Jupiter: Jurnal Pendidikan Terapan
Homepage : https://journal.diginus.id/jupiter/index
Email: jurnalpendidikanterapan@gmail.com

p-ISSN : 2985-3214; e-ISSN : 2964-3171
Jupiter, Vol. 4, No. 1, March 2026
Page 78-86

Enhancing Cardiovascular Disease Literacy Through Healthy Lifestyle-Based Biology Learning: A Quasi-Experimental Study of High School Students in North Sumatra, Indonesia

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ARTICLE INFO

Article history:
Submitted: March 13, 2026
Final Revised: March 25, 2025
Accepted: March 30, 2025
Published: March 31, 2026

Keywords:
Biology Learning; Cardiovascular Disease Literacy; Health Education; Healthy Lifestyle; Non Communicable Diseases

ABSTRACT

Purpose: This study examines the effectiveness of healthy lifestyle-based biology learning in improving cardiovascular disease literacy among high school students in North Sumatra, Indonesia. **Methods**: A quasi-experimental pretest posttest control group design was employed involving 120 Grade XI students. The experimental group received biology learning integrated with experiential health activities (body mass index measurement, heart rate monitoring, dietary analysis, and cardiovascular simulations), while the control group received conventional instruction. Data were collected using a validated cardiovascular disease literacy test covering functional, interactive, and critical dimensions ($\alpha = 0.82$). Data were analyzed using independent samples t-tests, ANCOVA, and normalized gain (N-gain). **Findings**: The results showed that the experimental group achieved significantly higher posttest scores than the control group ($p < 0.001$), with a large effect size (Cohen's $d = 0.92$). Literacy improvements were observed across functional, interactive, and critical dimensions, all within the moderate N-gain category. In addition, students demonstrated positive behavioral changes, including reduced sedentary time and increased daily physical activity. **Conclusion**: Healthy lifestyle-based biology learning is effective in enhancing adolescents' cardiovascular disease literacy and promoting healthier lifestyle behaviors. Integrating experiential health activities into biology instruction provides a practical approach to strengthening preventive health education in schools. **Implications**: The study highlights the potential of curriculum-integrated health education to address early risk factors of non-communicable diseases among adolescents. Ethical approval was obtained, and informed consent was secured from all participants and their guardians.

Doi: https://doi.org/10.61255/jupiter.v4i1.850

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of mortality worldwide and is increasingly associated with risk factors that develop during adolescence. Behaviors such as insufficient physical activity, unhealthy dietary patterns, and prolonged sedentary time contribute to early cardiovascular risk profiles that may persist into adulthood (World Health Organization, 2023; Djalalinia et al., 2021). In Indonesia, national health reports (*Riskesdas*) indicate a rising prevalence of overweight conditions, low levels of physical activity, and unhealthy eating habits among adolescents, reflecting broader lifestyle transitions driven by urbanization and digitalization (Ministry of Health of Indonesia, 2018). Similar patterns are observed in North Sumatra, where dietary habits and limited physical activity increase adolescents' vulnerability to cardiovascular risk factors.

Health literacy has been widely recognized as a critical determinant of preventive health behavior and long-term health outcomes. According to Don Nutbeam, health literacy encompasses three progressive dimensions functional, interactive, and critical which reflect individuals' ability to access, understand, interpret, and evaluate health-related information for informed decision-making. Empirical studies have consistently demonstrated that higher levels of health literacy are associated with healthier behaviors among adolescents, including increased physical activity and improved dietary practices (Liang et al., 2021; Geboers et al., 2021).

However, most existing research focuses on general health literacy rather than domain-specific constructs such as cardiovascular disease literacy. Within educational settings, biology instruction offers a potential platform for

integrating health literacy, particularly through topics related to the circulatory system. Nevertheless, classroom practices often emphasize conceptual knowledge of biological structures and processes, with limited connection to real-life health behavior. As a result, students may acquire theoretical understanding without developing the capacity to interpret cardiovascular risk factors or apply knowledge in everyday decision-making contexts.

Despite the growing attention to adolescent health literacy, several important gaps remain. First, empirical research examining cardiovascular disease literacy within formal school-based learning environments is still limited. Second, most health interventions targeting adolescents are implemented as extracurricular or short-term programs rather than being systematically embedded within academic subjects, which limits their sustainability. Third, previous studies rarely incorporate local lifestyle contexts, even though cultural and environmental factors play a crucial role in shaping adolescent health behavior.

To address these gaps, this study adopts a constructivist learning perspective by integrating healthy lifestyle based activities into biology instruction. The intervention includes experiential components such as body mass index (BMI) measurement, heart rate monitoring, dietary pattern analysis, and cardiovascular system simulations. These activities are designed to connect abstract biological concepts with students' personal health experiences, thereby promoting active engagement and reflective learning.

The novelty of this study lies in three key aspects. First, it integrates domain-specific health literacy particularly cardiovascular disease literacy into formal biology education. Second, it employs experiential learning strategies based on students' own health-related data. Third, it contextualizes learning within the local lifestyle environment of North Sumatra, enhancing the relevance and applicability of the intervention.

Based on the above considerations, this study aims to examine the effectiveness of healthy lifestyle-based biology learning in improving cardiovascular disease literacy among Grade XI high school students in North Sumatra, Indonesia. Specifically, the study investigates whether the integration of experiential health-related activities into biology instruction enhances students' functional, interactive, and critical health literacy related to cardiovascular disease prevention.

METHOD

Research Design

This study employed a quasi-experimental pretest–posttest control group design to examine the effectiveness of healthy lifestyle based biology learning in improving cardiovascular disease literacy. Two intact school groups were used: one assigned as the experimental group and the other as the control group.

Given that the assignment was conducted at the school level, potential school level confounding factors (e.g., differences in teacher characteristics, school culture, and student academic background) may have influenced the results. To mitigate this limitation, both schools were selected based on comparable characteristics, including curriculum implementation, school type (public high schools), and student grade level. In addition, pretest equivalence was assessed and controlled statistically using ANCOVA.

Participants

The participants consisted of 120 Grade XI high school students in North Sumatra, Indonesia, divided equally into an experimental group (n = 60) and a control group (n = 60). All participants were enrolled in biology classes covering the circulatory system topic during the study period.

Population and Sampling Method

The population included Grade XI students studying biology in selected districts of North Sumatra. A purposive sampling technique was applied using the following criteria:

1. Implementation of the national biology curriculum (circulatory system topic)
2. Teacher willingness to participate
3. Representation of typical adolescent lifestyle characteristics

Two comparable public high schools were selected. One school was assigned as the experimental group and the other as the control group to minimize treatment contamination.

Ethical Approval and Consent to Participate

This study was conducted in accordance with ethical standards for research involving human participants. Ethical approval was obtained from the Institutional Review Board (IRB) of Universitas Sisingamangaraja XII Tapanuli Utara Because the participants were minors (high school students), written informed consent was obtained from both students and their parents or legal guardians prior to data collection. Participation in the study was entirely voluntary, and students were informed of their right to withdraw at any time without academic consequences. All data were collected

anonymously, and no personally identifiable information was recorded. The research procedures were designed to ensure that all activities including BMI measurement, heart rate monitoring, and lifestyle observation were conducted in a safe, non-invasive, and educational context under teacher supervision.

Instrumentation

Data were collected using several instruments to measure cardiovascular disease literacy and supportive lifestyle-related indicators. The main outcome measure was a cardiovascular disease literacy test developed based on Nutbeam's three-level health literacy framework. The instrument comprised: (1) 15 multiple-choice items for functional literacy, assessing understanding of cardiovascular system structure, function, and disease concepts; (2) 10 short-answer items for interactive literacy, requiring interpretation of health-related data such as BMI values, heart rate graphs, and dietary patterns; and (3) 5 case-based items for critical literacy, assessing students' ability to evaluate health information and make decisions regarding healthy lifestyle practices. Multiple-choice items were scored dichotomously, while open-ended responses were evaluated using an analytic rubric. Content validity was assessed by three experts in biology education and public health, and internal consistency reliability was acceptable (Cronbach's alpha = 0.82).

Supportive non-cognitive data were collected using a healthy lifestyle questionnaire, classroom observation sheets, and a three-day food diary. In addition, several health-related indicators were recorded for descriptive and educational purposes, including body mass index (BMI), resting heart rate, daily physical activity duration, sedentary time, and healthy food diary compliance. BMI was calculated from body weight and height measured during classroom activities using a digital scale and portable stadiometer, following standard school health procedures. Resting heart rate was measured manually at the radial pulse for 60 seconds after students had been seated quietly for approximately five minutes. Physical activity duration, sedentary behavior, and dietary compliance were based primarily on student self-reports documented in activity logs and food diaries. Because these indicators were collected in a classroom-based educational context rather than under controlled clinical conditions, they should be interpreted as supportive short term behavioral or monitoring indicators, not as definitive physiological outcome measures.

Procedures and Time Frame

The study was conducted over approximately six weeks during the biology unit on the circulatory system. In the first week, students in both groups completed the pretest of cardiovascular disease literacy. During the intervention period, the experimental group participated in four to six healthy lifestyle-based biology learning sessions involving BMI measurement, resting heart rate monitoring, dietary pattern analysis through three-day food diaries, and classroom discussion of cardiovascular risk factors. The control group received conventional biology instruction consisting of lectures, textbook explanation, and standard discussion without the integrated experiential health activities.

Supportive lifestyle-related indicators were collected at the beginning and end of the intervention period for descriptive comparison within the experimental group. Weight and height were measured during supervised class sessions, while resting heart rate was recorded after a brief seated rest period. Physical activity duration, sedentary time, and dietary compliance were derived from student logs, food diaries, and classroom observation records. These supportive measures were intended to enrich interpretation of the educational intervention and student engagement, rather than to serve as primary endpoints for hypothesis testing.

Data Analysis

Prior to hypothesis testing, normality (Kolmogorov–Smirnov) and homogeneity (Levene's test) assumptions were evaluated. Independent samples t-tests were used to compare posttest scores, while ANCOVA controlled for baseline differences. Learning improvement was assessed using normalized gain (N-gain).

Scope and Limitations

Several methodological limitations should be acknowledged. First, the use of purposive sampling and the involvement of only two schools may limit the generalizability of the findings. Second, the relatively short intervention period may not fully capture long-term lifestyle changes among students. Third, external factors such as family diet patterns and extracurricular physical activity were not controlled in this study. Despite these limitations, the study provides valuable evidence regarding the potential effectiveness of healthy lifestyle based biology learning in improving cardiovascular disease literacy among adolescents.

Ethical Considerations

This study adhered to ethical principles for research involving human participants. Formal institutional ethical approval was not required according to the policy of Universitas Sisingamangaraja XII Tapanuli Utara for classroom-based educational research involving minimal risk. However, all procedures were conducted in line with international ethical standards (e.g., Declaration of Helsinki). Because participants were minors, informed consent was obtained

from both students and their parents or guardians prior to participation. Participation was voluntary, and students were informed that they could withdraw at any time without penalty. All data were anonymized, and measurements such as BMI and heart rate were conducted solely for educational purposes using non-invasive procedures under teacher supervision.

The conceptual framework of the study is presented in Figure 1, which illustrates how healthy lifestyle-based biology learning, through the integration of experiential activities, is designed to enhance students' cardiovascular disease literacy across functional, interactive, and critical dimensions.

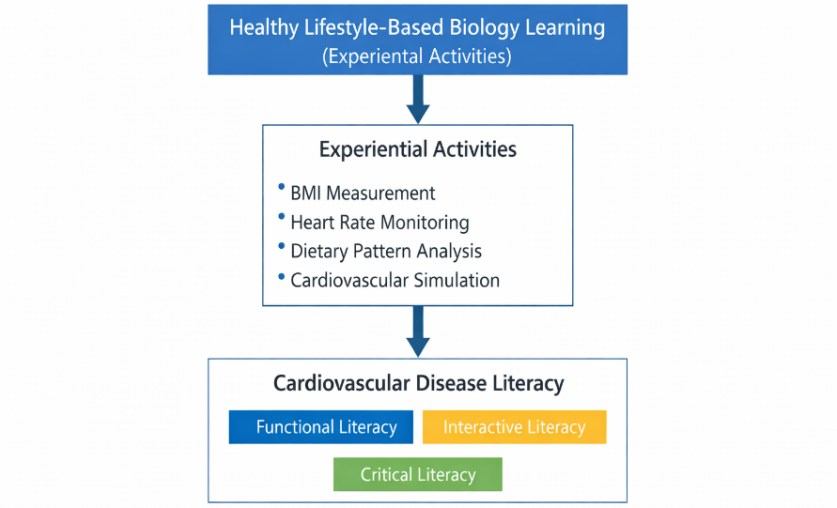

Figure 1. Conceptual Model Of The Intervention Linking Experiential Learning

RESULTS AND DISCUSSION

Descriptive Statistics of Cardiovascular Disease Literacy

Descriptive analysis was conducted to examine students' cardiovascular disease literacy before and after the learning intervention. The literacy test measured three dimensions: functional literacy, interactive literacy, and critical literacy. Table 1 presents the comparison of pretest and posttest scores for the experimental and control groups.

Table 1. Descriptive Statistics of Pretest and Posttest Scores

Literacy Dimension	Group	Pretest Mean (%)	Posttest Mean (%)	Increase
Functional Literacy	Experimental	54.12	81.76	+27.64
	Control	55.03	63.45	+8.42
Interactive Literacy	Experimental	48.30	78.45	+30.15
	Control	49.12	60.18	+11.06
Critical Literacy	Experimental	42.10	74.00	+31.90
	Control	43.21	56.12	+12.91

The results in Table 1 indicate that the experimental group showed substantially greater improvements in all dimensions of cardiovascular disease literacy compared with the control group. The largest improvement occurred in critical literacy, suggesting that the intervention effectively strengthened students' ability to evaluate health information and make informed decisions regarding healthy lifestyle behaviors.

Statistical Test of Learning Effectiveness

To determine whether the observed improvements were statistically significant, inferential statistical analyses were conducted. An independent samples t-test was performed to compare posttest scores between the experimental and control groups. Additionally, an analysis of covariance (ANCOVA) was conducted to control for potential baseline differences in pretest scores. The results are summarized in Table 2.

Table 2. Inferential Statistical Results of the Learning Intervention

Statistical Test	Variable	Mean (Experimental)	Mean (Control)	Test Statistic	p-value	Effect Size	Interpretation
Independent Samples t-test	Posttest Literacy Score	78.74	64.31	$t(118) = 8.37$	< 0.001	Cohen's $d = 0.92$	Large
ANCOVA	Treatment Effect (controlled by pretest)	–	–	$F(1,117) = 27.46$	< 0.001	Partial $\eta^2 = 0.19$	Large

The independent samples t-test results indicate that students in the experimental group achieved significantly higher literacy scores compared with those in the control group. Furthermore, the ANCOVA analysis confirmed that the healthy lifestyle–based biology learning intervention had a statistically significant effect on students' cardiovascular disease literacy after controlling for pretest differences. The calculated effect size values (Cohen's $d = 0.92$ and partial $\eta^2 = 0.19$) indicate a large practical impact of the intervention.

Learning Gain Analysis

To further evaluate the magnitude of learning improvement, normalized gain (N-Gain) analysis was conducted. Table 3 shows the N-Gain results for each literacy dimension.

Table 3. N-Gain Analysis of Cardiovascular Disease Literacy

Literacy Dimension	Experimental Group N-Gain	Category	Control Group N-Gain	Category
Functional Literacy	0.60	Medium	0.19	Low
Interactive Literacy	0.58	Medium	0.21	Low
Critical Literacy	0.55	Medium	0.23	Low

The N-Gain results indicate that the experimental group achieved moderate learning improvement across all literacy dimensions, while the control group demonstrated only low levels of improvement. This finding further supports the effectiveness of the healthy lifestyle–based biology learning approach.

Changes in Lifestyle and Health Indicators

In addition to literacy outcomes, the study documented several supportive short-term lifestyle and monitoring indicators in the experimental group to describe students' responses to the learning activities. These indicators were not specified as primary outcome variables and were collected mainly for descriptive and educational purposes.

Table 4. Changes in Students' Lifestyle and Health Indicators

Indicator	Before Intervention	After Intervention	Change
Students in overweight/obese category	32%	24%	−8%
Resting heart rate	92 bpm	84 bpm	−8 bpm
Daily physical activity	18–22 minutes	32–36 minutes	+55–60%
Sedentary behavior	6.1 hours/day	4.8 hours/day	−1.3 hours/day
Healthy food diary compliance	41%	73%	+32%

The indicators presented in Table 4 must be interpreted cautiously. First, these data were collected primarily as supportive descriptive indicators within the experimental group and were not the primary basis for evaluating intervention effectiveness. Second, the six-week duration of the classroom-based intervention is too short to support strong claims regarding meaningful physiological adaptation, particularly with respect to shifts in overweight/obesity status or reductions in resting heart rate. Third, some measures, especially physical activity, sedentary behavior, and dietary compliance, relied partly on self-report and observational documentation, making them more appropriate as indicators of short-term behavioral awareness and reported lifestyle adjustment than as robust clinical outcomes. Finally, because comparable control group data were not systematically analyzed for these indicators, causal attribution to the intervention cannot be established. Accordingly, the values in Table 4 should be understood as evidence of short-term engagement and behavioral response during the instructional process rather than proof of sustained physiological improvement.

Supplementary Analysis of Lifestyle Questionnaire

Descriptive analysis of the healthy lifestyle questionnaire indicated a general trend toward improved self-reported behaviors in the experimental group, particularly in increased physical activity frequency and improved dietary awareness. However, these changes were not subjected to inferential statistical testing and are presented only as supporting evidence, consistent with the study's primary focus on literacy outcomes.

Interpretation of Findings in Relation to Hypotheses

The results of this study provide consistent support for all proposed hypotheses (H_1, H_2, and H_3), demonstrating the effectiveness of healthy lifestyle-based biology learning in enhancing students' cardiovascular disease literacy. The significant improvement in functional literacy (H_1) indicates that integrating contextual learning activities into biology instruction strengthens students' foundational understanding of cardiovascular concepts. Compared with conventional instruction, the experimental approach enabled students to engage with content in a more meaningful way, thereby facilitating knowledge retention and comprehension.

Similarly, the improvement in interactive literacy (H_2) suggests that students developed stronger abilities to interpret and apply health-related information. Activities such as analyzing BMI values, interpreting heart rate data, and evaluating dietary patterns encouraged students to actively process information rather than passively receive it. This finding highlights the role of instructional design in promoting applied understanding within science education. The strongest support was observed for H_3 (critical literacy), where the largest increase was recorded. This indicates that the intervention was particularly effective in fostering higher-order cognitive skills, including evaluation, judgment, and decision-making related to health behavior.

Why Did Critical Literacy Improve the Most?

The greater improvement in critical literacy can be explained through the theoretical lens of Don Nutbeam, who conceptualizes health literacy as a hierarchical construct. In this framework, critical literacy represents the most advanced level, requiring individuals to critically analyze information and apply it in decision-making contexts. The instructional approach adopted in this study emphasized experiential and reflective learning processes. Students were not only exposed to health-related information but were also required to interpret personal data, evaluate lifestyle risks, and discuss real-life scenarios. Such activities inherently stimulate analytical thinking and self-reflection, which are central to the development of critical literacy.

In contrast, functional literacy can be improved through knowledge transmission alone, while interactive literacy involves moderate cognitive engagement through interpretation and communication. The experiential nature of the intervention therefore disproportionately benefited critical literacy, as it required deeper cognitive processing and personal relevance. This finding is consistent with constructivist learning theory, which posits that meaningful learning occurs when individuals actively construct knowledge through experience and reflection.

Comparison with Previous Studies

The findings of this study are consistent with prior research demonstrating that school-based health education can significantly improve adolescents' health literacy and related behaviors. Studies have shown that contextual and experiential learning approaches are more effective than traditional instruction in promoting health awareness and engagement among students. However, this study extends existing literature in several important ways. First, while previous research has largely focused on general health literacy, this study specifically examines cardiovascular disease literacy, providing a more targeted understanding of health education outcomes. Second, unlike many interventions implemented as extracurricular programs, the present study embeds health literacy within formal biology instruction, enhancing its sustainability and curricular relevance. Third, the integration of local lifestyle context strengthens the ecological validity of the findings, particularly in the setting of North Sumatra.

Theoretical Contributions

This study contributes to the development of health literacy theory by providing empirical evidence supporting the multidimensional model proposed by Don Nutbeam. The simultaneous improvement across functional, interactive, and critical dimensions demonstrates that classroom-based interventions can effectively address multiple levels of literacy within a single instructional framework. Furthermore, the findings highlight the importance of experiential learning as a mechanism for advancing higher-order literacy. By integrating real-life health data into biology instruction, the study illustrates how educational practices can move beyond knowledge transmission toward fostering critical thinking and decision-making skills. This extends the application of constructivist learning theory within the domain of health education.

Practical Implications

From a practical perspective, the results suggest that integrating healthy lifestyle–based activities into biology learning can serve as an effective strategy for promoting preventive health behavior among adolescents. Schools can play a pivotal role in early intervention by embedding health-related experiences into existing curricula rather than relying solely on external programs. Simple, non-invasive activities such as BMI measurement, heart rate monitoring, and dietary reflection can enhance student engagement while providing meaningful learning experiences. This approach is particularly relevant in regions where lifestyle-related risk factors are increasing, as it enables students to connect scientific knowledge with their daily lives.

Cautious Interpretation of Behavioral Indicators

Although improvements were observed in supportive behavioral indicators such as physical activity and dietary awareness, these findings should be interpreted with caution. The relatively short duration of the intervention and the lack of comprehensive control group comparison limit the ability to attribute these changes directly to the intervention. Therefore, the primary contribution of this study lies in demonstrating improvements in cardiovascular disease literacy rather than establishing definitive changes in long-term health behavior or physiological outcomes.

CONCLUSION

This study demonstrates that healthy lifestyle-based biology learning effectively improves cardiovascular disease literacy among Grade XI high school students in North Sumatra, Indonesia. The findings show significant enhancement across functional, interactive, and critical literacy, with the strongest improvement observed in critical literacy. These results indicate that integrating experiential health-related activities into biology instruction is an effective approach to strengthening students' ability to understand, interpret, and evaluate health information in meaningful contexts. From a practical perspective, the study highlights the potential of school-based interventions to support early prevention of non communicable diseases. Incorporating simple, non-invasive activities such as BMI measurement, heart rate monitoring, and dietary reflection into biology curricula can enhance student engagement while promoting health awareness. This approach enables schools to move beyond theoretical instruction toward more applied and contextually relevant learning. For future research, it is recommended that studies employ longitudinal designs to examine the sustainability of literacy improvement and its potential impact on long-term health behavior. Further research should also incorporate more rigorous behavioral and physiological measurements, include comprehensive control group comparisons, and explore additional influencing factors such as health self-efficacy, family environment, and peer influence.

REFERENCE

Álvarez-García, D., Núñez, J. C., García, T., & Barreiro-Collazo, A. (2020). Health literacy and associated factors in adolescents: A systematic review. *International Journal of Environmental Research and Public Health, 17*(18), 1–17. https://doi.org/10.3390/ijerph17186553

Asare, M., Sharma, M., & Bernard, A. (2020). School-based interventions for promoting physical activity among adolescents: A systematic review. *Health Promotion Practice, 21*(3), 456–468. https://doi.org/10.1177/1524839919881223

Biddle, S. J. H., & García Bengoechea, E. (2022). Sedentary behaviour and adolescent health: An updated review. *The Lancet Child & Adolescent Health, 6*(4), 251–260. https://doi.org/10.1016/S2352-4642(21)00335-1

Bröder, J., Okan, O., Bauer, U., Schlupp, S., Bollweg, T. M., Saboga-Nunes, L., Bond, E., Sørensen, K., Bitzer, E., Jordan, S., Domanska, O., Firnges, C., Carvalho, G. S., Bittlingmayer, U. H., Levin-Zamir, D., Pelikan, J. M., Sahrai, D., & Lenz, A. (2021). Health literacy in childhood and youth: A systematic review of definitions and models. *International Journal of Environmental Research and Public Health, 18*(11), 5890. https://doi.org/10.3390/ijerph18115890

Brown, T., Moore, T. H. M., Hooper, L., Gao, Y., Zayegh, A., Ijaz, S., Elwenspoek, M., Foxen, S. C., Magee, L., O'Malley, C., Waters, E., & Summerbell, C. D. (2022). School-based interventions to improve adolescent health literacy. *Health Promotion International, 37*(2), daab184. https://doi.org/10.1093/heapro/daab184

Chen, X., Hay, J., & Waters, E. (2020). Physical activity and cardiovascular health in adolescents: A systematic review. *Sports Medicine, 50*(2), 217–230. https://doi.org/10.1007/s40279-019-01198-3

Chua, J. Y. X., Nurhasanah, S., Lim, S. L., & Tan, K. H. (2023). Dietary patterns and cardiovascular risk factors in Southeast Asian adolescents. *Nutrients, 15*(2), 1–14. https://doi.org/10.3390/nu15020456

de Sousa, I. F., Oliveira, A. M., & Silva, R. M. (2020). Impact of school-based diet and lifestyle interventions on cardiometabolic markers. *Preventive Medicine, 132*, 105988. https://doi.org/10.1016/j.ypmed.2020.105988

Djalalinia, S., Qorbani, M., Peykari, N., & Kelishadi, R. (2021). Prevalence of cardiovascular risk factors among adolescents: A global analysis. *BMC Public Health, 21*(1), 1–13. https://doi.org/10.1186/s12889-021-10587-4

Dumuid, D., Olds, T., Martín-Fernández, J. A., Lewis, L. K., Cassidy, L., & Maher, C. (2020). Lifestyle patterns and adolescent health outcomes: A compositional analysis. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 1–12. https://doi.org/10.1186/s12966-020-0917-5

Elsborg, P., Melby, P. S., & Nielsen, G. (2021). Physical activity interventions in schools: Long-term impacts on adolescent health. *Scandinavian Journal of Medicine & Science in Sports, 31*(5), 1001–1015. https://doi.org/10.1111/sms.13902

Fitria, L., & Mustika, R. (2021). Health literacy and heart disease prevention among Indonesian youth. *International Journal of Public Health Science, 10*(4), 721–730.

Geboers, B., Brainard, J. S., Loke, Y. K., Jansen, C. J. M., Salter, C., Reijneveld, S. A., & de Winter, A. F. (2021). The role of critical health literacy in healthy lifestyle behaviors. *Health Education & Behavior, 48*(5), 591–600. https://doi.org/10.1177/10901981211008205

Hu, D., Liu, J., & Chen, X. (2020). Cardiovascular disease risk among adolescents: Current evidence and implications. *Nature Reviews Cardiology, 17*(12), 755–765. https://doi.org/10.1038/s41569-020-00428-8

Iannotti, R. J., & Janssen, I. (2022). Lifestyle risk behaviors and health outcomes in adolescents. *The Lancet Public Health, 7*(3), e244–e252. https://doi.org/10.1016/S2468-2667(21)00286-1

Kurniasih, D., & Pertiwi, N. (2022). STEM-based biology learning and critical reasoning skills in Indonesian high schools. *Journal of Biological Education, 56*(4), 550–560. https://doi.org/10.1080/00219266.2021.1880542

Lee, J. E., & Pope, Z. C. (2024). School health promotion and cardiovascular prevention in adolescents. *Journal of School Health, 94*(1), 22–31. https://doi.org/10.1111/josh.13312

Liang, Y., Lau, P. W. C., & Huang, W. Y. (2021). Health literacy and physical activity: A meta-analysis of adolescent populations. *American Journal of Preventive Medicine, 60*(2), 251–263. https://doi.org/10.1016/j.amepre.2020.09.015

Mulyani, S., Rahmawati, D., & Prasetyo, Z. K. (2023). Contextual biology learning to improve health understanding in Indonesian students. *Journal of Education and Learning, 17*(3), 456–465.

Mustafina, S., Wang, J., & Li, X. (2022). Adolescents' dietary habits and non-communicable disease risk in Asia. *Nutrients, 14*(10), 1–14. https://doi.org/10.3390/nu14102045

Nguyen, T. T., Hoang, V. M., & Nguyen, H. T. (2021). Education-based strategies to improve adolescent cardiovascular health. *Preventive Medicine Reports, 23*, 101445. https://doi.org/10.1016/j.pmedr.2021.101445

Nugroho, H., Sari, D. P., & Wijaya, A. (2023). Cardiovascular health awareness among Indonesian adolescents: A cross-sectional study. *BMC Pediatrics, 23*(1), 1–10. https://doi.org/10.1186/s12887-023-03921-7

Nutbeam, D. (2008). The evolving concept of health literacy. *Social Science & Medicine, 67*(12), 2072–2078. https://doi.org/10.1016/j.socscimed.2008.09.050

Park, S., & Lee, G. (2021). Effects of lifestyle-focused learning modules on adolescent health behavior. *Health Education Research, 36*(5), 421–435. https://doi.org/10.1093/her/cyab028

Pedersen, M. R., Hansen, B. H., Anderssen, S. A., & Kolle, E. (2023). Sedentary time and cardiometabolic health markers in adolescents. *JAMA Pediatrics, 177*(4), 405–413. https://doi.org/10.1001/jamapediatrics.2022.5678

Piaget, J. (1985). *The equilibration of cognitive structures*. University of Chicago Press.

Puspitasari, D., & Sumardi, Y. (2020). Evaluating health-based biology instruction in Indonesian high schools. *Journal of Baltic Science Education, 19*(3), 475–488.

Rachmawati, Y., Prasetyo, B., & Nugraha, A. (2022). Cardiovascular risk literacy among Indonesian students. *Asian Pacific Journal of Public Health, 34*(7), 789–798. https://doi.org/10.1177/10105395221112345

Shi, Y., Zhang, L., & Wang, H. (2023). Healthy lifestyle behaviors and cardiovascular risk among youth: A systematic review. *Journal of Adolescent Health, 72*(5), 720–731. https://doi.org/10.1016/j.jadohealth.2022.11.012

Song, Y., Hu, P., & Li, X. (2022). Lifestyle clustering and cardiovascular outcomes in adolescents. *European Journal of Preventive Cardiology, 29*(2), 281–291. https://doi.org/10.1093/eurjpc/zwab098

Supriyanto, A., & Nurhayati, E. (2021). Contextual biology learning and health awareness in Indonesian schools. *Cogent Education, 8*(1), 1–15. https://doi.org/10.1080/2331186X.2021.1912873

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wang, J., Liu, Y., & Chen, X. (2024). Integrating health education into science learning: Effects on adolescent health

literacy. *Science Education, 108*(1), 115–134. https://doi.org/10.1002/sce.21789
World Health Organization. (2023). *Adolescent health and cardiovascular risk*. WHO Press.
Zhang, Y., Li, Q., & Chen, R. (2023). Health literacy and lifestyle behavior among adolescents: Evidence from multi-country surveys. *Public Health, 220*, 32–39. https://doi.org/10.1016/j.puhe.2023.05.012

ACKNOWLEDGEMENT

This study received ethical clearance from Universitas Sisingamangaraja XII Tapanuli Utara, and all participants provided informed consent. The authors gratefully acknowledge the cooperation of the participating school, the biology teachers, and the students whose involvement made this study possible. We also extend our appreciation to the expert validators for their constructive feedback on the research instruments. Special thanks are due to the research assistants for their support during data collection and processing. Any remaining errors are solely the responsibility of the authors.

AUTHOR CONTRIBUTION STATEMENT

Robert Harianja led the conceptualization, methodology, data collection, and analysis, and drafted the manuscript. Sariayu Sibarani contributed to supervision, review, and editing. All authors approved the final manuscript.

AI DISCLOSURE STATEMENT

The authors used artificial intelligence tools (e.g., ChatGPT) to assist in language refinement, grammar correction, and structural improvement of the manuscript. The AI tools were used solely to enhance clarity and readability and did not contribute to the research design, data collection, data analysis, or interpretation of results. All content has been critically reviewed and validated by the authors, who take full responsibility for the accuracy and integrity of the work.

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