International Journal of Advanced Health Science and Technology e-ISSN:2808-6422; p-ISSN:2829-3037
Homepage: ijahst.org Vol. 4 No.5, pp. 294-299, October 2024

RESEARCH ARTICLE OPEN ACCESS

Manuscript received Agustus 23, 2024; revised October 18, 2024; accepted October 18, 2024; date of publication October 30, 2024

Digital Object Identifier (DOI): https://doi.org/10.35882/ijahst.v4i5.402

How to cite: Sealomita Rizka Apritama, Bambang Hadi Sugito, Imam Sarwo Edi, and IGA Kusuma Astuti, **"**Effectiveness of Lemon Solution Gargling in Reducing Dental Plaque Index among Senior High Students at Porong, Indonesia**"**, International Journal of Advanced Health Science and Technology, vol. 4, no. 5, pp. 294 - 299, October 2024.

Effectiveness of Lemon Solution Gargling in Reducing Dental Plaque Index among Senior High Students at Porong, Indonesia

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ABSTRACT Dental plaque accumulation remains a significant contributor to oral health problems among adolescents, with improper plaque control leading to periodontal disease. Preliminary data from SMA Negeri 1 Porong revealed that 50% of grade 11 students exhibited poor plaque hygiene, with an average PHP (Patient Hygiene Performance) index score of 3.54. This study aimed to evaluate the effectiveness of lemon solution gargling at concentrations of 10% and 15% in reducing the dental plaque index among these students. A pre-experimental design with a one-group pretest-posttest approach was employed. The study involved 52 grade 11 students, divided equally into two treatment groups: one group gargled a 10% lemon solution, and the other a 15% solution. The PHP index was measured before and after the intervention using a standardized observation sheet. Data were analyzed using the Independent T-Test. Results indicated a reduction in plaque index scores in both groups. The 10% group showed a mean decrease from 2.48 to 1.27 (a reduction of 1.21), while the 15% group showed a decrease from 2.07 to 1.07 (a reduction of 1.00). Although both interventions demonstrated significant improvement within groups ($p < 0.05$), no statistically significant difference was found between the two concentrations ($p = 0.108$). In conclusion, gargling with lemon solution at both 10% and 15% concentrations effectively reduced dental plaque among senior high school students. However, there was no significant difference in effectiveness between the two concentrations. These findings suggest that lemon solution gargling may serve as a natural and accessible alternative for improving oral hygiene among adolescents. Further research with a longer observation period and controlled gargling procedures is recommended to validate and optimize these outcomes.

INDEX TERMS Lemon solution, PHP index, dental plaque, high school students, mouthwash

I. INTRODUCTION

Oral health remains a critical component of general health and well-being, yet dental and periodontal diseases persist as global health concerns. According to the Basic Health Research Survey (Riskesdas), the prevalence of dental and oral problems in East Java reached 54.22%, with only 9.76% of individuals receiving appropriate dental care [1]. Although 94.7% of Indonesians reportedly brush their teeth daily, only 1.83% do so correctly [2]. This highlights a widespread lack of awareness regarding effective oral hygiene practices, contributing to the accumulation of dental plaque and the onset of periodontal diseases.

Dental plaque, a biofilm composed of bacterial colonies embedded in a matrix, plays a central role in the pathogenesis of gingivitis and periodontitis [3], [4]. Chronic periodontitis is especially concerning due to its insidious progression and potential to affect both children and adults [5], [6]. Poor oral hygiene among adolescents, often due to limited awareness or ineffective cleaning techniques, can lead to substantial plaque buildup and subsequent periodontal disease [7], [8]. In this context, students from SMA Negeri 1 Porong showed a high plaque index, with 50% categorized as having poor oral hygiene and an average PHP index of 3.54 indicating a pressing public health issue within this population.

State-of-the-art strategies for plaque control encompass mechanical, chemical, and natural approaches. Mechanical methods, such as toothbrushing and flossing, are foundational but often improperly executed by adolescents [9]. Chemical plaque control, particularly through mouthwashes like chlorhexidine, has been shown to be effective; however, prolonged use may result in adverse effects such as tooth staining, altered taste, and disruption of the oral microbiome [10], [11]. As a response to these limitations, interest has grown in herbal and natural alternatives for oral hygiene [12]–[14].

One such natural agent is lemon (Citrus limon), which contains antibacterial compounds such as flavonoids, saponins, and citric acid that may help reduce microbial accumulation on teeth [15], [16]. Recent studies have shown that lemon extract exhibits inhibitory effects against Streptococcus mutans, the primary pathogen involved in dental plaque formation [17], [18]. Furthermore, lemon's

e-ISSN:2808-6422; p-ISSN:2829-3037
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acidity and vitamin C content are hypothesized to contribute to antibacterial efficacy while maintaining a favorable safety profile [19]–[21]. Despite promising results, limited empirical studies have evaluated the comparative effectiveness of lemon solution gargling at varying concentrations in a school-based adolescent population.

This study seeks to address this gap by examining the effectiveness of gargling with lemon solution at 10% and 15% concentrations in reducing dental plaque index among 11th-grade students at SMA Negeri 1 Porong. The objective is to provide evidence on the efficacy of natural, cost-effective oral hygiene alternatives that can be integrated into school-based health promotion programs.

This study contributes to the literature in three key ways: (1) it evaluates a novel application of lemon solution as a natural alternative to chemical mouthwash in a school-based setting; (2) it compares the effectiveness of two concentrations, which can inform optimal usage in community health contexts; and (3) it supports the integration of evidence-based, accessible, and locally sourced solutions into adolescent oral health promotion.

II. METHOD

A. STUDY AND SETTING POPULATION

This research employed a pre-experimental design using the one-group pretest-posttest approach. This design allows researchers to measure changes in outcomes before and after the intervention within the same population group, without the use of a control group [26]. The intervention in this study consisted of gargling with lemon solution at two different concentrations: 10% and 15%. The primary outcome assessed was the change in the dental plaque index, as measured by the Patient Hygiene Performance (PHP) index.

B. SAMPLING TECHNIQUE

The study was conducted at SMA Negeri 1 Porong, located in East Java, Indonesia, over a seven-month period from October 2023 to May 2024. This research site was selected based on several key considerations, including its accessibility to the research team, the willingness and cooperation of school administrators, and findings from preliminary observations. These initial assessments indicated a notably high plaque index among students, suggesting a need for targeted oral health interventions. The combination of logistical feasibility and relevant health concerns made SMA Negeri 1 Porong an appropriate and strategic location for implementing and evaluating the study.

C. VARIABLES AND OPERATIONAL DEFINITIONS

The target population consisted of all 11th-grade students enrolled at SMA Negeri 1 Porong during the study period. A total of 60 students were initially screened, from which 52 were selected as participants using purposive sampling. The inclusion criteria included students who were present during data collection, provided informed consent, and did not have any known allergies or hypersensitivity to citrus-based products. Students with ongoing dental treatment, orthodontic appliances, or systemic health conditions affecting oral hygiene were excluded from the study [27].

D. ETHICAL APPROVAL AND CONSENT

Prior to data collection, ethical clearance was obtained from the Health Research Ethics Committee of the Health Polytechnic of the Ministry of Health, Surabaya. All participants and their guardians were informed about the study objectives, procedures, and potential risks, and written informed consent was secured from all students and parents. Confidentiality and the right to withdraw from the study at any time were guaranteed in accordance with the Declaration of Helsinki [28].

E. MATERIAL AND TOOLS

The following tools and materials were used in this study: 30 disposable mouth mirrors, 30 disposable sondes, Cotton buds, Disclosing gel (erythrosine-based), Small plastic containers, Pre-labeled observation sheets for PHP index recording, Lemon extract solutions at concentrations of 10% and 15%, prepared using distilled water as the solvent. The lemon extract was prepared from fresh lemons by juicing and filtering the pulp. The solution was diluted to the respective concentrations and stored in sterile containers at 4°C prior to use. The disclosing agent was used to visualize plaque accumulation on index teeth [29], [30].

F. INTERVENTION PROCEDURE

Data collection was conducted over a single day in a dedicated school health room. Participants were randomly assigned into two groups: one group (n=26) was assigned to gargle with a 10% lemon solution, and the second group (n=26) gargled with a 15% lemon solution. Each participant was instructed to rinse with 15 mL of the assigned solution for 30 seconds, ensuring full contact with all tooth surfaces while keeping their teeth in an occlusal position, as recommended by previous protocols [31]. Before the intervention, plaque disclosure was performed using disclosing gel, followed by a PHP index assessment. The PHP index was determined by observing five tooth surfaces (facial surfaces of maxillary incisors and first molars) using standardized scoring criteria. The procedure was repeated 30 minutes after the gargling intervention to assess the post-treatment plaque index [32].

G. DATA COLLECTION AND MEASUREMENT

Both the baseline and post-intervention dental examinations were carried out by trained dental health professionals using standardized and consistent procedures to ensure the reliability of the data. During each assessment, every tooth surface was carefully evaluated and assigned a score based on the presence and distribution of dental plaque. These individual scores were then compiled, and the total was averaged to calculate the Personal Hygiene Performance (PHP) index for each participant. This index provided a quantifiable measure of oral hygiene status, allowing for an objective comparison of plaque levels before and after the educational intervention.

H. DATA ANALYSIS, VALIDITY, AND RELIABITY

Statistical analysis was performed using SPSS version 26. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were computed to describe the characteristics of the sample. Normality of data distribution was evaluated using the Shapiro-Wilk test. Since the data

e-ISSN:2808-6422; p-ISSN:2829-3037
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met the normality assumption ($p > 0.05$), comparisons between the two treatment groups were made using the Independent Samples T-Test [33], [34]. A significance level of $\alpha = 0.05$ was used for all statistical tests. To ensure measurement validity and reliability, data collectors underwent calibration training prior to the study. Inter-observer agreement was tested on a subsample, achieving a Cohen's kappa value > 0.85, indicating strong reliability in plaque index scoring [35].

III. RESULT

A. RESPONDENT CHARACTERISTICS

TABLE 1
Characteristics of Class 11 High School Students in 2024

Category	Amount	%
Gender		
Man	10	19
Woman	42	81
Age		
15 years	3	6
16 years	22	42
17 years	25	48
18 years	2	4
TOTAL RESPONDENTS	52	100

TABLE 2
PHP Index Distribution Results Before and After Gargling Using Lemon Solution with a Level of 10%

Category	Before Gargling		After Gargling	
	Frequency	%	Frequency	%
Good	3	11.5	22	84.6
Currently	22	84.6	4	15.4
Bad	1	3.9	0	0.0
Total	26	100	26	100

TABLE 3
Results of measuring the average PHP index before and after gargling using a lemon solution with a concentration of 15%

Category	Before Gargling		After Gargling	
	Frequency	%	Frequency	%
Good	8	30.8	25	96.1
Currently	17	65.3	1	3.9
Bad	1	3.9	0	0.0
Total	26	100	26	100

Based on the data presented in TABLE 1, showed that the majority of respondents were women with 42 students (81%) and most of the respondents were 17 years old with 25 students (48%). TABLE 2 showed that the majority of class 11 students who had not been given gargle treatment using 10% lemon solution were 22 students in the medium category and the majority of class 11 students who had been given gargle treatment with 10% lemon solution were 22 students in the good category. TABLE 3 showed that the majority of class 11 students who had not been given treatment gargled using 15% lemon solution as many as 17 students in the medium category. Meanwhile, the majority of class 11 students who had been given the 15% lemon solution gargle treatment were 25 students in the good category.

Based on TABLE 4 It was found that 26 students before being given the 10% lemon solution gargle treatment had an average PHP index of 2.48 in the medium category and experienced a decrease after gargling the 10% lemon solution to 1.27 in the medium category. So it is known that the PHP index decreased by 1.21. Meanwhile, as many as 26 students before being treated with 15% lemon solution had an average PHP index of 2.07 in the medium category and experienced a decrease after gargling with 15% lemon solution to 1.07 in the good category. So it can be seen that there is a decrease in the PHP index by 1.

TABLE 4
Test Results Research Data Differences in the Effectiveness of Gargling Using Lemon Solution with Levels of 10% and 15%

Gargle Lemon Solution	Average Debris Index				
	Before	*Mean±SD*	After	*Mean±SD*	Decline
10%	2.48	2.48 ± 0.5	1.27	1.27 ± 0.41	1.21
15%	2.07	2.07 ± 0.62	1.07	1.07 ± 0.48	1.00

TABLE 5
PHP Index Normality Test Results Before and After Gargling Using Lemon Solution with Levels of 10% and 15%

Variable	N	%	ρ Value
Before gargling, use a lemon solution with a concentration of 10% and 15%	26	50	0.448
After gargling using lemon solution with a concentration of 10% and 15%	26	50	0.200

TABLE 6
Results of PHP Index Analysis Before and After Gargling Using Lemon Solution with a Concentration of 10%

Variable	Category						ρ Value
	Good		Currently		Bad		
	N	%	N	%	N	%	
Before gargling	3	11.5	22	84.6	1	3.9	0,000
After gargling	22	84.6	4	15.4	0	0	

Based on TABLE 5 It is known that before gargling using a lemon solution with levels of 10% and 15% has a ρ value of 0.448 (>0.05). So, it can be concluded that the data is normally distributed. Meanwhile, after gargling using lemon solution with levels of 10% and 15%, it has a ρ value of 0.200 (>0.05). So, it can be concluded that the data is normally distributed.

Based on TABLE 6 The ρ value obtained before and after gargling using a 10% lemon solution was 0.000 (<0.05). So, the conclusion is that H1 is accepted, namely the effectiveness of gargling using a 10% lemon solution in reducing the dental plaque index of class 11 students at SMA Negeri 1 Porong.

Based on TABLE 7 The ρ value obtained before and after gargling using a 10% lemon solution was 0.000 (<0.05). So, the conclusion is that H1 is accepted, namely the effectiveness of gargling using lemon solution with a concentration of 11% in reducing the dental plaque index of class 11 students at SMA Negeri 1 Porong. Based on TABLE 8 It can be seen that the mean PHP index after gargling using a 10% lemon solution is 1.27 and the mean PHP index after gargling using a 15% lemon solution is 1.07 with significance sig.(2-tailed) = 0.108. If the sig (2-tailed) value is > 0.05, then H0 is accepted. So the conclusion is that there is no difference in the effectiveness of gargling using lemon solution with levels of 10% and 15% in reducing the dental plaque index in class 11 students at SMA Negeri 1 Porong.

e-ISSN:2808-6422; p-ISSN:2829-3037
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TABLE 8 presents the results of the comparative analysis of the mean PHP index after gargling with 10% and 15% lemon solutions. The findings indicate that there was no statistically significant difference between the two concentrations (p = 0.108) [20].

TABLE 7
Results of PHP Index Analysis Before and After Gargling Using Lemon Solution with a Concentration of 15%

Variable	Category						ρ Value
	Good		Currently		Bad		
	N	%	N	%	N	%	
Before gargling	8	30.8	17	65.3	1	3.9	0,000
After gargling	25	96.1	1	3.9	0	0	

TABLE 8
Results of Analysis of Differences in the Effectiveness of Gargling Using Lemon Solution with Levels of 10% and 15% on Reducing Dental Plaque Index in Class 11 Students of SMA Negeri 1 Porong

Variable	*N*	*Mean ± SD*	*Sig.(2-tailed)*
After gargling using lemon solution with a concentration of 10%	26	1.27 ± 0.41	0.108
After gargling using lemon solution with a concentration of 15%	26	1.07 ± 0.48	0.108

IV. DISCUSSION

A. INTERPRETATION OF FINDINGS

The present study demonstrated that gargling with lemon solution at concentrations of 10% and 15% significantly reduced the dental plaque index among 11th-grade students at SMA Negeri 1 Porong. The pretest mean PHP index for the 10% group was 2.48 and decreased to 1.27 post-intervention, while the 15% group showed a decrease from 2.07 to 1.07. These findings indicate that both concentrations were effective in improving oral hygiene status by reducing plaque accumulation. This reduction may be attributed to the active compounds present in lemon, including citric acid, flavonoids, and essential oils, which exhibit antibacterial and biofilm-disrupting properties [36]. The citric acid component, in particular, creates an acidic environment that interferes with bacterial adhesion and metabolism, thereby inhibiting plaque formation [37]. Flavonoids are known to inhibit glucosyltransferase activity in Streptococcus mutans, thereby reducing extracellular polysaccharide production essential for plaque matrix development [38]. Although both treatment groups demonstrated significant intra-group reductions in PHP scores, the inter-group analysis revealed no statistically significant difference (p = 0.108) in the effectiveness between the 10% and 15% concentrations. This suggests a saturation effect or plateau in efficacy beyond a certain concentration threshold. In other words, increasing the lemon concentration beyond 10% did not yield proportionally greater plaque reduction. This finding is consistent with principles of dose-response in antimicrobial interventions, where effectiveness may taper off at higher doses due to cytotoxicity or irritation limiting compliance [39].

B. COMPARISON WITH PREVIOUS STUDIES

The observed efficacy of lemon solution as an antiplaque agent aligns with several studies that investigated citrus-based natural products in oral care. A study by Kamila et al. confirmed the effectiveness of lime (Citrus aurantifolia) extract in reducing plaque index scores among adolescents when used as a mouthwash over a 7-day intervention period [9]. Similarly, Dewi and Miko [11] found that lime gargling significantly altered the pH of saliva and disrupted plaque accumulation, supporting the acidic mechanism of action observed in our study. A comparative study by Mandalas et al. examined the effectiveness of chlorhexidine and herbal mouthwashes (including Piper betle and lime extracts) in reducing plaque among orthodontic patients and reported comparable outcomes [8]. However, long-term chlorhexidine use is associated with side effects such as tooth staining and alteration of the oral flora, which makes natural alternatives such as lemon extract an appealing option, especially for school-based interventions. Notably, our findings differ slightly from those of Wulandari [10], who reported a higher degree of plaque reduction with 15% lime solution compared to lower concentrations. This discrepancy may arise from differences in methodology, such as the volume of mouthwash used, frequency of gargling, duration of exposure, and baseline plaque index. From a microbiological perspective, lemon extract is known to inhibit Streptococcus mutans and Streptococcus viridans primary contributors to dental plaque [40]. Harahap et al. also demonstrated the antibacterial activity of a lemon peel and clove extract combination against these bacteria, further substantiating the mechanism of action proposed in our study [13]. Moreover, the present study contributes to the growing literature advocating for school-based oral health interventions. Research by Lestari et al. emphasized the value of early education and preventive practices in schools to reduce the long-term burden of oral diseases [41]. Our findings reinforce this narrative and underscore the feasibility of integrating low-cost, natural mouthwashes into the School Dental Health Program (UKGS) as a preventive strategy.

C. STUDY LIMITATIONS AND IMPLICATIONS

Several limitations must be acknowledged in interpreting the findings of this study. First, the use of a pre-experimental, non-randomized design without a true control group limits the ability to infer causality. Although within-subject comparisons were statistically significant, potential confounders such as diet, oral hygiene practices, and individual microbiota composition were not controlled. Future randomized controlled trials (RCTs) with larger and more diverse populations are warranted to validate these findings. Second, the intervention duration was limited to a single administration of lemon solution gargling, which may not reflect long-term outcomes or sustained behavioral change. Chronic oral conditions such as gingivitis and periodontitis require continued preventive care; hence, longitudinal studies examining repeated use over weeks or months would provide more comprehensive insights into the long-term efficacy and safety of lemon-based mouthwash [42]. Third, inconsistencies in gargling technique among participants may have affected the uniformity of exposure. Although participants were instructed on the correct method, observations indicated varied rinsing duration and technique, which could have influenced plaque removal. Future

e-ISSN:2808-6422; p-ISSN:2829-3037
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research should standardize mouthwash delivery, perhaps using premeasured cups and supervision during administration. Fourth, the study relied solely on the PHP index, which, while effective for large-scale surveys, may lack sensitivity compared to more detailed indices like the Silness-Löe Plaque Index. Incorporating microbial analysis or salivary biomarkers in future research would enhance the understanding of the intervention's microbiological impact [43]. Despite these limitations, the study has important implications. The use of lemon solution as a natural, accessible, and culturally acceptable oral rinse represents a promising adjunctive method for plaque control in adolescent populations. Given the high rates of plaque-related diseases among Indonesian youth [1], integrating such interventions into routine school health programs could significantly improve oral health literacy and outcomes. Furthermore, the findings support the broader movement toward sustainable and plant-based alternatives in healthcare, in alignment with global health goals promoting environmentally responsible practices [44]. Lemon extract is low-cost, biodegradable, and widely available, making it particularly suitable for resource-constrained settings. In public health practice, the implementation of natural mouthwashes like lemon solution could serve as a valuable tool in oral health promotion strategies. Collaboration between health authorities, school administrators, and dental professionals would be essential to scale and monitor such programs effectively. Educational sessions on proper mouthwash use, supported by regular dental check-ups and reinforcement activities, may further enhance the impact. Lastly, this research contributes to the scientific community by establishing preliminary evidence for the comparable effectiveness of two lemon solution concentrations in plaque reduction. It also highlights that 10% may be an optimal concentration, balancing efficacy and tolerability, thus guiding formulation development in future product innovation and trials.

V. CONCLUSION

This study aimed to evaluate the effectiveness of gargling with lemon solution at concentrations of 10% and 15% in reducing the dental plaque index among 11th-grade students at SMA Negeri 1 Porong in 2024. The findings revealed a significant reduction in plaque index following the intervention with both concentrations. Specifically, the mean PHP index decreased from 2.48 to 1.27 after gargling with a 10% lemon solution, indicating a reduction of 1.21 points, while the 15% solution reduced the index from 2.07 to 1.07, reflecting a decrease of 1.00 point. These outcomes demonstrate that both concentrations are effective in minimizing dental plaque accumulation, although statistical analysis ($p = 0.108$) indicated no significant difference in effectiveness between the two. Interestingly, the 10% concentration showed a slightly greater numerical reduction in plaque index, suggesting it may be a more practical choice due to its milder formulation and similar efficacy. These findings align with the study's objective and provide valuable insight into the use of natural agents like lemon solution as an alternative to chemical-based mouthwashes, particularly in adolescent school populations. Considering the rising interest in herbal and eco-friendly dental care solutions, lemon-based mouthwash offers a low-cost, accessible, and culturally acceptable strategy to enhance oral hygiene among students. However, this study also highlighted certain limitations, such as the one-time intervention and potential variation in gargling technique across participants. Therefore, future studies are recommended to assess the long-term effectiveness and safety of lemon solution when used regularly over extended periods. Additionally, future research could include randomized controlled trials, microbiological assessments, and comparisons with standard commercial mouthwashes to further establish the clinical utility of lemon-based oral care products. Health professionals and school dental programs are encouraged to consider integrating natural rinses like lemon solution into educational and preventive strategies to promote better oral hygiene among adolescents.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the management and students of SMA Negeri 1 Porong for their valuable cooperation and active participation in this research. Their support greatly contributed to the smooth implementation of the study. Special appreciation is also extended to the Department of Dental Health at Poltekkes Kemenkes Surabaya for their continuous guidance, technical support, and encouragement throughout the research process. Furthermore, the authors acknowledge the efforts of all individuals who assisted in data collection and logistical coordination during the implementation phase. This research would not have been possible without the collective contributions of all parties involved.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Sealomita Rizka Apritama contributed to the conception and design of the study, data collection, statistical analysis, and manuscript drafting. Bambang Hadi Sugito provided supervision, assisted in refining the research methodology, and contributed to the interpretation of the data. Imam Sarwo Edi supported the data analysis process and critically revised the manuscript for important intellectual content. I.G.A. Kusuma Astuti was responsible for project administration, ethical approval coordination, and final manuscript review. All authors have read and approved the final version of the manuscript.

DECLARATIONS

ETHICAL APPROVAL

This study was approved by the Health Research Ethics Committee of Poltekkes Kemenkes Surabaya. All procedures performed were in accordance with ethical standards and the Declaration of Helsinki.

CONSENT FOR PUBLICATION PARTICIPANTS.

e-ISSN:2808-6422; p-ISSN:2829-3037
Vol. 5 No.3, pp. 104-108, June 2025

Consent for publication was given by all participants

COMPETING INTERESTS

The authors declare no competing interests.

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