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AI IN MALNUTRITION DETECTION: A COMPREHENSIVE REVIEW OF METHODS AND CHALLENGES

Piyush*
Tanuj Yadav**
Shreya Jha***
Ms. Ruchi Patira****

Abstract

Malnutrition has been a global health issue that can affect anyone at any age, be it kids or elderly. Malnutrition refers to the biological process whereby an organism does not receive enough nutrients or energy needed to thrive, leading to serious diseases. The strategic unification of Artificial Intelligence (AI) in identifying such incidences plays a vital role in early diagnosis and prevention of such issues. This review critically analyzes many recent publications on the applications of AI in the detection of malnutrition in different populations, methodologies and challenges faced. The reviewed studies demonstrate the increasing adoption of Machine Learning (ML) and Deep Learning (DL) methods in malnutrition screening with supervised learning models and classifiers being the most preferred models. Also, image-based approaches using transformations on Convolutional Neural networks (CNN) or various transfer learning approaches based on pre-trained deep learning networks have been focused mostly on detecting child malnutrition. AI-driven frameworks have also been investigated for elderly nutrition monitoring and diet-related diseases diagnosis, but barriers to implementation continue to exist. One of the major conclusions of our review is that; a lot of exciting advances have been reported to develop AI-based models to identify malnutrition, but over 90% of these have been abandoned and are not using clinical practice. The motive for this discrepancy could be multi-fold, including limited dataset availability, differences in dietary patterns, and the absence of validated screening tools across various populations and groups of patients. Moreover, malnutrition detection using AI at hospitals previously was difficult as there was an inconsistency in meal tracking and patient data collection. The review highlights the problem of highly sophisticated systems that are difficult to train but need to be highly accurate and reliable for different populations. Hence, this review is very beneficial for anyone working to fight malnutrition. It connects the dots between cutting-edge AI research and real-world clinical practice, helping us make a bigger impact.

Keywords: *Malnutrition, Artificial Intelligence (AI), Machine Learning, Image Recognition.*

Introduction

The global health crisis of malnutrition impacts millions of people mainly among young children together with elderly adults and people who suffer from persistent illness conditions. Severe medical complications arise from malnutrition which causes growth delays and weakens immune functions while expanding disease vulnerability. Currently, 1 of 10 people is older than 65 y; the WHO has estimated this number to be 1 of 6 in 2050. Malnutrition is an increasing health problem in people older than 65 y even in developed countries and in nursing homes, hospitals, and acute care units [1]. The condition of malnutrition continued as a major worldwide issue in 2020 since it affected millions of young children. In 2022 WHO reported that wasting affected approximately 45 million children below five years of age at a

* BTech Artificial Intelligence Student, Department of Computer Science, World College of Technology and Management, Gurugram, Haryana, India.
** BTech Artificial Intelligence Student, Department of Computer Science, World College of Technology and Management, Gurugram, Haryana, India.
*** BTech Artificial Intelligence Student, Department of Computer Science, World College of Technology and Management, Gurugram, Haryana, India.
**** Assistant Professor, Department of Computer Science, World College of Technology and Management, Gurugram, Haryana, India.

rate of 6.8% while severe wasting affected 13.6 million children at a rate of 2.1%. More than three-quarters of Asia and another 22% of Africa was home to these severely malnourished children. [2] The tragic numbers reveal that society needs immediate action for fast and efficient detection methods alongside intervention strategies to tackle malnutrition. Artificial intelligence (AI) systems show potential to solve worldwide health obstacles through their merging with screening and diagnostic activities.

Next-generation technological approaches with artificial intelligence deliver effective ways to boost the quality and speed of malnutrition screening procedures. Current methods for malnutrition detection have several weaknesses because they depend on manual assessments, questionnaires and clinical observations which produce inconsistent results between different healthcare environments and geographical areas [3]. AI-powered system integration delivers stronger reliability alongside scalability by means of its ability to handle extensive datasets along with pattern recognition capabilities which yield early warning indicators inaccessible to human evaluators.

Convolutional neural networks together with machine learning and deep learning techniques show remarkable potential to detect malnutrition by analyzing both medical data and images in both children and adult populations [4]. The integration of AI into hospital systems enables continuous observation of patient nutrition through system-monitoring and risks of malnutrition assessment [5]. The application of AI-driven methods extends to medical detection of diseases because fuzzy-based learning systems help improve both accuracy and clinical choices in cancer diagnosis also [6]. Such AI models demonstrate their capacity to detect malnutrition in early stages thus enabling healthcare professionals to provide proper interventions and better treatment for their patients.

The adoption of AI-based detection systems for malnutrition encounters multiple implementation difficulties. The implementation of AI in clinical practice faces challenges because of restricted healthcare data diversity together with limited dietary data quality while screening practices remain inconsistent. Implementation of AI solutions faces barriers from ethical considerations which combine with data privacy challenges alongside requirements for human supervisors for effective deployment.

Literature Review

[7] The research paper titled "Artificial Intelligence in Malnutrition: A Systematic Literature Review" discusses the growing utilization of AI in screening and diagnosing malnutrition cases. The study reveals that a significant majority of AI models are not actively integrated into life scenarios. Supervised learning emerged as the AI method used in this context with an emphasis placed on malnutrition associated with various diseases. Key obstacles highlighted in the study include the uptake of AI technologies in practice and the call for more diverse datasets along, with comprehensive validation processes.

[8] In the study titled "Malnutrition Detection using AI" the researchers suggest a model that employs Convolutional Neural Networks (CNNs) to identify malnutrition, in kids efficiently using images. The program automates the categorization of kids, as either healthy or malnourished based on images. This method presents a scalable option compared to evaluations. It improves detection. Lessens the lasting effects of malnutrition.

[9] In the paper titled “Recognizing and Predicting the Risk of Malnutrition in the Elderly Using Artificial Intelligence: A Systematic Review”, the authors delve into utilizing AI techniques to evaluate the risk of malnutrition in individuals. The research emphasizes the significance of monitoring food intake and identifying deficiencies to enhance healthcare. However, the authors point out that differences in habits influenced by geography and culture obstacles to AI driven assessment models. They propose the establishment of recommendations, in healthcare facilities to address this challenge.

[10] Research on artificial intelligence in malnutrition detection receives bibliometric analysis in “Artificial Intelligence in Malnutrition Research: A Bibliometric Analysis” by the authors. The study demonstrates that machine learning stands as the dominant form of AI technique alongside deep learning and neural networks. The conducted research established malnutrition prediction as the primary objective while reinforcing the potential of both reinforcement learning and transfer learning.

[11] Scientists developed an AI diagnostic model for identifying malnutrition in acute abdomen patients using GLIM criteria according to the paper “Artificial Intelligence-Driven Malnutrition Diagnostic Model for Patients with Acute Abdomen Based on GLIM Criteria”. A machine learning system uses the Global Leadership Initiative on Malnutrition criteria to improve diagnostic precision in the study. The AI-based method helps medical staff identify patients early for intervention measures leading to better healthcare results.

Comparative Analysis

S. No.	Title	Year	Author	Description
1	Artificial Intelligence in Malnutrition: A Systematic Literature Review	2024	Sander MW Janssen, Yamine Bouzembrak, Bedir Tekinerdogan	This paper reviews artificial intelligence (AI) tools for malnutrition detection, highlighting the gap between development and clinical use to improve diagnosis and treatment.
2	Recognizing and Predicting the Risk of Malnutrition in the Elderly Using AI	2024	Joyeta Ghosh	This paper focus on AI predicts elderly malnutrition risk by analyzing nutrient intake and deficiencies, emphasizing standardized hospital diets for improved monitoring
3	AI-Driven Malnutrition Diagnostic Model for Patients with Acute Abdomen	2024	Wei Ma, Bin Cai, Yu Wang, Lu Wang, Ming-Wei Sun, Charles Damien Lu, Hua Jiang	This paper describe AI-driven model diagnoses malnutrition in acute abdomen patients using GLIM criteria, enhancing clinical efficiency and early detection
4	Malnutrition Detection using AI	2023	Bhakti Vichave, Nikhil Jain, Pankaj Garad, Namit Gandhi, Dewanand Meshram	The objective of this paper Uses AI and CNNs to detect child malnutrition via image analysis, enabling early, automated, and cost-effective diagnosis to improve healthcare outcomes
5	Artificial Intelligence in Malnutrition Research: A Bibliometric Analysis	2023	Herman Yuliansyah, Sulistyawati, Tri Wahyuni Sukesi, Surahma Asti Mulasari, Wan Nur Syamilah Wan Ali	This paper focus on Bibliometric analysis highlights AI trends in malnutrition research, with machine learning and deep learning emerging as key predictive tools

Challenges & Future Direction

The promising revolutionizing potential of AI for detecting malnutrition meets multiple barriers that slow down its universal implementation. The main hurdle in adopting malnutrition detection via AI stems from limited access to or poor-quality data. increasing transparency of ML models used should be one of the key components of a well-designed model. One way is to use simulations to empirically evaluate the variability of model metrics and explanatory algorithms to observe whether covariates match the literature are necessary for increased transparency, reliability, and utility of ML methods [12]. This can be done with bootstrapping simulations to quantify the statistical distributions of model accuracy metrics. Simulations of these distributions have been proven to work well in a cross-study comparison setting in which model evaluation metrics need to be compared [13,14]. The performance of AI models depends on their need for extensive high-quality databases with varied content and precise labeling for getting reliable results. The scarce and often fragmented nutritional data base prevents AI models from obtaining universal applicability because they cannot understand various population groups. Standardization of malnutrition detection methods faces additional complexity from the variations between dietary habits as well as genetic factors and socioeconomic conditions. A standard diagnosis criterion for AI-based screening of malnutrition remains absent from global acceptance which creates extra evaluation challenges. The AI-driven approaches face clinical validation difficulties because the existing tools including Malnutrition Universal Screening Tool (MUST) and Global Leadership Initiative on Malnutrition (GLIM) criteria have not fully integrated with these new approaches [15]. Concerns about ethical fairness alongside modeling bias in AI systems have created doubts about system inclusivity and unbiased practices. Database training of artificial intelligence models with unrepresentative healthcare data results in improper malnutrition diagnosis of specific population demographics which produces healthcare inequality [16]. The use of sensitive health data requires strict compliance with relevant laws like GDPR and HIPAA because of privacy and regulatory framework limitations.

AI adoption in healthcare presents a significant obstacle because of both data-related and ethical barriers. AI-based detection tools for malnutrition face hurdles because they do not integrate well with the current electronic health record (EHR) platforms used in medical centers [18]. Resource-limited

areas which experience the highest rates of malnutrition face additional barriers to AI-based solutions implementation because they lack both internet access along with complex imaging equipment.

The inability of AI models to provide clear explanations stands as an essential challenge when performing clinical decision-making. Deep learning algorithms lack clear explanation capabilities which causes healthcare providers to be reluctant to use AI-generated medical diagnoses. AI-driven malnutrition detection tools gain fewer clinical acceptances because of their unexplained nature which reduces the trust medical professionals can place in them [18].

The challenges of AI-based malnutrition detection do not prevent future opportunities for research and development. The improvement of AI model generalization targets two methods: transfer learning and multimodal data integration. Wider datasets of clinical records and dietary habits alongside biometric data improve AI model predictive accuracy as they enable better population adaptation. Real-time malnutrition assessment gains significant value from mobile health (mHealth) applications as well as wearable technology. Early malnutrition screenings for children along with adults can be conducted through facial recognition and biometric analysis AI tools on smartphones which help identify patients in remote locations [19]. Healthcare providers can trust AI better with XAI methods implemented at every stage of malnutrition detection systems. The adoption of AI systems improves through XAI methods which present explainable outcomes while showing how predictions get made.

The future development requires creating uniform regulatory guidelines to govern AI-based malnutrition detection systems. The combination of AI experts with medical staff and WHO and ESPEN regulatory entities will establish ethical protocols to deploy AI technology within nutritional evaluation systems. The use of Artificial Intelligence to create customized dietary suggestions demonstrates promising capability in enhancing patient wellness. Healthcare professionals can use AI to create customized nutrition advice by analyzing patients' eating habits with their hereditary factors and medical documents leading to better malnutrition prevention and handling.

AI systems enable medical facilities to enhance meal planning for at-risk patients by processing their live medical data for nutritional decision-making.

End-to-end malnutrition detection efforts must include the collaboration between non-governmental organizations (NGO) and public health agencies. AI systems work as a component in national-scale public health initiatives which support the assessment of dietary patterns alongside the detection of people most in danger to enable specific therapy plans. Such collaborative partnerships between AI technology and public health policies work to increase AI's ability to detect malnutrition along with its preventive impact.

The implementation of AI for malnutrition detection requires the resolution of multiple obstacles which include data limitations and ethical problems and healthcare system integration and model interpretation problems. The next research phase should develop AI models that generalize better and must implement explanation capabilities to AI models along with government regulations that protect ethical standards of implementation. Malnutrition detection and intervention will produce better global health results through the combination of mobile health programs and wearable devices together with public health partnerships under AI management systems [20].

Conclusion

AI-driven malnutrition detection shows great potential to change early diagnosis and intervention in health care although real-world integration of such approaches has proven elusive because less than 10% of available solutions can be used in practice. The capability of CNN supervised learning models to identify and categorize malnutrition conditions stands proven while their implementation faces obstacles from inaccurate nutrition databases and nonuniform nutritional assessment methods along with differences in nutritional practices among patients. AI implementation faces significant barriers because of ethical issues stemming from model bias and privacy concerns in addition to the barriers created by EHR integration difficulties and restricted imaging technology access in under-resourced environments. The inability of deep learning models to provide explanations about their internal processes disturbs healthcare practitioners and hampers their acceptance of these technologies.

Future research needs to develop improved AI model generalization methods by implementing transfer learning together with multimodal data merging for better adaptation across different population demographics. The incorporation of XAI will improve transparency because it builds healthcare providers' trust in AI diagnostic results. The use of mobile health apps in combination with wearable devices provides time-sensitive malnutrition assessments through AI-driven solutions thus increasing access to

health services particularly in distant regions. A worldwide regulatory system created through joint efforts between WHO, ESPEN, NGOs and government agencies will ensure both ethical application and standardization of AI in detecting malnutrition. Healthcare organizations can develop transformative AI solutions for malnutrition prevention and diagnosis by solving their current obstacles to achieve personalized nutritional interventions worldwide.

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