

Analysis of Junior High School Students' Misconceptions Regarding the Concept of Force and Motion in Science Learning

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Abstract

This study aimed to analyze junior high school students' misconceptions about the concepts of force and motion in science learning. A quantitative approach was employed using a Four-Tier Diagnostic Test as the research instrument. The participants consisted of 20 eighth- and ninth-grade students of SMPN Socah, Bangkalan. Data were collected using a diagnostic test that assessed students' conceptual understanding, reasoning, and confidence levels. The results indicated that students experienced misconceptions in several force and motion concepts, particularly regarding the relationship between force and motion and the interpretation of position-time graphs. The percentage of students categorized as having misconceptions was 62.5%, which falls into the high category. Meanwhile, 27% of students were categorized as not understanding the concepts, representing the moderate category, and only 10.5% demonstrated conceptual understanding, representing the low category. Factors contributing to these misconceptions included insufficient prior knowledge, less effective instructional methods, limited learning media, and difficulties in interpreting graphical representations. These findings highlight the need for more interactive learning strategies and the use of appropriate instructional media to improve students' conceptual understanding and reduce misconceptions in force and motion topics.

Keywords: Four-Tier Diagnostic Test, force and motion, misconceptions, science learning

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INTRODUCTION

One of the science topics frequently studied and directly related to everyday life is force and motion. These concepts are relatively concrete and can be more easily understood when explained through examples from students' everyday surroundings (Arruum & Desstya, 2024). In physics, motion can be examined through changes in an object's position over time and their relationship with velocity and acceleration (Triastutik *et al.*, 2021). Force represents an interaction capable of changing an object's state of motion (Alatas *et al.*, 2021). These relationships are described through Newtonian mechanics, particularly the relationship among force, mass, and acceleration (Alatas *et al.*, 2021). Newton's Second Law states that the force acting on an object is equal to the product of its mass and acceleration, while Newton's Third Law explains that every action will produce an equal but opposite reaction. By using the right learning approach, students can understand the concepts of force and motion comprehensively

and be able to apply them in everyday life (Munfaridah et al., 2017). In addition, objects that are already moving will tend to maintain their speed, and objects that are still will remain still or move in a straight line at a constant speed as long as there is no external force affecting them. The opposing force that occurs when an object stops suddenly results from the interaction that takes place during the stopping process (Alatas et al., 2021).

Physics instruction should extend beyond the transmission of facts and principles by involving students in examining, discovering, and interpreting scientific concepts (Alatas et al., 2021). Understanding motion and force is an important part of science learning, particularly in physics. The close connection between physics concepts and phenomena encountered in daily life makes physics relevant to students' everyday experiences (Maryani & Atmojo, 2024). Force and motion concepts provide a scientific framework for interpreting how objects move and interact in observable phenomena. By understanding this material, students can develop the critical and analytical thinking skills needed to solve problems scientifically (Baktiarso et al., 2023). A solid understanding of the concepts of motion and force can also help students avoid misconceptions, such as those related to Newton's laws. Therefore, effective learning about motion and force is crucial for students to have the right knowledge and be able to apply it in their daily lives and in science lessons at the next level (Amakraw & Kartika, 2022).

Misconceptions are understandings that are incorrect or inconsistent with actual scientific concepts. Misconception detection can be done through various diagnostic instruments, such as diagnostic tests that include multiple-choice questions and the four-tier method, which assesses students' answers, beliefs, and reasoning. This process helps identify misconceptions and their causes, including students' preconceptions and the teaching methods used (Mulyani et al., 2020). By understanding misconceptions, teachers can design more effective remediation strategies (Yuliati, 2017).

Natural Sciences (IPA) is a vital part of human life, directly related to various daily activities. In science education, conceptual understanding is essential because students are expected not only to recall scientific information but also to use it in explaining phenomena. Therefore, the science learning process must be presented in an engaging and challenging manner to encourage students to actively participate and develop a strong interest in the subject. Successful science learning is achieved when students understand the concepts accurately (Arruum & Desstya, 2024). Physics is a subject that demands a high level of intellectual ability to understand. Throughout the learning process, students are guided to optimally master the material. However, students often fail to fully absorb the information, especially in material that contains many scientific concepts (Asrida et al., 2024). Misconceptions are errors in understanding a concept that contradict scientific principles or theories that have been agreed upon and recognized as true by experts. Misconceptions are caused by factors such as limited learning media, inadequate basic knowledge, inappropriate teaching methods, and errors in textbooks (Arruum & Desstya, 2024). Research on identifying misconceptions in the material of motion and force identifies misconceptions using a four-tier diagnostic test. The study found that the Four-Tier Diagnostic Test provides more detailed and comprehensive information than the Three-Tier Diagnostic Test. The four-tier test is able to capture students' answers, reasoning, and confidence levels, providing more in-depth information about their conceptual understanding (Triastutik et al., 2021).

Misconceptions may originate from factors within students, particularly their pre-existing conceptions and ways of reasoning. These factors include pre-existing preconceptions, differences in understanding levels among students, humanistic mindsets, erroneous thinking, and low interest in learning. These various factors can cause students to lose concentration during learning, resulting in reduced attention to teacher explanations and erroneous understanding of concepts (Arruum & Desstya, 2024). One concept that is often misunderstood by students is the concept of force and dynamic motion. The concept of dynamic kinematics consists of several elements, including force, motion, and Newton's laws of motion. A common alternative conception is that an object must be acted upon by a force to remain in motion, and that the reaction force and action will cancel each other out, and also students misunderstand that Another misconception concerns the belief that the object with greater mass necessarily experiences or exerts a greater interaction force. Most of them believe that if two objects

with different masses interact with each other, the object with the greater mass will produce or receive a greater force (Alatas *et al.*, 2021). The field of mechanics is one of the physics topics most frequently misunderstood by students. It has a subtopic called dynamics, which explains why objects move. Within mechanics, this topic is crucial and often interconnected with other physical materials (Wuryanti *et al.*, 2017).

The purpose of this study was to analyze and understand students' misconceptions about force and motion. The study also aimed to identify factors that may contribute to misconceptions, including incorrect preconceptions, difficulties in understanding scientific concepts, and ineffective teaching methods. The research aims to provide teachers with information to remediate misconceptions, enabling students to develop correct understanding and avoid difficulties in future learning.

Previous studies have examined students' misconceptions of force and motion using diagnostic instruments such as isomorphic tests and Four-Tier Diagnostic Tests (Alatas *et al.*, 2021; Triastutik *et al.*, 2021). However, evidence concerning misconception patterns among junior high school students in Bangkalan Regency remains limited. Therefore, this study investigates students at SMPN Socah, Bangkalan, with particular attention to conceptual difficulties in interpreting representations of motion. This local context provides additional evidence regarding how students understand force and motion and may serve as a basis for developing more targeted remedial instruction.

METHODS

The study employed a quantitative descriptive design to characterize students' conceptual understanding and misconceptions regarding force and motion. The aim of the study was to identify and analyze junior high school students' misconceptions regarding force and motion using the Four-Tier Diagnostic Test. The study was conducted at Socah Public Junior High School, Bangkalan Regency, during the odd semester of the 2023/2024 academic year.

The study population was all eighth- and ninth-grade students of Socah State Junior High School who had studied force and motion. A sample of 20 students was selected using purposive sampling because the participants had previously completed instruction on force and motion, making them suitable for identifying misconceptions. The study was designed as an exploratory diagnostic investigation aimed at providing an in-depth description of students' misconception patterns rather than producing generalizable findings. The participants had previously studied force and motion in science and were therefore considered suitable for providing information about their conceptual understanding. Therefore, the findings should be interpreted as representative of the studied context rather than the broader junior high school population.

The research instrument was a Four-Tier Diagnostic Test developed based on competency indicators in the force and motion material at the junior high school level. The instrument consisted of 10 questions covering two main aspects, namely the concept of force and the concept of motion. Each item consisted of four response components: a conceptual answer, confidence in that answer, a reason supporting the selected answer, and confidence in the selected reason. The combination of these responses was used to distinguish conceptual understanding, lack of understanding, and misconception (Annisa *et al.*, 2019). This structure allows for more accurate identification of student understanding categories, namely understanding the concept, not understanding the concept, and misconceptions.

Before being used in research, the instrument underwent a validation process by experts to assess the suitability of the material, question construction, language, and readability of the instrument. Validation was conducted by a science education lecturer with expertise in measuring science learning. The content validity test conducted by experts produced an Aiken's V coefficient of 0.89, indicating that the instrument had very good content validity for identifying student misconceptions regarding force and motion. Furthermore, the instrument was also tested for reliability to ensure the consistency of the measurement results. The reliability test yielded a Cronbach's Alpha coefficient of 0.82, indicating high reliability and consistency of the instrument, making it suitable for use as a measurement tool in research. Prior to data collection, permission was obtained from the school administration. Students

participated voluntarily, and informed consent was obtained from the school and students' guardians. All participant data were anonymized to ensure confidentiality and ethical compliance throughout the research process.

Data analysis was conducted by grouping student responses into categories of conceptual understanding, conceptual incomprehension, and misconception based on the combination of answers, reasons, and confidence levels at each tier. The grouping criteria refer to the Four-Tier Diagnostic Test categories as shown in Table 1 (Imtiyaz, 2020) .

Table 1. Concept understanding categories

Category	Answer Combination			
	Answer	Confidence Answer	Reason	Belief Reason
Understand the Concept	True	Sure	Correct	Sure
Don't Understand the Concept	True	Not	Correct	Not
	True	Sure	Correct	Not
	True	Not	Correct	Sure
	True	Not	Wrong	Not
	Wrong	Not	Correct	Not
	Wrong	Not	Wrong	Not
	Correct	Sure	Wrong	Not
	Wrong	Not	Correct	Sure
Misconception	Correct	Not	Wrong	Sure
	Correct	Sure	Wrong	Sure
	Wrong	Sure	Correct	Not
	Wrong	Sure	Correct	Sure
	Wrong	Sure	Wrong	Not
	Wrong	Not	Wrong	Sure
	Wrong	Sure	Wrong	Sure

The analysis involved classifying students' responses into three categories: understanding the concept, not understanding the concept, and misconception. The percentage of students in each category was then calculated using Equation (1) (Annisa et al., 2019). P represents the percentage of students who understand the concept, do not understand the concept, or hold misconceptions; S refers to the number of students in each category of conceptual understanding, including those who fully understand the concept, partially understand it, do not understand it, or hold misconceptions; and J_s represents the total number of students who took the test.

$$P = \frac{S}{J_s} \times 100\% \quad \#(1) \quad \#$$

The results obtained from calculating the percentage of students who understand the concept, do not understand the concept, and have misconceptions can be seen in Table 2.

Table 2. Percentage criteria for misconception level

Percentage (%)	Category
0 - 30	Low
31 - 60	Medium
61 - 100	High

RESULTS AND DISCUSSION

Results

The study yielded data on the percentage of students' misconceptions regarding force and motion

for each question item. Furthermore, the percentage of students' understanding was also obtained, both those who understood the concept and those who did not. Figure 1 shows the percentage distribution of students who understood the concept, did not understand the concept, and experienced misconceptions for each question item. The analysis in Figure 1 uses the number of students answering each item (20 students) as the denominator.

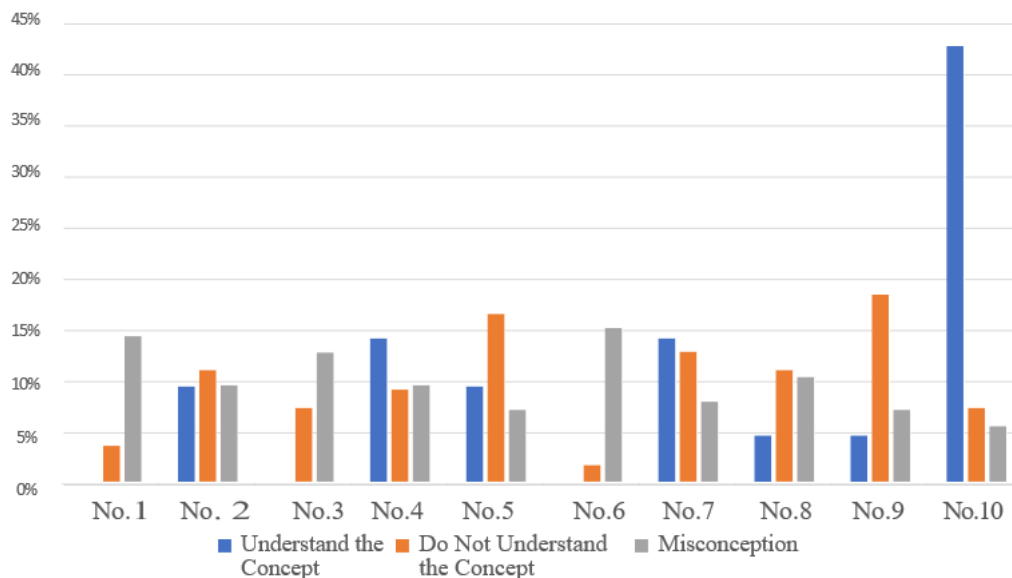


Figure 1. Distribution of students' conceptual categories for each question item

Based on Figure 1, misconceptions were identified across several indicators of force and motion, with question number 6 showing the highest proportion of misconception responses. This finding indicates that students experienced difficulties in interpreting position-time graphs and relating graphical representations to the concepts of position, velocity, and acceleration. Meanwhile, question number 10 showed a relatively higher proportion of students who understood the concept compared with other items. These differences indicate that students' conceptual difficulties varied depending on the specific concept assessed in each item.

To provide an overall description of students' conceptual categories across all diagnostic items, the percentage of conceptual understanding, lack of understanding, and misconceptions was calculated and is presented in Table 3.

Table 3. Percentage of misconception categories

No	Aspect	Percentage%	Category
1.	Understand the Concept	10,5	Low
2.	Do Not Understand the Concept	27	Medium
3.	Misconception	62,5	High

Table 3 shows the percentage of students' understanding of the concepts taught, which includes three categories: conceptual understanding, not understanding the concept, and misconceptions. The data show that 10.5% of students demonstrated conceptual understanding, which falls into the low category. Students in the category of not understanding the concept accounted for 27%, indicating a moderate level. Meanwhile, the majority of students, accounting for 62.5%, were categorized as having misconceptions.

Discussion

The results showed that misconceptions were the dominant category, accounting for 62.5% of the total responses, followed by students who did not understand the concept (27%) and students who

understood the concept (10.5%). This finding indicates that most students still experienced difficulties in constructing scientifically correct concepts of force and motion. Therefore, further analysis is needed to identify which specific concepts contributed to these misconceptions.

The highest proportion of misconceptions was observed in question number 6, which assessed the concept of motion. Question number 6 contains a graph of position versus time that describes the change in position of an object. Based on the given graph, the object is initially at rest (fixed position), then moves with increasing speed, and finally slows down until it stops. The majority of answers given by students are that initially the object is at rest, then moves forward rolling down the hill, and finally stops. The correct interpretation is that the object is initially at rest with a constant position. It then begins to move with acceleration, causing its position to increase at an increasing rate. After reaching a certain speed, the object experiences deceleration (downward gradient) until it stops. Several factors may contribute to the misconceptions observed in this question; the first is understanding the concept of position and velocity. Students often misinterpret the position graph as a physical path graph. Students do not understand that the gradient on the position graph indicates speed. The second factor is difficulty understanding the gradient of the graph; many students have difficulty connecting changes in the gradient of the graph with acceleration or deceleration. The third factor is the wrong visual context; students tend to use physical imagination (flat trajectory) rather than mathematical graph analysis.

The findings of this study are in line with research (Triastutik *et al.*, 2021) which shows that students still experience difficulties in understanding the concept of motion, especially in interpreting graphs and the relationships between kinematic quantities. This difficulty may cause students to interpret motion graphs as representations of an object's physical trajectory rather than as mathematical relationships among position, velocity, and time (Alatas *et al.*, 2021) also found that misconceptions about the concepts of force and motion are still common because students often rely on everyday intuition that is not in accordance with scientific concepts. The results of this study also support the findings of Maryani & Atmojo (2024), which reported that the concept of force and motion is one of the science topics with a relatively high level of misconception among students. The similarity of these results indicates that misconceptions regarding force and motion remain a consistent problem in science learning and require more systematic handling through learning that focuses on student conceptual change.

Based on the item-level analysis presented in Figure 1, misconceptions were identified across all indicators of force and motion concepts. The highest proportion of misconceptions occurred in question number 6, which assessed students' understanding of position-time graphs. This finding indicates that students experienced difficulties in connecting graphical representations with the scientific concepts of position, velocity, and acceleration. In contrast, question number 10 showed a relatively higher proportion of students who understood the concept compared with other items. The difference between each question item demonstrates that students' conceptual difficulties were not evenly distributed across all indicators. Therefore, questions with high misconception rates require further attention through learning strategies that emphasize conceptual understanding and interpretation of scientific representations.

Overall, misconceptions were more prevalent in the concept of motion than in the concept of force. This finding indicates that students still have difficulty interpreting graphic representations of position-time and the relationship between position, velocity, and acceleration. The results of this study align with research (Triastutik *et al.*, 2021) which states that the concept of motion often gives rise to misconceptions because students tend to interpret graphs as a form of the physical trajectory of an object, not as a mathematical representation of a movement. In addition, research (Alatas *et al.*, 2021) also found that students often make mistakes in connecting the concept of force with changes in the motion of objects according to Newton's laws.

Several factors can influence the results of observations. One of them is difficulty understanding the material. Without an adequate foundation in physics, students will struggle to master the concepts of motion and force (Arruum & Desstya, 2024). A lack of innovative teaching methods may also worsen the situation. Students' understanding of concepts and application of the material is highly dependent on the use of interactive learning methods. If this is neglected, the process of absorbing knowledge will

not be optimal (Lestari *et al.*, 2024). Internal student factors such as incorrect preconceptions, associative thinking, and inappropriate cognitive developmental stages can hinder their understanding of scientific concepts. Furthermore, differences in students' abilities and low levels of learning interest may also contribute to misconceptions. Problems also arise from the teaching side, ranging from minimal understanding of the material and inadequate educational backgrounds to ineffective communication with students (Mukhlisa, 2021). In addition to internal factors such as incompetent teachers and strained teacher-student relationships, learning resources such as textbooks also contribute to worsening the situation. If the textbook contains errors or is inappropriate for the student's ability level, the risk of misconceptions increases. Furthermore, students' social and cultural contexts, including everyday experiences, inappropriate language use, and influences from the media and parents, can reinforce existing misconceptions. Finally, monotonous teaching methods, such as relying solely on lectures without providing opportunities for students to express their ideas, can also cause misconceptions to become more ingrained (Nurwahidah, 2022).

This could be due to the lower level of difficulty or because students are more familiar with the concept. In general, the observed pattern indicates that misconceptions consistently occur across almost all questions, while the number of students who truly understand the material and concepts tends to be lower. Therefore, teachers need to pay special attention to questions with a high level of misconceptions by providing more in-depth explanations and adjusting teaching methods so that students can understand the concept more comprehensively (Rahayu *et al.*, 2021). Evaluation of questions with a low level of understanding also needs to be carried out, as well as increasing practice-based training concepts to reduce misconceptions and improve student understanding. Misconceptions and low understanding of concepts are often rooted in students' weak mastery of basic material. Considering that conceptual understanding is the main foundation in the educational process, mastering this aspect is a crucial competency for every student (Maryani & Atmojo, 2024; Nasution *et al.*, 2021). Students also experience difficulties in applying force and motion concepts to new situations because they often rely on everyday intuition rather than scientific reasoning. Similar findings have been reported by Alatas *et al.* (2021) and Triastutik *et al.* (2021), who found that misconceptions frequently arise from incorrect interpretation of motion graphs and Newtonian concepts.

Misconceptions experienced by teachers and prospective teachers significantly impact student understanding. This problem becomes even more serious when the textbooks used as learning resources also contain errors, so that instead of correcting the students, they actually reinforce their users' misconceptions (Resbiantoro & Nugraha, 2017). The ability of prospective physics teachers to teach really depends on their mastery of concepts. If there are misconceptions, this will hinder students from understanding the material. As a result, this chain of wrong understanding will continue and affect the teacher's teaching performance in the future (Munfaridah *et al.*, 2017). The direct impact of teaching methods, curriculum, and resources used can influence the quality of learning. Effective methods can increase student understanding, while inappropriate methods can cause confusion and misconceptions (Maryani & Atmojo, 2024).

The findings of this study have important implications for science learning, particularly in the area of force and motion. The high percentage of misconceptions suggests that teachers need to implement learning strategies that facilitate students' conceptual change. The use of experimental methods, virtual simulations, demonstrations of physical phenomena, and cognitive conflict approaches can help students compare their initial concepts with the correct scientific concepts. Furthermore, the Four-Tier Diagnostic Test can be used as a diagnostic tool at both the initial and final stages of learning to identify student misconceptions, enabling teachers to design more targeted remediation activities.

The limitations of this study include several aspects that may affect the validity and generalizability of the results. One major limitation is the study's sample size, which consisted of only 20 students. This relatively small sample size makes it difficult to generalize the study's findings to a broader population. Therefore, the misconception patterns identified in this study may only represent a small portion of the overall population of students studying motion and force (Resbiantoro & Nugraha, 2017).

The use of diagnostic tests as the primary measurement tool has limitations in revealing students'

thought structures. While these instruments can map misconceptions, they are not sufficiently precise to capture students' deeper, qualitative understanding of the topic of motion and force. The results showed that question number 6, which focuses on motion, had the highest proportion of students categorized as having misconceptions among all items. This finding indicates that students experienced considerable difficulty in interpreting position-time graphs and relating graphical representations to motion concepts. This indicates that motion, especially in certain contexts, requires greater attention in the learning process. However, because these measurement tools were not equipped with data triangulation methods or follow-up interviews, it was difficult to obtain a more detailed explanation of the underlying causes of these misconceptions (Resbiantoro & Nugraha, 2017).

Time and resource constraints also limited the scope of this study. The study was conducted over a short period of time, preventing in-depth exploration of various factors influencing student misconceptions, such as prior learning background or teacher teaching methods (Arruum & Dessty, 2024). Considering these limitations, the conclusions drawn from this study must be understood within the context of its limited scope. Further research is highly recommended, expanding the sample size and encompassing a wider range of student competency levels to obtain more representative data. Furthermore, diversification of evaluation instruments, such as concept-based diagnostic tests or in-depth interviews, is needed to more comprehensively uncover the complexity of student misconceptions (Resbiantoro & Nugraha, 2017). Additional research that examines the effectiveness of certain learning approaches is also expected to provide more appropriate solutions to overcome misconceptions in the material on motion and force (Nurwahidah, 2022).

The findings of this study have important implications for the science learning process in junior high schools. The high percentage of misconceptions in the topic of force and motion indicates that learning cannot simply focus on delivering concepts, but also needs to identify students' initial understanding. Teachers can utilize the Four-Tier Diagnostic Test as a diagnostic instrument to detect misconceptions early in the learning process so that appropriate remediation can be implemented. Furthermore, the use of learning methods based on experiments, demonstrations, virtual simulations, and cognitive conflict approaches needs to be increased so that students gain a more meaningful learning experience. These strategies are expected to help students build better conceptual understanding and reduce misconceptions in the topic of force and motion.

CONCLUSION

This study concludes that, among the 200 response classifications obtained from 20 students who answered 10 diagnostic items, 62.5% were categorized as misconceptions. This finding indicates that many students still experience difficulties in understanding force and motion concepts. Therefore, learning strategies that emphasize conceptual understanding, diagnostic assessment, and appropriate instructional approaches are needed to reduce misconceptions and improve students' conceptual understanding. The results of this study are expected to be the basis for the development of remediation programs and further research to improve students' conceptual understanding of the topic of motion and force.

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Conflict of Interest

The authors declare no conflicts of interest related to this study.

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Author Contributions

M.N.W., N.A.N.J., M.A.J., S.K., S.A.L.A.C., N.N.S., S.E.S.M., and S.I.P. contributed to the conceptualization, methodology, investigation, data analysis, and preparation of the manuscript. All authors participated in reviewing and editing the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

Official permission to conduct the research was obtained from the school administration. Participation was voluntary, informed consent was obtained from the students' guardians, and all participant data were anonymized to maintain confidentiality.

Generative AI Declaration

The authors declare that no generative artificial intelligence tools were used in the preparation, writing, or revision of this manuscript.

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