

ORIGINAL RESEARCH

Childhood Environment and Lifestyle Habits Associated with Immunity among STIS Polytechnic Students

Running title: Childhood Environment and Student Immunity

Abid Abiyyu Suwitra^{1*}, Muhammad Vitto Siregar², Oktovia Frinny Irianti Marimar Ivonne Leihitu³, Pitra Raditya Amanda Putri⁴, Tazkya Indira Putri⁵, Fitri Kartiasih⁶

¹⁻⁶Diploma IV Statistics Study Program, Politeknik Statistika STIS

*Corresponding author: Abid Abiyyu Suwitra | Email: abiyyuabid18@gmail.com

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Abstract

Background: Immune development is shaped by environmental exposures, lifestyle, and biological factors from early life, with potential effects extending into young adulthood. **Objective:** To examine associations of childhood environment and lifestyle with immunity levels among students of Politeknik Statistika STIS. **Methods:** Primary data were collected through an online questionnaire from 330 active students selected by two-stage sampling. **Results:** The independent variables were jointly associated with immunity level. Childhood environmental exposure, nutritional status, vaccination status, and sex were significant individually. Moderate and high environmental exposure had odds ratios (ORs) of 2.401 and 3.310; moderate and high nutritional status had ORs of 2.203 and 2.906; complete vaccination had an OR of 1.793; and male sex had an OR of 2.077. **Conclusion:** Childhood environmental conditions, nutrition, vaccination, and sex were associated with immunity in young adulthood, highlighting the long-term relevance of early-life health conditions.

Keywords: immunity; childhood environment; nutritional status; vaccination; ordinal logistic regression

Research Highlights

- Most students (58.5%) were in the moderate immunity category, while 23.0% were in the high category and 18.5% in the low category.
- Childhood environmental exposure, childhood nutritional status, vaccination status, and sex were significantly associated with higher ordinal immunity levels.
- Physical activity and childhood residential area were not statistically significant after adjustment, emphasizing the multifactorial nature of immunity in young adulthood.

1 Introduction

Health is a fundamental determinant of human quality of life, one manifestation of which is the body's level of immunity. Immunity serves as a major indicator of the body's capacity to defend itself against infectious diseases and to adapt to environmental change [1]. Individual immunity does not develop instantaneously; rather, it reflects long-term interactions among environmental factors, lifestyle, and biological characteristics beginning early in life. Childhood experiences may therefore leave health-related imprints that persist into adulthood.

Previous studies have shown that environmental and microbial exposures during childhood play important roles in shaping long-term immune development. McKay et al. [2] reported that microbial diversity early in life contributes to stronger immune responses and protection against immune disorders. Other evidence indicates that children who routinely play outdoors and interact with natural environments may develop better immune adaptation than children raised in highly sterile environments [3]. Nevertheless, excessive microbial exposure has also been associated with a higher risk of severe infections and subsequent systemic antibiotic use, indicating that the relationship between environmental exposure and immunity is complex and not necessarily linear [4].

Differences in childhood residential environments have also been associated with variation in immune profiles. Lunjani et al. [5] found that children raised in rural settings with animal exposure had more trained immune profiles than children living in urban areas. A study in Ecuador identified differences in the production of immunoregulatory cytokines between urban and rural children in response to sanitation conditions and microbial exposure [6]. Likewise, a large survey in Guangdong, southern China, reported that rural children had a gut microbiota composition considered more favorable for immune function than urban children, which was also correlated with a lower prevalence of allergy [7].

In addition to the physical environment, lifestyle habits established during childhood, including dietary patterns, personal hygiene, and physical activity, are related to long-term health. Healthy behaviors developed early in life tend to persist into adulthood and may contribute to better bodily resistance [8,9]. Research on the tracking of physical activity suggests that childhood activity patterns have a tendency to continue into adulthood and contribute to maintenance of physical health, including immune function [10]. Biological factors such as sex have also been reported to influence variation in immune responses in both children and adults [11-13].

Although empirical evidence on the influence of childhood environment and lifestyle on the immune system has been widely reported, most studies have focused on children or have used biological approaches such as blood biomarkers and microbiome analysis [2,14]. Research examining the longer-term relationship between childhood experiences and immunity among young adults remains relatively limited, particularly among university students in Indonesia. University students represent a population undergoing a substantial environmental transition from diverse childhood backgrounds into a relatively homogeneous campus environment, which may affect health and physical resilience [15].

Examining the relationship between childhood environment and lifestyle habits and current immunity among university students is therefore relevant. A retrospective quantitative self-reported approach makes it possible to examine the longer-term association of childhood experiences within a relatively homogeneous campus setting, which may be viewed as a natural experiment.

Accordingly, this study focused on the association of childhood environment and lifestyle habits with the immunity level of students from the time they first entered the campus until the present. The study was expected to improve understanding of the relationship between childhood living experiences and environments and current student health, and to provide insights for the development of preventive and health-promotion strategies in higher-education settings.

2 Materials and Methods

2.1 Study design and setting

This study used a quantitative observational design with a retrospective approach and was conducted at Politeknik Statistika STIS. It was associative in purpose because it not only described student immunity levels but also examined relationships between childhood experiences and current immunity. The analytical approach sought to identify childhood factors that contributed significantly to variation in immunity. Ordinal logistic regression was selected because the dependent variable, immunity level, was ordinal and the model included several categorical independent variables.

2.2 Population, sampling, and sample size

The study population comprised all active students of Politeknik Statistika STIS in the 2025/2026 academic year. Sampling was conducted using a two-stage design: Probability Proportional to Size Sampling Without Replacement (PPS WOR), followed by Systematic Sampling Without Replacement (SYS WOR). The sample size was determined using the Slovin formula with a 5% margin of error, yielding 330 selected respondents.

2.3 Variables and measurements

Primary data were collected using an online questionnaire developed in Google Forms and distributed to respondents through digital communication channels, including WhatsApp and email. This method was selected because it was considered efficient and practical and allowed broad respondent coverage within a relatively short period, particularly because all study participants were university students who routinely used digital media.

The questionnaire contained structured questions based on indicators for each study variable. Items were measured on ordinal and ratio scales according to the type of data. The variables analyzed were childhood environmental exposure, childhood nutritional status, childhood physical activity, childhood residential area, vaccination status, and sex; the dependent variable was immunity level on an ordinal scale. Before full administration, the questionnaire was subjected to validity and reliability testing to assess whether the items consistently and accurately represented the intended constructs.

Because standard categorization thresholds were not available, variable categories were defined according to the observed data distribution. Quartile-based categorization was used for ordinal variables and the median was used for dichotomous variables, following the quantitative approaches cited in the source manuscript [18,19].

2.4 Statistical analysis

Data processing included instrument-quality assessment and statistical analysis. Item validity was evaluated using Pearson correlation, while reliability was assessed using Cronbach's alpha; the instrument was considered acceptable when validity and reliability criteria were met [16,17]. Descriptive and inferential analyses were then performed. Inferential analysis used ordinal logistic regression with a proportional-odds model because the dependent variable was ordinal [20,21]. Before parameter estimation, multicollinearity was assessed using the Variance Inflation Factor (VIF), and the parallel-lines assumption was tested. Parameters were estimated using maximum likelihood estimation; overall model significance was assessed using the likelihood-ratio test, individual coefficients using the Wald test, and model fit using a chi-square statistic. Results were interpreted using odds ratios [20,22].

3 Results

3.1 Distribution of student immunity levels

Table 1 shows the distribution of immunity level by sex. Most students were classified as having moderate immunity, representing 58.5% of all respondents. Among male students, 56.1% had moderate immunity, compared with 60.8% of female students. High immunity was more common among male students (29.3%) than female students (16.9%), whereas low immunity was relatively more common among female students (22.3%) than male students (14.6%). Overall, the distribution of immunity was dominated by the moderate category in both sex groups.

Table 1. Distribution of student immunity levels by sex

Immunity level	Male	Female	Total
High	48 (29.3%)	28 (16.9%)	76 (23.0%)
Moderate	92 (56.1%)	101 (60.8%)	193 (58.5%)
Low	24 (14.6%)	37 (22.3%)	61 (18.5%)
Total	164 (100%)	166 (100%)	330 (100%)

3.2 Childhood environmental exposure, nutritional status, and physical activity

Based on the proportions presented in Figure 1, most students had moderate childhood environmental exposure and moderate childhood nutritional status, reported in the source text as 57.4% and 52.6%, respectively. The proportions with high environmental exposure and high nutritional status were relatively balanced with the corresponding low categories. Regarding physical activity, more than half of the students (53.5%) were classified as active during childhood, although the proportion classified as inactive was also substantial. These findings demonstrate heterogeneity in the students' childhood environmental experiences and lifestyle habits.

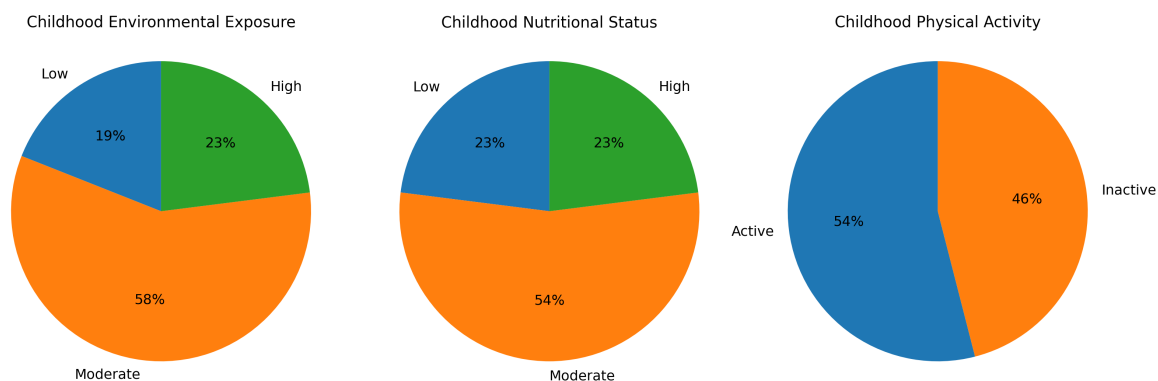


Figure 1. Proportions of childhood environmental exposure, nutritional status, and physical activity. Percentages shown in the figure reproduce the rounded values presented in the source figure.

3.3 Ordinal logistic regression analysis

Ordinal logistic regression was used to assess the associations of childhood environmental exposure, nutritional status, physical activity, residential area, vaccination status, and sex with student immunity level. The model was reported to satisfy the proportional-odds assumption, resulting in two logit equations with common slope parameters. The source manuscript also reports that the independent variables were jointly significant in the model.

Table 2 presents the estimated ordinal logistic regression parameters. Childhood environmental exposure, childhood nutritional status, vaccination status, and sex had p-values below 0.05, whereas physical activity and residential area had p-values above 0.05.

Table 2. Ordinal logistic regression results

Variable	Coefficient	Standard error	p-value	Odds ratio
Intercept (1)	-3.822	0.481	0.000	0.021
Intercept (2)	-0.840	0.418	0.179	0.431
Environmental exposure (Moderate)	0.876	0.302	0.004*	2.401
Environmental exposure (High)	1.197	0.375	0.001*	3.310
Nutritional status (Moderate)	0.790	0.283	0.005*	2.203
Nutritional status (High)	1.067	0.355	0.003*	2.906
Physical activity	0.116	0.242	0.631	1.879
Residential area	0.280	0.236	0.235	1.265
Vaccination status	0.584	0.260	0.025*	1.793
Sex	0.731	0.238	0.002*	2.077

Note: * $p < 0.05$. Numerical values are reproduced from the source manuscript.

4 Discussion

4.1 Childhood environmental exposure and immunity

Statistical testing showed a significant association between childhood environmental exposure and student immunity, with p-values of 0.004 and 0.001 for the moderate and high exposure categories, respectively. The ordinal logistic regression yielded an odds ratio (OR) of 2.401 for moderate environmental exposure, indicating that students who experienced moderate environmental exposure during childhood had 2.401 times the odds

of being in a higher immunity category than students with low exposure. High environmental exposure had an OR of 3.310, indicating 3.310 times the odds of being in a higher immunity category than the low-exposure group.

The source results reported that 57.4% of respondents were in the moderate environmental-exposure category. The discussion interprets moderate-to-high environmental exposure as potentially supporting immune maturation through the hygiene hypothesis. Early antigen exposure may contribute to greater microbiota diversity and regulation of regulatory T cells [2,23]. This mechanism has been linked to Toll-like receptor activation and development of immune tolerance, which may help prevent immune dysregulation associated with very low environmental exposure or excessively sterile conditions [3]. The source manuscript further notes that the proportion of students with high immunity increased with environmental exposure and relates this pattern to findings by Lunjani et al. [5], reporting an odds ratio of 2.8 in African children.

These findings support the study hypothesis that childhood environmental exposure is related to longer-term immunity and are discussed as consistent with rural-urban cytokine differences observed by Cooper et al. [6] and microbiota findings reported by Yang et al. [7] in China.

4.2 Childhood nutritional status and immunity

Childhood nutritional status was also significantly associated with student immunity, with p-values of 0.005 and 0.003 for the moderate and high nutritional-status categories. The OR for moderate nutritional status was 2.203, meaning that students classified as having moderate childhood nutritional status had 2.203 times the odds of being in a higher immunity category than students with low nutritional status. High nutritional status had an OR of 2.906, indicating 2.906 times the odds of being in a higher immunity category than the low-nutritional-status group.

The source text reports that 52.6% of respondents were in the moderate nutritional-status category. Its discussion proposes that moderate-to-high nutritional status supports B- and T-cell proliferation through nutrients such as zinc and fatty acids and may protect against thymic atrophy associated with malnutrition [8,9]. Nutritional deficiency is described as potentially impairing dendritic-cell differentiation and contributing to weaker long-term immune responses [1]. García-Hermoso et al. [10] are cited in the source manuscript as reporting an OR of 2.5 in a comparable childhood-to-adulthood tracking cohort.

The findings were interpreted as supporting the hypothesis that childhood nutrition contributes to adult immunity and as being consistent with the early-life microbiome perspective discussed by Ardesir et al. [14].

4.3 Childhood physical activity and immunity

In contrast with the preceding factors, childhood physical activity was not significantly associated with student immunity. The p-value was 0.631, providing insufficient statistical evidence of an association between childhood physical activity and current immunity level.

Although 53.5% of students were reported as active during childhood, the source discussion suggests that the immune effects of physical activity may be more acute, including cytokine responses such as interleukin-6, rather than persistent, and that recall bias from self-reported childhood activity may obscure long-term patterns [10]. The source further proposes that early physical activity may not necessarily track into adulthood without mediating factors such as nutrition [8], and cites Klein and Flanagan [12] in relation to indirect effects in comparable populations.

This finding did not support the partial hypothesis for physical activity and was discussed as consistent with evidence that sex-related variation may dominate some physical-activity effects [13]. The lack of significance may reflect limitations of self-reported physical-activity measurement, recall bias regarding childhood

behavior, and the possibility that physical activity has more short-term effects on immunity that depend on current conditions rather than only past habits.

4.4 Childhood residential area and immunity

Childhood residential area was not significantly associated with student immunity ($p = 0.235$). Thus, differences in the characteristics of childhood residential areas, as defined in this study, were not statistically associated with variation in current immunity.

The source discussion suggests that residential-area effects may operate indirectly through more specific environmental exposures. Urbanization may reduce microbiota diversity without producing a strong direct trend in the STIS sample [7]. A sanitation-related paradox is proposed as one explanation for the non-significant rural-urban effect after other variables are controlled [5], while Cooper et al. [6] are cited as reporting a comparable mediation pattern in Ecuador.

This result did not support a direct residential-area hypothesis and was discussed as consistent with findings by Brustad et al. [4] in a European cohort. The source manuscript therefore suggests that the influence of residential area may be mediated by factors such as specific environmental exposures, sanitation conditions, or socioeconomic status, some of which may already be represented by other variables in the model. Consequently, the direct association of residential area with immunity became non-significant after these factors were considered.

4.5 Vaccination status and immunity

Vaccination status was significantly associated with immunity ($p = 0.025$). The estimated OR was 1.793, indicating that students with complete vaccination had 1.793 times the odds of being in a higher immunity category than students who had never been vaccinated or whose vaccination status was incomplete.

The source discussion explains that complete vaccination induces adaptive immune memory through specific antibodies, whereas incomplete vaccination may be associated with gaps in herd immunity [11]. Epitope-specific T-cell mechanisms are also described as strengthening long-term responses [1]. Khair [15] is cited in the source manuscript as reporting an OR of 1.8 among a comparable group of Indonesian students.

The finding supports the vaccination hypothesis and is discussed as consistent with the microbiome and immune-development perspective presented by McKay et al. [2]. It also aligns with the basic immunological principle that vaccination supports adaptive immune responses. However, the smaller OR compared with childhood environmental exposure and nutritional status suggests that vaccination is one contributing factor rather than the sole determinant of immunity.

4.6 Sex and immunity

Sex was significantly associated with student immunity ($p = 0.002$). The OR of 2.077 indicates that male students had 2.077 times the odds of being in a higher immunity category than female students.

The source manuscript relates this difference to biological and hormonal factors as well as differences in environmental exposure and lifestyle habits beginning in childhood. This interpretation is linked to studies describing sex-based variation in immune responses, although the direction and magnitude of such differences may vary across populations. In the study sample, 29.3% of male students were in the high-immunity category compared with 16.9% of female students. The source discussion proposes a hormonal explanation involving testosterone-related suppression of inflammation through TLR4 and pro-inflammatory effects of estrogen [12], and describes the pattern as potentially reflecting epigenetic influences extending from childhood [13]. Engler et al. [11] are cited as reporting an OR of approximately 2.1 among young adults.

The source manuscript interprets these results as supporting the sex-related hypothesis and as being consistent with the literature reviewed in the Introduction.

4.7 Synthesis of findings

Overall, the findings indicate that factors related to biological and environmental experiences during childhood—particularly environmental exposure, nutritional status, vaccination status, and sex—were significantly associated with immunity level in young adulthood. This pattern suggests that early-life conditions may contribute to longer-term immune capacity, although the magnitude of association differed across factors.

By contrast, the absence of significant associations for childhood physical activity and residential area indicates that not all childhood characteristics had direct relationships with current immunity. Their influence may be indirect, temporary, or mediated by other factors not fully captured in the present model.

Conceptually, the results support a framework in which immunity reflects complex interactions among biological factors, environmental conditions, and health interventions beginning in childhood. However, although the study collected retrospective information, exposures and current immunity were assessed in a single survey, giving the analysis a retrospective cross-sectional character. Together with the use of self-reported data, this design means that the observed relationships should be interpreted as associations rather than causal effects. Longitudinal studies and more objective measurements are required to clarify the causal mechanisms linking childhood factors with immunity in adulthood.

4.8 Public health implications and recommendations

The findings are expected to improve parents' understanding of the importance of providing a healthy developmental environment, balanced nutrition, and complete vaccination from early childhood as long-term investments in health through adulthood. For universities and health-sector stakeholders, the results may inform the formulation and strengthening of student health-promotion programs, particularly those focused on disease prevention and maintenance of physical resilience. Education concerning healthy lifestyles and immunization, together with continued monitoring of student health conditions, should be developed as part of a healthy campus environment.

Future studies should consider additional variables that may influence student immunity, including sleep patterns, stress levels, smoking, alcohol consumption, mental-health conditions, and histories of infectious and chronic diseases. Longitudinal or cohort designs should also be considered to observe changes in immunity over time and strengthen causal inference regarding childhood environment and lifestyle habits. Expanding the study population and geographic coverage would further improve generalizability and relevance to broader public-health contexts.

5 Conclusion

The immunity level of students at Politeknik Statistika STIS was predominantly moderate. Students reported heterogeneous childhood environmental and lifestyle backgrounds despite currently sharing a relatively homogeneous campus environment. The source analysis reports that childhood environmental exposure, childhood nutritional status, childhood physical activity, residential area, vaccination status, and sex were jointly associated with student immunity. Individually, childhood environmental exposure, childhood nutritional status, vaccination status, and sex were statistically significant, whereas physical activity and residential area were not.

Students with higher childhood environmental exposure, more favorable childhood nutritional status, and complete vaccination tended to have higher ordinal immunity levels. Male students also showed higher odds of being in a higher immunity category than female students. These findings support the relevance of childhood

environmental and health conditions to immunity in young adulthood, while the retrospective self-reported design requires the associations to be interpreted without causal inference.

6 Declarations

Ethics approval and consent to participate

This study involving human participants was conducted in accordance with applicable ethical standards. All participants were informed about the purpose and procedures of the study, and informed consent was obtained from all participants prior to data collection. Participation was voluntary, and the confidentiality and anonymity of participants were maintained throughout the study.

Consent for publication

Not applicable. The manuscript contains no identifiable personal images or individual-level case information.

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Competing interests

The authors declare that they have no financial or non-financial competing interests that could have influenced the work reported in this study.

Author contributions (CRediT)

Abid Abiyyu Suwitra: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Visualization, and Writing – Original Draft.

Muhammad Vitto Siregar: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, and Writing – Original Draft.

Oktovia Frinny Irianti Marimar Ivonne Leihitu: Methodology, Investigation, Data Curation, Formal Analysis, and Writing – Original Draft.

Pitra Raditya Amanda Putri: Methodology, Investigation, Data Curation, Formal Analysis, Visualization, and Writing – Original Draft.

Tazkya Indira Putri: Methodology, Investigation, Data Curation, Formal Analysis, and Writing – Original Draft.

Fitri Kartiasih: Conceptualization, Methodology, Supervision, Validation, and Writing – Review & Editing.

All authors contributed to the preparation of the manuscript, reviewed its intellectual content, and approved the final version for publication.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Access to the data is subject to applicable ethical requirements and institutional policies concerning participant confidentiality and data protection.

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Generative AI statement

Generative AI was used to assist with English-language translation, language editing, structural organization, and manuscript formatting. The authors reviewed the output and remain responsible for the accuracy, originality, citations, and integrity of the manuscript.

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