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Status of artificial intelligence and machine learning in Indian traditional medicine systems- A systematic review

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The traditional medicine system is gaining more importance and has provided a lot of very important drugs for modern medicine. However, traditional medicines lack strong scientific evidence by modern pharmacology standards, and the safety and efficacy of such interventions have not been established. Machine learning (ML) and artificial intelligence (AI) can play a significant role in various aspects of the Ayush (Ayurveda, Yoga, Naturopathy, Unani, Siddha, and Homeopathy) system to provide scientific evidence. Therefore, this systematic review aims to understand the gaps in ML and AI applications in Ayush systems and provide research directions for future researchers in these fields. We have conducted literature searches using databases such as Scopus, PubMed, IEEE Xplore, and Science Direct to retrieve published and unpublished research articles related to the use of -ML and AI in Ayush systems. We have included various study designs, such as case studies, case series, cohort studies, case-control studies, RCTs, and non-randomized controlled trials. We have included the articles that were written in English. Our systematic review identifies gaps in the use of ML and AI in these fields, providing research directions. Indian traditional medicine systems have shown some usage of DL and ML, with yoga and Ayurveda being the most commonly used. However, other areas such as diagnosis, prognosis, biomarker identification, and pharmacokinetics hold potential for the adoption of ML and DL. Evidence-based medicine and the proper use of ML and DL techniques in all areas of Ayush research are crucial for precision medicine.

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KEYWORDS

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Introduction

Traditional Medicine (TM) is a collection of medical procedures and practices that have been used for a long time. It prioritizes holistic and individualized approaches to patients, in contrast to Western (allopathic) medicine, which emphasizes suppressing undesirable symptoms and providing faster relief [1]. Around the world, there has always been a demand for using traditional medication as an alternative, and complementary medicine has

always existed [2]. According to the World Health Organization (WHO), around 80% of the world's population uses traditional medicine. The Indian Traditional Medicine System includes Ayurveda, Yoga, Unani, Siddha, Sowa-Rigpa, and Homoeopathy (Ayush) and is one of the world most prominent and oldest traditional medicine systems. 40 per cent of people in the western countries use herbal medicine for some ailments and in India, 7% of the population seek outpatient care relies on Ayush medicine for primary care [3]. Although Western medicine is currently dominant in the mainstream of healthcare practices, integrating Ayush systems with biomedicine could greatly improve the effectiveness of India's healthcare system [4]. In India, Ayush medicine has steadily gained recognition as an alternative treatment for non-communicable diseases [5-7], and infectious disease conditions [8,9] and has played a significant role in managing disease in India [10,11]. In drug discovery, reverse pharmacology and pharmacognosy screen new molecules to evaluate traditional medicines and plant extracts.

In terms of theory, practice, and data, Ayush and Western medicine are fundamentally different. Disease symptoms, prevention and diagnosis methods, drug formulas, and proportions are some of the important data available in Ayush texts [1]. To align with the gradual increase in the usage and generation of Ayush data, pragmatic tools, and techniques are required to analyze and extract the hidden relationships, information, and knowledge ensembled in the data to enhance its utility in medical and treatment decisions [12]. Although Ayush systems have been used for thousands of years, the lack of procedures to gather practice-based evidence triggers the need for additional research. Recent developments in machine learning (ML) techniques and artificial intelligence (AI) look promising to significantly improve data analysis and evidence presentation in the field of Ayush systems. The Ministry of Ayush digital efforts were an essential component in the process of reforming the old medical systems. This initiative had the potential to enhance education, the quality of research, and the accessibility of the Ayush healthcare services [13].

In the past decade, the application of AI and ML in healthcare has accelerated prediction, diagnosis, and preventive methods aimed at supporting professionals in clinical decision-making [14,15]. Recent evidence states the initial efforts to implement AI in Ayush and alternative medicines [16-18]. Integrating ML methods or AI extracts valuable information from huge Ayush datasets, which in turn paves the way for future research on drug discovery, ethnopharmacology, pharmacodynamics, and drug precision [19,20]. A few studies looked into combining ML and deep learning (ML/DL)- based AI techniques in the Ayush system of medicines [21]. To the best of our knowledge, no systematic review was performed to gather and synthesize outcomes from ML /AI-based studies implemented in the Ayush system.

Aim and objectives

This systematic review aims to collect, analyse, and consolidate results from available research studies that explored the application of ML and AI techniques in any Ayush system to enhance the understanding of the current status of ML and AI in this system of medicine and to identify the potential areas where ML and AI can be tapped effectively to bring more evidence-based medicine into Ayush streams.

Experimental

Search strategy

Initial searches were performed in four electronic databases: PubMed, SCOPUS, IEEEXplore, and Science Direct, followed by manual searches from the National Institute of Health and the Ayush Research Portal

(http://www.ayushportal.nic.in). While searching databases, the search terms were continually examined to make sure they reflected terminology changes in the subject area. The period taken into consideration is until April 30, 2023, without a start date. Only publications in English are taken into account for the review.

The following search terms: "Ayush, Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowgaripa, traditional medicine, indigenous medicine, complementary medicine, herbal medicine, alternative medicine, natural medicine, holistic medicine, unconventional medicine for Ayush interventions, and artificial intelligence, machine learning, NLP, natural language processing, knowledge discovery, KDD, algorithm, and data mining" were used to build the search strategy. "Booleans" operators were also used in the search strategy, such as AND, OR, and NOT, to acquire the best information between the following keywords. The search strategy for individual databases has been provided in Appendix 1. This systematic review followed PRISMA guidelines [22].

Inclusion and exclusion criteria

Research studies conducted in Ayush (Ayurveda, Yoga, Naturopathy, Unani, Siddha, Sowa-Rigpa, and Homeopathy) systems of medicine using any form of machine learning or deep learning algorithms or artificial intelligence tools published in English are considered. No limitation is kept for the type of study design, as this systematic review is to explore the possible areas for application of these methods in the future.

Selection and extraction of data

All the data from the eligible studies were extracted, title screening, abstract screening, and full-length screening in a Microsoft Excel sheet by the two authors autonomously (MP, DK), and consensus if any during the whole process was addressed by the third author (MBD). The name of the first and corresponding author, journal name, year of publication, affiliation, country, objectives of the study, sample size, and type of analysis were extracted from (mention the number of) articles. In addition, intervention details such as types of systems of medicine and the purpose of the study (fundamental research, drug identification, herb identification, pose identification, and correction) were collected. Outcome-related information, including the type of analysis, machine learning, deep learning algorithms used, and AI methods employed with reasons for the method of choice, such as text analytics, image processing, and video processing, was also captured in the data extraction form. All evaluations were carried out individually by the authors (MP, DK), and any discrepancies that occurred were resolved through discussions with the third author (MBD).

Assessment of the risk of bias

The risk of bias in the included studies was assessed by the JBI risk of bias assessment tool applicable to specific studies. The tools were adopted due to their inclusive nature. The risk of bias assessment included a clear objective of the study defined, selection criteria, settings, unit of measurement, groups comparable, time of exposure, statistical methods used, sample frame, sample size, incomplete outcome data, and selective reporting. This systematic review followed PRISMA guidelines [22]. The data is not supported to do meta-analysis.

Results

A total of 599 articles were initially found in 4 different databases. After using automation tools, 172 duplicates and 78 articles that did not meet the eligibility criteria were removed, resulting in 349 articles. Further screening of abstracts led to the removal of 204 articles, leaving 145 articles. However, 34 of these did not meet the inclusion criteria for ML or AI. Out of the remaining 111 articles, the full text of 37

articles was not available for review despite multiple attempts to retrieve it, and 7 articles were not relevant to Ayush interventions. Finally, after a thorough review, 54 out of the 111 articles that met all the inclusion and exclusion criteria were selected for full article review, as displayed in Figure 1.

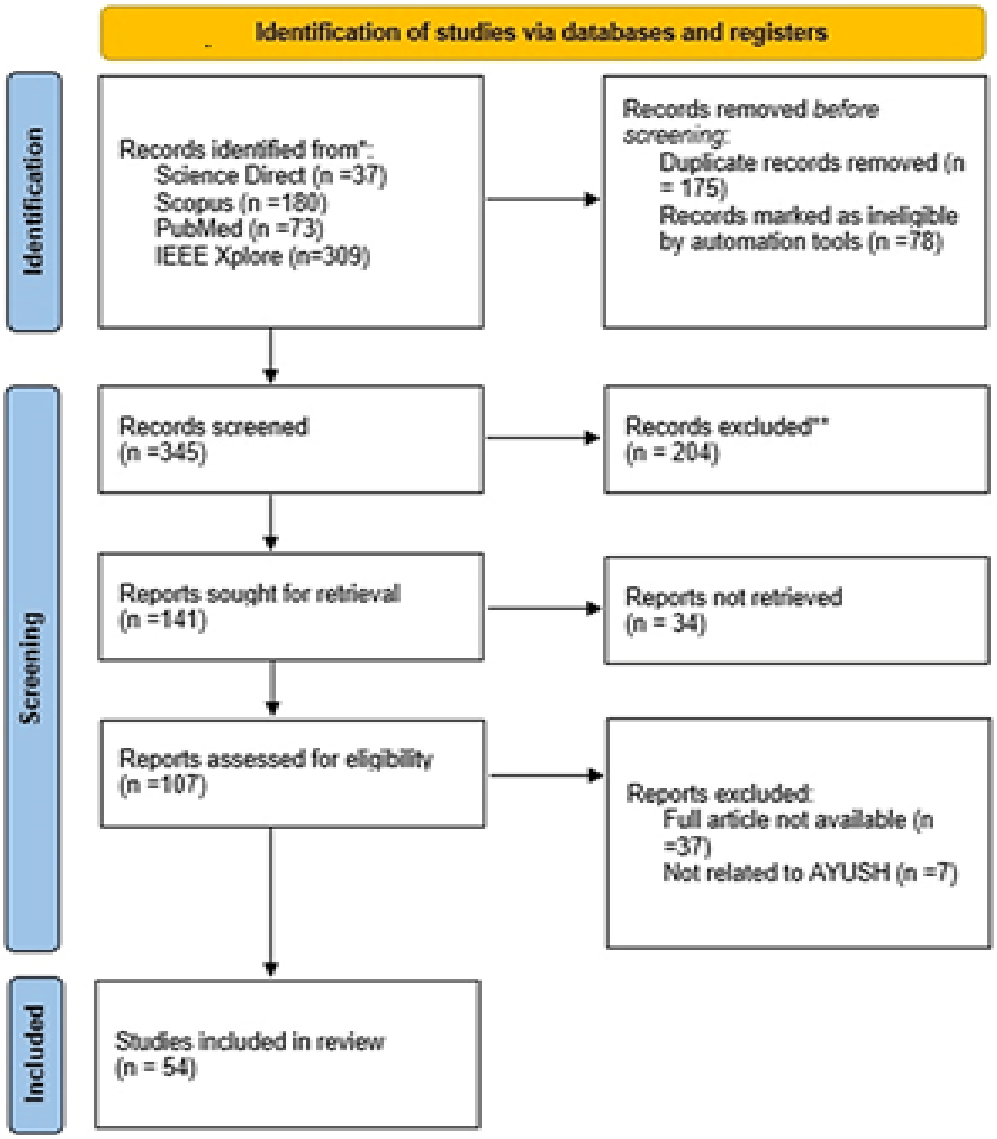

FIGURE 1 PRISMA flow diagram of included studies, we identified 54 articles from PubMed (MEDLINE), EMBASE, and Cochrane Library

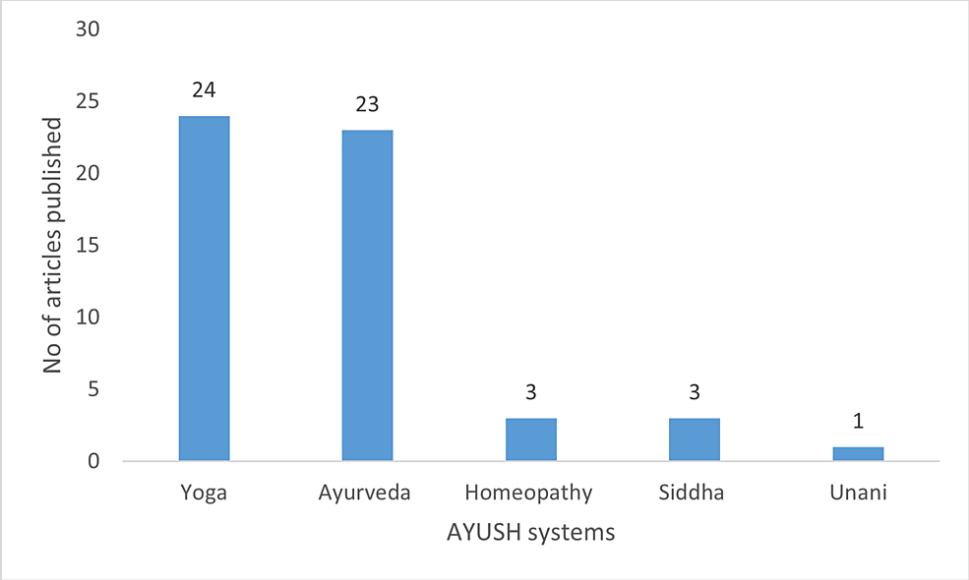

FIGURE 2 Number of articles published by Ayush system using ML and AI Geographical Distribution of Reviewed Articles

Out of the 54 articles, 36 are from India, while the other 12 are from various Asian countries such as China, Indonesia, Japan, Korea, Oman, Sri Lanka, and Thailand. The remaining articles come from the USA, Africa, Australia, and Europe. The use of machine learning (ML) and artificial intelligence (AI) in IT management has gradually increased from 2009 to 2022.

System-wise analysis

Out of the 54 studies that were reviewed, 24 were related to Yoga, 23 were related to Ayurveda, 3 were related to Siddha, 3 were related to homeopathy, and 1 was related to Unani, as depicted in Figure 2. The majority of the ML and AI research on Yoga was published in India (16 out of 26), while the rest were from other Asian countries. Indian articles accounted for 18 out of 23 research studies in Ayurveda, 14 out of 24 research studies in Yoga, 2 out of 3 research studies in Homeopathy, and 3 out of 3 research studies in Siddha.

TABLE 2 Type of Machine learning and Deep learning methods adopted

Study ID	SVM	K Means	Random Forest	Naïve Bayes	Logistic regression	PCA	Decision tree	KNN	PNN	CNN	ANN	DNN	AI
[23]	Yes	No	No	No	No	No	No	No	No	No	No	No	No
[24]	No	No	No	No	No	No	No	No	No	Yes	No	No	No
[25]	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No
[26]	No	No	No	No	No	No	No	No	No	Yes	No	No	No
[27]	Yes	No	No	No	No	No	No	No	No	No	No	No	No
[28]	Yes	No	No	No	No	No	No	No	No	No	No	No	No
[29]	Yes	No	No	Yes	Yes	No	No	Yes	No	No	No	No	No
[30]	No	No	No	No	No	Yes	No	No	Yes	Yes	No	No	No
[31]	No	No	No	No	No	No	No	No	No	No	No	No	No
[32]	No	No	No	Yes	Yes	No	Yes	No	No	No	Yes	No	No

[33]	No	No	No	No	No	No	No	No	No	No	No	No	No
[34]	No	No	No	No	No	No	No	No	No	No	No	No	No
[35]	No	No	Yes	No	No	No	No	No	No	Yes	No	No	No
[36]	Yes	No	Yes	No	No	No	No	Yes	No	Yes	No	No	Yes
[37]	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No
[38]	No	No	No	Yes	No	No	No	Yes	No	Yes	No	No	No
[39]	Yes	No	No	Yes	No	No	No	Yes	No	No	No	No	No
[40]	Yes	No	No	Yes	No	No	Yes	Yes	No	No	Yes	No	No
[41]	No	No	No	No	No	No	No	No	No	No	Yes	No	Yes
[42]	No	No	No	No	No	No	Yes	No	No	No	No	No	No
[43]	No	No	No	No	No	No	No	No	No	No	No	Yes	No
[44]	No	No	No	No	No	No	No	No	No	No	No	No	Yes
[45]	No	No	No	No	No	No	No	No	No	No	No	No	Yes
[46]	No	No	No	No	No	No	No	No	No	No	No	No	No
[47]	Yes	No	No	Yes	No	No	No	Yes	No	No	Yes	No	Yes
[48]	No	No	No	No	No	No	No	No	No	Yes	No	No	No
[49]	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No
[50]	No	No	No	No	No	No	No	No	No	No	No	No	No
[51]	Yes	No	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes
[52]	No	No	No	No	Yes	No	No	No	No	No	No	No	No
[53]	No	No	No	No	No	No	No	No	No	No	No	No	No
[54]	No	No	No	No	No	No	No	No	No	No	Yes	No	No
[55]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[56]	No	No	No	No	No	No	No	No	No	Yes	No	No	No
[57]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[58]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[59]	No	No	No	No	No	No	No	Yes	No	No	No	No	No
[60]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[61]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[62]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[63]	No	Yes	No	No	No	No	No	Yes	No	No	No	No	No
[64]	No	Yes	No	No	No	No	No	No	No	No	No	No	No
[65]	No	No	No	No	Yes	No	No	No	No	No	No	No	No
[66]	No	No	Yes	No	No	No	No	No	No	No	No	No	No
[67]	No	No	No	No	No	No	No	Yes	No	No	No	No	No
[29]	Yes	No	No	No	No	No	No	Yes	No	No	No	No	No
[68]	Yes	No	No	No	No	No	No	No	No	No	No	No	No
[69]	Yes	No	No	No	No	No	No	No	No	No	No	No	No
[70]	No	Yes	No	No	No	No	No	No	No	Yes	No	No	No
[71]	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No
[72]	No	No	No	No	No	No	No	No	No	No	Yes	No	No
[73]	No	No	No	No	No	No	No	No	No	No	Yes	No	No
[74]	No	No	No	No	No	No	No	No	No	No	No	No	No
[75]	No	No	No	No	No	No	No	No	No	Yes	No	No	Yes

*SVM: Support vector machine, ANN: Artificial Neural network, CNN: Convolutional neural network, DNN: Deep neural network, KNN: k Nearest Neighbor, PNN: Probabilistic Neural network, AI: Artificial neural network, and PCA: Principal Component analysis

Types of research studies

Broad areas of research in Indian traditional medicine (Ayush) are classified as Basic research exploring fundamental concepts (Tridosha concept in Siddha and Ayurveda system of medicine), Text analytics, Drug Discovery, Diagnosis, Treatment, Drug standardization, and Pose correction in Yoga. Out of 54 studies in this review, a major (37%) proportion focused on Yoga Pose recognition and pose correction, 10 studies on basic research in the Traditional medicine system, 11 studies on Diagnosis and Treatment, and 13 studies on Drug identification and standardization as shown in table 2. Ayurveda studies focused more on Drug identification (12/23) followed by Fundamental research (7/23), whereas yoga mostly focused on pose correction (14/24) followed by pose recognition (6). In Siddha, 2 articles are related to fundamental research and another 1 for Treatment. Diagnosis and treatment procedure articles are the 2 available for Homeopathy. The only study found in the Unani system of medicine was on Drug standardization.

TABLE 2 Type of research done by Ayush system

	Ayurveda	Homeopathy	Siddha	Unani	Yoga
Basic research	8	0	2	0	0
Drug identification	12	0	0	1	0
Treatment	3	3	1	0	4
Yoga pose correction	0	0	0	0	20
Total	23	3	3	1	24

Types of Machine learning or deep learning algorithms used

57% of the studies used Machine learning (ML) techniques namely Logistic Regression, Support vector machine (SVM), K-Nearest Neighbor (KNN), and Decision tree and 43% used Deep learning (DL) techniques, namely Convolutional neural network (CNN) and Artificial Neural Network (ANN). Ayurveda and Yoga used ML and AI equally around 50% whereas Siddha, Homeopathy, and Unani system didn't use AI techniques. Within the system of yoga, AI methods are predominantly used for yoga pose detection and correction. ML and AI both were used in 8/23 studies for exploring fundamental research in Ayurveda. Convolutional neural network (CNN) is the most commonly used Algorithm in AI methods and SVM among ML methods, as shown in Table 1. 14 out of 31 studies that used ML achieved accuracy of more than 95% 2 out of 32 studies achieved accuracy less than 40% and 8 studies not reported accuracy achieved. Similarly, AI shows that 12 out of 23 studies achieved more than 95% accuracy, 7 reported less than 95 % accuracy, and 5 didn't report the accuracy they achieved.

Discussion

This systematic review reveals that ML and AI have been used in all ITM systems, with a relatively high usage in Yoga followed by Ayurveda for Drug identification, fundamental research, and yoga pose correction. AI methods usage in Ayush is progressing over machine learning because of the nature of data (non-linear) that we get from traditional medicine. Support vector machine algorithm (SVM) and Convolutional neural network (CNN) are the most commonly used methods. The Asian continent accounts for nearly 85% of the studies in Ayush that use deep learning and machine learning. The bulk of these is from India and use traditional Indian medicine.

Traditional Chinese medicine, Kampo, Koryo, and Sri Lankan medicine are among the various traditional medical practices practiced for several centuries throughout the Asian continent [76]. An expansion of research on Ayush medicine is observed in diverse geographical areas, as demonstrated by studies from the USA, Africa, Australia, and Europe. Medical universities from European countries like Italy, Germany, and the UK recognize Ayurveda medicine in their medical education [77].

Trends of machine learning and deep learning usage in medicine are increasing drastically, especially in Western medicine and Traditional Chinese medicine. In Traditional medicine it has been used to address the problem of diagnosis, prognosis, text analytics, basic research, herb identification, syndrome differentiation, and precision medicine [78-80]. The Ayush research portal and DHARA are two important initiatives by ministry of Ayush (MoA) to store and retrieve paper published in Ayush systems. Another two significant contributions by government are implementing A-HMIS a database of Ayush beneficiaries and Ayush Suraksha to document the adverse drug events. Ministry of Ayush has recently created an umbrella project to bring all digital interventions under one roof called AYUSH Grid [81].

Government has made significant effort in digitizing Ayush research and innovations, using these data, ML and AI can empower Ayush systems by providing personalized care, optimizing treatments, and advancing research.

In ITM, the research is classified into 5 broad domains Literature, fundamentals or basic research, drug development, pharmaceutical, and clinical research[82]. Though there are five broad domains, ML and AI are predominantly applied in Drug Development, Treatment research, and yoga poses correction. More than half of the studies in the review applied Machine learning some studies used a single algorithm and some used multiple techniques together to get better results. SVM is the most commonly used algorithm followed by Random Forest either alone or with some other ML and deep learning algorithms. This result is similar to another systematic review on predicting medical images conducted by Rana and Bhushan where the combination of CNN, random forest, and SVM provided more accuracy [83].

In traditional medicine research, Machine learning, and deep learning could bring out more scientific evidence because of their ability to handle nonlinear data, which is more commonly seen in TM practices and TM-based data sets [84]. ML and DL were applied mostly for classification and clustering followed by text analysis and image processing. In this review, the classification technique has been used predominantly in Ayurveda and Yoga systems of medicine. Similarly, TCM used classification algorithms more commonly for Herbal medicine identification, disease risk prediction, and Herbal analysis.

Deep learning models gave more accurate results compared to machine learning models. Though DL provides more accurate results, proper de-noising methods have to be used to overcome the problems of data in the healthcare industry [83].

Conclusion

Machine learning and AI techniques have been adopted in Indian traditional medicine, with a majority of these papers focusing on the Ayurvedic and Yoga systems. The priority areas for research were drug and herb identification, and yoga pose identification. However, this review highlights that there is still much to be explored and advanced in the field of Ayush. While traditional medicine systems globally have garnered extensive research, Ayush offers untapped potential for groundbreaking drug discoveries and diagnostic tools.

Personalized medicine is the next goal for today's pharmaceutical industries. Siddha and

Ayurveda already use personalized medicine based on Prakrithi as their basic concept. Prakriti refers to an individual's behavioral trait, which is determined at birth and cannot be altered later. This concept is similar to genomics, and its combination, named Ayur genomics, takes Ayurveda from personalized medicine to precision medicine. The application of computational methods involving machine learning, deep learning, and artificial intelligence can verify such fundamental principles in traditional medicine.

Recommendations

Precision medicine is essential in the modern scientific world and can only be achieved through evidence-based medicine. Therefore, there is a significant requirement for a database that includes all aspects affecting an individual's health, including patients' data, prescription data, drug-drug interaction, drug target interaction, environmental aspects, etc. in Ayush systems. Proper utilization of machine learning and deep learning methods in all dimensions of Ayush research can lead to the future of Indian traditional medicine taking a global stand. Many research dimensions of individual health systems in Ayush have yet to be explored.

AI can help codify and analyze vast amounts of traditional knowledge, making it accessible for future generations and enriching research efforts. Modern computational methods can generate strong evidence, but machine intelligence has to be evaluated and used based on human intelligence, as we are dealing with people's lives.

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Authors' Contributions

Prakash Muthuperumal (PM): involved right from Conceptualization, research question, Methodology, Analysis, Draft writing and revision. Dr Dhivya Karmegam (DK).: Provided additional support in data collection, designing search strategy, Risk of bias assessment and finalizing the manuscript. Prof: Bagavandas mappilairaju (MBD) was involved in Conceptualization, Supervision, methodology, manuscript finalization

Conflict of Interest

The authors have declared that no competing interests exist.

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