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Review

Application of Artificial Intelligence in Biostatistics for Medical Education

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Abstract

The integration of artificial intelligence into biostatistics has become an important issue in medical education, offering new ways to improve the accuracy and objectivity of data analysis. This review provides an overview of current studies on the application of artificial intelligence in biostatistics and identifies effective approaches for training future healthcare professionals. The aim of this review is to assess the current state of artificial intelligence use in biostatistics for medical education and its potential to improve training quality, objectivity of analysis, and the development of professional skills. A systematic literature search was conducted in Embase, Web of Science, Google Scholar, and Ovid Medline up to December 2024. Studies focusing on artificial intelligence applications in biostatistics and medical education were analyzed. From 1.000 identified publications, only seven met the inclusion criteria. Two explored artificial intelligence in evaluating biostatistical data quality, while five examined its role in student learning outcomes. Artificial intelligence opens new perspectives for biostatistics in medicine. Deep learning models achieved sensitivity up to 95.4% in clinical case analysis and visualization. The creation of an international biostatistical database could support the broader integration of artificial intelligence into education and strengthen students' understanding of statistical methods.

Ключевые слова: artificial intelligence, biostatistics, medical education, deep learning, data analysis, learning technologies.

1. Introduction

Artificial intelligence (AI) is increasingly being applied in biostatistics within medical education, particularly when dealing with complex and large-scale datasets. Methods such as machine learning and deep learning make it possible to process statistical information more efficiently and to extract meaningful patterns that would otherwise require considerable time and effort. For instance, deep learning models have demonstrated strong performance in tasks such as

recognizing patterns in clinical data and classifying medical images [1-2].

A persistent difficulty in medical education lies in the time-consuming nature of statistical analysis of extensive data sources, including imaging materials, experimental results, and biomedical records. Traditionally, this work required the direct participation of experienced specialists. By introducing AI-based approaches, however, it becomes possible to automate many of these steps. Students can receive standardized and reproducible feedback, which not only ensures objectivity in assessment but also supports the development of analytical skills and improves the overall quality of training in medical schools.

Basic artificial intelligence models rely on predefined attributes—such as color, shape, or texture—for data classification. In contrast, more sophisticated approaches, including convolutional neural networks (CNNs), are able to identify and extract relevant features without explicit programming. This capacity makes them particularly effective in processing unstructured materials, for example, medical images or raw clinical records. Increasingly, such methods are being introduced into educational platforms, where they assist medical students in analyzing statistical data and interpreting clinical cases with greater accuracy [3].

At the same time, incorporating AI into medical education requires careful oversight. Reliable outcomes depend on access to high-quality training datasets, transparent algorithmic design, and the use of standardized evaluation procedures [4-6]. Furthermore, AI applications must be validated under real-world conditions and updated regularly to align with evolving standards of medical training [7-11].

This review brings together current practices related to AI in biostatistics and medical education, assessing both their benefits and their limitations. Based on this analysis, several recommendations are proposed for the responsible integration of AI tools. The educational potential of these technologies is substantial, offering the possibility to:

- promote more interactive and personalized learning experiences;
- equip future healthcare professionals with the competencies needed to navigate an increasingly complex healthcare environment.

2. Methodology

A systematic search of the literature was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [12-14]. The databases Embase.com, MEDLINE via Ovid, Web of Science Core Collection, and Google Scholar were searched up to January 4, 2024.

The search strategy combined controlled vocabulary (e.g., MeSH and Emtree terms) with free-text key-words, using Boolean operators (AND, OR) and truncation symbols (*). The search terms reflected the main concepts of artificial intelligence, biostatistics, and medical education. Examples of the applied search strings are presented in Table 1.

Table 1 - Systematic literature search strategy

Embase.com (1971-)
('Artificial Intelligence'/exp OR 'Machine Learning'/exp OR 'Deep Learning'/exp OR '))
Medline ALL Ovid (1946-)
(Exp Artificial Intelligence/ OR exp Machine Learning/ OR exp Deep Learning/ OR Neural Networks, Computer/ OR Software/ OR Algorithms/ OR Automation/ OR Diagnosis, Computer-Assisted/ OR Image Processing, Computer-Assisted/)
Web of Science Core Collection (1975-)
TS= (((artificial* NEAR/2 intelligent*) OR (machine NEAR/2 learning) OR (deep NEAR/2 learning) OR (compute* NEAR/2 (aided OR assist* OR technique*)) OR software* OR algorithm* OR automat* OR (image NEAR/2 (processing OR matching)))
Google Scholar
"Artificial intelligence" OR "machine learning" OR "deep learning" OR "software" OR "algorithm" OR "automated" OR "image processing" OR "support vector"; "medical education" OR "clinical training" OR "digital learning" OR "e-learning" OR "computer-assisted instruction" OR "virtual simulation"

All retrieved records were imported into a reference manager, and duplicates were removed. Article selection was carried out in two stages: (i) screening of titles and abstracts, followed by (ii) full-text review of potentially relevant studies. Two reviewers independently assessed all records, with disagreements resolved through discussion and consensus. In addition, the reference lists of included publications were manually searched to identify further relevant sources not captured in the electronic search.

The inclusion criteria were:

- Studies describing AI algorithms applied to biomedical or biostatistical data in the context of education;
- Assessment of model performance (accuracy, sensitivity, specificity, reliability;
- Evidence of integration of AI tools into medical education, clinical training, or simulation platforms.

Exclusion criteria were:

- Studies employing outdated or purely theoretical AI methods without educational application;
- Publications without a clear biostatistical or medical education focus;
- Non-peer-reviewed sources such as editorials, commentaries, or opinion papers.

3. Results

A total of 1135 records were retrieved from electronic databases, including 520 from Embase.com, 150 from MEDLINE (Ovid), 250 from Web of Science, and 215 from Google Scholar. After the removal of 135 duplicates, 1000 unique publications were screened by title and abstract. Of these, 896 articles were excluded because they did not specifically address the use of artificial intelligence in biostatistics, were unrelated to medical education, or lacked direct relevance to the research objective. The remaining 114 publications were assessed in full text, and 105 were excluded for not meeting the inclusion criteria. No additional sources were identified through manual reference searching.

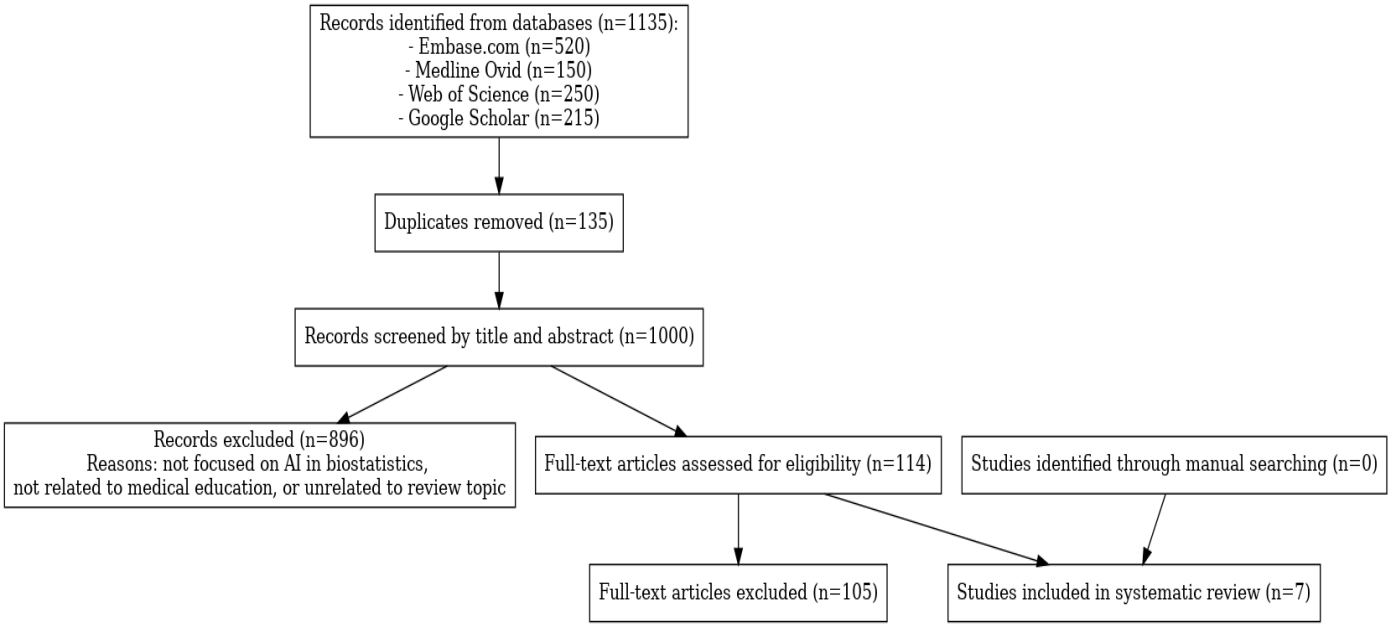

Figure 1 – PRISMA flow diagram

Ultimately, seven studies were included in the final systematic review. The key characteristics of these studies are summarized in Table 2. All of the included works were full-text articles focused on the application of AI to the analysis of biostatistical data in medical education.

Table 2 - Characteristics of seven studies on AI in biostatistics for medical education

First Author, Year, Country	Application Area	Type of AI Model	Training Data	Testing Data	Reference Standard
Ivanova, 2023, Russia [15]	Assessment of biostatistics learning outcomes	Red-Green Analysis Index	N/A	406	2 instructors
Nielsen, 2018, Denmark [16]	Diagnosis of learning difficulties	Nonlinear evaluation model	Unknown	N/A	4 instructors
Figueiredo, 2018, Portugal [17]	Identification of knowledge gaps	SVM model	N/A	1700	Final test data
Ismail, 2022, Malaysia [18]	Analysis of understanding statistical concepts	Classification algorithm after selection	N/A	18968	Verified student scores
Ketonen, 2019, Helsinki [19]	Assessment of engagement level	CNN	7910	1695	Unknown number of experts
Okamura 2022, Japan [20]	Evaluation of critical thinking in biostatistics	CNN	15,33	4784	3 instructors
Watson, 2018, Portugal [21]	Detection of calculation errors	CNN	2912	792	2 instructors

Among them, two studies described the use of AI for evaluating the quality of biostatistical data, while five studies examined student learning outcomes when AI was applied in biostatistical analysis (Table 3). Within the subgroup of studies related to educational programs, one assessed individual training effectiveness, whereas another evaluated outcome at the group level. Regarding the applied AI techniques, five studies employed CNNs as deep learning models, which required specific datasets for training. To validate model performance, all studies used separate test sets. In terms of reference standards, five studies relied on expert evaluations provided by instructors, one drew upon established data from a medical education database, and another used results from subsequent medical examinations.

Table 3 - Evaluation of the methodological quality of included studies

Author	Risk of Bias: Student Selection	Risk of Bias: Index Test (AI Model)	Applicability Concerns: Student Selection	Applicability Concerns: AI Model
Ivanova, 2023, Russia [15]	+	+	+	-
Nielsen, 2018, Denmark [16]	+	-	-	+
Figueiredo, 2018, Portugal [17]	+	-	-	-
Ismail, 2022, Malaysia [18]	+	+	-	-
Ketonen, 2019, Helsinki [19]	+	+	-	-
Okamura 2022, Japan [20]	+	-	-	+
Watson, 2018, Portugal [21]	+	-	-	-

Automated classification of educational data quality has potential applications in medical training, particularly for verifying the accuracy of student-entered values, assessing their statistical validity, and ensuring compliance with established standards [22-23]. Techniques such as color channel ratios and machine learning approaches, including SVM, have been explored for detecting data errors and evaluating training cases (Table 4).

Table 4 – Results of studies evaluating AI methods for automated classification of statistical data quality in educational cases

Study	Type of AI	Data Volume (frames / videos)	Specificity, %	Misclassification, %
Figueiredo, 2018, Portugal	R/G ratio	216 frames / 192 videos	78.2% / 63.0%	- / -
Watson, 2018, Portugal	Index model /SVM	41 videos	-	32%

However, the level of agreement between algorithmic outputs and expert assessments remains inconsistent, underscoring the need for further refinement and validation of these methods before broader adoption in educational practice.

4. Discussion

To the best of our knowledge, this is the first systematic review to provide a comprehensive overview of AI methods applied to biostatistics in medical education. Biostatistics is central to the preparation of future healthcare professionals, fostering skills in data analysis and critical reasoning. Yet, traditional teaching methods often face difficulties due to the complexity of statistical procedures and the limited opportunities for practical application. In this context, AI-driven approaches and the automation of data analysis can enrich the learning process by making it more visual, adaptive, and efficient.

Several studies demonstrate that AI, particularly CNNs, can be effective for tasks such as the automatic classification of data, interpretation of biomedical signals, and visualization of training datasets. For instance, CNN models have achieved high sensitivity and specificity in classifying medical data, underscoring their potential for educational use. However, only one study formally assessed model performance in terms of sensitivity and specificity, reporting high sensitivity values (86.5% and 95.5%) but only moderate specificity (78.2% and 63.0%) when evaluating the quality of educational materials. These findings suggest that AI can reliably identify and categorize relevant data, although false positives remain a concern, particularly when training datasets are small or inconsistently prepared. The application of AI in detecting key elements in biostatistics training cases—for example, recognizing data structures, identifying patterns, and spotting anomalies—has also shown encouraging outcomes, with sensitivity and specificity values reaching up to 96%. In studies using object-based evaluation (e.g., classification by case or task), sensitivity increased further, to as high as 98%. These results indicate that, with careful model calibration, AI systems can achieve performance comparable to experience instructors and deliver reliable analytical outcomes. At the same time, it should be noted that effective CNN models require access to large volumes of annotated training data. In biostatistics education, where such resources are often limited, this remains a key challenge.

Nevertheless, promising results have been obtained even with smaller datasets, particularly in the recognition of patterns in medical data and the development of personalized educational trajectories. In addition, AI has been applied to the automatic detection of calculation errors, assessment of student preparedness, and classification of tasks by difficulty level [24-25]. Despite these advances, most available studies remain heterogeneous in design and include relatively small participant samples, which precludes the conduct of a formal meta-analysis. Even so, the overall body of evidence highlights the potential of AI to accelerate the teaching of biostatistics, improve objectivity and reproducibility, and reduce instructor workload. Looking ahead, AI is likely to become an integral component of adaptive educational systems [26-27], supporting the effective training of future medical professionals in the analysis and interpretation of complex data.

5. Conclusions

This systematic review, conducted in line with PRISMA recommendations, identified only a limited body of literature addressing the application of artificial intelligence in biostatistics for medical education. From more than 1.000 records initially screened, just seven studies fulfilled all eligibility criteria, underscoring the modest representation of this topic within current research.

The majority of these works focused on the use of deep learning methods for the analysis of biomedical data and on evaluating student learning outcomes.

In summary, although the number of rigorous studies remains small, the review highlights several important avenues for integrating artificial intelligence into biostatistics teaching in medical education. Further empirical investigations are needed to improve the robustness, generalizability, and educational value of AI models, ensuring their effective application in future educational programs.

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Медициналық білім берудегі биостатистикада жасанды интеллектті қолдану

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Түйіндеме

Биостатистикаға жасанды интеллект әдістерін енгізу медициналық білім беруде өзекті болуда, себебі ол деректерді талдаудың дәлдігі мен объективтілігін арттыруға мүмкіндік береді. Мақаладағы шолу осы саладағы заманауи зерттеулерді жинақтап, болашақ денсаулық сақтау мамандарын даярлаудағы ең тиімді тәсілдерді

айқындайды. Медициналық білім беру жүйесінде биостатистикада жасанды интеллекты қолданудың қазіргі жағдайын бағалау және оның даярлық сапасын арттыруға, талдаудың объективтілігін күшейтуге және студенттердің кәсіби құзыреттерін қалыптастыруға әлеуетін анықтау. 2024 жылғы желтоқсанға дейін Embase, Web of Science, Google Scholar және Ovid Medline дерекқорларында жүйелі әдеби іздеу жүргізілді. Биостатистика мен медициналық білім беруде жасанды интеллекты қолдануға арналған жарияланымдар талдауға енгізілді. Анықталған 1000 жарияланымның тек жетеуі ғана іріктеу критерийлеріне сәйкес келді. Олардың екеуінде жасанды интеллект биостатистикалық деректердің сапасын бағалау үшін қолданылды, ал бесеуінде студенттердің оқу нәтижелеріне ықпалы қарастырылды. Жасанды интеллект әдістері медициналық саладағы биостатистиканы қолдану мүмкіндіктерін кеңейтеді. Атап айтқанда, тереңдетіп оқыту үлгілері клиникалық жағдайларды талдау мен визуализациялау барысында 95,4%-ға дейін сезімталдық көрсетті. Халықаралық биостатистикалық деректер базасын құру жасанды интеллекты білім беру процесіне кеңінен енгізуге және студенттердің статистикалық әдістерді тереңірек меңгеруіне ықпал етуі мүмкін.

Түйін сөздер: жасанды интеллект, биостатистика, медициналық білім, терең оқыту, деректерді талдау, оқыту технологиялары.

Применение искусственного интеллекта в биостатистике медицинского образования

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Abstract

Интеграция методов искусственного интеллекта в биостатистику приобретает все большее значение в медицинском образовании, так как позволяет повысить точность и объективность анализа данных. Настоящий обзор обобщает современные исследования в данной области и выделяет наиболее эффективные подходы к подготовке будущих специалистов здравоохранения. Целью обзорной статьи является оценка текущего состояния применения искусственного интеллекта в биостатистике медицинского образования и определить его потенциал для повышения качества подготовки, объективности анализа и формирования профессиональных компетенций студентов. Систематический поиск литературы был проведен до декабря 2024 года в базах Embase, Web of Science, Google Scholar и Ovid Medline. В анализ включены публикации, рассматривающие применение искусственного интеллекта в биостатистике и медицинском обучении. Из 1000 выявленных публикаций только семь соответствовали критериям отбора. В двух из них искусственного интеллекта использовался для оценки качества биостатистических данных, в пяти — для изучения влияния на результаты обучения студентов. Методы искусственного интеллекта расширяют возможности применения биостатистики в медицине. В частности, модели глубокого обучения достигали чувствительности до 95,4% при анализе и визуализации клинических случаев. Создание международной базы биостатистических данных может способствовать более широкому внедрению искусственного интеллекта в образовательный процесс и углубить понимание статистических методов студентами.

Keywords: искусственный интеллект, биостатистика, медицинское образование, глубокое обучение, анализ данных, обучающие технологии.