesia remains one of the highest-burden countries, contributing substantially to global TB incidence and mortality[1,2]. Despite sustained national control strategies, transmission remains ongoing, particularly among populations facing occupational and socioeconomic vulnerabilities.

The disease spreads predominantly through inhalation of airborne particles carrying *Mycobacterium tuberculosis*[3]. The likelihood of infection and progression to active disease is shaped by the interplay between host immunity, environmental conditions, and duration or intensity of exposure[3,4]. Work environments characterized by inadequate ventilation, crowding, and prolonged indoor activity may amplify the probability of airborne transmission[4].

Livestock farming may represent an occupational context with heightened respiratory risk. Routine activities inside animal shelters expose farmers to organic dust, bioaerosols, ammonia, and elevated humidity, often within poorly ventilated structures[5]. These microenvironmental factors can support aerosol persistence and compromise pulmonary defense mechanisms, potentially facilitating infection or reactivation[4,6]. Moreover, long-term cumulative exposure, combined with age-related immune decline, may further increase vulnerability among older farmers[7].

Grobogan Regency, a prominent livestock-producing area in Central Java, provides a relevant rural setting where demographic, occupational, and environmental factors converge. Although the One Health perspective highlights the interdependence of human, animal, and environmental health[9], empirical evidence examining TB determinants among livestock farmers in Indonesia remains scarce.

Few studies have simultaneously evaluated host characteristics, occupational exposures, and environmental conditions within rural agricultural communities. Therefore, this study sought to investigate sociodemographic, occupational, and environmental factors associated with TB among livestock farmers in Grobogan Regency[8].

Figure 1. Grobogan Regency

Methods

A. Study Design and Population

This research employed a community-based case–control design. The case group comprised livestock farmers aged 18 years or older with confirmed tuberculosis diagnoses documented at primary healthcare centers in Geyer and Toroh Districts. Controls were livestock farmers residing in the same villages who had no prior history or clinical diagnosis of TB at the time of enrollment, ensuring comparability in environmental and socio-demographic background.

Cases were identified through health facility records, while controls were selected from the surrounding communities of confirmed cases. Sample size calculation was performed assuming 80% statistical power, a 5% level of significance, an expected exposure prevalence of 40% among controls, an anticipated odds ratio of 2.5, and a 1:1 case–control ratio. Based on these parameters, the minimum required sample was 156 participants, consisting of 78 cases and 78 controls.

Participants were recruited using a convenience sampling approach. Eligible individuals who were accessible and consented during the data collection period were included in the study. This method was considered appropriate given the relatively homogeneous characteristics of the study

population and field-based recruitment constraints.

Statistical Analysis

Data entry was performed using EpiData version 3.1 (Odense, Denmark), followed by verification procedures through random cross-checking of electronic records against source documents to minimize entry errors. The validated dataset was subsequently processed in Microsoft Excel and analyzed using R software version 4.2.1.

Logistic regression modeling was conducted to evaluate associations between potential determinants and TB status. Variables demonstrating statistical significance at $p < 0.05$ in univariate analysis were considered candidates for multivariable modeling. A forward selection procedure was implemented, beginning with the variable showing the strongest crude association. Model refinement was guided by statistical significance ($p < 0.05$) based on the Wald test, while likelihood ratio tests were applied for categorical variables with multiple levels. Adjusted odds ratios (aORs) with 95% confidence intervals were calculated to quantify independent effects.

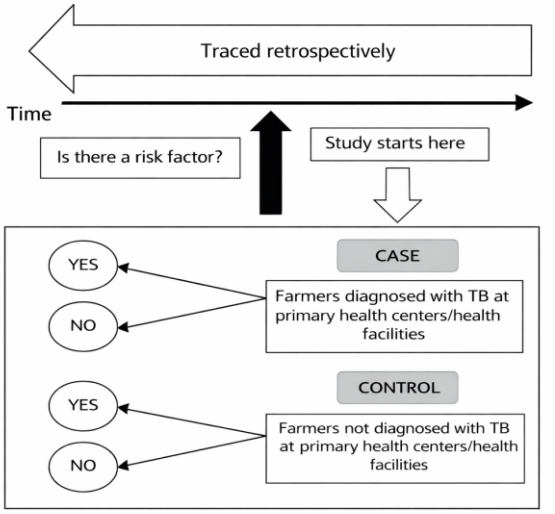

Figure 2. Research Diagram

Ethical clearance was granted by the Ethics Committee of the Faculty of Public Health, Diponegoro University (Ref: 299/EA/KEPK-FKM/2025).

Result

Table 1 Distribution of Respondents by Age, Gender and Education Level

Variable	Category	Frequency	Percentage (%)
Age	< 30 years	2	1.28
	30 – 50 years	70	44.87
	> 50 years	84	53.85
Gender	Male	91	58.33
	Female	65	41.67
Level of education	Elementary School	92	58.97
	Junior High School	49	31.41
	Senior High School	14	8.97
	Undergraduate	1	0.64

Independent variables that meet the requirements of logistic regression to be included in multivariate modeling ($p<0.05$), namely age (0.000), gender (0.003), nutritional status (0.042), ventilation (0.002), sanitation (0.003), livestock waste processing (0.037), frequency of contact with livestock (0.026) and knowledge about TB (0.029) After obtaining the important predictor variables in logistic regression, an interaction analysis was then carried out together to see the possibility of interaction between variables. The best model equation was considered with a significance value of $p<0.05$.

Table 2. Bivariate Analysis Results

No	Variable	OR	95% CI	χ^2	*p*-value
1	Age	4.019	2.082-7.962	16.641	0.000*
2	Gender	2.650	1.371-5.122	8.584	0.003*
3	Level of education	3.037	0.923-9.995	3.614	0.057
4	Length of work	1.765	0.936-3.327	3.103	0.078
5	Nutritional status	0.464	0.219-0.980	4.137	0.042*
6	Ventilation	3.255	1.511-7.013	9.562	0.002*
7	Sanitation	2.802	1.477-5.541	9.062	0.003*
8	Residential density with livestock	1.448	0.764-2.745	1.292	0.256
9	Livestock waste processing	1.962	1.038-3.710	4.340	0.037*
10	Contact with TB Patients	0.528	0.225-1.240	2.195	0.138
11	Frequency of contact with livestock	0.354	0.138-0.910	4.294	0.026*
12	Use of PPE	1.351	0.292-6.247	0.150	0.699
13	Consumption of Raw Milk	2.603	0.489-13.840	1.346	0.246
14	TB Knowledge	2.097	1.072-4.104	4.746	0.029*
15	Smoking	1.000	0.468-2.139	0.000	1.000

*Variables related to the dependent variable (p<0.05) as variables that meet the requirements in the logistic regression test.

The bivariate analysis results for variables meeting a *p-value* <0.05 were then subjected to multivariate analysis using logistic regression. The Nagelkerke R-square value was 0.236, concluding that the independent variables collectively contributed 23.6% to the dependent variable. The table above shows that the sig. value for the age variable is 0.001 <0.05, indicating that age has a partial effect on TB incidence. Calculation of the probability of an effect:

$$p = \frac{1}{1+e^{-(-0,784+1,284)}} = \frac{1}{1,606} = 62,26\%$$

Tabel 3. Multivariate Analysis Results

Variable	Sig.	Exp(B)	95%CI for EXP(B)
Age	0,001*	3,612	1,689-7,684
Gender	0,198	1,632	0,774-3,443
Nutritional status	0,503	0,735	0,299-1,809
Ventilation	0,362	1,670	0,555-5,023
Sanitation	0,796	1,164	0,367-3,694
Livestock waste processing	0,500	0,700	0,248-1,976
Knowledge about TB	0,388	1,472	0,611-3,546
Frequency of contact with livestock	0,080	0,382	0,130-1,120
Constant	0,198	0,456	

Discussion

This study aimed to identify risk factors for tuberculosis (TB) among livestock farmers in Geyer and Toroh Districts, Grobogan Regency, using a case-control approach. Multivariate analysis results showed that age was the only dominant risk factor significantly associated with TB incidence among livestock farmers, after controlling for other variables in the model.

A. Age as a Dominant Risk Factor

The multivariable analysis identified age as the only independent predictor of TB among livestock farmers. Participants older than 50 years exhibited more than a threefold increase in odds compared with younger counterparts (OR=3.612; 95% CI: 1.689–7.684). This pattern reinforces evidence that advancing age substantially shapes TB vulnerability[10,12]. From a biological standpoint, aging is accompanied by progressive alterations in immune regulation, commonly referred to as immunosenescence. Reduced T-lymphocyte responsiveness and impaired macrophage function weaken host capacity to contain *Mycobacterium tuberculosis* infection10. Structural changes in pulmonary tissue, including diminished lung elasticity, may further compromise respiratory defense mechanisms. Over time, cumulative environmental exposures combined with declining immune surveillance increase the probability that latent infection progresses to active disease[7].

Epidemiological studies in Indonesia have similarly reported higher TB incidence among older adults, particularly in rural populations where healthcare access and early detection may be limited[12]. At the global level, TB in older individuals is more frequently attributed to reactivation of latent infection acquired earlier in life rather than recent transmission events[13]. This mechanism plausibly explains why age retained significance after adjustment for occupational and environmental factors in the present model.

B. Gender

Sex differences were apparent in the crude analysis, with male farmers exhibiting higher TB occurrence. However, this association did not persist after adjustment for covariates, suggesting that gender itself may not function as an independent biological determinant in this context. Rather, the observed disparity is likely explained by differential exposure patterns and behavioral factors correlated with male occupational roles[14].

In many rural settings, men are more frequently engaged in prolonged outdoor or high-intensity agricultural activities and may experience greater cumulative exposure to potentially hazardous environments. In addition, gender-related differences in healthcare utilization—where men often delay seeking medical care—can contribute to higher observed TB rates[15]. Once variables capturing age, occupational exposure, and related behaviors were incorporated into the regression model, the apparent gender effect diminished, indicating that it was largely mediated through these interconnected pathways rather than representing an intrinsic risk factor.

C. Nutritional Status

Although nutritional status demonstrated a crude association with TB, this relationship was attenuated after adjustment for other variables. From an epidemiological standpoint, inadequate nutritional intake compromises cell-mediated immunity, thereby facilitating progression from latent infection to active tuberculosis[16]. However, within the present analysis, the influence of nutritional status may have been overshadowed by stronger host-related determinants, particularly advanced age.

Methodological considerations may also explain the null finding in the multivariable model. Nutritional status was categorized using body mass index (BMI), which may limit sensitivity in detecting gradations of immune vulnerability[17]. BMI reflects overall body mass relative to height but does not account for micronutrient deficiencies or protein-energy malnutrition that are more directly implicated in impaired immune responses to *Mycobacterium tuberculosis*[3,4]. The predominance of participants within the normal BMI range may have further reduced

variability, limiting statistical power to detect an independent effect.

D. Ventilation and Sanitation

Measures of ventilation and sanitation in both residential and livestock housing environments were associated with TB in crude analysis; however, these effects were not sustained after multivariable adjustment. From a transmission dynamics perspective, limited air exchange and suboptimal sanitary conditions may facilitate persistence and concentration of airborne infectious particles in enclosed spaces[18]. Such environmental characteristics are biologically plausible contributors to airborne disease spread.

Nevertheless, the absence of independent associations in the final model may indicate limited variability in environmental conditions across participants. In rural agricultural communities where housing structures and barn designs are relatively similar, exposure patterns may be largely homogeneous, thereby reducing the capacity to detect differential risk. Comparable observations have been reported in other rural settings with structurally uniform living environments[19]. These findings suggest that, within this context, environmental factors may function as background conditions rather than primary drivers of TB occurrence.

E. Livestock Waste Management

Livestock waste handling practices demonstrated an association with TB in unadjusted analysis; however, this relationship did not remain statistically significant after controlling for other variables. Although improperly managed animal waste may contribute to environmental bioaerosol formation and microbial contamination, its direct relevance to human tuberculosis transmission is biologically limited[21].

Tuberculosis in humans is predominantly spread through inhalation of airborne droplets generated by infectious individuals. In contrast, exposure to contaminated animal waste is more commonly implicated in zoonotic infections, particularly those caused by *Mycobacterium bovis*[21]. In the absence of confirmed zoonotic transmission within the study population, the crude association observed may reflect confounding by age or other correlated environmental factors rather than a causal pathway.

Thus, after multivariable adjustment, livestock waste management did not emerge as an independent determinant of TB, reinforcing the predominance of human-to-human transmission dynamics in this setting.

F. Frequency of Contact with Livestock

The inverse association observed in crude analysis between frequency of livestock contact and TB incidence did not persist after multivariable adjustment. This pattern may reflect a healthy worker effect, a well-recognized epidemiological phenomenon in which individuals who remain actively engaged in physically demanding occupations tend to represent a healthier subset of the population[22]. Farmers experiencing declining health may reduce their occupational activities, thereby attenuating the apparent risk among those with more frequent livestock exposure.

In addition, the disappearance of the protective association after adjustment suggests that livestock contact itself is unlikely to constitute a primary transmission pathway in this setting. Although zoonotic tuberculosis caused by *Mycobacterium bovis* has been documented, evidence indicates that TB among livestock workers more commonly results from human-to-human airborne transmission rather than direct animal exposure[23]. Therefore, the observed crude association may be attributable to selection dynamics rather than a true biological protective effect.

G. TB Knowledge

Although TB-related knowledge demonstrated an association in crude analysis, it did not retain statistical significance after multivariable adjustment. This finding suggests that cognitive awareness alone may be insufficient to alter disease risk in this population. From the perspective of the *Health Belief Model*, preventive behavior is influenced not only by knowledge but also by perceived susceptibility, perceived severity, perceived barriers, and cues to action. In informal occupational settings such as livestock farming, structural and economic

barriers may outweigh individual awareness, thereby limiting translation of knowledge into sustained preventive practices.

Moreover, within a broader social determinants of health framework, TB vulnerability is shaped by socioeconomic conditions, access to health services, and occupational constraints rather than information alone. Previous studies have similarly reported that increased awareness does not necessarily reduce diagnostic delay or improve preventive behaviors when systemic limitations persist[24]. Effective TB control strategies therefore require integration of educational interventions with structural support mechanisms, including improved service accessibility, community-based screening initiatives, and strengthened primary healthcare engagement[25].

H. Epidemiological and Public Health Implications

The prominence of age as an independent determinant suggests that tuberculosis prevention strategies in livestock-farming communities should adopt a life-course perspective. Older farmers represent a priority group for systematic case finding, including both active disease detection and assessment of latent infection, integrated within routine primary health services. Periodic clinical evaluation and strengthened linkage to care may enhance early diagnosis and reduce delayed treatment initiation.

Although environmental and occupational conditions remain important within the broader One Health framework, the present findings indicate that host-related vulnerability plays a more decisive role in this setting. Consequently, interventions emphasizing age-targeted surveillance and immunological risk management may yield greater impact than structural workplace modifications alone[26].

I. Research Limitations

Several methodological constraints should be acknowledged. First, the retrospective case–control approach may have led to differential recall, particularly for self-reported behaviors and past environmental conditions. Second, participant recruitment based on accessibility rather than probability sampling reduces representativeness and may restrict the external validity of the findings. Finally, the absence of microbiological testing in livestock prevented confirmation of animal TB status, thereby limiting assessment of potential zoonotic transmission pathways.

Conclusions

Among livestock farmers in Grobogan Regency, advanced age emerged as the primary determinant of tuberculosis. Environmental and occupational exposures were not independently associated after adjustment. TB prevention programs in rural agricultural settings should therefore focus on age-targeted surveillance and early diagnosis strategies.

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