

Investigation of the Dunning–Kruger Effect Among Medical Students and the Effectiveness of Academic Experiences in Evidence-Based Medicine Training

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Abstract

Randomized clinical trials (RCTs) are essential for building the scientific evidence that supports medical decision-making. However, the ability of medical students to read and interpret scientific articles has been shown to be heterogeneous in Brazil. Therefore, this study aimed to assess medical students' knowledge of topics related to RCTs, as well as their self-perception of this knowledge. An analytical cross-sectional study was conducted using an online questionnaire. The analysis included 159 students enrolled in medical programs in Brazil, who answered questions regarding previous academic experience, self-perceived scientific knowledge, and a five-item questionnaire addressing relevant aspects of RCT interpretation. The mean questionnaire score was 2.93 out of 10. Presenting scientific work at conferences was associated with better questionnaire performance, whereas scientific mentorship had no significant effect. Overestimation of one's own knowledge of RCTs was inversely correlated with questionnaire performance ($\rho = -0.656$). Students who scored below five showed a significantly higher level of knowledge overestimation than those who scored above five, consistent with the pattern expected according to the Dunning–Kruger effect. These findings indicate that the ability of medical students in Brazil to interpret and understand RCTs remains limited, suggesting the need to strengthen practical approaches and active participation in scientific activities during medical training to foster the development of skills in reading, understanding, and interpreting scientific articles.

KEYWORDS: Randomized clinical trials; Dunning–Kruger effect; Evidence-based medicine; Medical education.

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Introduction

It is estimated that between 1907 and 2007, the number of scientific publications doubled every 10 years (LARSEN & VON INS, 2010). A study published in 2015 by Bornmann reported an annual increase of approximately 9% to 10% in the volume of scientific publications (BORNMANN & MUTZ, 2015). However, the expansion of scientific production does not necessarily translate into greater incorporation of knowledge into clinical practice (IOANNIDIS, 2005). In this context, Evidence-Based Medicine (EBM) has become an essential component of medical practice by integrating the best available scientific evidence into clinical decision-making (MANDELL, 2014; ARAUJO *et al.*, 2021). Accordingly, healthcare professionals must develop the skills required to locate, critically interpret, and assess the methodological quality of available scientific evidence.

Among the study designs used in clinical research, randomized clinical trials (RCTs) play a prominent role and are considered a reference standard for evaluating the efficacy and safety of therapeutic and preventive interventions (BRASIL, 2014). Their importance derives from methodological features such as randomization, blinding, and systematic bias control, which allow more reliable estimates of cause-and-effect relationships (IOANNIDIS, 2005; SCHULZ *et al.*, 2010; FLETCHER *et al.*, 2014). For this reason, RCTs provide a robust basis for the development of clinical guidelines and healthcare recommendations (SACKETT *et al.*, 1996). However, their proper interpretation requires methodological and statistical knowledge that frequently represents a challenge for undergraduate medical students (BASHEER *et al.*, 2021; DAOU *et al.*, 2022).

Contemporary medical education includes activities designed to enable students to locate, critically interpret, and appropriately apply scientific evidence to clinical practice, while also contributing to the production of

scientific knowledge (ARAÚJO *et al.*, 2020; BAUTISTA-GÓMEZ *et al.*, 2020; DA SILVEIRA & PAIVA, 2025). Nevertheless, studies have shown that the development of these competencies is heterogeneous among medical students, reflecting differences in exposure to scientific training activities and research experiences (DELEON *et al.*, 2024; SILVA JÚNIOR *et al.*, 2025). Objective differences in these competencies have been observed among medical students, including in the critical appraisal of RCTs (BASHEER *et al.*, 2021; DAOU *et al.*, 2022). Some studies have shown that students exposed to continuous scientific training and research participation perform better on objective assessments of Evidence-Based Medicine (EBM) (SASANNIA *et al.*, 2022; DELEON *et al.*, 2024; SILVA JÚNIOR *et al.*, 2025), and that these experiences are associated with consistent and sustained improvements in knowledge and skills related to the critical appraisal and use of scientific evidence (AHMADI *et al.*, 2015; BURGESS *et al.*, 2018; HILL *et al.*, 2024).

However, the development of objective competence does not necessarily imply an accurate perception of one's own performance (RAHMANI, 2020; TABIBZADEH *et al.*, 2020). Accurate assessment of one's own knowledge requires the ability to recognize that the limitations underlying poor performance may also impair the ability to identify those same limitations (RAHMANI, 2020; TABIBZADEH *et al.*, 2020). One proposed explanation for this phenomenon is the Dunning–Kruger effect, according to which individuals with lower competence tend to overestimate their abilities because they have difficulty recognizing their own limitations, whereas more competent individuals tend to provide self-assessments that more closely reflect their actual performance (KRUGER; DUNNING, 1999). This calibration may be improved through academic and scientific experiences, such as mentorship, feedback, and research involvement throughout medical training, which may foster the development of self-reflection regarding one's own knowledge (BURGESS *et al.*, 2018; TABIBZADEH *et al.*, 2020; DELEON *et al.*, 2024).

In Brazil, evidence regarding the relationship between objective performance and self-perceived competence in the interpretation of RCTs remains limited (DAOU *et al.*, 2022). Therefore, the present study aimed to assess medical students' ability to interpret RCTs, analyze the relationship between perceived competence and objective performance in this skill, and investigate the association between different scientific training experiences and student performance. The central hypothesis was that students tend to overestimate their own knowledge of the subject and that this overestimation is significantly greater among those with lower overall knowledge.

Methods

A cross-sectional study was conducted using data collected through an online questionnaire. The target population consisted of students regularly enrolled in undergraduate medical programs in Brazil. Students enrolled from the first to the twelfth semester of medical school were considered eligible if they agreed to participate by providing electronic informed consent. Incomplete responses in the objective performance section, duplicate submissions, and responses containing inconsistencies identified during data verification were excluded. Convenience sampling was used, with participants recruited through dissemination of an electronic form via social media, institutional channels, student associations, and academic leagues.

The online questionnaire was structured into three main sections: (a) personal information and academic experience; (b) self-assessment of competence in RCT interpretation; and (c) objective assessment, consisting of multiple-choice questions on the topic (Supplementary Material 1).

First section (a): personal information and academic experience

The following information was collected:

- administrative category of the educational institution (federal, state, municipal, or private);
- history of participation in scientific mentorship during medical school (current, previous, or none);
- number of full-text scientific articles read (none, 1–5, 6–10, 11–20, or more than 20);
- participation in scientific research projects (yes/no);
- number of studies presented at scientific conferences (none, 1–3, or more than 3).

Second section (b): self-perceived knowledge

- Self-perceived ability to interpret RCTs was assessed using a 0-to-10 scale, on which participants rated their own ability to interpret these studies.

Third section (c): objective assessment

The objective assessment addressed the following topics:

- characteristics of a well-designed RCT;
- interpretation of p-values;
- main limitations of RCTs;

- ethical aspects related to RCTs;
- interpretation of statistical results.

The objective performance score was calculated as the sum of the scores obtained on the five questions in the third section. Each correct answer was worth two points, resulting in a maximum score of 10. To minimize response bias, participants first rated their ability to interpret clinical trials without being informed that they would subsequently undergo an objective assessment on the topic. This approach was intended to reduce the possibility that anticipation of the assessment would influence their self-evaluation.

Accordingly, the 0-to-10 self-assessment scale was used as a continuous measure of perceived competence rather than as a direct estimate of the proportion of questions participants believed they had answered correctly. Self-assessment therefore represented a subjective measure, whereas the questionnaire score represented an objective measure. Both were expressed on the same 0-to-10 scale to allow assessment of calibration between perceived knowledge and objective performance and to calculate an overestimation index. This index was obtained by subtracting the objective performance score from the self-assessment score, thereby combining subjective and objective measures for investigation of the Dunning–Kruger effect.

The number of correct answers was analyzed according to each student's academic experience, with comparisons between students with and without experience in scientific mentorship and scientific conference presentations. Differences among categories were assessed using analysis of variance (ANOVA), with statistical significance defined as $p < 0.05$. When a statistically significant difference was identified in the overall analysis,

Tukey's post hoc test was applied to identify pairwise differences between groups. Statistical analyses were performed using Jamovi.

Associations were also assessed between categorical variables representing academic experience: scientific conference presentations (none, 1–3, or more than 3) and number of full-text scientific articles read (none, 1–5, 6–10, 11–20, or more than 20), in relation to scientific mentorship status (no/yes). The statistical significance of these associations was evaluated using the chi-square test.

Spearman's rank correlation analysis was performed among the quantitative variables self-assessed knowledge, overestimation index, and objective performance score to evaluate the strength and statistical significance of the relationships among these measures and to investigate whether the observed pattern was consistent with the Dunning–Kruger effect among participating students.

Additionally, linear regression analysis was performed using the objective performance score as the dependent variable. Academic experience was included as an explanatory variable and was initially constructed from four binary components related to academic experience, resulting in a quantitative index ranging from 0 to 4 points. The components were scientific mentorship, scientific article reading, participation in research projects, and presentation of studies at scientific conferences.

In a second linear regression analysis, these components were entered separately as explanatory variables, allowing the individual contribution of each component to be assessed. The self-perceived knowledge score was also included as an explanatory variable to evaluate its effect after adjustment for the other variables. Before conducting the linear regression analyses, the assumptions of absence of multicollinearity among

the independent variables and appropriate residual distribution were assessed, including inspection of Q–Q plots.

Results

A total of 159 medical students from Brazil were included in the analysis. Most participants were enrolled in private higher education institutions (90.5%), compared with federal public (8.2%) and municipal public institutions (1.3%) (**Figure 1**). Most of these institutions were located in the states of Espírito Santo (39.3%), Amazonas (25.2%), Minas Gerais (17.6%), Pernambuco (4.4%), São Paulo (3.8%), and Rio Grande do Sul (3.1%) (**Figure 1**).

Objective performance scores ranged from 0 to 8 points on a 0-to-10 scale (2 points per correct answer). The mean score was 2.93 (SD = 2.54), corresponding to 29.3% of the maximum possible score. The median score was 2.0. No participant achieved the maximum score, and the highest score recorded was 8.0 points (**Table 1**).

Item-level analysis showed a low proportion of correct responses across all five questions. Only the question addressing ethical aspects of RCTs had a correct response rate above 50% (85/159; 53.5%). For the remaining questions, the proportions of correct responses were 25.6% for characteristics of a well-designed clinical trial, 25.2% for p-value interpretation, 26.4% for identification of the main limitation of RCTs, and 21.4% for interpretation of statistical results (**Table 1**).

Figure 1. Percentage distribution by type of higher education institution (a) and Brazilian state in which the institution is located (b) among students participating in the study.

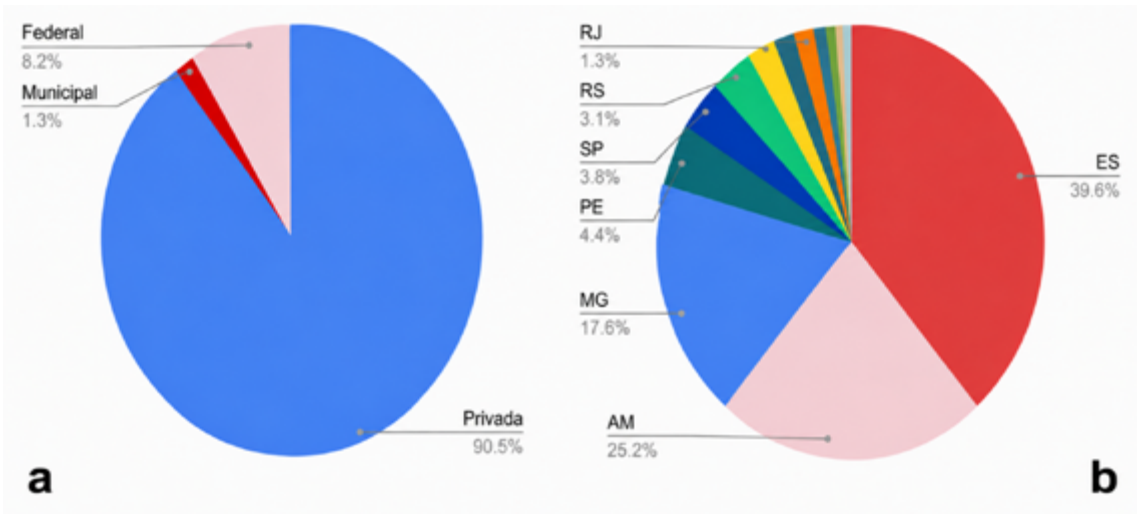


Table 1. Frequency of correct responses (CR) to questions on the interpretation of randomized clinical trials among medical students (n = 159).

Question topic	CR: N (%)
Characteristics of a well-designed clinical trial	32 (25.6%)
Interpretation of the p-value	40 (25.2%)
Main limitation of the clinical trial	42 (26.4%)
Ethical aspects	85 (53.5%)
Interpretation of statistical results	34 (21.4%)

Analysis of variance indicated a significantly lower objective performance score ($p < 0.05$) among students with no experience presenting academic work at scientific conferences compared with those who had presented more than three times, with a mean difference of 2.022 points. In addition, a marginally significant difference ($p = 0.08$) was observed between students with one to three conference presentations and those with more than three. Students with more than three presentations scored, on average, 1.411 points higher on the objective assessment section of the online questionnaire, suggesting a dose–response relationship. In contrast,

no significant difference was detected according to previous experience with scientific mentorship (**Table 2**).

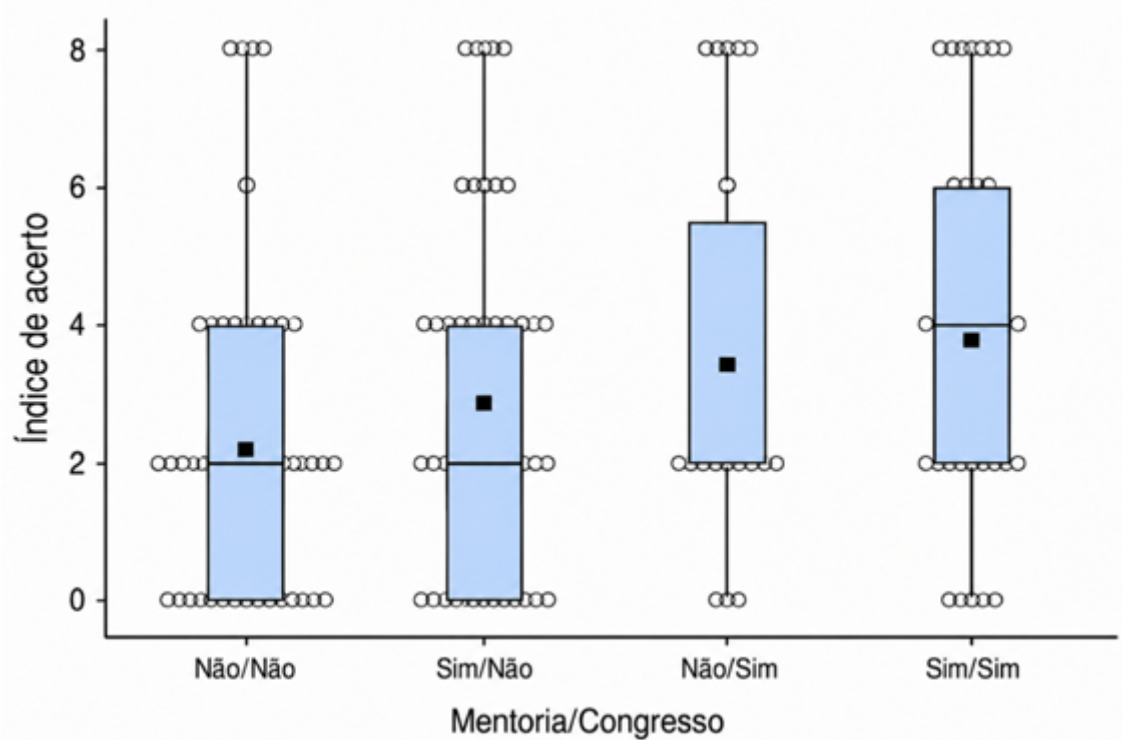
The highest mean and median objective performance scores were observed among students who had experience with both conference presentations and scientific mentorship. However, these scores did not differ significantly from those of students who had experience presenting at conferences but had not received scientific mentorship (**Figure 2**).

Table 2. ANOVA significance values for differences in objective performance scores according to categories of conference presentation experience and scientific mentorship.
(MD) = Mean difference; (SE) = Standard error.

Conference presentation	Conference presentation	MD	SE	ptukey
None	1 - 3	-0.611	0.478	0.41
	More than 3	-2.022	0.569	0.001
1 - 3	More than 3	-1.411	0.657	0.084
Scientific mentorship	Scientific mentorship	MD	SE	ptukey
No	Yes	-0.821	0.399	0.042

The association between scientific mentorship and the number of studies presented at conferences was statistically significant. Among students without scientific mentorship, 73.1% were in the “no conference presentations” category, whereas only 9.0% were in the “more than three presentations” category. Students who had received scientific mentorship also had the highest proportion in the “none” category, although this proportion was lower, at 53.1%. This group also had the lowest proportion in the “more than three” category, but this value increased to 19.8% (**Table 3**).

Figure 2. Box plot showing the median, interquartile range, minimum and maximum values, as well as mean values (black squares) of objective performance scores among students with and without experience in scientific mentorship (yes or no) and presentation of scientific work at conferences (yes or no), with “Mentorship experience/Conference experience” on the x-axis. White circles represent the distribution of the data.



The association between scientific mentorship and the number of full-text scientific articles read was also statistically significant. Among students without scientific mentorship, the highest proportion was observed in the “1–5 full-text articles read” category (35.9%), whereas the lowest proportion was observed in the “none” category (11.5%). Among students who had received scientific mentorship, the highest proportion was observed in the “more than 20” category (34.6%), while the lowest proportion was also found in the “none” category, at only 3.7% (**Table 4**).

Table 3. Association between scientific mentorship and the number of studies presented at scientific conferences, assessed using a contingency table.

		Conference presentation			
Scientific mentorship		None	1 - 3	More than 3	Total
No	Observed	57	14	7	78
	% (in line)	73.1%	17.9%	9.0%	100.0%
Yes	Observed	43	22	16	81
	% (in line)	53.1%	27.2%	19.8%	100.0%
Total	Observed	100	36	23	159

Table 4. Association between scientific mentorship and the number of full-text scientific articles read, assessed using a contingency table.

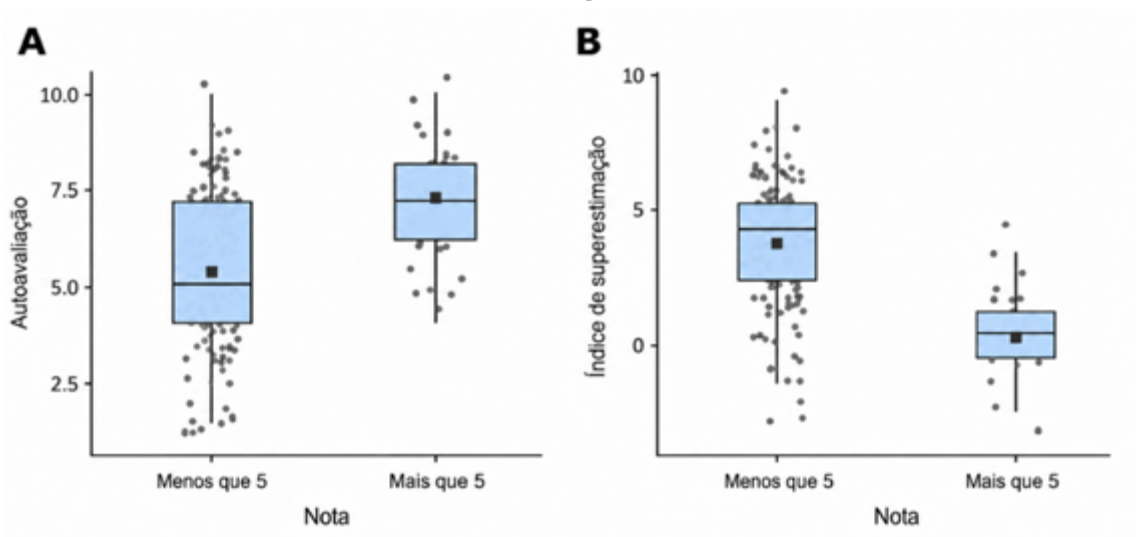
		Leitura de artigos completos					
Scientific mentorship		None	1 - 5	6 - 10	11 - 20	More than 20	Total
No	Observed	9	28	11	13	17	78
	% (in line)	11.5%	35.9%	14.1%	16.7%	21.8%	100.0%
Yes	Observed	3	16	17	17	28	81
	% (in line)	3.7%	19.8%	21.0%	21.0%	34.6%	100.0%
Total	Observed	12	44	28	30	45	159

Among the variables examined pairwise using Spearman's rank correlation, the strongest association was observed between the objective performance score and the overestimation index, with a significant inverse correlation of -0.656 (**Table 5**). In addition, students who scored below 5 had a mean overestimation index 3.54 points higher than that of students who scored above 5, on a 0-to-10 scale. This difference was statistically significant (ANOVA, $p < 0.05$) (**Figure 3**).

Table 5. Spearman’s rank correlation (rho) among self-assessment, objective performance score, and overestimation of self-perceived knowledge of RCTs.

	Self-assessment	Objective performance score
Objective performance score	0.369	—
P value	<.001	—
Overestimation index	0.406	-0.656
P value	<.001	<.001

Figure 3. Box plots showing the median, interquartile range, and minimum and maximum values for self-assessed knowledge of RCTs (A) and the overestimation index of knowledge about RCTs (B) among students who scored below 5 and above 5 on the RCT knowledge test.



Linear regression analysis using the objective performance score on the online questionnaire as the dependent variable showed a positive association between self-perceived knowledge and objective performance. Higher self-assessment scores were associated with better objective performance, with an estimated increase of 0.405 points in the objective performance score for each one-point increase in self-assessment, after adjustment for the other variables included in the model ($p = 0.001$). Academic experience also showed a trend toward a positive association with the objective performance score ($F = 3.52$; $p = 0.063$), with an estimated

increase of 0.325 points for each additional component of academic experience, including scientific mentorship, reading scientific articles, participation in research projects, and presentation of studies at scientific conferences (**Figure 4**).

When the individual components of academic experience were analyzed separately, only presentation of studies at scientific conferences showed a significant positive association with the objective performance score ($F = 4.141$; $p = 0.044$; $\beta = 0.405$). Scientific mentorship ($F = 0.353$; $p = 0.553$; $\beta = 0.248$), scientific article reading ($F = 0.278$; $p = 0.599$; $\beta = -0.385$), and participation in research projects ($F = 0.241$; $p = 0.624$; $\beta = 0.201$) were not significantly associated with objective performance after adjustment for the other variables included in the model (**Figure 5**).

Figure 4. Results of the linear regression analysis with the objective performance score as the dependent variable, ranging from 0 to 10; self-perceived knowledge (self-assessment) as a quantitative explanatory variable, ranging from 0 to 10; and academic experience as a quantitative explanatory variable, ranging from 0 to 4, representing the number of academic experiences reported by each student, including scientific mentorship, scientific article reading, participation in research projects, and presentation of studies at scientific conferences.

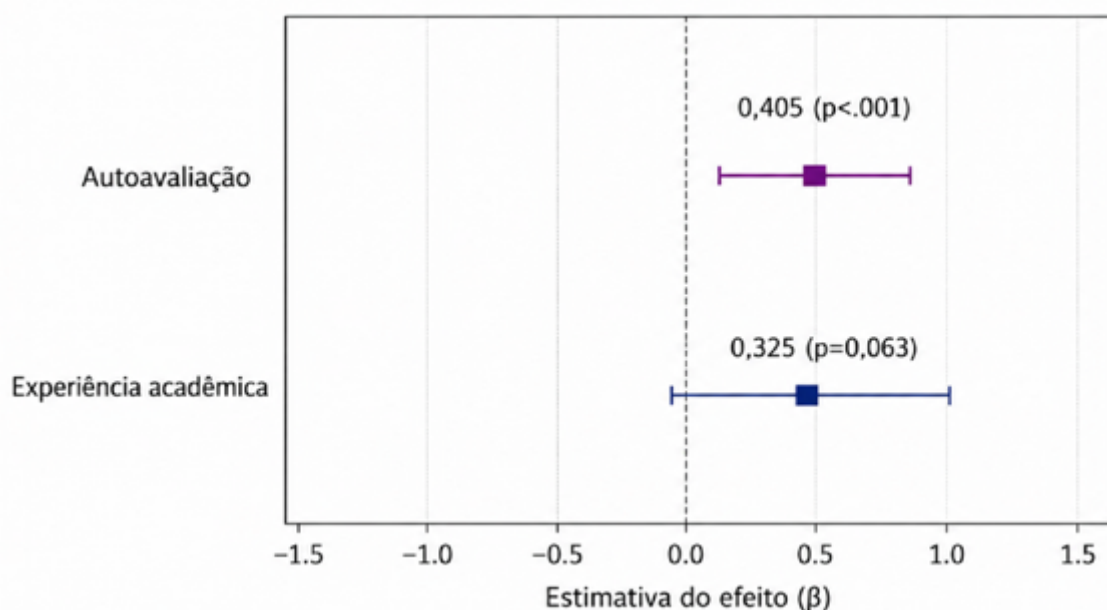
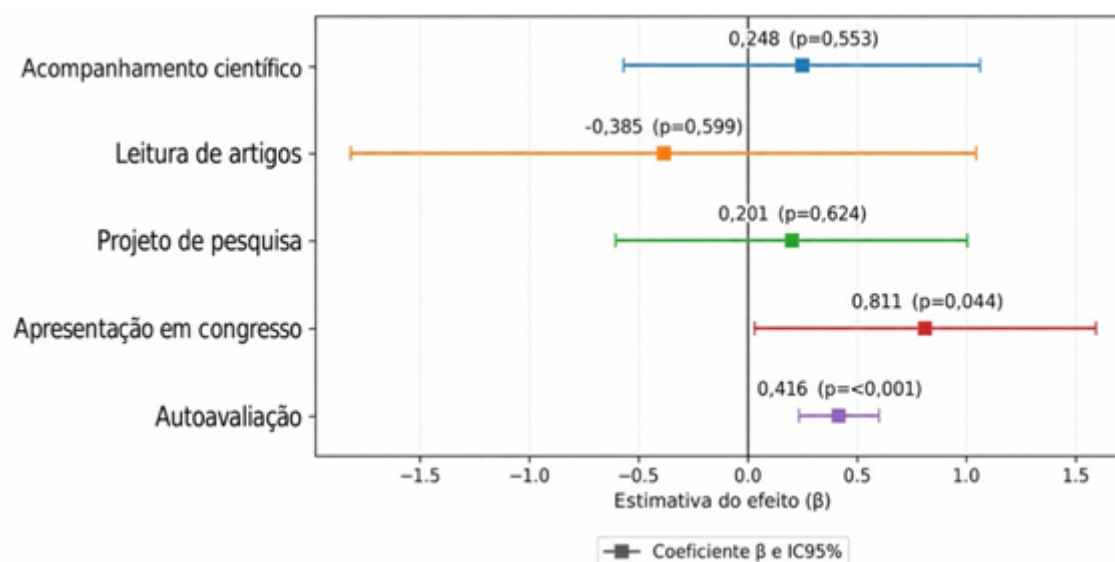


Figure 5. Results of the linear regression analysis with the objective performance score as the dependent variable (0–10). The binary categorical explanatory variables (yes/no) were scientific mentorship, scientific article reading, participation in research projects, and presentation of studies at scientific conferences. Self-perceived knowledge (self-assessment) was included in the model as a quantitative explanatory variable ranging from 0 to 10.



Discussion

The central hypothesis of this study, that medical students tend to overestimate their ability to interpret scientific articles and that this overestimation is significantly greater among students without scientific training experience, was supported by our findings. Therefore, our results are consistent with the pattern expected according to the Dunning–Kruger effect.

The Dunning–Kruger effect has been described in different educational settings, including the health sciences (CANADY & LARZO, 2023), although its occurrence appears to vary according to the population and the type of skill assessed. In general, individuals with lower levels of knowledge tend to overestimate their abilities to a greater extent than those with higher levels of knowledge (KRUGER; DUNNING, 1999; TABIBZADEH *et al.*, 2020). A similar pattern was observed in the present study, as students

with lower objective performance showed significantly greater overestimation of their competence, in addition to a negative association between objective performance and overestimation.

Overall performance on the objective questionnaire was low. The mean score corresponded to only 29.3% of the maximum possible score, and no participant achieved the maximum score. In addition, four of the five questions had correct response rates below 30%. These findings suggest that competencies related to the interpretation of RCTs remain insufficiently developed during undergraduate medical training. Previous studies have reported similar difficulties among medical students, particularly regarding the interpretation of methodological aspects, statistical concepts, and critical appraisal of the scientific literature (TAHERI *et al.*, 2008; ILIC & FORBES, 2010; YOUNG *et al.*, 2014). Similarly, Figueiredo *et al.* reported low familiarity among Brazilian students with statistical concepts commonly used in the medical literature. Taken together, these findings reinforce the importance of strengthening Evidence-Based Medicine education during undergraduate medical training.

Among the academic experiences evaluated, only the presentation of scientific work at conferences remained associated with better performance on the objective questionnaire after adjustment for the other variables. One possible explanation is that this type of activity requires active student participation in different stages of the scientific process, including literature review, interpretation of results, and discussion of the study with evaluators and other researchers. Such experiences may promote the development of skills related to the critical appraisal of scientific articles (LANDIM *et al.*, 2021). In contrast, participation in a research project under scientific mentorship without clearly defined educational goals, or reading scientific articles in an unsystematic manner without critical feedback, may not, by themselves, lead to an adequate and comprehensi-

ve understanding of scientific research concepts (SASANNIA *et al.*, 2022; DAOU *et al.*, 2022).

A cross-sectional study published in 2023 showed that students who received scientific mentorship perceived this model of supervision as an important component of scientific knowledge development. Mentored students reported improvements in the quality of their scientific work, research engagement, interest, learning, and scientific productivity during undergraduate training. Thus, mentorship may contribute to the development of competencies and skills required both for understanding the scientific method and for research-oriented education. However, active engagement from both mentors and students is necessary to achieve the best outcomes (QUINTANILHA *et al.*, 2023).

This interpretation is consistent with studies evaluating teaching strategies in Evidence-Based Medicine. Boedeker *et al.* demonstrated that students exposed to active learning methodologies performed better than those receiving traditional instruction alone. Similarly, Basheer *et al.* observed improvement in the critical appraisal of RCTs following a simulation-based educational intervention. Other studies have also shown that structured strategies for teaching critical appraisal of the scientific literature improve student performance (DAOU *et al.*, 2022; SASANNIA *et al.*, 2022). These findings reinforce the importance of educational approaches that promote active participation throughout the learning process.

The findings of this study have implications for medical education. The low performance observed indicates that skills related to the interpretation of randomized clinical trials require further development during undergraduate medical training. In addition, the association between presentation of scientific work and better performance suggests that strate-

gies encouraging active student participation in research activities may contribute to the development of these competencies.

Conclusions

Convenience sampling resulted in a predominance of students from private institutions located in the states of Espírito Santo, Minas Gerais, and Amazonas, which may limit the representativeness of the Brazilian medical student population. Nevertheless, this study provides relevant evidence showing that substantial gaps in scientific knowledge remain among medical students and are not fully addressed by scientific mentorship as currently structured. In contrast, the findings suggest that academic experiences involving active participation in scientific production, such as presenting research at scientific conferences, are associated with greater scientific literacy. In addition, the identification of a pattern consistent with the Dunning–Kruger effect in this sample, together with the low scores obtained on the objective assessment, indicates that medical students with lower levels of knowledge on the topic are those who tend to overestimate their abilities to the greatest extent.

From an educational and public policy perspective, these findings reinforce the need to strengthen the teaching of scientific methodology during undergraduate medical training. Such strategies may contribute to the education of better-prepared physicians, support safer clinical decision-making, and improve the quality of healthcare provided to the population. As a next step, multicenter studies with more representative samples, including public and private institutions from different regions of the country, may increase the external validity of these findings. In addition, educational interventions aimed at developing scientific competence

should be evaluated to determine their effectiveness in improving methodological knowledge and critical appraisal skills in the medical literature.

Author contributions

Conceptualization: RVL, JMS, GSDC, ISA, MSZ, RRS

Data curation: GSS, GQC

Formal analysis: GSS, GQC, APON, MBS

Investigation: APON, MBS

Methodology: GSS, GQC, APON, TFZ, MBS

Software: DSC

Supervision: TFZ

Validation: DSC

Visualization: DSC, APON

Writing – original draft: RVL, JMS, GSDC, ISA, MSZ, RRS

Writing – review and editing: JVCP

Conflict of Interest

The authors declare no conflicts of interest related to this study. This work was conducted independently, without influence from institutions, organizations, or sponsors that could affect the results or the interpretation of the data presented.

Data Availability

The authors declare that the data supporting the results of this study are available in the article. Derived data supporting the study's conclusions that are not found in the article may be requested from the corresponding author.

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