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Improving medical imaging interpretation through a clerkship anatomy selective

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A R T I C L E I N F O

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A B S T R A C T

Background: Medical students poorly retain their anatomy knowledge and there is an increased desire among students for more exposure to medical imaging. Therefore, this study sought to evaluate the change in student image interpretation skills following a 4th year radiologic anatomy course designed to address both issues.
Methods: Fourth-year medical students enrolled in either "Regional Anatomy through Diagnostic Imaging" selective ($n = 36$) or "Advanced Gross Anatomy" selective ($n = 19$) completed a pre and post-test evaluating their ability to identify anatomical structures. The assessment utilized x-ray, CT scan, MRI and ultrasound images from eight different body regions. Data was analyzed using one-way ANOVA and independent t-tests.
Results: At baseline, the students' mean score was 63.8% ± 22 (25 – 97%) with no significant difference in performance between groups. Performance on x-ray imaging questions (74.5% ± 1.8) was significantly higher compared to other imaging modalities ($p < 0.05$). Post selective, there was a 15.1% mean increase in performance among Regional Anatomy through Diagnostic Imaging students but no significant increase in skills assessment among their colleagues. The independent t-test analysis showed a statistically significant difference ($p < 0.05$) in performance between the two groups at the post-test level.
Conclusion: An elective that integrates anatomy and medical imaging improves graduating medical students' ability to interpret medical images and identify anatomical structures. This approach can be used by other institutions to address student demand for additional exposure to medical imaging while also reinforcing anatomy knowledge.

1. Introduction

Anatomy is a central component of undergraduate medical education, establishing a solid foundation which can be built upon throughout clinical training and future medical practice. Apart from supporting safe clinical practice, it has been noted that knowledge of anatomy enhances competence in physical examination skills, improves clinical reasoning skills and facilitates clinical diagnosis (Smith et al., 2022; Triepels et al., 2018). Despite these benefits, a steady decline in its curricular time has been recorded across undergraduate medical education (Chew et al., 2020; Rockarts et al., 2020; Singh et al., 2015; Wilder et al., 2023). Limited competent anatomy faculty, scarcity of resources, increased curricular content and financial challenges are all contributing factors (Ahmad et al., 2020; Singh et al., 2015; Smith et al., 2022). Additionally, changing the curricula from a systems-based to a problem-based approach has reduced the demand for cadaveric dissection and less time spent in small group learning of anatomy (Ahmad et al., 2020; Chew et al., 2020).

The deterioration of anatomy knowledge is a significant consequence stemming from these changes. Medical students also report low confidence in their anatomy knowledge by the clinical years of training, and this is supported by relatively low performance on assessments of knowledge (Arya et al., 2013; Jurjus et al., 2014). Assessments among recently graduated clinicians and practicing specialists follow a similar pattern of underperformance (Holda et al., 2019; Duraes et al., 2023). The poor correlation between anatomy education delivered in preclinical training and its practical application which is not presented until clinical years is another plausible explanation for the decline in knowledge retention.

Besides linking anatomy with its clinical relevance, several other strategies have been described to deliver anatomy content (Smith et al., 2022). One of the most notable is the integration with medical imaging, a method which has been espoused for more than a century (Bardeen, 1927). Other studies support this notion and demonstrate that the use of

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medical images is still an excellent adjunct to the traditional ways for teaching and learning anatomy (Haver et al., 2023; Heptonstall et al., 2016). Radiology is usually integrated into the anatomical sciences particularly gross anatomy with the goal of spanning the gap between basic and clinical anatomy (Jack and Burbridge, 2012). Nonetheless, there is also a steady decline in the teaching time devoted to radiology instruction and currently fewer medical schools mandate a radiology clerkship (Ganske et al., 2006; Grimm et al., 2022; Lee et al., 2020; Zafar, 2009).

Students recognize the impact of these changes and have consistently described their radiology exposure as minimal (Rohren et al., 2022; Visscher et al., 2015). Low confidence in radiology interpretation skills and the appropriate criterion for ordering diagnostic images is also related to the curricular changes (Dmytriw et al., 2015; Saha et al., 2013). Since medical images are depictions of anatomy, a decrease in anatomy knowledge retention over time could be related to low confidence in image interpretive skills. Therefore, medical students should be given opportunities throughout undergraduate medical education, particularly in clinical training that would reinforce human anatomy knowledge and increase exposure to medical imaging. A radiological anatomy course can achieve this purpose, and it has been shown that the integrated model increases understanding of clinical applications of anatomy, confidence in medical image interpretation and residency preparedness (Branstetter et al., 2007; Kamel et al., 2022; Saha et al., 2013).

A study designed to enable third-year students to reinforce their anatomy knowledge and situate it in clinical relevancy was found to be engaging and facilitated recall and comprehension of anatomy (Arya et al., 2013). In a cross-sectional study by Murphy et al. (2015) first-year medical students indicated that a radiological anatomy course assisted their anatomy learning, and they desired more content delivery in this approach. Similarly, Dettmer et al. (2013) also sought the perspectives of medical students in a second-year radiological anatomy elective. Most students agreed that the combination of anatomy and radiology simplified their understanding of anatomy and improved their understanding of its relevance. These studies indicate that the integrated approach has several benefits and has been well-received by medical students but most of the data evaluating program effectiveness focuses on students' perceptions and opinions and usually consists largely of qualitative data. There is a need to quantitatively determine the effectiveness of radiologic anatomy courses as it pertains to improving medical students' anatomy and medical imaging learning. This study focused on this paucity in the current literature. The aim was to evaluate the change in students' abilities to correctly identify normal anatomical structures in various imaging modalities following a 4th year radiologic anatomy course designed to reinforce anatomy knowledge and increase exposure to medical imaging. The outcomes were expected to have positive impacts for student's transition to residency and serve as the foundation for the development of strategies that would address the various issues medical students experience pertaining to medical imaging education and training.

2. Material and methods

2.1. Course design

Fourth-year students at the Max Rady College of Medicine at the University of Manitoba are required to complete selective courses which allow them to choose subjects based on their interest. The *Regional Anatomy through Diagnostic Imaging* selective has been offered since 2021. It is designed as a three-week course delivered in-person to 4th year students in the final months of their undergraduate medical education. The course consisted of 8 two-hour sessions with topics including anatomy of the upper limb, lower limb, back, brain and spinal cord, head, neck, thorax, abdomen, and pelvis. Each laboratory session included region specific cadaveric prosections, regional osteology, cross-sectional anatomy and medical imaging with relation to clinical cases. There were 15 min of ultrasound scanning built into the upper limb, lower limb, head, neck, thorax, and abdomen regions. One instructor demonstrated the scans on a student volunteer who served as the model. Students then performed scanning on their colleagues with guidance from the instructor. A mixture of small group learning sessions, case-based learning and independent study were utilized in the course. Teaching resources included voice-over PowerPoint recordings, clinical case handouts, and e-anatomy from IMAIOS.com. Students were required to complete pre-reading activities and quizzes before each session. A total of 15 students could enroll in each of the two iterations of the course offered each year. Two anatomists delivered the course content which provided a 1: 7.5 faculty to student ratio.

2.2. Study design

The participants for this study were fourth-year medical students enrolled in the Max Rady College of Medicine at the University of Manitoba for the 2023–2024 and 2024–2025 academic years. A pre-test/post-test group design was used to assess the effectiveness of the 4th year selective *Regional Anatomy through Diagnostic Imaging* to improve medical imaging interpretive skills and reinforce anatomy knowledge.

Students in another 4th year selective *Advanced Gross Anatomy* offered during the same time were used as a control group to determine whether being exposed to anatomy without exposure to medical imaging translates to increases in medical imaging interpretation skills. *Advanced Gross Anatomy* enables 4th year students to perform cadaveric dissections which augments their anatomy knowledge and dissection skills prior to graduation. Participants completed a pre-test before their respective courses which provided baseline data pertaining to their knowledge and retention of anatomy. The pre-test consisted of 32 questions. The images were of normal anatomical structures from the modalities of X-ray, CT, MRI, ultrasound, and angiogram. Additionally, Alliance of Medical Student Educators in Radiology (AMSER) identifies "Must See" images that medical students should see during their training. Most questions on the assessment reflected the normal anatomical structures that would enable students to identify the diagnoses. The anatomical regions included were upper limb, lower limb, back and vertebral column, head, neck, thorax, abdomen, and pelvis. This pre-test was derived from similar questionnaires in the literature (Feigin et al., 2002) and was hosted through Qualtrics®. At the conclusion of the courses, study participants completed the post-test which consisted of the same questions as the pre-test. Select questions from each cohort's mid-term and final exams during the preclinical years were retrospectively grouped into the eight matching regions allowing for observation of differences in performance between the two time points. For each of the eight body regions percentage of students answering correctly was calculated. The questions from the preclinical assessments were only image-based and required students to correctly identify normal anatomical structures in radiological images.

Apart from the pre and post-test, participants in the second year of the study also completed survey questions assessing their medical imaging exposure, motivations for enrolling in the selective, medical imaging confidence levels, and specialty areas of interest. Questions measuring confidence level used a 4-point Likert scale ranging from "not at all confident", "slightly confident", "very confident" and "extremely confident". Other questions used a "select all that applies" or multiple-choice option and open-ended responses.

The study was conducted following institutional ethics board approval (Ethics #: HS26275).

2.3. Data analysis

Each question on the assessment was worth one point and a raw score out of 32 was converted to a percentage for each participant. The independent *t*-test was used to compare performance between the pre-test and post-test. The one-way ANOVA was used to compare performance across the four different imaging modalities. The data from questions on the 4-point Likert scale were assigned scores ranging from "not at all confident" indicated by 1 and "extremely confident" indicated by 4. The Kruskal-Wallis test was used to compare Likert-type questions. Responses to open-ended questions were tallied and descriptive statistics were applied as necessary. The results were considered statistically significant if $p \leq 0.05$. Statistical analysis was performed using Microsoft Excel software (Microsoft Office Professional Plus 2016, Santa Rosa, California) and Statistics Kingdom: Website for Statistical Computation (https://www.statskingdom.com/).

3. Results

The seventy-six students enrolled in both selectives were invited to participate in the study with fifty-five (55/76) enrolled for a response rate of 72% ($n = 36$ and $n = 19$ from the *Regional Anatomy through Diagnostic Imaging* selective and *Advanced Gross Anatomy* selective respectively). Twenty participants did not complete the post-test. Table 1 indicates that 65% of the students had no additional medical imaging exposure except from mandatory training within the curriculum. All but two participants identified improving diagnostic image reading skills as the main reason for enrolling in the course. Participants were matched to a range of specialties with Family Medicine having the highest representation (40%) closely reflecting the match results for their class.

There was no significant difference in performance between groups prior to the start of the courses. Table 2 shows that 81.8% of participants were able to correctly answer questions related to the thoracic region. Similarly, 78.2% and 72.7% of participants correctly answered questions related to the head and abdomen regions respectively. The lowest performance was recorded on questions specific to the neck (35.9%), indicating a lower retention rate. Additionally, comparison of pre-test performance to similar questions on the preclinical assessments illustrated a general decline in retention across all body regions except the abdomen and thoracic region. Fig. 1 demonstrates that confidence levels were different across the imaging modalities and non-parametric analysis using Kruskal Wallis with post hoc testing indicated a significant difference ($p \leq 0.05$) between x-ray, MRI and ultrasound as well as a significant difference in confidence ratings between CT scan, MRI and ultrasound.

Table 1
Prior exposure to medical imaging, reasons for enrolling in the selective and specialty areas of interest.

Question	No. of Participants
How would you describe your exposure to medical imaging	
a. I have taken a medical imaging elective	8
b. I have not taken a medical imaging elective	14
What are your reasons for enrolling in the Regional Anatomy through Diagnostic Imaging Selective?*	
a. Review of Anatomy	15
b. Improve diagnostic image reading skills	18
c. Correlation of clinical understanding to anatomy and radiology	14
Specialty Area of Interest	
Family Medicine	8
Internal Medicine	3
General Surgery	2
Ophthalmology	1
Anesthesiology	2
Hematopathology	1
Urology	1
Psychiatry	1
Obstetrics and Gynecology	1
Radiology	1
Gap Year	1

Data was collected for the second cohort of students from each selective enrolled in the study ($n = 22$)

* responses from only participants enrolled in *Regional Anatomy through diagnostic Imaging* (experimental group)

The mean score on the pre-test was 63.8% ± 22 (range 25 – 97%). Students performed best on questions utilizing x-ray imaging with mean score of 74.5% ± 16.5 compared to ultrasound imaging questions with the lowest mean of 59.3% ± 19.8 (Fig. 2). One-way ANOVA testing indicated a statistically significant difference ($p \leq 0.05$) in mean scores between x-ray and the other imaging modalities. Post selective, students enrolled in *Regional Anatomy through Diagnostic Imaging*, showed an increase from 65.6% to 80.7% on skills assessment (Fig. 3). This 15.1% mean increase was statistically significant ($p \leq 0.05$) demonstrating the effectiveness of the selective. There was no significant increase in performance among students enrolled in *Advanced Gross Anatomy*. Overall, Fig. 3 indicates that students enrolled in the *Regional Anatomy through Diagnostic Imaging* selective performed significantly better on the post-test compared to their counterparts enrolled in *Advanced Gross Anatomy* selective and the independent *t*-test analysis indicated that the difference in performance was statistically significant ($p < 0.001$).

4. Discussion

This study examined the efficacy of a fourth-year radiologic anatomy course to improve image interpretation skills. A comparison of pre-test data and student performance on pre-clinical imaging assessments revealed a decline in the ability to identify anatomical structures by the end of clinical training. Participants in the experimental group outperformed their counterparts on the final assessment. The results demonstrated that the three-week course has the potential to enhance knowledge and image interpretive skills. Overall, the study highlights the effectiveness of a feasible method which can address the deterioration of anatomy knowledge and inadequacies in medical imaging exposure among graduating medical students.

The data from the pre-test indicating a general decline in ability to identify anatomical structures is consistent with the results from other studies (Arya et al., 2013; Jurjus et al., 2014; Wilder et al., 2023; Hołda et al., 2019; Heptonstall et al., 2016). This decay can be attributed to lack of regular practice and reinforcement throughout the clinical years of medical education. Ebbinghaus using the forgetfulness curve describes this as the limitations of human memory which allows for the rapid loss of information after a lecture or training (Ebbinghaus, 2013; Wollstein and Jabbour, 2022). Medical students are expected to absorb larger volumes of knowledge in a continuously shrinking instructional timeframe which provides few opportunities for evidence-based approaches that can optimize retention. Strategies such as scaffolding, testing effect or retrieval practice can prevent knowledge attrition (Wollstein and Jabbour, 2022; Donker et al., 2022). Apart from these methods, spaced learning that allows for longer intervals between learning and revisiting the new information has positive learning outcomes which limits forgetfulness (Ebbinghaus, 2013; Wollstein and Jabbour, 2022; Donker et al., 2022). Nonetheless, early imaging exposure is still beneficial as it establishes a foundation which should be broadened through repetition, practice and clinical experience throughout undergraduate medical training (Saha et al., 2013). Finally, the baseline performance on questions of the thoracic region deviated from the general trend. Among medical students and first-year residents, chest radiographs were considered the most important images to interpret, which offers a plausible explanation for the improvement observed in our study (Saha et al., 2013; Subramaniam et al., 2006).

Analysis of Likert-type questions showed that x-ray interpretation was rated at the *slightly confident* level and was positively reflected in performance on questions utilizing this modality. Similarly, confidence levels for the three remaining modalities were consistent at the *not at all confidence* level with ultrasound receiving the lowest rating. These findings may be related to the difficulty in interpreting ultrasound

Table 2
Percentage of students correctly answering questions on pre-clinical assessment in comparison to pre-test.

	Performance in Pre-Clinical Training			Performance Prior to 4-th year Selective		
Region	No. of Questions	Imaging Modalities	% Correct (N = 214)	No. of Questions	Imaging Modalities	% Correct (N = 55)
Head	7	MRI, x-ray	80	4	x-ray, CT scan, MRI, Ultrasound	78.2
Neck	3	MRI, CT scan	83	4	x-ray, CT scan, MRI, Ultrasound	35.9
Upper Limb	15	x-ray	75	4	x-ray, CT scan, MRI, Ultrasound	64.1
Thorax	7	x-ray, ultrasound	81	4	x-ray, CT scan, MRI, Ultrasound	81.8
Abdomen	4	x-ray, CT scan, MRI	70	4	x-ray, CT scan, MRI, Ultrasound	72.7
Spine	6	x-ray, MRI	67.5	4	x-ray, CT scan, MRI, Ultrasound	52.3
Pelvis	7	Ultrasound, MRI, x-ray	84.5	4	x-ray, CT scan, MRI, Ultrasound	59.5
Lower Limb	10	x-ray	81.3	4	x-ray, CT scan, MRI, Ultrasound	60

MRI: magnetic resonance imaging CT: computed tomography

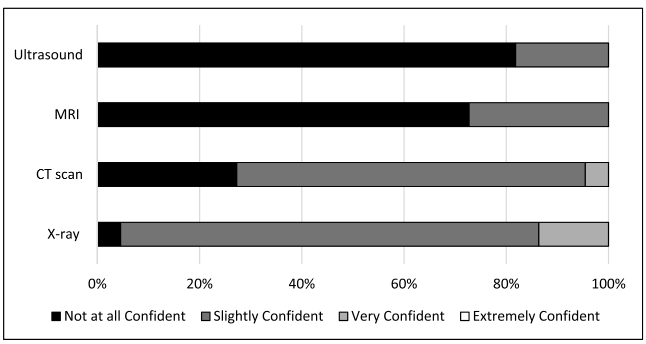

Fig. 1. Confidence level across different imaging modalities at baseline MRI: magnetic resonance imaging; CT: computed tomography. Kruskal-Wallis analysis indicated that confidence ratings were significant ($p \leq 0.05$).

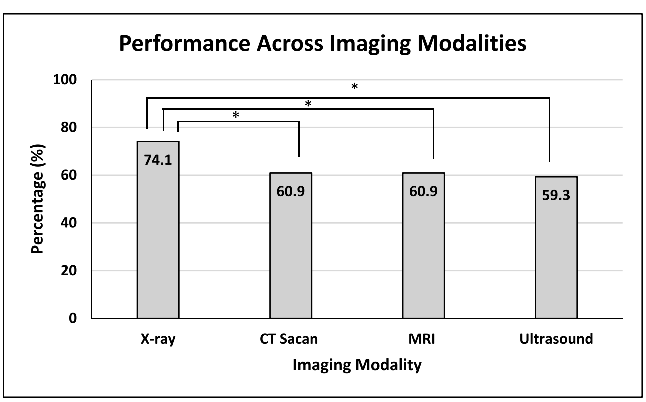

Fig. 2. Performance across imaging modalities at baseline. MRI: magnetic resonance imaging; CT: computed tomography. One-way ANOVA analysis indicated statistical significance between x-ray and other imaging modalities ($p \leq 0.05$).

images, and low levels of training and exposure within the curriculum. The performance and confidence levels in x-ray imaging may be linked to its emphasis in the current curriculum. The preclinical assessments which provide insights into the delivered and experienced curriculum in preclinical training lends support to this assertion as more than 70% of questions utilized x-ray imaging. Another potential factor may be the decreased instructional time allotted to anatomy and radiology teaching underscoring the need for greater inclusion of imaging within a clinical context (Chew et al., 2020; Ganske et al., 2006; Grimm et al., 2022; Lee et al., 2020; Smith et al., 2022; Triepels et al., 2018; Wilder et al., 2023; Zafar, 2009).

The improvement in performance following the three-week selective demonstrated the effectiveness of this integrated approach to deliver

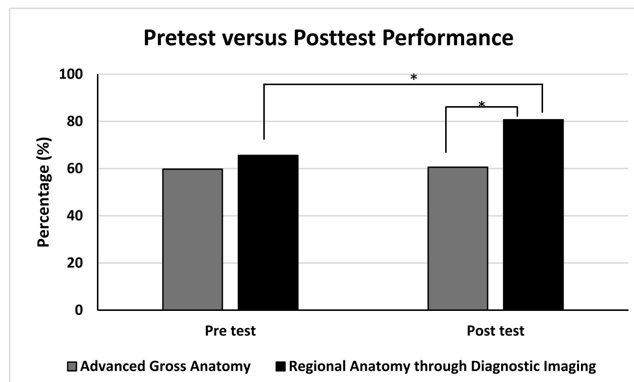

Fig. 3. Performance comparison of pre-test and post-test between students enrolled in *Advanced Gross Anatomy* and *Regional Anatomy through Diagnostic Imaging*. *Independent *t*-test analysis indicated a statistically significant improvement on the post-test ($p \leq 0.05$).

anatomy content (Chew et al., 2020). Failure to replicate these results in the control group illustrates that anatomy learning in isolation is inadequate to meaningfully enhance image interpretation skills. It has been previously shown that integration of disciplines limits the challenges that students experience when knowledge is not coherently linked to skill acquisition (Brauer and Ferguson, 2015). As such, the design of the course followed the Kolb's experiential learning cycle, an effective model for learning which employs four specific stages: experiencing, reflecting, conceptualizing and experimenting (Armstrong and Parsa-Parsi, 2005; Lee and Kumar, 2023). Students progressed through each of the first three stages during the course. First, the recorded lectures, faculty-led prosection along with anatomical models provided students with a concrete experience. Second, labelling and identifying the structures on medical images enabled students to reflect followed by solving clinical case scenarios which allowed conceptualization. As learners apply their knowledge with patient encounters in their remaining clinical rotations and subsequent residency training, they progress through the final stage – experimenting. This approach enhances knowledge retention, bridges the gap between anatomy knowledge and its clinical relevancy, and fosters a deeper understanding of medical concepts.

Appropriate teaching resources, the learning environment, and teaching strategies are factors which influence the successful implementation of anatomy courses. This study utilized cadaveric prosection which is the preferred laboratory teaching resource among medical students (Abdullah et al., 2021). Cadaveric dissection is key to identifying normal anatomical structures, variants, pathologies and relationships between structures (Triepels et al., 2018). While its declining use has been associated with a decrease in anatomy knowledge, cadaveric dissection is not superior to other teaching methods (Smith et al., 2022; Triepels et al., 2018). Cadaveric prosection is a feasible and effective alternative which also addresses resource limitations, time constraints and challenges associated with securing donors for anatomy teaching.

Additionally, student motivation for enrolling in the course provided some insights which impacted the overall success of the study. This course allowed students to reinforce their anatomy knowledge and improve diagnostic imaging skills. The latter was highly ranked among students as a motivating influence. The self-determination theory (SDT) states that this motivation can be extrinsic or intrinsic, but enhancement in learning and improvement in academic performance is closely linked to high levels of intrinsic motivation (Pless et al., 2024; Ten Cate et al., 2011). Another highlight of this course is that it satisfied the need for autonomy, competence and relatedness which are the hallmarks of SDT. The course is not mandatory but is one of the many available choices that students can select which enable them to exercise their autonomy while engaging in learning activities of interest. The small group teaching format and the desire to improve diagnostic image skills satisfy the need for relatedness and competence (Ten Cate et al., 2011).

4.1. Limitations

This study was limited by a small sample size, but the course could only accommodate 15 students per iteration, and the demographic characteristics of the participants were representative of the larger student body. The study only investigated the immediate effects of the course on student learning. Future studies can examine long-term retention at the postgraduate level. Additionally, the assessment in this study utilized normal anatomical structures and first order questions. Nonetheless, the questions mimicked similar questions on the preclinical assessment which also used normal anatomical structures and allowed for a fair comparison.

5. Conclusion

The results of this study show that a three-week course combining medical imaging and anatomy can enhance graduating medical students' ability to identify anatomical structures in different medical images. It provided an effective strategy to address student desire for increased imaging exposure while reinforcing anatomy knowledge. Future studies could focus on assessments which include anatomical variants, pathologies, and higher-order questions.

CRediT authorship contribution statement

Terry Li: Writing – review & editing. **Eola Saltibus:** Writing – original draft, Visualization, Investigation, Formal analysis, Conceptualization. **Alexa Hryniuk:** Writing – review & editing, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization.

Ethics approval statement

This study was approved by the University of Manitoba Research Ethics Board (Ethics #: HS26275). Informed consent was obtained from all participants.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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

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