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# Effectiveness of a Quartet-Based Educational Game in Improving Thalassemia Knowledge and Screening Awareness Among Senior High School Students

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**ABSTRACT**

**Introduction:** Thalassemia is one of the most common genetic disorders in Indonesia, however, the knowledge and awareness are still low, especially in rural area. This study aimed to evaluate the effectiveness of a game-based educational tool to increasing knowledge and awareness about thalassemia among senior high school students in rural area.

**Methods:** This quasi-experimental study explored the effectiveness of the Quartet card game in improving thalassemia knowledge and awareness among 93 high school students in rural East Java. An 11-item validated questionnaire was administered before and after the intervention. Their willingness to undergo the screening was measured in the end of the activity.

**Results:** Prior to the intervention, the respondents had poor knowledge ($2.3 \pm 2.8$), which increased to a moderate level ($7.4 \pm 2.9$, $p < 0.001$) after the intervention. Even though there is an increase in knowledge and decrease in misconceptions, but some persisted, particularly regarding contagiousness and differentiation from leukemia. No associations were observed between knowledge improvement and demographic characteristics.

**Conclusion:** The findings indicate that game-based education might enhance adolescent genetic literacy and may serve as a scalable strategy for health promotion. While effective in deliver fundamental concepts, additional strategies are needed to address persisted misconceptions and psychosocial aspects. Longer follow-up and more advanced or immersive serious games may help improve understanding and long-term knowledge retention.

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## INTRODUCTION

A genetic disease is a disorder caused by mutations or changes in DNA, which can be passed on to offspring. These mutations can lead to the malfunction of proteins crucial for normal bodily functions, ultimately resulting in various clinical manifestations, from mild to severe (1). Thalassemia is among the most common genetic disorders in Indonesia, with many carriers unaware of their condition and unknowingly passing it on to their children. Physical and socioeconomic burden heavily carried by patient, family, and the nation (2,3). Early detection before marriage and genetic screening are essential. Cyprus and Italy have successfully reduced thalassemia rates to around 0%, after they launched prevention programs in 1980 (4). The first two key steps taken were widespread public education and carrier detection for thalassemia among all citizens.

In Indonesia, thalassemia remains a significant public health concern, with approximately 5% to 10% of the population estimated to be carriers (5). The Indonesian Ministry of Health highlights the need for preventive education and early screening as crucial measures to lower the prevalence of genetic disease such as thalassemia, especially among young people (6). However, awareness and knowledge about the disease remain limited among adolescents, particularly in rural regions (7). Adolescents in senior high schools are at a critical age to receive targeted health education, particularly regarding genetic conditions like thalassemia, as they are nearing the age of marriage and are in a developmental stage where health behaviours and attitudes begin to solidify (8). Introducing thalassemia and necessity of genetic testing at this stage can empower students to make health decision, such as premarital screening and family well-being (9). However, traditional educational approaches may fail to capture the attention of students, especially when dealing with complex or abstract medical concepts (10). Study in 40 orphans adolescents in rural area showed traditional education succeed to increase thalassemia knowledge (11). Another study involving 57 high school students in an urban area of East Java showed that online peer-group activities, during pandemic, successfully increased thalassemia knowledge ( (12).

Game-based health education, including Quaret, offers an innovative and engaging approach to delivering health information. Games can capture students' attention through enjoyable and interactive experiences, and moreover, they can motivate active participation. These experiences accommodated and encouraged students to explore health concepts in depth and might apply them in realistic scenarios (13). Moreover, serious games can improved knowledge retention, changed positive behavior, and might bring benefit to the students' health (14). The flexibility of games allows learners to progress at their own pace, helping students to understand the theory and the concepts. In addition, game-based education provides collaboration and creating positive environment, enriching the overall educational experience. Thus, game-based health education not only enhances knowledge but also fosters positive behavioral changes (15).

The theory used in this study is the Health Belief Model (HBM) and the gamification theory. The Heath Belief Model emphasizes on how perceived susceptibility, severity, benefits, and barriers affect the health behaviors such as genetic screening (16), while gamification theory also supports the use of interactive elements, competition, feedback, and engagement, to enhance learning motivation (17). Thus, the Quartet game aims not only to transmit factual knowledge but also to influence attitudes by making genetic concepts more accessible.

Taken together, this study aims to evaluate the effectiveness of the game-based genetic diseases education, with thalassemia as an example. Quartet card game as a health education tool for increasing thalassemia awareness among students in rural area. The research investigates whether this method can significantly improve students' understanding of genetic diseases, especially thalassemia, and whether game-based learning offers a promising approach within high schools.

## METHOD

### Study design and data collection

This study was a quasi-experimental design, with Quartet used as a game-based health education intervention. The respondents were high school students from a rural area in East Java, Indonesia. Participants were recruited through convenience sampling by selecting one rural public high school in East Java, all students in X and XI grade levels were invited to participate, and 93 students completed both pre- and post-tests. Data collection was conducted before and after the health education activity, which took place in June 2025.

**Education media**

Quartet was chosen as a game-based health education tool; it consisted of 40 cards, which were divided into 10 categories. Each categories have four cards explaining the categories. The Quartet cards were developed by a panel of two physicians and two medical students based on published literature. Content validity was assessed by two physicians, followed by one revision cycle. The cards were pilot-tested in five adolescents to ensure clarity and appropriate difficulty.

**Survey Instrument**

Respondents' knowledge of thalassemia was assessed using an established questionnaire (18) administered both before and after the online activity. The questionnaire included three parts: basic demographic information, eleven closed-ended questions evaluating knowledge about thalassemia, and items related to the respondents past experience with and willingness to undergo thalassemia screening. Internal consistency reliability was acceptable (Cronbach's alpha = 0.77).

**Analytical Procedure**

Knowledge responses were captured using "yes," "no," and "don't know" choices, with scores assigned as 1 for "yes" and 0 for both "no" and "don't know." The overall knowledge score was determined by adding the scores from all 11 questions and was categorized into three levels: poor (0–3), moderate (4–7), and good (8–11) (11). Data distribution was assessed using the Shapiro–Wilk test. Because total knowledge scores were normally distributed, they are presented as mean ± SD, and pre-/post-intervention differences were analysed using a paired t-test. Categorical variables are presented as proportions (%) and compared using Fisher's exact test using SPSS version 25.00 (IBM, Chicago, IL) and presented graphically using GraphPad Prism version 5.00 (La Jolla, California, USA).

**Ethical Approval**

This study received approval from the Health Research Ethics Committee of Faculty of Medicine Airlangga University (No. 137/EC/KEPK/FKUA/2025). Informed consent was obtained from the principals of both schools, acting as guardians and responsible parties for the students. The confidentiality of all participants was carefully protected throughout the entire research process.

## RESULTS

**Education Media**

The Thalassemia Quartet consist of ten topics, including definition, types, symptoms, complications, therapy, prevention, social support, detection and screening, blood donation requirements, and nutrition. Each topic consists of four cards, resulting in a total of 40 cards (Figure 1). It is played by three to five players with the objective of collecting four cards with the same theme (a quartet) related to information about thalassemia. Each player is dealt four cards from a total of 40 cards, while the remaining cards are placed face down in the center of the table as the draw pile. Players take turns asking another player for a specific card by stating the group name and the card they want. If the opponent has the requested card, they must hand it over. If the player successfully receives the card, they may continue their turn. If not, they must draw one card from the draw pile and their turn ends. Each completed quartet is placed face up and counts as one point. The game ends when there are no more cards left in the draw pile. The winner is the player who collects the most quartets. By mentioning the groups and short term about thalassemia, the respondents learned about the disease.


**Figure 1.** Thalassemia Quartet Educational Cards with ten key topics including definition, types of thalassemia, symptoms, complications, therapy options, prevention strategies, social support, screening and detection methods, blood donor eligibility, and recommended nutrition. Each card includes concise information supported by visual elements to improve comprehension and engagement among adolescents.

## Respondents Characteristics

Hundred respondents joined the activity, however only 93 students completed the pre and post-test, meaning completion rate was 93%. The mean age of the respondents was 16.21 years old, with majority of them was female, and study in the grade 10$^{th}$. One of them ever heard about thalassemia and ever undergo thalassemia testing/screening (Figure 2A).

## Thalassemia Knowledge

To assess the impact of the game-based thalassemia education, an 11-item questionnaire was administered before and after the activity. Normality testing indicated that the knowledge scores followed a normal distribution; therefore, pre- and post-test scores were analyzed using a paired t-test. Participants initially demonstrated poor knowledge (mean ± SD: 2.3 ± 2.8), which significantly improved to a moderate level after the activity (7.4 ± 2.9; $p < 0.001$) (Figure 2B). Knowledge improvement was not associated with age, sex, or grade ($p > 0.05$).

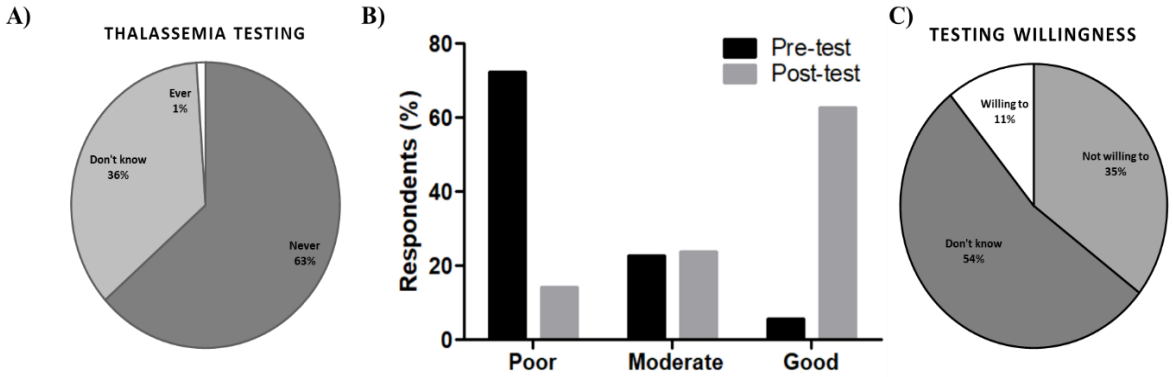


**Figure 2**. Thalassemia testing experience, knowledge improvement, and testing willingness among students.
(A) Proportion of students reporting prior thalassemia testing before participating in the activity (Ever/Never/Don't know). (B) Distribution of students' thalassemia knowledge levels before and after the educational activity, categorized as poor, moderate, or good. Percentages represent the proportion of respondents. (C) Students' willingness to undergo thalassemia testing after the activity (Willing/Not willing/Don't know). All values are presented as percentages.

After playing the Quartet game, the majority of respondents understood that thalassemia is a genetic disease inherited from one or both parents (Q1), and that the condition involves a deficiency in red blood cells (Q3). They also demonstrated improved understanding of the symptoms, including anemia, fatigue, pale skin, and icteric sclera (Q5), as well as the available prevention and screening methods (Q8 and Q9). However, some misconceptions remained. Respondents were still confused about whether thalassemia is contagious (Q2), whether it is the same as blood cancer or leukemia (Q4), and whether there are other types of anemia besides thalassemia (Q6). Surprisingly, half of the respondents were unable to recognize the social burden experienced by patients with thalassemia (Q11) (Table 1). These low scores indicate that the methods used in this community development program were only partly effective in increasing respondents' knowledge of thalassemia.

**Table 1**. Respondents' knowledge on thalassemia before and after game-based education

| Item | Pre-test (%) | Post-test (%) |
|---|---|---|
| Q1: Do thalassemia can be inherited from one or both parents? | 29 | 84.9 |
| Q2: Is thalassemia an infectious disease? | 21.5 | 52.7 |
| Q3: Is thalassemia a disease with a defect in red blood cells? | 31.2 | 77.4 |
| Q4: Is thalassemia similar to blood cancer? | 23.7 | 38.7 |
| Q5: Do anemia, fatigue, pale skin, yellow sclera are the symptoms of thalassemia? | 29 | 81.7 |
| Q6: Do all anemia is thalassemia? | 21.5 | 46.2 |
| Q7: Does thalassemia major need blood transfusion whole life? | 14 | 80.6 |
| Q8: Does thalassemia can be prevented by not marrying between thalassemia carriers or patients? | 9.7 | 64.5 |
| Q9: Does knowing the history of thalassemia in the family, repeated blood transfusion, anemia, and blood checking can help to diagnose thalassemia? | 25.8 | 79.6 |
| Q10: Does blood donation can help thalassemia patients | 20.4 | 80.6 |
| Q11: Does negative stigma, economic problems, physical changes cause mental illness in thalassemia patients? | 19.4 | 52.7 |
| **Mean score±SD (p-value)** | **2.3±2.8** | **7.4±2.9 (p< 0.001)** |

Source: Primary Data

### Thalassemia Testing Attitude

To determine whether knowledge influences respondents' attitudes toward thalassemia testing, a related question was asked after the activity. The result revealed that only 11% of the respondents willing to undergo thalassemia testing, 35% do not willing, and 54% of the respondent still do not know if they would like to undergo thalassemia testing (Figure 2C). Fisher exact test revealed that there was no association between knowledge and willingness to undergo thalassemia testing ($p > 0.05$).

## DISCUSSION

### Interpretation of Key Findings

This study demonstrates that game-based education through the Quartet card game can be an effective method for increasing factual knowledge about thalassemia among adolescents in rural areas. By promoting interactive and peer-driven learning, the approach successfully engaged students and enabled them to retain important biomedical concepts, particularly those related to disease inheritance, symptoms, and prevention. However, increasing of the knowledge does not merely translate into behavioral change, as most students remained undecided or reluctant to undergo thalassemia testing. This highlights a persistent gap between awareness and action, suggesting that while educational games may clarify disease concept, but they failed in addressing emotional, cultural, or social barriers associated with genetic testing, such as thalassemia.

Additionally, the persistence of misconceptions about thalassemia's contagiousness and its confusion with blood cancer points to the limitations of brief or one-time interventions. Some topics, especially those involving social stigma and mental health, may require more longer exposure to have a lasting impact. The lack of association between knowledge gains and demographic factors such as age, sex, or grade suggests that the Quartet game has

broad applicability across diverse student groups, which strengthens its potential for scaling up in school-based health education programs.

**Comparison with Previous Studies**

The poor knowledge on thalassemia in this study was in line with other study in 878 Indonesian youth, which 62.1% of the respondents has a poor knowledge (19). Similar finding also reported in 389 Indian woman, as 73% of them still convince that consanguine marriage is not related with thalassemia and 70% of them agree that screening is not important to prevent thalassemia (20). Partial and poor knowledge also become a challenge in Pakistan and Bangladesh (21,22).

The results of this study support the previous findings that game-based education enhances learning outcomes among adolescents, particularly in health education (13,15). These studies emphasize the role of engagement and peer interaction in facilitating knowledge retention, both of which are integral to the Quartet gameplay format. The use of repetition, strategic questioning, and group competition within the game framework likely contributed to students' improved recall of thalassemia-related facts. Similarly, a qualitative study in Malaysia found that adolescents are more receptive to learning about genetic conditions when the material is delivered in a relatable and interactive manner (9). This reinforces the value of gamified, peer-based learning tools in enhancing comprehension of complex medical topics.

In the Indonesian context, seminars and visual media were used to to raise thalassemia awareness among 40 orphan adolescents and showing significant gains in knowledge (11). Moreover, active involvement of the patients and the family successfully improving the awareness on thalassemia (18). A study involving 65 Malaysian adolescents also showed that web-based thalassemia education effectively increases the knowledge and awareness (23). Misconception still remained in the mentioned strategies, including game-based education, especially on the concept of genetic diseases was incontiguous, type of anemia, and burden of the disease. The current study found no correlation between knowledge with demographic factors, such as age, sex, and grade. Furthermore, our results confirm that awareness of genetic testing remains low among Indonesian adolescents, particularly in rural areas, which in line with study about genetic testing in 332 Indonesian adolescents and 135 Indonesian adults (6). Thus, while the Quartet game proved effective in conveying core knowledge, these findings highlight the need for supplementary strategies to address stigma, emotional resistance, and behavioral intentions related to genetic screening (24,25).

This study also provides the theoretical value, especially the Health Belief Model which emphasized that health behaviors are influenced by perceived risk, perceived benefits, and perceived barriers (16). The game-based education provides these constructs in simplified, visual, and interactive formats, allowing adolescents to engage with genetic concepts in a manner consistent with behavior-change theory. Moreover, this activity also supports the gamification theory which explains the importance of competition, feedback, and peer interaction on increasing the knowledge (17). Taken together, these insights offer a theoretically informed foundation for designing future interventions aimed at improving genetic literacy and encouraging preventive behaviors.

Despite increasing of factual knowledge, persistent misconceptions still need to be addressed. A sociocultural background where the negative stigma, moral value, and lack of communication about genetic diseases might overshadow the knowledge (6) and leads adolescents to associate thalassemia with contagion or weakness and limit their willingness to undergo thalassemia screening. Not only sociocultural, cognitive factors also contribute to these misconceptions making single learning exposure is insufficient to replace the pre-existing knowledge. N addition, systemic factors, including lack of genetic education, limited health information, and the absence of national screening awareness campaigns, contribute to persistent misconceptions. These interacting sociocultural, cognitive, and structural influences highlight the need for more sustained, context-sensitive educational strategies beyond single-session interventions.

**Practical Implications**

This study highlights the feasibility and effectiveness of integrating gamified learning tools into school-based health education, particularly in under-resourced or rural settings where traditional health promotion methods may be less effective. The Quartet game requires minimal infrastructure, is cost-effective, and can be easily adapted for

various health topics beyond thalassemia. More serious game or longer exposure might help to increase the understanding and longer knowledge retain (26).

Importantly, the study also illustrates the importance of timing health education initiatives. Senior high school students are at a formative stage for making future reproductive and health decisions, including premarital screening. Introducing genetic literacy at this stage could contribute to long-term reductions in the prevalence of hereditary diseases, as demonstrated in countries like Cyprus and Italy (4).

**Strengths and Limitations**

A key strength of this study lies in its innovative and contextualized approach, designing a locally relevant educational game and testing it in rural Indonesian schools. The high completion rate (93%) supports the acceptability of the intervention. Furthermore, by comparing pre- and post-test scores, we were able to quantitatively assess the immediate educational impact. However, this study has several limitations. First, it employed a short-term pre-post design without a long-term follow-up, so knowledge retention over time remains unknown. Second, the use of closed-answer questions may have oversimplified complex understandings or misconceptions.

**Recommendations for Future Research**

Evaluation of knowledge retention and its translation into behavior can be explored in future studies. Additionally, combining game-based learning with traditional teaching methods or interactive web-based health education may help reduce misconceptions. Collaboration with schools, teachers, and curriculum developers could also support the integration of game-based health education into the Indonesian school system, making it not only engaging but also impactful (27).

## CONCLUSION

This study investigated the effectiveness of Quartet-based education in increasing awareness of genetic diseases, specifically thalassemia, among senior high school students in rural Indonesia, and aimed to evaluate its impact on participants' thalassemia knowledge. The findings demonstrated a significant improvement in knowledge scores after the intervention, highlighting the potential of game-based learning to enhance engagement in health education. These results underscore the practical value of incorporating interactive, gamified strategies into school health programs, suggesting their broader application in promoting genetic literacy and preventive health behaviors. While this study provides valuable insights into adolescent health education, certain limitations should be noted, including the lack of long-term follow-up and limited assessment of behavioral outcomes. Future research should focus on evaluating knowledge retention and exploring behavioral impacts, such as the willingness or undergo thalassemia screening.

## AUTHOR'S CONTRIBUTION STATEMENT

AdA contributed to study design and conceptualization, education material preparation, data collection, data analysis, and writing the original draft.
MZN contributed to data collection, data analysis, and manuscript review.
DNI contributed to education material preparation, data collection, and manuscript review.
KK contributed to education material preparation, data collection and manuscript review.
NFS contributed to education material preparation, data collection and manuscript review.
JS contributed to data analysis and manuscript review.
All authors reviewed and approved the final manuscript.

## CONFLICTS OF INTEREST

All authors declare no conflict of interest.

## DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

AI tools were used to assist with language refinement, improve clarity, and enhance the overall readability and structure of the manuscript. The authors reviewed and edited the content and remain fully responsible for the accuracy and integrity of the information presented.

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## BIBLIOGRAPHY

1. Jackson M, Marks L, May GHW, Wilson JB. The genetic basis of disease. Essays Biochem. 2018;62(5):643-723. https://doi.org/10.56808/2586-940X.112510.1042/ebc20170053
2. Sari TT, Rahmartani LD, Wirahmadi A, Selene NB, Iskandar SD, Wahidiyat PA. Psychological Burden among Pediatric Thalassemia Major Patients in Indonesia: A Review. Thalassemia Reports. 2024;14(2):33-43. https://doi.org/10.3390/thalassrep14020005
3. Zhen X, Ming J, Zhang R, Zhang S, Xie J, Liu B, et al. Economic burden of adult patients with β-thalassaemia major in mainland China. Orphanet J Rare Dis. 2023;18(1):252. https://doi.org/10.1186/s13023-023-02858-4
4. Angastiniotis M, Petrou M, Loukopoulos D, Modell B, Farmakis D, Englezos P, et al. The Prevention of Thalassemia Revisited: A Historical and Ethical Perspective by the Thalassemia International Federation. Hemoglobin. 2021;45(1):5-12. https://doi.org/10.1080/03630269.2021.1872612
5. Kemenkes. Angka Pembawa Sifat Talasemia Tergolong Tinggi. Jakarta: Ministry of Health, Republic of Indonesia; 2019 [cited 2025 9 March]. Available from: https://www.kemkes.go.id/article/view/19052100003/angka-pembawa-sifat-talasemia-tergolong-tinggi.html.
6. Fillah AM, Akram M, Hartono CE, d'Arqom A, Faizah Z, Indiastuti DN, et al. Knowledge and Attitude Towards Genetics and Genetic Testing Among Late Adolescents and Adults in Indonesia. Journal Health Research. 2025;39(1):87-96. https://doi.org/10.56808/2586-940X.1125
7. Wahidiyat PA, Sari TT, Rahmartani LD, Iskandar SD, Pratanata AM, Yapiy I, et al. Thalassemia in Indonesia. Hemoglobin. 2022;46(1):39-44. https://doi.org/10.1080/03630269.2021.2023565
8. Pulimeno M, Piscitelli P, Colazzo S, Colao A, Miani A. School as ideal setting to promote health and wellbeing among young people. Health Promot Perspect. 2020;10(4):316-24. https://doi.org/10.34172/hpp.2020.50
9. Tan HY, Hussein N, Lee YK, Abdul Malik TF. Adolescents' experiences and views of the national school-based thalassaemia screening programme in Malaysia: a qualitative study. J Community Genet. 2023;14(4):361-9. https://doi.org/10.1007/s12687-023-00656-w
10. Teschers C, Neuhaus T, Vogt M. Troubling the boundaries of traditional schooling for a rapidly changing future – Looking back and looking forward. Educational Philosophy and Theory. 2024;56(9):873-84. https://doi.org/10.1080/00131857.2024.2321932
11. Indiastuti DN, Doman ZA, Fatimah N, Nasution MZ, d'Arqom A. Thalassemia Literacy: Increasing Knowledge of Orphan Adolescents on Thalassemia. Jurnal Layanan Masyarakat (Journal of Public Services). 2024;8(1):86-95. https://doi.org/10.20473/jlm.v8i1.2024.086-095

12. d'Arqom A, Indiastuti DN, Nasution Z. Online peer-group activism for thalassemia health education during the COVID-19 pandemic: a case study from East Java, Indonesia. Journal of Health Research. 2021;36(1):158-65. https://doi.org/10.1108/jhr-09-2020-0442
13. Huang H, Yu H, Li W. Assessing the Importance of Content Versus Design for Successful Crowdfunding of Health Education Games: Online Survey Study. JMIR Serious Games. 2024;12:e39587. https://doi.org/10.2196/39587
14. Xu M, Luo Y, Zhang Y, Xia R, Qian H, Zou X. Game-based learning in medical education. Front Public Health. 2023;11:1113682. https://doi.org/10.3389/fpubh.2023.1113682
15. Hellín CJ, Calles-Esteban F, Valledor A, Gómez J, Otón-Tortosa S, Tayebi A. Enhancing Student Motivation and Engagement through a Gamified Learning Environment. Sustainability. 2023;15(19):14119. https://doi.org/10.3390/su151914119
16. Elkefi S, Choudhury A, Strachna O, Asan O. Impact of Health Perception and Knowledge on Genetic Testing Decisions Using the Health Belief Model. JCO Clin Cancer Inform. 2022;6:e2100117. 10.1200/cci.21.00117
17. Zainuddin Z, Chu SKW, Shujahat M, Perera CJ. The impact of gamification on learning and instruction: A systematic review of empirical evidence. Educational Research Review. 2020;30:100326. https://doi.org/10.1016/j.edurev.2020.100326
18. Asa P, Indiastuti DN, Andarsini MR, Fauziah JN, d'Arqom A. Empowering Thalassemia Patients and Family to Increase Public Knowledge on Thalassemia. 2021. 2021;7(4):6. https://doi.org/10.22146/jpkm.69349
19. Wahidiyat PA, Yo EC, Wildani MM, Triatmono VR, Yosia M. Cross-sectional study on knowledge, attitude and practice towards thalassaemia among Indonesian youth. BMJ Open. 2021;11(12):e054736. https://doi.org/10.1136/bmjopen-2021-054736
20. Rishmitha, Badagabettu S, M V A, Lakshmi R V, C U J. Awareness on thalassemia and opinion of carrier screening among young women from selected undergraduate colleges of udupi district. Clinical Epidemiology and Global Health. 2022;14:100978. https://doi.org/10.1016/j.cegh.2022.100978
21. Gul Z, Malik M, Uzair U, Baloch A, La QD, Sadiq N, et al. Awareness About Thalassemia Among the Parents of Thalassemic Children in Balochistan: A Cross-Sectional Study. Health Sci Rep. 2025;8(4):e70715. https://doi.org/10.1002/hsr2.70715
22. Alam NE, Islam MS, Khabir MIU, Suriea U, Islam MM, Mohiuddin RB, et al. The scenario of knowledge, attitude and practice of the Bangladeshi population towards thalassemia prevention: A nationwide study. PLOS Glob Public Health. 2022;2(10):e0001177. https://doi.org/10.1371/journal.pgph.0001177
23. Ngim CF, Ibrahim H, Abdullah N, Lai NM, Tan RKM, Ng CS, et al. A web-based educational intervention module to improve knowledge and attitudes towards thalassaemia prevention in Malaysian young adults. Med J Malaysia. 2019;74(3):219-25.
24. Maaoui F, Arboix-Calas F, Safra I, Menif S, Moumni I. From misconceptions to empowerment: assessing health and genetic literacy on thalassemia among Tunisian secondary school students. BMC Public Health. 2025;25(1):3400. https://doi.org/10.1186/s12889-025-24536-9
25. Boardman FK, Clark C, Jungkurth E, Young PJ. Social and cultural influences on genetic screening programme acceptability: A mixed-methods study of the views of adults, carriers, and family members living with thalassemia in the UK. J Genet Couns. 2020;29(6):1026-40. https://doi.org/10.1002/jgc4.1231
26. Zhonggen Y. A Meta-Analysis of Use of Serious Games in Education over a Decade. International Journal of Computer Games Technology. 2019;2019(1):4797032. https://doi.org/10.1155/2019/4797032
27. Thesen T, Bahner I, Belovich AN, Bonaminio G, Brenneman A, Brooks WS, et al. Not Just Fun and Games: Game-Based Learning in Health Professions Education. Med Sci Educ. 2023;33(5):1301-6. https://doi.org/10.1007/s40670-023-01859-z