Review

Application and Future Prospects of Intelligent Technologies in the Field of Aging

WuBuLi ALiMuJiang[1], Yan Lou[2*], Liu Cao[3*]

[1]China Medical University, Shenyang, Liaoning Province, China 110122
[2]Department of Computer, School of Intelligent Medicine, China Medical University, Shenyang, Liaoning Province, China 110122
[3]Basic Medicine School, China Medical University, China Medical University, Shenyang, Liaoning Province, China 110122

Fundation: 1210200105/127 Yan Lou: Funds for key disciplines

***Correspondence to:** Liu Cao, **Email:** lcao@cmu.edu.cn; Yan Lou, **Email:** ylou04@cmu.edu.cn;

Keywords： Intelligent Technologies; Aging; Artificial Intelligence; Machine Learning; Deep Learning; Big Data

Received: November 2, 2024 **Accepted:** February 3, 2025 **Published:** March 21, 2025

ABSTRACT

This article offers an in - depth and comprehensive review of the applications and future prospects of intelligent technologies in the aging field. It begins with a precisely defined and scientifically grounded concept of intelligent technologies, followed by a detailed, chronological exploration of their historical development in aging - related research and practical applications. The current applications across various aspects of aging, such as aging mechanism research, geriatric disease management, and elderly care, are systematically elaborated. The challenges encountered during the application process are critically analyzed, and well - founded predictions regarding future development directions are provided. By integrating a vast body of research findings and real - world applications, this article aims to provide a holistic understanding for researchers, medical practitioners, and relevant stakeholders in the fields of aging and intelligent technologies.

1. INTRODUCTION

Aging is an extremely complex biological process that has a profou-nd impact on all aspects of an organism. It leads to a progressive decline in physiological functions, an increased susceptibility to diseases, and significant changes in cognitive and social abilities. With the global population aging at an accelerating pace, understanding the aging process and formulating effective strategies to promote healthy aging have become crucial research imperatives. In recent years, intelligent technologies have emerged as powerful tools, revolutionizing the field of aging research and elderly care, and providing novel insights and innovative solutions[1].

2. DEFINITION OF INTELLIGENT TECHNOLOGIES

In the context of modern science and technology, intelligent technologies refer to a sophisticated and integrated system of advanced techniques centered around computer science. These technologies combine multiple disciplines, including mathematics, statistics, neuroscience, and cognitive science, endowing machines with intelligent capabilities similar to human cognitive functions, such as learning, reasoning, decision - making, and natural language processing[2].

2.1 Artificial Intelligence (AI)

AI, the core concept of intelligent technologies[3], encompasses a wide range of methods and algorithms designed to simulate human intelligence. AI can be classified into narrow AI and general AI. Narrow AI, also known as weak AI, is designed to perform specific tasks. For example, it can be used for image recognition in medical imaging to diagnose age - related diseases like Alzheimer's disease from brain scans[4]. General AI, although still in the theoretical and experimental stages, aims to possess comprehensive human - like intelligence across various domains. In the aging field, AI can process large - scale, multi - dimensional data related to aging, such as genetic data, lifestyle information, and medical records, to identify latent patterns and accurately predict the aging process and age - related diseases[4].

2.2 Machine Learning (ML)

ML, a fundamental sub - field of AI[5], enables computers to learn from data without explicit programming. In the context of aging, ML algorithms are widely used for data analysis. Supervised learning algorithms, for instance, can be trained on labeled data (e.g., data from elderly patients with and without a particular age - related disease) to predict the likelihood of disease occurrence in new cases[6]. Unsupervised learning algorithms can discover hidden patterns in unlabeled data, such as clustering elderly individuals based on their physiological and behavioral characteristics to identify different aging phenotypes[7].

2.3 Deep Learning (DL)

DL, an advanced subset of ML[8], is based on artificial neural networks with multiple hidden layers. In the aging research and care field, DL has demonstrated remarkable performance. In medical imaging, DL algorithms can automatically extract high - level features from MRI, CT, and PET scans, enabling the early and accurate detection of neurodegenerative diseases associated with aging. For example, it can precisely identify early - stage brain atrophy in Alzheimer's disease patients[9]. Additionally, DL can be applied to analyze large - scale population - based data to predict the rate of biological aging and the risk of age - related diseases[10].

2.4 Big Data and Its Role in Intelligent Technologies

Big data, characterized by volume, velocity, variety, and veracity[11], plays a crucial and indispensable role in intelligent technologies in the aging field. The large - scale data collected from multiple sources related to the elderly, such as medical records, genetic data, wearable device - generated data, and social media data, can be processed and analyzed by intelligent technologies. Big data analytics combined with ML algorithms, for example, can uncover subtle correlations between lifestyle factors (such as diet, exercise, and sleep patterns) and the development of age - related diseases, which may not be easily detectable through traditional data analysis methods[12].

3. HISTORICAL EVOLUTION OF INTELLIGENT TECHNOLOGIES IN THE AGING FIELD

3.1 Early Exploration Stage (1950s-1980s)

The origin of intelligent technologies can be traced back to the 1950s when the concept of AI was first proposed[13, 14]. In the early days, research mainly focused on basic algorithm development and theoretical exploration. In the aging field, some simple rule - based expert systems were tentatively developed to assist in the diagnosis of age - related diseases. These early expert systems attempted to mimic the decision - making process of medical experts for diagnosing common geriatric diseases, such as diabetes and hypertension, based on a limited number of symptoms and test results[15]. However, due to the complexity of medical knowledge and the limited computing power and data - handling capabilities at that time, these systems had significant limitations and were not widely applied in clinical practice[16].

3.2 Gradual Development Stage (1990s - 2000s)

With the development of computer technology and the improvement of algorithms[16], the 1990s and 2000s saw the gradual growth of ML in the aging field. Scientists began to apply basic ML algorithms, such as decision trees, support vector machines, and naive Bayes classifiers, to analyze medical data related to the elderly[17]. These algorithms could handle more complex data relationships compared to the early rule - based systems. For example, ML algorithms were used to analyze bio-marker data to predict the risk of cardiovascular diseases in the elderly[18]. However, the data collection methods were still relatively primitive, and the integration of different data sources was a significant challenge. Moreover, the amount of available data was limited, which restricted the performance of these algorithms[19].

3.3 Rapid Expansion and Breakthrough Stage (2010s - Present)

In recent years, the combination of big data, powerful computing hardware (such as GPUs), and advanced DL algorithms has led to significant breakthroughs in the application of intelligent technologies in the aging field[20]. DL has been widely used in medical imaging analysis for detecting age - related diseases. For example, it can accurately identify early - stage signs of Alzheimer's disease from brain MRI scans by automatically learning the characteristic features of the disease[21]. In addition, natural language processing (NLP), a sub - field of AI, has been applied to analyze electronic health records of the elderly, extracting valuable information for disease diagnosis, treatment planning, and health management[22]. Wearable devices and sensor - based systems, integrated with intelligent technologies, have also become popular for real - time monitoring of the elderly's health and daily activities[23, 24].

4. CURRENT APPLICATIONS OF INTELLIGENT TECHNOLOGIES IN THE AGING FIELD

4.1 Aging Mechanism Research

4.1.1 Omics Data Analysis

Intelligent technologies are extensively used to analyze omics data, including genomics, proteomics, and metabolomics, to uncover the underlying mechanisms of aging[25]. ML and DL algorithms can process and analyze large - scale omics data to identify key genes, proteins, and metabolites associated with the aging process[26, 27]. In genomics, DL algorithms can analyze gene expression profiles to detect differentially expressed genes between young and old individuals[28]. These genes may be involved in important biological processes related to aging, such as cell senescence, oxidative stress, and DNA damage repair[29]. In proteomics, ML algorithms can analyze protein - protein interaction networks to identify hub proteins that play central roles in the aging process[30, 31].

4.1.2 Computational Modeling of Aging

Intelligent technologies can be used to develop computational models of aging[32]. These models can integrate multiple types of data, including genetic, epigenetic, and physiological data, to predict an individual's biological age and the risk of age - related diseases[33]. Some ML - based models, for example, can calculate a biological age score based on a set of biomarkers, such as telomere length, DNA methylation patterns, and blood metabolite levels. This biological age score can be used to assess an individual's aging rate and health status more accurately than chronological age, providing valuable information for personalized aging interventions[34, 35].

4.2 Geriatric Disease Management

4.2.1 Disease Diagnosis

In the diagnosis of geriatric diseases, intelligent technologies have shown great potential[36, 37]. In medical imaging, DL - based algorithms can analyze X - rays, CT scans, MRIs, and ultrasound images to detect diseases such as osteoporosis, lung diseases, and neurodegenerative disorders in the elderly[38]. These algorithms can automatically detect subtle pathological changes that may be overlooked by human observers. For example, a DL algorithm for analyzing chest X - rays can accurately detect early - stage lung cancer in the elderly, improving the chances of early treatment[39]. ML algorithms can also analyze a combination of clinical symptoms, laboratory test results, and genetic markers to diagnose other age - related diseases, such as Parkinson's disease and diabetes[40].

4.2.2 Treatment Planning and Drug Discovery

Intelligent technologies enable personalized treatment plans for geriatric diseases[41]. ML algorithms can analyze a patient's genetic makeup, disease history, and treatment response data of similar patients to suggest the most suitable treatment options[42]. In cancer treatment for the elderly, the model can recommend the optimal combination of chemotherapy drugs, radiotherapy doses, or targeted therapies based on the patient's genetic mutations and tumor characteristics, considering the elderly's unique physiological conditions[43, 44]. Intelligent technologies can also assist in drug discovery for age - related diseases. By analyzing the molecular mechanisms of diseases and the structure - activity relationships of compounds, AI - based algorithms can screen potential drug candidates, accelerating the drug development process[45].

4.3 Elderly Care

4.3.1 Smart Health Monitoring

Wearable devices and sensor - based systems, integrated with intelligent technologies, are widely used for real - time monitoring of the elderly's health and daily activities[46, 47]. These devices can continuously monitor physiological parameters such as heart rate, blood pressure, sleep quality, and physical activity. AI algorithms analyze the collected data in real - time. If abnormal changes are detected, such as a sudden fall or a significant change in heart rate, the system can alert caregivers or medical staff immediately, allowing for early intervention and preventing serious accidents or health problems in the elderly[48].

4.3.2 Assistive and Rehabilitation Technologies

Intelligent assistive technologies are improving the quality of life for the elderly[49]. For example, robotic exoskeletons can assist the elderly with mobility problems to walk more easily. These exoskeletons are controlled by AI algorithms that can adapt to the elderly's movements and physical conditions[49]. Intelligent rehabilitation systems, based on virtual reality and AI, can provide personalized rehabilitation training for the elderly after stroke or other injuries, enhancing their recovery speed and effectiveness[50].

5. CHALLENGES IN THE APPLICATION OF INTELLIGENT TECHNOLOGIES IN THE AGING FIELD

5.1 Data - related Challenges

5.1.1 Data Quality and Standardization

High - quality data is essential for the effective application of intelligent technologies in the aging field[51]. However, aging - related data often has issues such as missing values, noise, and inconsistent formats. Different research groups and medical institutions may use different data collection methods and measurement standards. For example, the measurement of cognitive function in the elderly may vary among different studies, making it difficult to compare and integrate data[34]. Establishing unified data standards and quality control mechanisms is crucial for the effective application of intelligent technologies in aging research[52, 53].

5.1.2 Data Privacy and Security

Aging - related data, especially medical and genetic data, contains sensitive personal information[51]. Protecting the privacy and security of this data is of utmost importance. With the increasing use of intelligent technologies, large - scale data collection, storage, and transmission are involved, which pose potential risks of data leakage and unauthorized use. If genetic data related to aging - related diseases is leaked, it may lead to genetic discrimination[54]. Therefore, strict data - protection measures, including encryption, access control, and anonymization, are necessary to ensure the security of aging - related data[55].

5.2 Model - related Challenges

5.2.1 Interpretability of Machine - learning Models

Although ML and DL models have shown excellent performance in the aging field, their internal mechanisms are often complex and difficult to interpret[56-58]. In medical decision - making for the elderly, understanding how the model arrives at a particular conclusion is crucial[59]. For example, in the diagnosis of age - related diseases, doctors need to know the basis for the model's diagnosis. Lack of interpretability may limit the acceptance and application of these models in clinical practice. To solve this problem, research is being carried out to develop explainable AI (XAI) techniques, such as feature importance analysis and model visualization, to make the decision - making process of the model more transparent[60, 61].

5.2.2 Generalizability of Models

Aging - related data is highly heterogeneous due to differences in individual genetic backgrounds, living environments, and lifestyle factors[62]. A machine - learning model trained on a specific dataset may not perform well when applied to a different dataset. For example, a model for predicting the risk of age - related diseases trained on a dataset from a specific ethnic group may not be accurate when used for other ethnic groups. Ensuring the generalizability of models is a challenge that needs to be addressed to expand the application scope of intelligent technologies in the aging field. Strategies such as multi - center data collection, data augmentation, and transfer learning are being explored to improve the generalizability of models[63].

6. FUTURE PROSPECTS

6.1 Integration of Multiple Intelligent Technologies

In the future, the integration of multiple intelligent technologies, such as AI, ML, DL, blockchain, and the Internet of Things (IoT), is expected to bring new breakthroughs in the aging field[64]. Blockchain technology can be used to ensure the security and integrity of aging - related data, while IoT devices can collect real - time data on the elderly's health and daily activities. AI and ML algorithms can then analyze this data to provide more accurate and personalized aging - related services. For example, blockchain - based medical data platforms can securely store the elderly's medical records, and intelligent algorithms can access and analyze this data in a privacy - preserving manner, enabling seamless sharing of medical information among different medical institutions and researchers[65].

6.2 Development of Explainable AI in the Aging Field

The development of XAI will be a key direction in the future application of intelligent technologies in the aging field[60, 66]. XAI techniques will make the decision - making process of AI models more understandable and interpretable for researchers and medical professionals. This will help them trust the model's predictions and recommendations and integrate them more effectively into aging - related research and clinical practice. Developing visualization tools to show how the model processes aging - related data and arrives at a diagnosis or prediction will enhance the transparency of the model and improve the acceptance of intelligent technologies in the field[67].

6.3 Expansion of Precision Aging Medicine

Intelligent technologies will play a crucial role in the development of precision aging medicine[68]. By integrating individual - level genetic, epigenetic, lifestyle, and environmental data, intelligent algorithms can accurately predict an individual's risk of age - related diseases and develop personalized prevention and treatment strategies. In the future, precision aging medicine may become the standard of care, enabling more effective management of aging - related health problems and promoting healthy aging[69, 70].

6.4 Human - Machine Collaboration in Elderly Care

In the future, there will be more emphasis on human - machine collaboration in elderly care. Intelligent technologies will not replace human caregivers but will work together with them to provide better care services[71]. AI - powered chatbots can provide companionship and basic health advice to the elderly, while human caregivers can focus on more complex care tasks that require emotional support and physical assistance. This combination of human and machine capabilities can improve the quality and efficiency of elderly care[72].

7. CONCLUSION

Intelligent technologies have made remarkable contributions to the field of aging, with applications ranging from understanding aging mechanisms to improving geriatric disease management and elderly care. Although there are still challenges in data quality, model interpretability, and generalizability, the future prospects are highly promising. With continuous technological innovation and the joint efforts of researchers, medical practitioners, and policymakers, intelligent technologies are expected to revolutionize the aging field, bringing new hope for promoting healthy aging and improving the quality of life of the elderly.

8. REFERENCES

[1] Ma B, Yang J, Wong F, et al. Artificial intelligence in elderly healthcare: A scoping review. Ageing Res Rev. 2023. 83: 101808.

[2] Mintz Y, Brodie R. Introduction to artificial intelligence in medicine. Minim Invasive Ther Allied Technol. 2019. 28(2): 73-81.

[3] Sebastian S. Implementing robotics and artificial intelligence. Elife. 2022. 11: e80609.

[4] Kann BH, Hosny A, Aerts H. Artificial intelligence for clinical oncology. Cancer Cell. 2021. 39(7): 916-927.

[5] Choi RY, Coyner AS, Kalpathy-Cramer J, Chiang MF, Campbell JP. Introduction to Machine Learning, Neural Networks, and Deep Learning. Transl Vis Sci Technol. 2020. 9(2): 14.

[6] Chen LK. Machine Learning Improves Analysis of

Multi-Omics Data in Aging Research and Geroscience. Arch Gerontol Geriatr. 2021. 93: 104360.

[7] Cheng J, Dalca AV, Fischl B, Zöllei L, Alzheimer's Disease Neuroimaging Initiative, . Cortical surface registration using unsupervised learning. Neuroimage. 2020. 221: 117161.

[8] Wu S, Roberts K, Datta S, et al. Deep learning in clinical natural language processing: a methodical review. J Am Med Inform Assoc. 2020. 27(3): 457-470.

[9] Sayed N, Huang Y, Nguyen K, et al. An inflammatory aging clock (iAge) based on deep learning tracks multimorbidity, immunosenescence, frailty and cardiovascular aging. Nat Aging. 2021. 1: 598-615.

[10] Ashiqur Rahman S, Giacobbi P, Pyles L, Mullett C, Doretto G, Adjeroh DA. Deep learning for biological age estimation. Brief Bioinform. 2021. 22(2): 1767-1781.

[11] Callaghan CW. Developing the Transdisciplinary Aging Research Agenda: New Developments in Big Data. Curr Aging Sci. 2018. 11(1): 33-44.

[12] Khachaturian AS, Meranus DH, Kukull WA, Khachaturian ZS. Big data, aging, and dementia: pathways for international harmonization on data sharing. Alzheimers Dement. 2013. 9(5 Suppl): S61-2.

[13] Koski E, Murphy J. AI in Healthcare. Stud Health Technol Inform. 2021. 284: 295-299.

[14] Stanfill MH, Marc DT. Health Information Management: Implications of Artificial Intelligence on Healthcare Data and Information Management. Yearb Med Inform. 2019. 28(1): 56-64.

[15] Caudai C, Galizia A, Geraci F, et al. AI applications in functional genomics. Comput Struct Biotechnol J. 2021. 19: 5762-5790.

[16] Howard J. Artificial intelligence: Implications for the future of work. Am J Ind Med. 2019. 62(11): 917-926.

[17] Deo RC. Machine Learning in Medicine. Circulation. 2015. 132(20): 1920-30.

[18] Lüscher TF, Wenzl FA, D'Ascenzo F, Friedman PA, Antoniades C. Artificial intelligence in cardiovascular medicine: clinical applications. Eur Heart J. 2024. 45(40): 4291-4304.

[19] Niel O, Bastard P. Artificial Intelligence in Nephrology: Core Concepts, Clinical Applications, and Perspectives. Am J Kidney Dis. 2019. 74(6): 803-810.

[20] Nayarisseri A, Khandelwal R, Tanwar P, et al. Artificial Intelligence, Big Data and Machine Learning Approaches in Precision Medicine & Drug Discovery. Curr Drug Targets. 2021. 22(6): 631-655.

[21] Warren SL, Moustafa AA. Functional magnetic resonance imaging, deep learning, and Alzheimer's disease: A systematic review. J Neuroimaging. 2023. 33(1): 5-18.

[22] López-Úbeda P, Martín-Noguerol T, Juluru K, Luna A. Natural Language Processing in Radiology: Update on Clinical Applications. J Am Coll Radiol. 2022. 19(11): 1271-1285.

[23] Liu G, Lv Z, Batool S, et al. Biocompatible Material-Based Flexible Biosensors: From Materials Design to Wearable/Implantable Devices and Integrated Sensing Systems. Small. 2023. 19(27): e2207879.

[24] Huang X, Xue Y, Ren S, Wang F. Sensor-Based Wearable Systems for Monitoring Human Motion and Posture: A Review. Sensors (Basel). 2023. 23(22): 9047.

[25] Aging Atlas Consortium, . Aging Atlas: a multi-omics database for aging biology. Nucleic Acids Res. 2021. 49(D1): D825-D830.

[26] Prelaj A, Miskovic V, Zanitti M, et al. Artificial intelligence for predictive biomarker discovery in immuno-oncology: a systematic review. Ann Oncol. 2024. 35(1): 29-65.

[27] Azeredo J, Azevedo NF, Briandet R, et al. Critical review on biofilm methods. Crit Rev Microbiol. 2017. 43(3): 313-351.

[28] Bostanci E, Kocak E, Unal M, Guzel MS, Acici K, Asuroglu T. Machine Learning Analysis of RNA-seq Data for Diagnostic and Prognostic Prediction of Colon Cancer. Sensors (Basel). 2023. 23(6): 3080.

[29] Premkumar R, Srinivasan A, Harini Devi KG, et al. Single-cell classification, analysis, and its application using deep learning techniques. Biosystems. 2024. 237: 105142.

[30] Grapov D, Fahrmann J, Wanichthanarak K, Khoomrung S. Rise of Deep Learning for Genomic, Proteomic, and Metabolomic Data Integration in Precision Medicine. OMICS. 2018. 22(10): 630-636.

[31] Jamialahmadi H, Khalili-Tanha G, Nazari E, Rezaei-Tavirani M. Artificial intelligence and bioinformatics: a journey from traditional techniques to smart approaches. Gastroenterol Hepatol Bed Bench. 2024.

17(3): 241-252.

[32] Kaye JA, Maxwell SA, Mattek N, et al. Intelligent Systems For Assessing Aging Changes: home-based, unobtrusive, and continuous assessment of aging. J Gerontol B Psychol Sci Soc Sci. 2011. 66 Suppl 1(Suppl 1): i180-90.

[33] Zhavoronkov A, Li R, Ma C, Mamoshina P. Deep biomarkers of aging and longevity: from research to applications. Aging (Albany NY). 2019. 11(22): 10771-10780.

[34] Abadir P, Oh E, Chellappa R, et al. Artificial Intelligence and Technology Collaboratories: Innovating aging research and Alzheimer's care. Alzheimers Dement. 2024. 20(4): 3074-3079.

[35] Qiu W, Chen H, Kaeberlein M, Lee SI. ExplaiNAble BioLogical Age (ENABL Age): an artificial intelligence framework for interpretable biological age. Lancet Healthy Longev. 2023. 4(12): e711-e723.

[36] Kondo I, Ozaki K, Osawa A. [Support for Patients and Their Family Using Artificial Intelligence]. Brain Nerve. 2019. 71(7): 759-764.

[37] Louka AM, Tsagkaris C, Christoforou P, et al. Current Trends of Computational Tools in Geriatric Medicine and Frailty Management. Front Biosci (Landmark Ed). 2022. 27(8): 232.

[38] Chalopin C, Nickel F, Pfahl A, et al. [Artificial intelligence and hyperspectral imaging for image-guided assistance in minimally invasive surgery]. Chirurgie (Heidelb). 2022. 93(10): 940-947.

[39] Zhao W, Liu J. Artificial intelligence in lung cancer: Application and future thinking. Zhong Nan Da Xue Xue Bao Yi Xue Ban. 2022. 47(8): 994-1000.

[40] Cadamuro J, Cabitza F, Debeljak Z, et al. Potentials and pitfalls of ChatGPT and natural-language artificial intelligence models for the understanding of laboratory medicine test results. An assessment by the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) Working Group on Artificial Intelligence (WG-AI). Clin Chem Lab Med. 2023. 61(7): 1158-1166.

[41] Lyu YX, Fu Q, Wilczok D, et al. Longevity biotechnology: bridging AI, biomarkers, geroscience and clinical applications for healthy longevity. Aging (Albany NY). 2024. 16(20): 12955-12976.

[42] Kordi M, Bansal MS. Exact Algorithms for Duplication-Transfer-Loss Reconciliation with Non-Binary Gene Trees. IEEE/ACM Trans Comput Biol Bioinform. 2019. 16(4): 1077-1090.

[43] Jones OT, Matin RN, van der Schaar M, et al. Artificial intelligence and machine learning algorithms for early detection of skin cancer in community and primary care settings: a systematic review. Lancet Digit Health. 2022. 4(6): e466-e476.

[44] Majumder A, Sen D. Artificial intelligence in cancer diagnostics and therapy: current perspectives. Indian J Cancer. 2021. 58(4): 481-492.

[45] Li J, Li XH, Ebrahimie E, Huang L. Editorial: Exploring genetic characteristics and molecular mechanisms of host adaptation of viruses with artificial intelligence (AI) or (and) biological (BIO) approaches. Front Cell Infect Microbiol. 2024. 14: 1474097.

[46] Yang C, Wang H, Cao Z, et al. Memristor-Based Bionic Tactile Devices: Opening the Door for Next-Generation Artificial Intelligence. Small. 2024. 20(19): e2308918.

[47] Zhang Y, Hu Y, Jiang N, Yetisen AK. Wearable artificial intelligence biosensor networks. Biosens Bioelectron. 2023. 219: 114825.

[48] Baig MM, GholamHosseini H, Moqeem AA, Mirza F, Lindén M. A Systematic Review of Wearable Patient Monitoring Systems - Current Challenges and Opportunities for Clinical Adoption. J Med Syst. 2017. 41(7): 115.

[49] Gu Y, Xu Y, Shen Y, et al. A Review of Hand Function Rehabilitation Systems Based on Hand Motion Recognition Devices and Artificial Intelligence. Brain Sci. 2022. 12(8): 1079.

[50] Chu CH, Nyrup R, Leslie K, et al. Digital Ageism: Challenges and Opportunities in Artificial Intelligence for Older Adults. Gerontologist. 2022. 62(7): 947-955.

[51] Pavon JM, Previll L, Woo M, et al. Machine learning functional impairment classification with electronic health record data. J Am Geriatr Soc. 2023. 71(9): 2822-2833.

[52] Chen X, He L, Shi K, Wu Y, Lin S, Fang Y. Interpretable Machine Learning for Fall Prediction Among Older Adults in China. Am J Prev Med. 2023. 65(4): 579-586.

[53] Puterman-Salzman L, Katz J, Bergman H, et al. Artificial Intelligence for Detection of Dementia Using Motion Data: A Scoping Review. Dement Geriatr Cogn Dis Extra. 2023. 13(1): 28-38.

[54] Kamikubo R, Dwivedi U, Kacorri H. Sharing Practices for Datasets Related to Accessibility and Aging. ASSETS. 2021. 1.

[55] Rong J, Ji X, Fang X, Jee MH. Research on Material Design of Medical Products for Elderly Families Based on Artificial Intelligence. Appl Bionics Biomech. 2022. 2022: 7058477.

[56] Goronzy JJ, Weyand CM. Successful and Maladaptive T Cell Aging. Immunity. 2017. 46(3): 364-378.

[57] Galluzzi L, Vitale I, Aaronson SA, et al. Molecular mechanisms of cell death: recommendations of the Nomenclature Committee on Cell Death 2018. Cell Death Differ. 2018. 25(3): 486-541.

[58] Goronzy JJ, Weyand CM. Mechanisms underlying T cell ageing. Nat Rev Immunol. 2019. 19(9): 573-583.

[59] Kuhlmann T, Moccia M, Coetzee T, et al. Multiple sclerosis progression: time for a new mechanism-driven framework. Lancet Neurol. 2023. 22(1): 78-88.

[60] Kalyakulina A, Yusipov I, Moskalev A, Franceschi C, Ivanchenko M. eXplainable Artificial Intelligence (XAI) in aging clock models. Ageing Res Rev. 2024. 93: 102144.

[61] Nguyen T, Ong J, Masalkhi M, et al. Artificial intelligence in corneal diseases: A narrative review. Cont Lens Anterior Eye. 2024. 47(6): 102284.

[62] Zaidan AM. The leading global health challenges in the artificial intelligence era. Front Public Health. 2023. 11: 1328918.

[63] GBD 2021 Fertility and Forecasting Collaborators, . Global fertility in 204 countries and territories, 1950-2021, with forecasts to 2100: a comprehensive demographic analysis for the Global Burden of Disease Study 2021. Lancet. 2024. 403(10440): 2057-2099.

[64] Lee EE, Torous J, De Choudhury M, et al. Artificial Intelligence for Mental Health Care: Clinical Applications, Barriers, Facilitators, and Artificial Wisdom. Biol Psychiatry Cogn Neurosci Neuroimaging. 2021. 6(9): 856-864.

[65] Abhari S, Morita P, Miranda P, Garavand A, Hanjahanja-Phiri T, Chumachenko D. Non-fungible tokens in healthcare: a scoping review. Front Public Health. 2023. 11: 1266385.

[66] Choubey A, Choubey SB, K P, Daulatabad VS, John N. Healthcare Transformation: Artificial Intelligence Is the Dire Imperative of the Day. Cureus. 2024. 16(6): e62652.

[67] Thamm JR, Daxenberger F, Viel T, et al. Artificial intelligence-based PRO score assessment in actinic keratoses from LC-OCT imaging using Convolutional Neural Networks. J Dtsch Dermatol Ges. 2023. 21(11): 1359-1366.

[68] Abdelhalim H, Berber A, Lodi M, et al. Artificial Intelligence, Healthcare, Clinical Genomics, and Pharmacogenomics Approaches in Precision Medicine. Front Genet. 2022. 13: 929736.

[69] Lochhead C, Fisher RB. On the Necessity of Multidisciplinarity in the Development of at-Home Health Monitoring Platforms for Older Adults: Systematic Review. JMIR Hum Factors. 2025. 12: e59458.

[70] Attenberger UI, Biber S, Wichtmann BD. Technological Advances of Magnetic Resonance Imaging in Today's Health Care Environment. Invest Radiol. 2020. 55(9): 531-542.

[71] Leghissa M, Carrera Á, Iglesias CA. Machine learning approaches for frailty detection, prediction and classification in elderly people: A systematic review. Int J Med Inform. 2023. 178: 105172.

[72] Wang Y, Wang X, Zhao L, Jones K. A case for the use of deep learning algorithms for individual and population level assessments of mental health disorders: Predicting depression among China's elderly. J Affect Disord. 2025. 369: 329-337.