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# Exploring Pre-Service Teachers' Critical Thinking and Mathematical Beliefs Through Contextual Problem Analysis

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**Abstract**

The ability to create contextual problems is essential for pre-service teachers. However, many teachers simply adapt or adopt existing problems when creating contextual problems. This study aims to explore the critical thinking skills in analysing contextual problems and the mathematical beliefs that underlie the analysis process. This qualitative study involved 40 pre-service primary school teacher participants, with four participants selected for in-depth interviews. The research instruments included vignettes, interview guidelines, and observation sheets. The data were validated using triangulation methods. The study indicates that pre-service primary school teachers can be categorised into non-critical thinkers (35 participants), emergent critical thinkers (3 participants), and advanced critical thinkers (2 participants). Non-critical thinkers demonstrate an ability to understand problems that they have previously studied, as their understanding constrained to the formulae and procedures demonstrated by their teachers. Emergent critical thinkers showed the ability to question the problem formulation and evaluate its contextual relevance, although their reasoning remained influenced by teacher authority. Advanced critical thinkers are characterised by a high level of critical thinking aptitude, often attributed to their perception of mathematics as a discipline rooted in logical reasoning.

**Keywords:** Critical thinking; Contextual problems; Mathematical beliefs; Vignette

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## INTRODUCTION

Contextual problems demonstrate the usefulness of mathematics in solving real-life problems (Tambychik & Meerah, 2010; Vos, 2011). Solving contextual problems requires various cognitive abilities such as linguistic and numerical abilities (Jaffe & Bolger, 2023) and demands the ability to interpret, identify relevant data, construct mathematical models, and find logical solutions (Akhsani et al., 2025). Therefore, contextual problems have the potential to develop integrative mathematical knowledge that is relevant to life; improve conceptual understanding and interest in learning (Rocha et al., 2024); and develop problem-solving, critical thinking, and creative thinking e (Applebaum, 2025; Toheri et al., 2020). Contextual problems can predict problem-solving performance.

However, the importance of contextual problems is not aligned with the fact that many teachers or pre-service teachers experience difficulties to design hight-quality contextual questions. Primary and secondary school teachers in Kosovo tend to create questions that are inapplicable, closed, and symbolic in nature (Berisha et al., 2020). The single variable linear equation questions in mathematics textbooks lack context and are closed-ended (Tarim & Tarku, 2022). The same is true of the questions in he 2013 Curriculum and the Cambridge Curriculum (Raditya & Iskandar, 2021). Most pre-service primary school teachers create questions by simply replacing the numbers in the textbook questions (Rahaju et al., 2019b).

Pre-service mathematics teachers in Kendari also lack the appropriate context and sufficient information in the questions they create (Kadir et al., 2020). Some of the mathematical problems created by pre-service teachers contain illogical answers (Desfitri, 2018). These findings indicate that pre-service teachers may encounter difficulties not only in designing contextual problems but also in critically evaluating their logical consistency and contextual appropriateness.

These difficulty creating contextual problems are associated with low critical thinking skills (Rahaju et al., 2019b). Critical thinking refers to the ability to analyze assumptions, evaluate arguments, and make reasoned judgments based on evidence (Ennis, 2018; Facione, 1990). Critical thinking skills can be improved through problem posing (Toheri et al., 2020), hybrid learning (Goto & du Toit, 2025), and engagement with contextual problem tasks that foster deeper interaction with mathematical structures (Furtado et al., 2019). Non-routine problems can be used to explore critical thinking skills in collaborative problem solving (Khusna et al., 2024). Although critical thinking has been widely examined through standardized tests, rubric-based assessments, and problem-solving tasks, limited attention has been given to how critical thinking is enacted when pre-service teachers analyze and evaluate contextual mathematical problems constructed by others. This activity requires individuals to identify implicit assumptions, detect inconsistencies, and evaluate the coherence between mathematical procedures and real-world contexts, which represent essential dimensions of critical thinking beyond procedural problem solving.

In addition to cognitive aspects, affective aspects such as mathematical beliefs also play a role in mathematical performance, including mathematical problem-solving activities (Habók et al., 2020). Mathematical beliefs influence motivation and perseverance in learning mathematics (Furtado et al., 2019) as well as problem-solving abilities (Hidayatullah & Csíkos, 2022). Teachers' mathematical beliefs also influence their teaching methods (Kasa et al., 2024). Mathematical beliefs reflect individuals' views about the nature of mathematics, such as whether mathematics is perceived as a fixed set of procedures or as a logical and meaningful discipline (Kasa et al., 2024; Philipp, 2007). These beliefs may influence how pre-service teachers interpret and evaluate mathematical problems, including whether they focus primarily on procedural correctness or attend to contextual coherence and logical consistency.

Although critical thinking and mathematical beliefs have been widely studied, most previous studies have examined critical thinking in the context of problem solving. However, limited research has explored how critical thinking is enacted when pre-service teachers analyze and evaluate contextual mathematical problems constructed by others. This activity requires individuals to examine the correctness, clarity, and logical consistency of the problem. In addition, mathematical beliefs may influence how pre-service teachers evaluate such problems. Those who view mathematics as a fixed set of procedures may focus primarily on procedural correctness, whereas those who perceive mathematics as a meaningful and logical discipline may attend to contextual coherence and reasoning. Therefore, examining critical thinking and mathematical beliefs through contextual problem analysis is important for understanding pre-service teachers' professional competence. Examining critical thinking through contextual problem analysis therefore provides an important perspective for understanding how pre-service teachers evaluate mathematical tasks as part of their emerging professional competence.

Therefore, the purpose of this study is to explore pre-service teachers' critical thinking and mathematical beliefs through contextual problem analysis. Specifically, this study addresses the following research questions: (1) How do pre-service teachers analyze inconsistencies in contextual mathematical problems? (2) What patterns of critical thinking are reflected in their analyses? (3) How are these patterns associated with their expressed mathematical beliefs? This study contributes to the literature by conceptualizing contextual problem analysis as a lens for examining enacted critical thinking and by providing empirical evidence on how mathematical beliefs are reflected in pre-service teachers' analytical processes.

## METHOD

### Research Design

This study employed a qualitative descriptive method to provide insight into participants' reasoning processes. A qualitative descriptive approach was considered appropriate because it allows researchers to explore and describe participants' thinking based on their written and verbal responses in a natural context. This approach is consistent with findings that tasks requiring creative mathematical reasoning promote deeper understanding of mathematical structures (Jonsson et al., 2020). This methodology enabled researchers to collect holistic data, both verbal and written, which were subsequently described naturally 5 (Gök et al., 2021).

### Participants

The participants were 40 pre-service primary school teachers enrolled in a teacher education program at a private university in Malang, Indonesia. The participants had studied the topics of roots and exponents prior to the study, in accordance with the problems developed in the research instrument. All participants completed the vignette task. Based on their responses, participants were classified into four categories of critical thinking: non-critical thinker, emergent critical thinker, developing critical thinker, and advanced critical thinker (As'ari et al., 2017). From these participants, four were purposively selected to represent each critical thinking category for in-depth interviews. This selection aimed to obtain rich and varied information regarding participants' critical thinking and mathematical beliefs.

### Instrument and Procedure

The data were collected using a vignette, interview guidelines, and field notes. A vignette presents realistic situations with the aim of eliciting critical opinions from respondents (Skilling & Stylianides, 2023). In this study, the vignette was designed to explore participants' critical thinking in analysing contextual problems related to roots and exponents. Figure 1 shows the vignette used in this study. The original task was written in Indonesian.

Ajeng was assigned the task of formulating a contextual problem and its respective solution.The problem is outlined below along with the proposed solution.

Mr Roni constructed a swimming pool for his one-year-old son in the shape of a cube with a size of 4,096 cm³. What is the length of each side of the pool?
Known : the size of the pool= 4,096 cm³
Unknown: the size of the pool's sides
Solution : $\sqrt[3]{4,096}$
$\sqrt[3]{4,096}=16$
Separate the last three digits of 4,096, leaving with the number 4. Find the the highest perfect cube less than or equal to 4, which is 1. The last digit of 4,096 is 6 and any number that ends in 6 has a cube root that also ends in 6. It is concluded that the cube root of 4,096 is 16.
$16 \times 16 \times 16 = 4,096$ (for verification)
Therefore, the size of the pool's side is 16.

What is your opinion on the contextual problem and the solution that are proposed by Ajeng?

**Figure 1.** Contextual problem vignette used to explore participants' critical thinking (Source: Developed by the authors)

The vignette also served as a stimulus for the interviews. The vignette instrument was validated by two experts in mathematics education with doctoral qualifications and more than ten years of experience in teacher education. The validation focused on content relevance, contextual authenticity, clarity of language, and alignment with critical thinking indicators. Based on expert feedback, revisions were made to improve contextual clarity and remove ambiguous wording. The final instrument was considered valid. The instrument was subsequently tested to ensure its reliability (Murniasih et al., 2020).

The interview guidelines were developed based on participants' responses to the vignette and were used to explore participants' reasoning and mathematical beliefs in greater depth. Field notes were used to record important observations during the research process.

**Data Collection**

Data collection was conducted in two stages. First, the vignette was administered to all 40 participants. Their written responses were used to identify their critical thinking levels and to select interview participants. Second, in-depth interviews were conducted with four selected participants representing different critical thinking categories. The interviews aimed to explore participants' rationales, reasoning processes, and mathematical beliefs. The vignette and interviews were the primary data sources, while field notes were used as supporting data.

**Data Analysis**

The data were analysed using thematic analysis. The analysis involved several steps: (1) The participants' vignette responses and interview transcripts were read repeatedly to gain familiarity with the data. (2) Meaningful units related to critical thinking indicators and mathematical beliefs were identified and assigned initial codes. (3) The codes were compared and grouped into categories based on similarities and differences. (4) The categories were interpreted to describe participants' critical thinking and mathematical beliefs.

Critical thinking was analysed based on five indicators: (a) identifying problems, (b) identifying facts, (c) providing reasons, (d) drawing conclusions, (e) reflecting on answers (Rahaju et al., 2019b). Mathematical beliefs were classified into availing beliefs and non-availing beliefs. Availing beliefs refer to beliefs that support reasoning, conceptual understanding, and meaningful engagement with mathematical problems, whereas non-availing beliefs tend to constrain thinking by emphasising rote procedures, fixed rules, and dependence on authority (Ekmekci et al., 2019). Participants' statements during interviews were used as the primary basis for identifying their mathematical beliefs, particularly in how they justified solutions, interpreted contextual information, and positioned the role of procedures and teachers in mathematical reasoning.

**Trustworthiness**

To ensure the credibility of the findings, triangulation was conducted by comparing vignette responses and interview data (Noble & Heale, 2019). In addition, the coding results were reviewed and discussed with another mathematics education researcher until agreement was reached. Field notes were also used to support and confirm the interpretation of the data.

## RESULTS AND DISCUSSION

Based on their responses to the vignette, the participants were classified into three categories: non-critical thinkers, emergent critical thinkers, and advanced critical thinkers. In this study, no participants were identified as developing critical thinkers. This classification was derived from predefined critical thinking indicators grounded in the theoretical framework that underpins the conceptualization of enacted critical thinking in this study. The distribution of participants across the categories, along with the number of participants selected for in-depth interviews, is presented in Table 1.

**Tabel 1.** Distribution of Participants Across Critical Thinking Categories

| Category | Participants | |
|---|---|---|
| | Vignette | Interview |
| Non-critical thinker | 35 | 2 |
| Emergent critical thinker | 3 | 1 |

| Category | Participants | |
|---|---|---|
| | Vignette | Interview |
| Advanced critical thinker | 2 | 1 |
| Total | 40 | 4 |

As shown in Table 1, the majority of participants were classified as non-critical thinkers, indicating that most participants experienced difficulty in critically evaluating the contextual problem and its proposed solution.

**Description of the Responses Provided by Non-Critical Thinkers**

The majority of participants were classified as non-critical thinkers, comprising 35 pre-service teachers. This finding is consistent with previous studies indicating that most pre-service teachers tend to demonstrate low levels of critical thinking (As'ari et al., 2017). To illustrate the characteristics of this group, two participants, P1 and P2, were selected for in-depth analysis. Participant P1 stated that the problem and its proposed solution were correct (Figure 2: *original response written in Indonesian*).

> In my opinion, Ajeng's solution [to the word problem] is correct. Ajeng solved the problem in a clear and appropriate manner, employing the known tricks to do so.

**Figure 2.** Response provided by Participant P1

This response was further confirmed during the interview, as shown below:

R : 'What are your thougts on the problem and solution proposed by Ajeng?'
P1 : 'The problem and solution are both correct.'
R : 'Please explain why you think so.'
P1 : 'My teacher has previously provided me with a similar math problem.'

This response indicates that P1 accepted the solution based on prior exposure rather than critically evaluating its logical consistency.

Participant P2 added the phrase "volume of a cube" to the problem formulated (Figure 3: *original response written in Indonesian*). This addition was intended to clarify the given information. Participant P2 also provided a more detailed solution by explicitly presenting the formula used.

> In my opinion, Ajeng's final answer is correct. However, I disagree with how the word problem was expressed and solved. In my opinion, the problem should be rephrased as follows: Mr Roni constructed a swimming pool for his one-year-old son in the shape of a cube with a volume of 4,096 cm$^3$. What is the side length of the pool?
> Known : V = 4,096 cm
> Unknown: side length of the cube
> Solution : $V = s^3$
> $4.096 = s^3$
> $s = \sqrt[3]{4.096}$
> $s = 16$

**Figure 3.** Response provided by Participant P2

Participants P1 and P2 demonstrated limited critical evaluation, as they accepted the correctness of the problem and its solution without questioning the logical validity of the context. Their evaluation appeared to rely primarily on familiarity with similar routine problems rather than analytical reasoning. This finding supports previous research indicating that pre-service teachers often interpret problems based on surface similarity rather than examining their underlying structure (Rahaju et al., 2019a).

Furthermore, participant P1 stated that the cube root calculation was correct because it followed familiar procedures. This suggests that the participant relied on memorised procedures rather than examining whether the context itself was meaningful or realistic. Routine problems can often be solved by applying standard formulas taught by teachers (Jankvist & Niss, 2018; Mairing, 2020). Such reliance reflects a non-availing mathematical belief, in which mathematical correctness is associated primarily with procedural accuracy rather than logical justification (Ekmekci et al., 2019). This belief may hinder the development of critical thinking because participants may assume that solutions are correct as long as familiar procedures are applied. Learners who are highly dependent on teachers may have fewer opportunities to develop independent reasoning and critical evaluation skills (Jonsson et al., 2020).

In general, participants in this category assumed that the problem was correct because it was presented within an instructional context. They appeared to believe that mathematical problems provided by teachers or textbooks are inherently valid and do not require further evaluation. This perception may stem from prior learning experiences in which mathematical problems are typically well-structured and error-free. Participants who viewed teachers as the primary source of knowledge tended to accept the problem without question (Rahaju et al., 2024), limiting their willingness to challenge assumptions—an essential characteristic of critical thinking.

The analysis further revealed that non-critical thinkers focused primarily on the surface structure of the problem rather than evaluating its contextual validity. They failed to identify the inconsistency between the contextual situation and the mathematical solution and were unable to support their responses with logical justification. They also did not engage in reflective evaluation of the solution. This contrasts with the characteristics of critical thinkers, who examine assumptions, verify reasoning, and assess the coherence of a problem (Verawati et al., 2024). Overall, non-critical thinkers demonstrated procedural reliance, limited analytical evaluation, and strong dependence on teacher authority, which constrained their ability to critically analyse contextual mathematical problems.

**Description of the Responses Provided by Emergent Critical Thinkers**

Three participants were categorised as emergent critical thinkers. One of them, participant P3, was selected for in-depth analysis. Participants in this category demonstrated an ability to understand the structure of the contextual problem and to question certain aspects of its formulation. This behaviour reflects the early stages of critical thinking, particularly in identifying assumptions and evaluating problem statements (As'ari et al., 2017). Unlike non-critical thinkers, emergent critical thinkers did not immediately accept the problem and its solution without reflection, indicating a developing capacity for evaluative judgement.

R : 'Could you please clarify what you mean by [saying that this problem is] a contextual problem?'
P3 : 'This problem represents those [likely encountered] in everyday situations.'
R : 'For instance?'
P3 : '[A situation in which] someone is constructing a pool for their child?'

The excerpt shows that P3 attempted to connect the mathematical problem to everyday experiences. Rather than focusing solely on numerical procedures, P3 interpreted the problem in relation to a real-life situation, indicating an emerging awareness of contextual meaning.

Subsequently, participant P3 questioned whether the size of 4,096 $m^3$ (Figure 5: The original task was written in Indonesian) referred to the pool's physical dimensions or its volumetric capacity. This indicates that P3 did not accept the given information uncritically but sought clarification regarding its interpretation. Although P3 had never observed a pool filled to its maximum capacity, the participant assumed that a cube-shaped pool's water volume could be calculated as the volume of a cube. This reasoning demonstrates an understanding of the relationship between three-dimensional space and water volume. These observations suggest that emergent critical thinkers are at an initial stage of linking mathematical representations to real-world contexts (Verawati et al., 2024). P3 further illustrated this by providing additional explanations of the problem before the interview question was posed, showing the capacity to identify the main issue and question the problem, consistent with critical thinking indicators (As'ari et al., 2017).

> The word problem prepared by Ms Ajeng is [both] coherent and meets the required criteria. However, in the bit that specifies "a size of 4,096 $cm^3$," what size does it refer to? Does it refer to the size of the entire pool or the water storage volume?

**Figure 3**. The response provided by P3

During the interview, participant P3 also described the process of solving word problems by emphasizing the importance of identifying knowns and unknowns before formulating a solution. The following excerpt illustrates this perspective:

R : '[When solving word problems] Is it necessary to write down the knowns, the unknowns, and the solution [on the test paper]?'
P3 : 'Yes, Ma'am. Otherwise, the score awarded will not be optimal.'
R : 'Could you please explain further?'
P3 : "'Even if the [final] answer is correct, a score of 100 is unattainable [if the knowns, the unknowns, and the solution are not written down on the test paper].'

This excerpt indicates that although P3 demonstrated emerging evaluative thinking regarding the contextual meaning of the problem, the participant's approach to problem solving remained influenced by procedural expectations shaped by prior instructional practices. The emphasis on writing knowns and unknowns was justified primarily in terms of scoring, rather than conceptual necessity. This suggests a belief that problem solving follows a fixed and teacher-directed structure. Such a belief may limit deeper analytical engagement and creative reasoning, particularly in complex contextual tasks (Jankvist & Niss, 2018; Jonsson et al., 2020).

**Description of the Responses Provided by Advanced Critical Thinkers**

Two participants were identified as possessing advanced critical thinking skills, and one of them (Participant P4) was selected for in-depth analysis. Observations indicated that P4 engaged in careful reading to understand the problem and identify relevant data before proceeding to the solution process. This behaviour reflects key components of critical thinking, including analysis, evaluation, and reflection (Ennis, 2018; Facione, 1990), and is consistent with prior empirical observations in mathematics education contexts (Rahaju et al., 2019b, 2024). After examining both the solution process and the final answer, P4 engaged in deliberate reflection on the coherence between the mathematical result and the contextual information presented in the problem.

During this reflective phase, P4 identified a discrepancy between the calculated pool dimensions and the real-life context described in the word problem. The final answer yielded a pool side length of 16 cm. Although mathematically correct based on the given calculation, P4 considered this result unrealistic, particularly because the pool was intended for a one-year-old child. Rather than accepting the numerical result at face value, P4 evaluated its plausibility by comparing the pool's dimensions with the approximate body length of a child. On this basis, P4 concluded that the problem was illogical. This demonstrates advanced critical thinking, characterised by the ability to evaluate outcomes, question underlying assumptions, and assess contextual coherence (Figure 6; original task written in Indonesian).

> Furthermore, in my opinion, mathematics is predicated on logic. The condition stipulates that the word problem is about "everyday life." However, if we examine the final answer to the word problem posed by Ajeng, it becomes apparent that the problem is illogical. The problem states "Mr Roni constructed a swimming pool for his one-year-old child," yet the final answer states that the length of the poolside is 16 cm. Is it feasible that a 16-cm pool would accomodate the physique of a one-year-old child?

**Figure 4.** The response provided by participant P4

The activities demonstrated by P4 encompass higher-order critical thinking processes, including problem comprehension, identification of relevant data, reflective evaluation, reasoned conclusion drawing, and justification of decisions (Rahaju et al., 2019b). Importantly, P4 did not stop at procedural correctness but scrutinised whether the result was logically and contextually valid. This indicates a shift from procedural validation to conceptual and contextual validation.

P4's analysis appears to be influenced by the belief that mathematics is inherently logic-based and meaningfully connected to real-life situations. From this perspective, mathematical problems are not merely numerical exercises but must demonstrate logical coherence and contextual applicability (Açıkgöz & Yıldız, 2025, 2025; Bekiroğlu & Güllühan, 2024; Purnomo et al., 2024). Such a belief system supports deeper evaluative engagement, guiding learners to ensure that solutions are both mathematically sound and contextually reasonable (Varlık, 2024). Consequently, P4's reasoning reflects a mature integration of mathematical logic and real-world sensibility, distinguishing advanced critical thinkers from those at earlier developmental stages.

Taken together, the findings reveal a consistent relationship between levels of critical thinking and types of mathematical beliefs. Participants classified as non-critical thinkers predominantly expressed non-availing beliefs, particularly those positioning mathematics as procedural and teacher-dependent. Emergent critical thinkers demonstrated transitional belief patterns, combining contextual awareness with residual procedural reliance. In contrast, advanced critical thinkers exhibited availing beliefs that emphasised logical coherence, justification, and contextual plausibility. These results suggest that mathematical beliefs function as an underlying lens shaping how pre-service teachers analyse, interpret, and evaluate contextual mathematical problems.

## CONCLUSION

This study identifies three distinct levels of critical thinking among pre-service primary school teachers when analysing contextual mathematical problems: non-critical thinkers, emergent critical thinkers, and advanced critical thinkers. These categories reflect not only differences in problem-solving performance but also distinctions in epistemological orientations towards mathematics and reasoning.

Non-critical thinkers rely predominantly on memorised formulae and fixed procedures. Their reasoning is procedural in nature, and they position teachers as the primary authority in determining the correctness of solutions. In this orientation, mathematical activity is perceived mainly as the execution of established steps rather than as a reflective or evaluative process.

Emergent critical thinkers demonstrate a developing capacity to question problem clarity and interpret contextual meaning. They begin to evaluate assumptions and connect mathematical representations to real-life situations. However, their reasoning remains partially constrained by procedural dependence and adherence to teacher-directed approaches. This group represents a transitional stage in the development of critical thinking.

Advanced critical thinkers exhibit integrated reasoning that combines procedural accuracy with logical and contextual evaluation. They assess not only whether a solution is mathematically correct but also whether it is logically coherent and contextually plausible. Their thinking reflects an understanding of mathematics as a discipline grounded in logic, justification, and real-world relevance.

Overall, the findings indicate that the development of critical thinking involves a shift from procedural validation towards conceptual and contextual evaluation. This progression is closely associated with the formation of mathematical beliefs during teacher education, suggesting that how future teachers perceive mathematics significantly influences their evaluative judgement when engaging with contextual problems. The study demonstrates that contextual problem analysis functions effectively as a lens for revealing enacted critical thinking and underlying mathematical beliefs.

## RECOMMENDATION

The development and assessment of critical thinking skills in pre-service teachers can be facilitated through structured contextual problem analysis activities. Such activities should encourage learners not only to compute solutions but also to examine assumptions, evaluate contextual information, and assess the logical coherence of results.

Given the significant role of mathematical beliefs in shaping reasoning patterns, teacher education programmes should be carefully designed to prevent the formation of non-availing beliefs—particularly those that frame mathematics as merely procedural and teacher-dependent. Instead, instructional practices should cultivate beliefs that emphasise reasoning, justification, and contextual applicability.

Furthermore, contextual problem analysis can be extended into problem-posing activities. Engaging pre-service teachers in constructing and evaluating their own contextual problems may strengthen reflective judgement, deepen conceptual understanding, and promote more advanced critical thinking skills. Such approaches can support the transition from procedural reliance towards independent and evaluative mathematical reasoning.

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### AUTHOR CONTRIBUTIONS STATEMENT

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| Hafis | | | | | | | | | ✓ | ✓ | | | | |

### CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

### INFORMED CONSENT

Informed consent was obtained from all participants involved in this study.

### ETHICAL APPROVAL

The research involving human participants was conducted in accordance with relevant institutional and national research ethics guidelines and in line with the principles of the Declaration of Helsinki.

### DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy considerations of research participants.

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