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Management models for myopia as a chronic disease

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近视作为慢性病的管理模式

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摘要

文章探讨了一种全面管理屈光不正的模型,重点聚焦近视问题。研究分析了屈光不正的流行病学背景及其社会经济影响,强调早期发现与管理的重要性,特别是针对视网膜病变和青光眼等严重眼部疾病。文章简述了现有屈光不正管理模式的局限性,并指出无症状近视患者管理的挑战。提出"近视慢性病管理(MCDM)"模型作为创新性综合管理方案,该模型建立了涵盖筛查、诊断、干预、随访和反馈的数字化闭环管理路径。通过与慢性病管理模型(CCM)及世界卫生组织(WHO)患者中心眼科护理(IPCEC)的对比分析,凸显其在整合数字技术与多层级医疗网络方面的创新优势。该模型涵盖整个屈光矫正流程,并整合了通过互联网和新媒体开展公众教育的策略。在策略实施方面,文章讨论了建立眼部健康档案和长期随访计划的必要性,以及医疗联盟模式和家庭合约服务在管理中的潜在应用。此外,文章着重强调了智能软件系统在慢性眼病健康管理中的重要性,系统梳理了这种新型管理模式的优势与挑战,并为未来研究方向及潜在改进方案提出了建议。通过深入分析,研究揭示了在屈光不正管理中实施全面、多维度且持续性策略的关键作用与显著成效。

关键词:屈光不正;近视管理;慢性病;近视慢性病管理

Abstract

• This article examines a comprehensive model for managing refractive errors, with a specific focus on myopia. It investigates the epidemiological context of refractive errors and their socio-economic implications. It underscores the importance of early detection and management, especially for severe ocular conditions like retinal lesions and glaucoma. The article critiques existing refractive error management models' limitations and highlights challenges in managing asymptomatic myopic patients. It proposes a "Myopia Chronic Disease Management (MCDM)" model as an innovative comprehensive management approach. The model establishes a data-driven closed-loop management pathway that encompasses screening, diagnosis, intervention, follow-up, and feedback. Through a comparative analysis with the chronic care model (CCM) and the World Health Organization's (WHO) Integrated Patient-Centered Eye Care (IPCEC), it highlights its innovative strengths in integrating digital technologies with multi-tiered healthcare networks. This model encompasses the entire refractive correction process and incorporates strategies for public education *via* the internet and new media. In terms of strategy implementation, the article discusses the necessity of establishing eye health records and long-term follow-up plans, as well as the potential applications of medical consortium models and family contract-based services in management. Moreover, the article emphasizes the importance of intelligent software systems in chronic ocular condition health management. It provides an overview of the benefits and challenges associated with this novel management model and proposes directions for future research and potential enhancements. Through this thorough examination and analysis, the article highlights the critical importance and effectiveness of implementing comprehensive, multifaceted, and sustained strategies in the management of refractive errors.

• KEYWORDS: refractive error; myopia management; chronic disease; myopia chronic disease management
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INTRODUCTION

The increasing prevalence of refractive errors worldwide has become a critical public health challenge. It is estimated that approximately 1.4 billion people globally had myopia in 2000, and projections suggest that nearly 50% of the world's population will be myopic by 2050, with about 10% having high myopia[1]. Uncorrected refractive errors are one of the leading causes of global visual impairment, accounting for 44%. Epidemiological studies indicate that in 2010, 285 million people had vision impairment, including approximately 39 million who were blind[2]. In Asian and Caucasian populations, the proportion of visual impairment or

blindness caused by pathological myopia ranges from 0.2%−1.5% and 0.1%−0.5%, respectively[3]. The 2021 Global Burden of Disease Study highlighted myopia as a major contributor to moderate−to−severe vision impairment, accounting for 7.4% of global disability−adjusted life years (DALYs) associated with eye diseases[4]. Additionally, refractive errors impose socioeconomic burdens such as educational and occupational limitations, as well as increased risk of accidents[5-6].

Early−stage refractive errors and related ocular diseases often present with no obvious symptoms[7], leading most adult patients to not seek medical attention proactively. Guiding asymptomatic patients to seek care and implementing scientific supervision are key challenges in myopia prevention and control. This is especially critical for progressive myopia and pathological myopia, conditions defined by their relentless, long−term progression and potential for irreversible visual damage. These forms impose a substantial chronic disease burden through progressive axial elongation and associated, sight−threatening fundus pathologies. To confront this challenge, we innovatively advocate establishing a "Myopia Chronic Disease Management (MCDM)" model as a robust scientific framework. This model aims to formally integrate myopia, particularly its progressive and pathological subtypes, into the scope of chronic disease management and develop a corresponding comprehensive management framework. Public education is vigorously conducted through dedicated science popularization bases and dynamic new media platforms. This initiative aims to create eye health records and follow−up plans for adult myopia patients. Early diagnosis and treatment are essential to prevent disease progression and avoid vision loss. Public health strategies should highlight the importance of regular eye examinations, especially for children and adolescents. Comprehensive vision health education should be incorporated into school health programs to raise awareness among students, parents, and teachers about refractive errors and their potential complications.

RISK ASSESSMENT FOR REFRACTIVE ERRORS

The degree of refractive error shows a dose−dependent relationship with the risk of complications[1]. Axial elongation of the eyeball wall results in scleral thinning [an axial length (AL) greater than 26.5 mm is associated with an 80% risk of posterior staphyloma development[8] and retinal stretching, which increases the risk of the following pathophysiological changes: 1) peripheral retinal degeneration: in high myopia patients, 67% of cases exhibit at least one type of peripheral retinal lesion[9]; 2) choroidal neovascularization (CNV): the prevalence is approximately 0.04%−0.05% in the general population but increases to 5%−10% in patients with pathological myopia[10]; 3) glaucoma: the relative risk is about 1.9−2.5 times that of emmetropic individuals[11]. Cohort studies suggested that for every 1 D increase in myopia, the risk of primary openangle glaucoma (POAG) rises by 26%[12]. 4) vitreoretinal interface changes: vitreous liquefaction and detachment (present in 93% of myopic eyes by age 60[13]) combined with equatorial retinal thinning (a mean 37% reduction in retinal nerve fiber layer thickness in high myopia[14]) significantly increase the incidence of tractional retinal detachment. Compared to emmetropic eyes, eyes with spherical equivalents of −1.00 to −3.00 D have a 4−fold higher risk of retinal detachment, while those exceeding −3.00 D have an approximately 10−fold increased risk[15].

Population−based studies estimated that over 60% of myopia−related retinal breaks and 78% of early−stage glaucoma cases go undiagnosed[16]. This diagnostic gap highlights the necessity of establishing standardized chronic disease management records. Regular screening and personalized monitoring strategies can lead to early identification of issues and the implementation of preventive measures, thereby reducing severe complications and lowering the risk of blindness. Personalized monitoring strategies, guided by baseline AL and progression rates, show particular promise. Five−year longitudinal data demonstrate that biennial assessments significantly reduce severe complications[17], playing a crucial role in preventing ocular diseases.

This study employed a systematic literature review combined with conceptual model construction. The literature search was executed across PubMed, Web of Science, and the China National Knowledge Infrastructure (CNKI), spanning January 2000 to December 2023. The search strategy incorporated both subject terms and free text, featuring English terms such as: ("myopia" OR "refractive error") AND ("management" OR "model" OR "chronic disease") AND ("digital health" OR "telemedicine" OR "screening"); Chinese terms encompassed: "myopia management" and ("chronic disease model" or "health management"). Literature inclusion criteria encompassed: original research, reviews, and theoretical framework articles addressing myopia/refractive error management models, epidemiology, digital health applications, or chronic disease care systems. Exclusion criteria eliminated studies focused solely on single treatment techniques without management frameworks, case reports, and non−Chinese/English publications. A preliminary search yielded 534 articles; progressing through title screening, abstract review, and full−text assessment ultimately identified 112 highly pertinent studies for inclusion. These studies covered four pivotal domains: epidemiology, clinical interventions, health systems, and digital technologies, thereby laying the evidence foundation for this model's construction. Analysis revealed that established chronic disease management models, such as the chronic care model (CCM) and the World Health Organization's (WHO) Integrated Patient−Centered Eye Care (IPCEC), have proven effective for conditions like diabetes and hypertension, yet none systematically address myopia's lifelong, progressive, and technology−dependent nature. Building on this foundation, we introduce the MCDM, specifically designed for myopia. Through critical inheritance and innovation of existing frameworks, we constructed a comprehensive closed−loop management pathway (Figure 1).

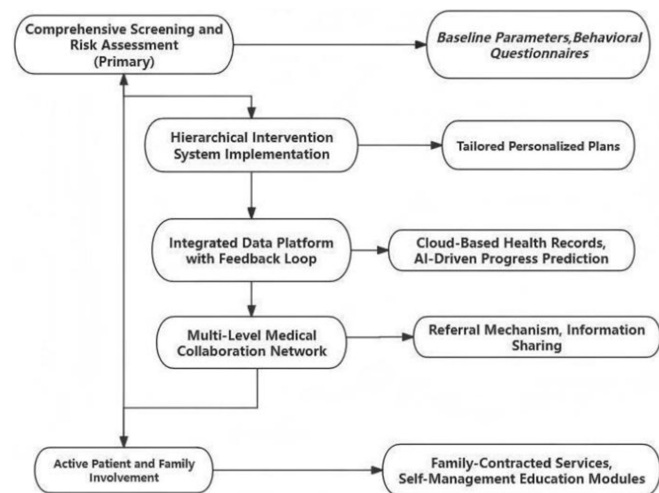

Figure 1　Schematic diagram of "MCDM" model structure
MCDM: Myopia Chronic Disease Management.

LIMITATIONS OF CURRENT REFRACTIVE ERROR MANAGEMENT MODELS

Currently, managing asymptomatic myopia faces two major challenges: insufficient patient awareness of risks and structural deficiencies in monitoring systems. Globally, over 30% of the population has myopia[18], yet only 12%–28% of adult myopia patients (with a refractive error of −6.00 D or worse) fully understand their vision risks[19]. Even in advanced healthcare systems, 63% of myopia patients believe that optical correction alone is sufficient for managing myopia[20].

In the study by Li[21], an in–depth discussion was conducted on the current status and issues of chronic disease health management models. She pointed out that the existing chronic disease management models have limitations in various aspects.

Clarify the Ambiguity in Management Objectives and Standards　Refractive error management lacks personalized strategies and fails to include all affected populations. There is no consensus on key parameters for myopia monitoring; for example, various healthcare systems have inconsistent follow-up intervals, ranging from 6 to 24 mo[18], regarding the axial elongation rate (with a ΔAL of ≥0.3 mm/y indicating high-risk progression[22]).

Technology Implementation Gap　New monitoring tools are underutilized in primary care settings. For example, smartphone-based vision testing apps with automatic calibration, such as WHOeyes, have been shown to accurately measure both distance and near vision[23]. However, models that predict refractive errors through retinal imaging[24] have low adoption rates globally in community clinics. Likewise, cloud-based longitudinal AL tracking has been found to improve the detection of rapid progress by up to 34%, yet its utilization rate remains at only 22%[25].

Deficiencies in the Informationization Mechanism　In the management of chronic eye diseases, effective information collection, processing, and sharing are crucial to ensuring patients receive continuous and consistent care. There is a lack of comprehensive eye health examinations and education on eye health science in society, while constraints on human resources impede decentralized screening: shortages of optometrists in low- and middle-income countries lead to delayed detection[26]. Furthermore, inadequate government and legal support for primary healthcare, along with limited resources and expertise within the tiered diagnosis and treatment system, hinders the full realization of its potential for early identification and management of refractive errors.

Overall, the current management of refractive errors is faced with numerous challenges. It is essential to raise public awareness about the potential risks of myopia, optimize the chronic disease management system, andparticularly focus on the development of information infrastructure and the enhancement of primary healthcare service capabilities. Systemic improvements and innovations are required to tackle these challenges.

PROPOSITION OF A NEW MANAGEMENT MODEL

The rise in global myopia rates, which has reached epidemic proportions[1], has highlighted the shortcomings of current management models. We propose an innovative approach to chronic disease management that redefines myopia as a lifelong condition necessitating multidimensional interventions. This approach involves long–term systematic management with a focus on prevention, intervention, treatment, and follow–up.

In the field of optometry, there is a strong emphasis on comprehensive and continuous refractive correction processes for children and adolescents. This includes early screening during the critical window of visual plasticity, ages 3–6 y, with assessments of visual acuity and biometric parameters such as AL and corneal curvature[19]. For children with refractive errors, dynamic correction plans that combine optical interventions (such as glasses and orthokeratology lenses) with pharmaceutical interventions (like low-dose atropine) are implemented, along with regular evaluations of visual changes. For adolescents, especially those considering corrective surgery, strict adherence to International Society of Refractive Surgery/American Academy of Ophthalmology (ISRS/AAO) guidelines is followed to select suitable candidates[27], assess appropriateness, and provide comprehensive care and guidance.

The internet and new media play a significant role in managing myopia[28]. Platforms such as social media, online videos, and blogs have become effective tools for raising public awareness about myopia and its potential risks, while also emphasizing the importance of regular eye examinations—especially in school and community settings—for early identification and intervention.

The MCDM framework presents a novel approach by incorporating modern technological advancements into a comprehensive and systematic management strategy. This enhances the prevention, diagnosis, and treatment of myopia, ultimately leading to more holistic and effective eye health management (Table 1).

IMPLEMENTATION STRATEGIES FOR THE MANAGEMENT MODEL

Implementing the MCDM model requires three synergistic pillars: a digital health infrastructure, a multi-tiered care network, and a patient empowerment ecosystem. The key lies in establishing a comprehensive eye health profile and a long-term follow-up protocol.

Data-Driven Monitoring Architecture The blockchain-based visual health registry system encompasses baseline parameters such as cycloplegic refraction and AL, as well as choroidal thickness enhanced deep imaging optical coherence tomography (EDI-OCT)[29]; behavioral indicators including the duration of near work and outdoor exposure; and follow-up intervals of ≤90 d for axial elongation $\Delta AL \geq 0.3$ mm/y[30]. Develop a personalized monitoring and follow-up system centered on key biological parameters like AL, enabling real-time refinement of risk stratification and intervention strategies.

Integrated Nursing Provision Network In managing eye health, valuable insights can be gleaned from the WHO's recommended "IPCEC" approach to achieve Universal Eye Health Coverage (UEHC)[31], as well as from the research by Wang *et al*[32] on the "medical consortium" model for managing diabetic retinopathy. A multi-tiered care network, as detailed in Table 2, should be constructed, grounded in the grid-based layout principle and clearly delineating responsibilities according to the medical institution hierarchy: primary clinics spearhead expansive community initial screenings and fundamental health education utilizing portable devices [*e.g.*, WHO portable eye examination kit (PEEK)]; tertiary ophthalmic centers undertake mainstream myopia control interventions (*e. g.*, orthokeratology, low-dose atropine) alongside diagnosing and treating common complications; academic medical centers concentrate their expertise on managing complex cases, conducting genetic risk analysis (*e.g.*, *PAX*6, *BMP*2 variants), and pioneering novel technologies. Through a unified information platform, instantaneous upload of screening data, streamlined automated two-way referral processes, and intelligent distribution of follow-up tasks are achieved, forging a seamless "screening-diagnosis-intervention-follow-up" closed loop. This ensures patients experience continuous, efficient care throughout cross- institutional transfers. For instance, primary care physicians conduct initial vision screenings and basic myopia management, while complex cases are referred to specialized hospitals for further diagnosis and treatment. Future integration of artificial intelligence (AI), virtual reality (VR), and other technologies could enable remote expert consultations and teleoperated treatments. Such cross-tier collaboration not only enhances resource utilization efficiency but also ensures patients receive continuous and comprehensive care.

Family-Centered Intervention Cycle Referencing the research by Tang[33], family-contracted services may play a significant role in the management of refractive errors. This service model establishes long-term cooperative relationships between doctors or medical teams and patients, along with their families, providing customized health management and education. In terms of myopia management, family-contracted services help families better understand the potential risks of myopia and guide family members on effective prevention and management strategies, particularly among children and adolescents. According to the Family-Integrated Myopia Management (FIMM) protocol[34], family physicians can conduct regular vision examinations, utilize embedded monitoring and behavioral guidance for real-time tracking of eye habits and vision changes, and offer health recommendations such as increasing outdoor activity time, reducing prolonged near work, and selecting appropriate vision correction solutions. This service model emphasizes personalized and continuous care, contributing positively to improving myopia management outcomes.

Table 1 Comparison of MCDM with existing chronic disease management models

Model features	CCM	WHO-IPCEC	MCDM
Core goal	Improve overall outcomes of chronic diseases	Nationwide eye health coverage	Lifetime management of myopia and prevention of complications
Technical support	Electronic health record	Basic eye care tools	AI prediction, blockchain archives, wearable devices
Medical collaboration	Primary care team	Multi-level referral system	Grid-based medical alliance and family contract
Patient role	Self-management support	Participatory care	Data sharing and closed-loop behavioral feedback
Data usage	Clinical decision support	Epidemiological surveillance	epidemiological surveillance

MCDM: Myopia Chronic Disease Management; AI: Artificial intelligence; CCM: Chronic care model; WHO: World Health Organization; IPCEC: Integrated Patient-Centered Eye Care.

Table 2 Multi-levelcare network simulation

Healthcaretier	Responsibilities	QC metrics
Primary clinics	Community screening using WHO portable eye examination kit	85% referral accuracy
Tertiary centers	Myopia modulation therapies (orthokeratology, 0.01% atropine)	$\Delta SE \leq 0.50$ D/y
Academic hubs	Genomic risk profiling (*PAX*6, *BMP*2 variants)	AUC>0.81 in progression prediction

WHO: World Health Organization; QC: Quality control, SE: Spherical equivalent; AUC: Area under the curve.

Integrating the aforementioned strategies, implementing a chronic disease management model for myopia necessitates a multi - party collaborative framework. This includes establishing comprehensive eye health records, devising long-term follow-up plans, enhancing cooperation among medical consortia, and promoting family-contracted services. Through this comprehensive management approach, myopia can be effectively managed, thereby reducing its impact on individuals and society. This ensures that myopia patients receive sustained and personalized attention and treatment, while also raising public awareness of myopia and its potential hazards. This, in turn, promotes better prevention and early intervention strategies.

EVALUATION OF THE EFFECTIVENESS AND CHALLENGES OF MANAGEMENT MODELS

Studies have demonstrated[35] that the CCM exhibits systematic advantages in managing age-related macular degeneration (AMD). By enhancing self-management, integrating medical information systems, and providing evidence-based decision support, CCM significantly improves intervention outcomes: it increases medication adherence by 32% (95% *CI*: 1.15, 1.52) and raises the National Eye Institute Visual Function Questionnaire-25 (NEI-VFQ-25) quality-of-life score by an average of 15.7 points ($P<0.001$).

The research by Liu *et al*[36] further validated the application value of the Intelligent Chronic Disease Management System (CEDMS) in patients with refractive errors. Their developed cloud platform integrates wearable vision sensors and remote diagnosis interfaces to accurately track changes in spherical equivalent, automatically generate follow-up plans, and achieves an 89.4% accuracy rate in predicting myopia progression [area under the curve (AUC) = 0.91]. However, the system faces challenges such as cybersecurity risks, algorithm calibration requirements, and low adoption rates among elderly patients. Therefore, establishing a hybrid management model combining "human professional judgment with digital technology" has emerged as the future direction for ophthalmic chronic disease management.

IMPLEMENTATION CHALLENGES OF MANAGEMENT MODELS, CROSS - SYSTEM INTEGRATION STRATEGIES, AND FUTURE DEVELOPMENT TRAJECTORIES

Although the chronic disease management model for myopia boasts significant theoretical advantages, it grapples with multiple hurdles in practical implementation. Cost and infrastructure emerge as the foremost impediments, particularly in resource-poor areas. For instance, blockchain-based record systems demand substantial initial investment and continuous information technology (IT) maintenance. Drawing inspiration from the China Diabetes Eye Disease Comprehensive Management Project, a "central-radiating" model can be implemented. Here, regional ophthalmic centers manage complex data processing and analysis, while primary institutions utilize low-cost tools—such as smartphone vision testing apps—to gather data, synchronizing information through a hybrid offline-online mode. Concurrently, robust data governance and interoperability are paramount. Unified data standards, like adherence to HL7 FHIR (FastHealthcare Interoperability Resources), must be established. This requires clear definitions for data ownership, access permissions, and sharing protocols, coupled with privacy protection mechanisms compliant with regulations like the General data protection regulation (GDPR). To bridge the digital divide, strategies should encompass: installing public access terminals in community centers to aid elderly or low-income populations; designing minimalist, intuitive user interfaces; and conducting comprehensive digital health literacy training. Promotion necessitates a tiered strategy: first validating the model's efficacy in resource-rich areas to accumulate experience, then progressively extending tailored solutions to rural and remote regions, bolstered by policy support and dedicated special funds.

An effective chronic disease management system should be capable of covering various types of chronic conditions while providing comprehensive disease monitoring, health interventions, and long-term follow-up services. The development priorities include enhancing user-friendliness and data analytics, as well as improving interoperability with other health information systems. The focus lies in advancing system usability and analytical capabilities, fostering customized management and information sharing to elevate operational efficiency and outcomes. Future integrations may encompass digital technologies, AI, VR, nanotechnology, and holographic projections—such as smart contact lenses embedded with nanosensors for intraocular pressure monitoring, metaverse-based vision therapy, or holographic systems simulating outdoor light environments (equivalent to 10 000 lx phototherapy). These innovations aim to enable real-time health record updates, analysis, and sharing, alongside cross-regional and international remote guidance and diagnosis, thereby delivering more convenient, precise, and efficient services to communities.

In summary, the implementation and future evolution of MCDM models require in-depth evaluation and refinement, including assessing model efficacy, building technical support systems, and optimizing application databases. Through these efforts, the overall efficiency and effectiveness of chronic disease management can be strengthened to better address the health needs of myopia patients.

ETHICAL AND CULTURAL IMPERATIVES

When implementing the chronic myopia management model, ethical and cultural considerations demand careful attention. 1) Data privacy protection stands as a paramount concern, demanding strict adherence to the Personal Information Protection Law, the Cybersecurity Management Measures for Medical and Health Institutions, and rigorous international standards like the GDPR. Core principles—including robust data anonymization, secure encrypted storage, and strictly minimal access permissions—must be rigorously implemented. Furthermore, establishing a clear and effective data breach

emergency response mechanism is essential. Together, these measures safeguard the security of patient information throughout its collection, storage, and sharing processes; 2) Algorithmic fairness and transparency: AI models employed for progress prediction can inadvertently develop algorithmic biases stemming from training data bias, resulting in inaccurate predictions for specific populations. It is imperative to utilize diverse and representative datasets for both training and rigorous validation, coupled with dedicated efforts to enhance algorithmic interpretability, thereby ensuring truly equitable decision-making; 3) Health equity and inclusivity: actively identifying and eliminating barriers to service access is crucial. To bridge the digital divide, non-digital alternatives—such as telephone follow-ups and printed educational materials—must be offered. In rural settings, village doctors or contracted family physicians can be empowered through training to deliver vital health education, leveraging local dialects and visual tools; 4) Informed consent and cultural adaptation: when introducing new technologies like remote monitoring and AI-assisted decision-making, healthcare providers must provide truly informed and easily understandable consent. Patients deserve clear explanations of data purposes, potential risks, and benefits. Health education materials should avoid technical jargon and be presented in culturally resonant formats, like text-and-image combinations or scenario simulations, to boost acceptance and compliance. Furthermore, the model must actively address regional and demographic variations in health literacy and healthcare-seeking behaviors. For instance, in rural settings, primary screening and education can be effectively delivered through village doctors and family contract services, utilizing local dialects alongside vivid visual aids to maximize comprehension. In multicultural contexts, health education materials must eschew technical jargon, prioritizing visual-textual integration and scenario-based simulations to boost acceptance and practical application.

CONCLUSION

This review synthesizes the evidence framework for comprehensive management models of refractive errors, with a focus on myopia as an emerging global public health issue. Our proposed MCDM model integrates digital health, multi-level healthcare networks, and family-centered interventions, showcasing compelling systematic advantages. Yet, significant challenges remain concerning resource allocation, scalability, and implementation across diverse regions and populations. In the future, prospective pilot studies should be conducted in real-world environments to further verify their clinical effects and health economic benefits, and promote the transformation of myopia management from the "conceptual framework" to the "empirical model".

Conflicts of Interest: Meng XD, None; Wang Q, None; Zhang YX, None.

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