

The Effects of Whole Brain Teaching on Form One Students' Historical Knowledge in Hilir Perak

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Abstract

This study examined the effect of the Whole Brain Teaching (WBT) approach on the historical knowledge of Form One students in Hilir Perak, Perak. A quasi experimental design was employed using pre-test and post-test measures involving treatment and control groups. Cluster sampling was used to select participating schools while intact classes were used as the study sample. Four hypotheses were tested at the 0.05 significance level. Pre-test results showed no significant difference between the treatment and control groups, $t(65) = -0.209$, $p = .835$, indicating that both groups had comparable baseline knowledge prior to the intervention. After the intervention, both groups showed improvement. However, the treatment group demonstrated substantially higher achievement than the control group. The control group recorded a post-test mean score of 44.85 (SD = 4.31), whereas the treatment group achieved a mean score of 65.00 (SD = 6.93), with a mean difference of 20.15 marks. These findings indicate that WBT was effective in improving students' historical knowledge. Therefore, the study suggests that WBT should be considered as an innovative pedagogical strategy for History instruction as it promotes a more active, engaging and effective learning environment.

Keywords: Whole Brain Teaching, Historical Knowledge, History Education, Student Engagement, Form One Students

INTRODUCTION

Improving the quality of student learning has become a central focus of national educational reform. This is in line with the aspirations of the KPM (2013), Malaysia Education Blueprint (2013–2025) which emphasises academic achievement, higher-order thinking skills, and student-centred learning as key dimensions of student development (Ministry of Education Malaysia, 2013). In the context of the History subject, the Ministry of Education regards historical knowledge as a fundamental element in fostering national identity, patriotism and an understanding of the Curriculum Development Division (Bahagian Pembangunan Kurikulum, 2016). Achieving these goals requires the collective commitment of all stakeholders, particularly teachers, in implementing effective pedagogical practices.

Through the Secondary School Standard Curriculum (KSSM), the Ministry has outlined the need for active pedagogical approaches such as collaborative learning, inquiry-based learning, and project-based learning (Curriculum Development Division, 2016). In response to these changes, alternative instructional approaches such as Whole Brain Teaching (WBT) have gained increasing attention in global education.

WBT is a teaching approach that integrates visual, linguistic, kinaesthetic, emotional and social interaction elements to activate the whole brain during teaching and learning sessions (Biffle, 2013).

According to Spence et al. (2022), WBT strategies such as Class-Yes, Teach-Okay, Mirror Words and Switch are effective in maintaining students' attention and classroom focus. These strategies also enable students to reinforce acquired knowledge and communicate learning content more effectively (Abrenica & Casuncad, 2022). However, despite its growing recognition, WBT has been more widely implemented in preschool settings, with limited application at the secondary school level (Escultura & Ricafort, 2022).

Although national education policies emphasise the implementation of active pedagogical approaches, previous studies have reported that many students still struggle to explain fundamental historical concepts such as chronology, historical sources and interpretations of past events (Kaviza, 2021; Nur Atiqah Ismady et al., 2024). Earlier researchers noted that some students continue to rely heavily on rote memorisation, limiting their ability to explain historical facts meaningfully. As a result, students often fail to connect acquired knowledge with real life contexts and contemporary issues (Muhamad Nazrul Zainol Abidin et al., 2021). Such learning practices may also reduce students' focus, weaken their interest in classroom activities and hinder deeper knowledge acquisition (Zurina Mustaffa et al., 2022). These findings suggest that memorisation oriented teaching practices are still prevalent, largely to ensure students achieve satisfactory results in written assessments.

In addition, previous studies and field reports from teachers have identified classroom management as a major challenge during teaching and learning sessions. This issue has become one of the factors affecting the effectiveness of History instruction (Lohmann et al., 2021; Nurmallasari, 2021). Under such conditions, students tend to lose attention, engage in side conversations, participate less actively and display passive or unresponsive behaviour. Consequently, teachers often face difficulties in implementing more interactive instructional strategies (Anis Firdaus Asmi et al., 2024; Lisah Sapudin & Norasmah Othman, 2022; Niveetha Mookan et al., 2021). In many cases, teachers revert to traditional lecture based methods because they are perceived as easier for classroom control, despite being less effective in promoting knowledge mastery (Abrenica & Casuncad, 2022). Furthermore, an overreliance on written assessment practices may also contribute to low student engagement in learning activities (Nur Atiqah Ismady et al., 2024). As a consequence, active and meaningful pedagogical approaches often fail to achieve the objectives envisioned under the KSSM curriculum.

At the same time, studies examining the implementation of WBT in small group classroom settings to enhance secondary students' historical knowledge in Malaysia remain limited or almost non existent (Biffle, 2013). Existing WBT literature indicates that most prior studies have been conducted overseas and have primarily involved primary school pupils (Choirun Nisak Aulina, 2018; Devana, 2020; Siami, 2022). Moreover, previous research has largely focused on Mathematics, Science and early childhood education rather than History as a subject area. The absence of empirical studies evaluating the effects of WBT in History education, particularly within the context of the Secondary School Standard Curriculum (KSSM) and Malaysian classroom culture, represents a significant gap in the existing literature.

This gap provides strong justification for undertaking research on the WBT approach in History education, particularly in assessing its effects on the historical knowledge of Form One students through small group engagement during classroom learning. Such a study not only addresses an important gap in current scholarship but also contributes new insights into the effectiveness of whole brain instructional strategies in enhancing students' understanding of historical content. The purpose of this study was to examine the effects of Whole Brain Teaching on students' historical knowledge. The objectives of this study were to identify students' level of historical knowledge and to determine the effectiveness of Whole Brain Teaching on students' historical knowledge.

LITERATURE REVIEW

Whole Brain Teaching (WBT) is grounded in Herrmann's Whole Brain Theory (Herrmann, 1998), which posits that learning becomes more effective when students are simultaneously engaged through visual, verbal, emotional and kinaesthetic dimensions. The WBT model proposed by Biffle (2013) places strong emphasis on paired student interaction. In the context of History learning, paired engagement is intended to enhance students' focus through small-group collaboration while activating multiple senses to help students remember

facts, explain chronology and connect historical concepts more meaningfully following activities such as Mirror Words (Mugot, 2019).

Spence and Christman (2022) found that paired WBT instruction improved students' sustained attention and information processing ability. Similarly, Devana (2020) reported that verbal restatement of content enhanced long-term memory retention. Handayani et al. (2020) further demonstrated that students' achievement improved when they consistently participated in WBT activities. Collectively, these findings indicate that WBT promotes knowledge mastery through active participation and effective communication.

In Malaysia, studies on interactive learning in History education have shown improvements in conceptual understanding and the internalisation of patriotic values when students are engaged in two-way communication (Kumaran et al., 2024; Mohd Nasir Rayung et al., 2023). However, empirical research examining the effects of WBT on students' historical knowledge in authentic classroom settings remains scarce. Therefore, this study was conducted to address this gap by providing new empirical evidence on the effectiveness of WBT in improving the historical knowledge of Form One students in Malaysian secondary schools. This study not only extends the scope of WBT research into History education but also contributes to the local educational literature through a systematic, data-driven and classroom oriented evaluation.

RESEARCH DESIGN

This study employed a quantitative quasi-experimental design for data collection. Participants were divided into a control group and a treatment group. Prior to the instructional intervention, a pre-test was administered to both groups to determine their initial cognitive level and existing historical knowledge. Subsequently, the implementing teacher conducted Whole Brain Teaching instruction for the treatment group, while the control group received conventional teaching methods. After the intervention period, a post-test was administered to both groups to identify the effects of the instructional treatment. The test results were then used to compare students' performance between the pre-test and post-test.

This quasi-experimental design was considered appropriate because it allowed the researcher to evaluate the effects of the intervention in an authentic school setting without randomly assigning students to groups (Campbell & Stanley, 1984; Chua, 2014). Such a design is widely used in educational research where intact classroom groups are maintained for practical and administrative reasons.

METHODOLOGY

The study employed a cluster random sampling technique in selecting the research sample. An initial screening process was conducted to ensure that only ordinary daily secondary schools that met the study criteria and were willing to cooperate in the implementation of the research were considered. Through the fish bowl method, two daily secondary schools were selected as the sites for this quasi experimental study. Of the two selected schools, one was assigned as the control group, while the other was designated as the treatment group for the implementation of the Whole Brain Teaching intervention.

This study utilised an achievement test instrument in the form of objective questions to obtain the required data through both pre-test and post-test assessments. The pre-test and post-test instruments each consisted of 40 items. The test items were constructed according to three levels of difficulty, moderate, and high using a 5:3:2 ratio, based on the assessment instrument format issued by the Ministry of Education Malaysia (Bahagian Pembangunan Kurikulum, 2016) (Kementerian Pendidikan Malaysia, 2023). In addition, the items were developed in accordance with the revised Anderson and Bloom's Taxonomy.

During the instrument development process, the test items were constructed following procedures established by the Ministry of Education Malaysia, including determining the test content and preparing a Table of Test Specifications (TTS). The instrument was subsequently reviewed by seven experts in the field of History education for face validity and content validity. The purpose of conducting face and content validity procedures was to ensure that the items were appropriate, accurate, and aligned with the objectives of the study.

The reliability of the test instrument was evaluated using the test retest method following the pilot study. The pilot test results were subsequently analysed using Pearson's Correlation in Statistical Package for the Social Sciences (SPSS) Statistics to determine the relationship between the scores obtained in the first and second administrations of the test. Item reliability was considered satisfactory when a high Pearson's r value was obtained ($r \geq 0.70$). A coefficient of $r \geq 0.70$ indicates that the test results are stable and reliable over time.

Based on Table 1, the Pearson correlation analysis for instrument reliability yielded a coefficient of $r = 0.823$ with a significance value of $p < 0.001$. This result indicates a very strong positive relationship between the scores obtained in the first test administration (pre-test) and the second test administration (post-test) during the pilot study. In terms of relationship strength, the value of $r = 0.823$ falls within the range of $r \geq 0.80$, which reflects very high reliability for the instrument.

Table 1 Pearson correlation values based on the instrument reliability test

Variables	Statistics	Test	Retest
Test	Pearson Correlation	1.000	0.823
	Sig. (2-tailed)		0.000
	N	30	30
Retest	Pearson Correlation	0.823	1.000
	Sig. (2-tailed)	0.000	
	N	30	30

This finding suggests that the scores obtained by respondents across both testing occasions were highly consistent. From a statistical perspective, the significance value of Sig. (2-tailed) < 0.001 indicates that the relationship was highly significant at the 0.01 level ($p < 0.01$). Therefore, these results provide strong evidence regarding the stability and dependability of the test instrument used in this study.

In this research, the WBT intervention was implemented over a period of eight weeks based on the regular History teaching timetable in the participating school. This arrangement ensured that the intervention was conducted within the normal instructional schedule without disrupting the existing academic programme. The eight-week duration was considered appropriate to provide sufficient exposure for students to experience the WBT approach consistently across multiple lessons. It also enabled the researcher to observe the cumulative effects of the intervention on students' historical knowledge over time. Throughout the intervention period, the treatment group received History instruction using WBT strategies integrated into regular classroom teaching sessions, while the control group continued with conventional instructional methods. By embedding the intervention within the actual school timetable, the study maintained a realistic classroom environment and strengthened the ecological validity of the findings. This approach allowed the effectiveness of Whole Brain Teaching to be evaluated under authentic teaching and learning conditions commonly experienced in Malaysian secondary schools.

At the initial stage of the study, the pre-test instrument was administered to both groups in order to obtain baseline data prior to the intervention. In the subsequent phase, the treatment group received instruction using the Whole Brain Teaching approach, whereas the control group received conventional teaching methods. After the intervention sessions were completed, the post-test instrument was administered to both groups of respondents.

DATA ANALYSIS

Data analysis in this study was conducted quantitatively using IBM Statistical Package for the Social Sciences (SPSS) Statistics to determine differences in students' historical knowledge based on the quasi-experimental design involving control and treatment groups. Four research questions were analysed using t-tests, involving two forms of analysis, which is Independent Samples t-Test and Paired Samples t-Test. The selection of these tests was appropriate for the research design, which required comparisons of mean scores between two groups as well as between pre-test and post-test results.

FINDINGS AND DISCUSSION

1. Findings or Research Question One

The first research question examined whether there was a significant difference in the mean pre-test historical knowledge scores between the control group and the treatment group. Table 2 presents the comparison of pre-test mean scores between both groups. The control group recorded a mean score of 32.60 (SD = 5.15), while the treatment group obtained a mean score of 32.88 (SD = 5.66).

Table 2 Comparison of mean pre-test historical knowledge scores between the control and treatment

Variable	Group	N	Mean	SD	t	df	p	Decision
Pre-Test Historical Knowledge	Control	34	32.60	5.15	-0.209	65	.835	Not Significant
	Treatment	33	32.88	5.66				

An independent samples t-test was conducted to determine whether there was a difference in the mean pre-test historical knowledge scores between the control group and the treatment group. The findings indicated that the control group obtained a mean score of 32.60 (SD = 5.15), while the treatment group recorded a mean score of 32.88 (SD = 5.66). The t-test results showed that there was no significant difference between the two groups, $t(65) = -0.209$, $p = 0.835$. Furthermore, effect size reporting revealed a Cohen's d value of -0.051, indicating a negligible effect size. These findings suggest that both groups were at a comparable baseline level of historical knowledge prior to the intervention. Therefore, the null hypothesis for the first research question was accepted.

The equivalence of pre-test knowledge scores between the treatment and control groups indicates that the Form One students involved in the study possessed relatively similar academic abilities in the tested topic area. The analysis also demonstrated that variations in prior knowledge did not create a substantial gap between the two groups. Consequently, these findings provide a sound basis for attributing any subsequent post-intervention improvement to the teaching approach employed, student engagement, and the learning experiences that occurred during the study.

2. Findings for Research Question Two

The second research question examined whether there was a significant difference in the mean historical knowledge scores of the control group between the pre-test and post-test. Table 3 shows that the control group's mean score increased from 32.60 (SD = 5.15) in the pre-test to 44.85 (SD = 4.31) in the post-test.

Table 3 Comparison of mean historical knowledge scores of the control group in the pre-test and post-test

Variable	Test	N	Mean	SD	Mean Difference	t	df	p	Decision
Historical Knowledge (Control Group)	Pre	34	32.60	5.15	12.25	-10.713	33	< .001	Significant
	Post	34	44.85	4.31					

Based on Table 3, the mean historical knowledge score of the control group in the pre-test was 32.60 with a standard deviation of 5.15, while the post-test mean score increased to 44.85 with a standard deviation of 4.31. These findings indicate an improvement of 12.25 marks following the teaching sessions. This increase suggests that students in the control group demonstrated positive progress in terms of knowledge mastery after participating in the learning process throughout the study period.

The paired-samples t-test results revealed a significant difference between the pre-test and post-test scores of the control group, $t(33) = 10.713$, $p < .001$. The significance value obtained was lower than the .05 threshold. Therefore, the null hypothesis stating that there was no significant difference in the mean historical knowledge scores of the control group between the pre-test and post-test was rejected.

Additional analysis using gain scores showed that the improvement in the control group was calculated from the difference between the post-test and pre-test means, $44.85 - 32.60 = 12.25$. This indicates that the control group improved by 12.25 marks, representing a clear and positive increase that reflects the effectiveness of the learning process implemented throughout the study.

Furthermore, effect size reporting indicated a Cohen's d value of 1.837, which is categorised as large effect size. According to Cohen's interpretation, a value of 0.20 represents a small effect, 0.50 a medium effect, 0.80 a large effect, while values exceeding 1.00 indicate a very large effect. Therefore, the increase in the control group's historical knowledge scores was not only statistically significant but also demonstrated a strong practical impact on student achievement. This suggests that the observed changes were educationally meaningful.

These findings further indicate that the control group also experienced an improvement in historical knowledge after the teaching process, despite not receiving a specific intervention such as that provided to the treatment group. This suggests that conventional teaching practices employed by teachers are still capable of contributing positively to students' academic achievement when implemented systematically and effectively.

3. Findings for Research Question Three

The third research question examined whether there was a significant difference in the mean historical knowledge scores of the treatment group between the pre-test and post-test. Table 4 shows that the treatment group's mean score increased substantially from 35.83 (SD = 5.85) to 65.00 (SD = 6.93).

Table 4 Comparison of mean historical knowledge scores of the treatment group in the pre-test and post-test

Variable	Test	N	Mean	SD	Mean Difference	t	df	p	Decision
Historical Knowledge (Treatment Group)	Pre	33	35.83	5.85	29.17	-19.945	32	< .001	Significant
	Post	33	65.00	6.93					

Based on Table 4, the mean historical knowledge score of the treatment group in the pre-test was 35.83 (SD = 5.85), while the post-test mean score increased substantially to 65.00 (SD = 6.93). This indicates an improvement of 29.17 marks following the intervention. The paired-samples t-test results showed a significant difference between the pre-test and post-test scores of the treatment group ($t_{32} = -19.945$, $p < .001$). Therefore, the null hypothesis stating that there was no significant difference in the mean historical knowledge scores of the treatment group between the pre-test and post-test was rejected.

The findings for the third research question indicate that the treatment group experienced a substantial improvement in historical knowledge after receiving the Whole Brain Teaching (WBT) intervention. Additional analysis using gain scores further demonstrated highly encouraging progress following the intervention. The gain score was calculated based on the difference between the post-test and pre-test mean scores, $65.00 - 35.83 = 29.17$. This result shows that the treatment group improved by 29.17 marks after participating in the instructional sessions. Such an increase represents a considerable academic gain and clearly reflects positive changes in students' level of mastery. From an educational perspective, an improvement of nearly 30 marks suggests that the intervention enabled students to understand the subject content more effectively than before the treatment was introduced.

Furthermore, effect size reporting through Cohen's $d = 3.472$ indicates that the intervention produced a very large effect size. According to Cohen's interpretation, a value of 0.20 is considered small, 0.50 moderate, and 0.80 large, while values exceeding 1.00 indicate a very large effect. Therefore, the value of 3.472 far exceeds the minimum threshold for a large effect, providing strong evidence that the intervention had a substantial impact on improving students' historical knowledge.

The findings for this research question are consistent with the study conducted by Elfiky (2022), which also reported that WBT can enhance students' attention, memory retention, and comprehension. In addition, these findings support Herrmann's Whole Brain Theory (1998), which emphasises that the

simultaneous activation of multiple brain quadrants leads to deeper and more meaningful learning experiences.

4. Findings For Research Question Four

The fourth research question examined whether there was a significant difference in the mean post-test historical knowledge scores between the control and treatment groups. Table 5 shows that the control group recorded a post-test mean score of 44.85 (SD = 4.31), whereas the treatment group obtained a much higher mean score of 65.00 (SD = 6.93). The mean difference between the two groups was 20.15 points.

Table 5 Comparison of mean post-test historical knowledge scores between the control and treatment groups

Variable	Group	N	Mean	SD	t	df	p	Mean Difference	Decision
Post-Test Historical Knowledge	Control	34	44.85	4.31	-14.242	53.218	< .001	-20.15	Significant
	Treatment	33	65.00	6.93					

Table 5 shows the independent-samples t-test results showed a significant difference in post-test historical knowledge scores between the control group and the treatment group, $t(53.218) = -14.242$, $p < .001$. The significance value obtained was substantially lower than the .05 threshold, indicating that the probability of this difference occurring by chance was extremely low. Therefore, the null hypothesis stating that there was no significant difference in the mean post-test historical knowledge scores between the control and treatment groups was rejected.

Additional analysis of the effect size revealed a Cohen's d value of 3.504, which is interpreted as a very large effect size. According to Cohen's guidelines, a value of 0.20 represents a small effect, 0.50 a medium effect, and 0.80 a large effect, while values above 1.00 indicate a very large effect. Thus, the value of 3.504 is exceptionally high and demonstrates that the difference between the two groups was not only statistically significant but also of substantial practical importance. This indicates that the intervention had a meaningful impact on improving students' academic achievement. Nurul Asyikin Hassan et al. (2024) explained that effective instructional strategies that actively engage students and promote meaningful participation can significantly enhance learning outcomes, academic performance, and overall knowledge retention.

Furthermore, percentage comparison analysis showed that the treatment group scored approximately 44.9% higher than the control group in the post-test. From the perspective of research discussion, these findings indicate that students in the treatment group achieved considerably higher outcomes than those in the control group after the intervention was implemented. A difference exceeding 20 marks represents a substantial gap in academic performance, suggesting that the instructional approach applied to the treatment group was highly effective in enhancing students' historical knowledge. These findings are consistent with previous studies indicating that overly teacher-centred instruction often reduces active student engagement and limits the mastery of new information (Devana, 2020). Similarly, Nursila Abdul and Shakila Che Dahalan (2024) also reported that interactive and student-centred instructional practices contribute positively to students' understanding, motivation, and academic achievement, particularly when learners are actively involved in the learning process.

Moreover, the findings support Herrmann's Whole Brain Theory (1998), which proposes that learning that activates multiple brain functions can enhance information retention and student understanding. Through strategies such as Class-Yes, Teach-Okay, Mirror Words and Switch, students were not only directly involved in listening to explanations but also actively engaged verbally, visually, kinaesthetically, and socially throughout the learning process. Such holistic engagement is intended to improve focus, memory retention and conceptual understanding during classroom instruction.

The findings also demonstrate that although the control group improved from pre-test to post-test, the increase was still substantially lower than that of the treatment group. This suggests that conventional teaching methods remain functional and can produce positive outcomes, but their effectiveness is not comparable to the intervention implemented in the treatment group. Therefore, innovative instructional

approaches such as Whole Brain Teaching should be considered as an effective alternative for improving students' knowledge achievement, particularly in the subject of History.

In addition, the almost twofold increase in post-test knowledge scores among the treatment group reflects that teaching strategies based on active student engagement in small groups are more effective than instruction conducted in larger groups. This conclusion is supported by several international studies reporting that multisensory learning and paired social interaction lead to stronger knowledge mastery, particularly when applied in subjects such as history (Bauddh, 2022; Kharsati & G.S Prakasha, 2017). Overall, the pattern of findings across all four hypotheses indicates that Whole Brain Teaching had a significant positive effect on improving students' historical knowledge. Also, WBT required students to think, speak, move actively and reteach their peers, thereby creating a more dynamic and effective learning process.

CONCLUSION AND RECOMMENDATIONS

The findings of this study carry significant implications for assessment practices in the teaching and learning of History, particularly in evaluating students' knowledge mastery in a more systematic, valid, and curriculum-aligned manner consistent with the Secondary School Standard Curriculum (KSSM). The use of pre-test and post-test measures in this study demonstrates that well-designed assessment instruments are capable of identifying students' prior knowledge, measuring achievement changes after an intervention, and providing clear evidence regarding the effectiveness of a particular instructional approach.

From the perspective of classroom implementation, the findings indicate that tests developed based on the KSSM History curriculum possess important content validity, as the items constructed were aligned with learning standards, subject objectives, and the cognitive level of Form One students. This implies that teachers need to ensure that every assessment instrument genuinely measures the intended construct of historical knowledge rather than merely testing isolated factual recall.

In addition, the reliability of assessment instruments is equally important, as consistent and stable findings indicate that the tests used are capable of producing dependable measurements. The implication for teachers is the need to design clear test items, balanced in terms of difficulty levels, and supported by standardised marking schemes to ensure fair and consistent assessment outcomes. Within the school context, reliable assessment enables teachers to make pedagogical decisions such as identifying students' weaknesses, planning remedial interventions, and adapting instructional strategies according to students' actual performance levels.

Furthermore, this study highlights the importance of practical classroom assessment implementation. Pre-tests and post-tests that are manageable, easy to administer, time-efficient, and straightforward to interpret can assist teachers in conducting continuous assessment without overburdening the teaching and learning process. This is consistent with current educational demands that require teachers to use student performance data promptly in order to improve instruction.

Although this study yielded significant findings, several avenues for future research remain open. First, future studies are recommended to involve larger sample sizes and include multiple states or different school types to enhance the generalisability of the findings. The inclusion of urban schools, rural schools, regular day schools, fully residential schools, and private schools would provide a more comprehensive understanding of the effectiveness of WBT within the Malaysian educational context.

Second, future research could compare the effectiveness of WBT with other instructional approaches such as Project-Based Learning (PBL), Flipped Classroom, Gamification or Cooperative Learning. Such comparisons would help determine the most suitable pedagogical approach according to topic, student level, and specific school contexts.

Overall, the findings of this study contribute to the advancement of knowledge in the field of History pedagogy and demonstrate that innovative approaches such as Whole Brain Teaching have strong potential to strengthen student learning. Nevertheless, continued research is needed to expand the empirical evidence base, refine implementation practices, and ensure that this approach remains relevant to current and future educational needs.

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DATA AVAILABILITY STATEMENT

Data will be made available on request.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DECLARATION OF GENERATIVE AI

In the preparation of this manuscript, the author(s) utilized ChatGPT, Paraphrasing Tool, Claude and Grammarly to assist with language editing, grammar checking and language refinement. Following the use of these AI-assisted tools, the author(s) carefully reviewed, revised and edited the manuscript to ensure the accuracy, clarity and validity of the content. The author(s) assume full responsibility for the integrity, quality and content of the final publication.

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