

Development and Evaluation of Chronic Disease Care Management System in High-Altitude Regions: Evidence from Nyingchi, Xizang

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Abstract

Objective: To evaluate the development and implementation of a chronic disease care management system in high-altitude regions, aiming to address challenges including geographical barriers, limited healthcare resources, and improving primary care quality. **Methods:** A three-tier chronic disease management network (township health centers, county hospitals, municipal tertiary hospital) was established in Nyingchi, Xizang. This system incorporated multifunctional health kiosks, teleconsultation platforms, and electronic health records management. The intervention covered prevalent chronic conditions (hyperglycemia, diabetes mellitus, coronary artery disease, and Kashin-Beck disease) through coordinated data collection, remote nursing consultation, and targeted interventions. Specialized nursing clinics (e.g., Diabetes Care Clinic, PIVC Care and Consultation Clinic) were introduced in the system. Improvements in primary care capacity, health record quality, and care efficiency were assessed post-implementation. **Results:** Following system implementation across 271 primary care institutions, the chronic disease management system now covered 114 facilities, representing a 42% increase in coverage. We also observed: significant improvement in health record completeness (rising from 68% to 91%); reduced teleconsultation response time (within 4 hours); and a 37% decrease in referral rates for acute chronic disease exacerbations. **Conclusion:** This integrated chronic disease management system effectively addresses healthcare disparities in high-altitude regions by optimizing resource allocation through digital health solutions, demonstrating particular utility for remote, medically underserved settings.

Keywords

Chronic Disease, Nursing Management, High-Altitude Regions, Information System, Nyingchi, Telemedicine, Nursing Consultation

1. Introduction

Chronic disease management in China remains largely limited to surveillance, with regional variations in implementation strategies. High-altitude regions face unique challenges due to extreme environmental conditions (hypoxia, cold, and large diurnal temperature variations) and lifestyle factors, leading to significantly higher chronic disease prevalence than lowland areas [1]. Epidemiologic studies demonstrate a northward-increasing gradient in hypertension prevalence across China, with ethnic disparities observed [2]. Chronic hypoxia and harsh climatic conditions induce physiological adaptations that contribute to elevated risks of hypertension and other chronic conditions [3]. Recent researches indicate that Xizang has higher hypertension rates than inland regions [4]. Due to its unique geographical and climatic conditions, the Qinghai-Xizang Plateau exhibits significantly higher morbidity and mortality rates of chronic diseases compared to plain regions. The prevalence of hypertension in high-altitude areas reaches 33.0%, markedly exceeding the national average (27%) [5]. Similarly, the incidence rates of coronary heart disease (CHD) and chronic obstructive pulmonary disease (COPD) are notably higher than the national average [6]-[9].

However, healthcare delivery in these areas is constrained by geographic remoteness, sparse populations, underdeveloped infrastructure, and limited primary care capacity. Township health centers and county hospitals often lack adequate resources, maintain disorganized health records, and struggle to provide timely care. Frequent delays in specialist referrals exacerbate clinical outcomes for severe cases. Suboptimal health management and medical records management manifest in: poor-quality health records (incomplete/inaccurate data compromising risk assessment); absence of digital solutions (hindering data sharing and real-time updates); inadequate chronic disease follow-up and insufficient monitoring of high-risk populations. These systemic deficiencies perpetuate healthcare access disparities, characterized by long travel distances, delayed treatments, and high costs. There is an urgent need to enhance the quality and efficiency of health management and medical record management to improve primary health outcomes.

The integration of digital health technologies, particularly internet-based platforms and mobile health solutions, has shown marked efficacy in chronic disease management. In Switzerland, each canton maintains an independent electronic health record (EHR) system that is interoperable across all healthcare facilities within the canton, enabling paperless health information exchange [10], while Clement *et al.* in Australia demonstrated that a blended intervention model (com-

binning public health education with professional guidance) has proven effective for type 2 diabetes and chronic kidney disease management [11] [12]. In China, more than 90% of primary care facilities require substantial improvements in health management and health record management—a gap particularly acute in high-altitude regions. Therefore, developing an integrated chronic disease management system tailored to high-altitude environments—incorporating centralized data collection, telemedicine, and precision interventions—is critical to addressing these disparities.

2. Methods

2.1. Study Subjects

The study was conducted across primary healthcare facilities in Nyingchi, Xizang, including 271 township health centers, 6 county hospitals, and 1 municipal tertiary hospital (Nyingchi People's Hospital). These facilities served a catchment population of 126,000 permanent residents across six counties/districts.

2.2. System Development

2.2.1. Three-Tier Network Structure

Primary nodes (township health centers):

Equipped with multifunctional health kiosks for 20+ measurements (height, weight, BMI, blood glucose, blood pressure, 12-lead ECG, etc.). Trained personnel provided 24/7 testing assistance and uploaded real-time data.

Secondary nodes (county hospitals):

Conducted preliminary data analysis, identified high-risk patients (e.g., acute hyperglycemia, ECG abnormalities), initiated teleconsultations, and managed regional health records.

Tertiary node (Nyingchi People's Hospital):

Specialists (endocrinology, cardiology, etc.) analyzed aggregated data, provided diagnosis/treatment plans via remote triage/consultation, and facilitated bidirectional referrals when needed.

2.2.2. Functional Modules

Data acquisition and transfer: ID-based login, automated test data entry, and tiered data routing ensured real-time accuracy.

Telemedicine platform: Incorporated e-registration, video consultations, and online Q & A to overcome geographic barriers.

Health record management: Automatically integrated patients' test results, treatment records, and intervention plans into a dynamically updated electronic health record, enabling multi-terminal access for authorized queries.

2.2.3. Intervention Protocol

For system-identified high-risk patients (e.g., blood glucose > 13.9 mmol/L, ST-segment abnormalities on ECG), county hospital physicians/nurses conducted on-site interventions (e.g., medication adjustment, lifestyle guidance) based on

system alerts, with simultaneous notification to municipal-level specialists. For complex cases, tertiary hospital experts developed personalized treatment plans via the teleconsultation platform, which were then implemented by primary care providers (Figure 1).

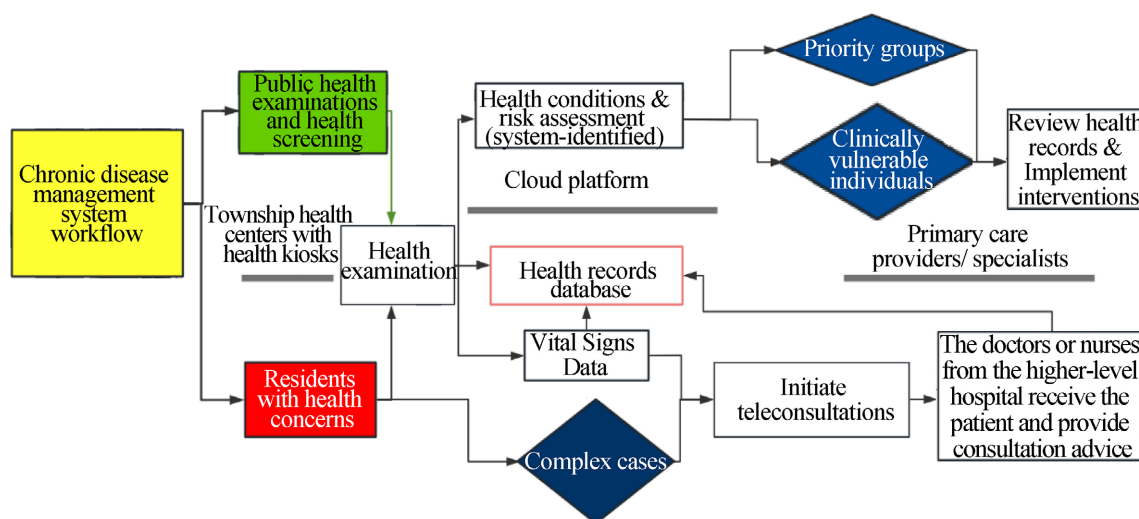


Figure 1. Chronic disease management system flow chart.

2.3. Outcome Measures

2.3.1. Primary Care Capacity

Chronic disease management coverage, teleconsultation frequency, intervention adherence rate.

2.3.2. Health Record Quality

Completeness (containing data, treatments, and interventions) and timeliness (data synchronization latency ≤ 24 hours).

2.3.3. Patient Outcomes

Acute exacerbation referral rate, complication incidence, and patient satisfaction (assessed via questionnaire, scored out of 100) were measured. These metrics evaluated how effectively primary healthcare institutions utilized the chronic disease management system to obtain guidance from higher-level hospitals, thereby improving treatment success rates, reducing complications, and avoiding unnecessary referrals—ultimately enhancing satisfaction by preventing delays in care.

3. Results

3.1. System Implementation Outcomes

3.1.1. Devices and Platforms Development

Chronic disease management systems were implemented in 114 out of 271 primary healthcare institutions, achieving a 42% increase in coverage rate. Township health centers were equipped with multifunctional health kiosks, including height-weight scales, glucometers, 12-lead ECG devices, and other devices capable of

measuring 20 health parameters. These stations supported ID card recognition, report printing, and real-time data upload. A three-tier (municipal-county-village) chronic disease management platform was developed, enabling real-time data flow (from primary detection → county-level analysis → municipal-level consultation) and a telemedicine system for video consultations and e-prescription transmission. Specialized nursing clinics (e.g., Diabetes Care Clinic, PIVC Care and Consultation Clinic) were also included in the system.

Leveraging IoT technology, the platform achieved intelligent health data collection, storage, and retrieval across medical institutions, significantly enhancing workflow efficiency and measurement accuracy in the closed-loop health management system (Figure 2).

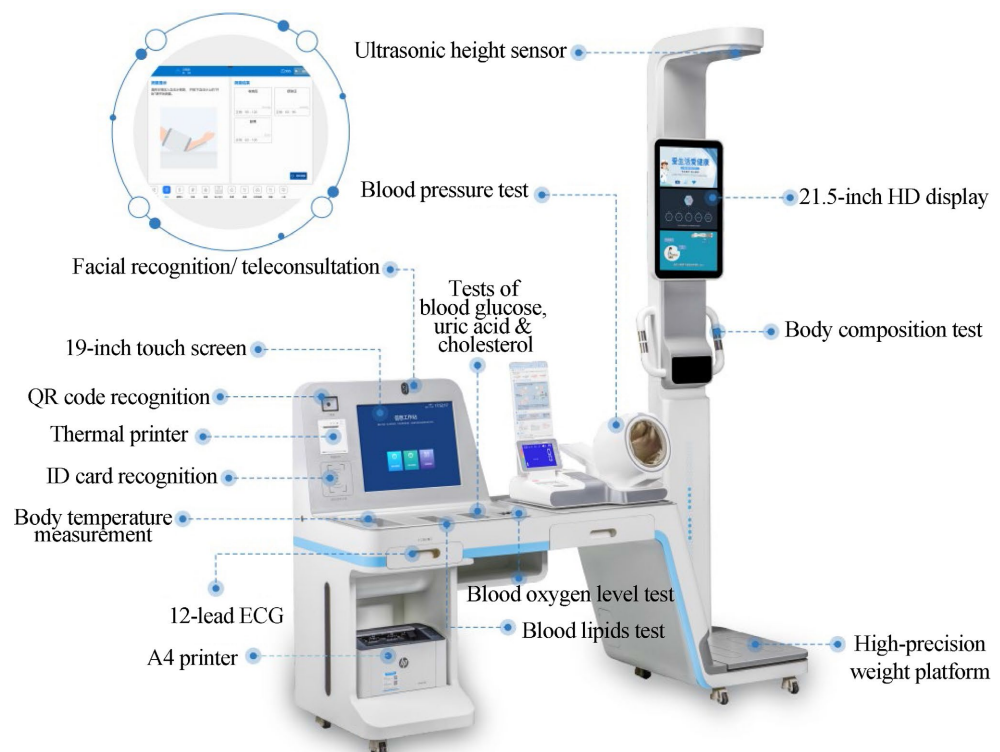


Figure 2. Multifunctional health kiosk.

3.1.2. Staff Training and Protocol Standardization

32 training sessions for primary care providers were conducted, achieving 100% proficiency in equipment operation and data upload protocols. The “High-Altitude Chronic Disease Management Operational Guidelines” were developed to clearly define tier-specific responsibilities: Township health centers: data collection; County hospitals: preliminary interventions; Municipal hospital: consultations and referral decisions.

3.2. System Performance Outcomes

3.2.1. Enhanced Primary Care Capacity

The internet-based hospital platform enabled online appointment scheduling,

registration, and teleconsultation services for both patients and healthcare facilities. Primary care providers utilized connected health monitoring devices to perform real-time health assessments, electronic health record queries, and remote consultations. This digital transformation eliminated the need for physical hospital visits, significantly reducing time and logistical burdens for patients, and enhanced care coordination through remote consultations and centralized health data access for doctors to provide personalized medical services.

The chronic disease management system was successfully implemented in 114 out of 271 primary healthcare institutions, achieving 42% coverage. Through this system, primary care physicians initiated 326 teleconsultations, which received a 100% response rate from municipal hospitals with an average response time of 3.8 hours. The protocol adherence rate among primary healthcare providers for chronic disease management significantly improved to 89% (including dietary guidance and medication adjustments for hyperglycemic patients).

3.2.2. Optimized Health Record Management

Portable health kiosks featured multi-modal login (ID card, mobile number, facial recognition, QR code) with dual-network connectivity (4G/WiFi). Users could select preferred login and network options for efficient health monitoring and data recording. Key performance improvements were observed: Health record completeness increased from 68% to 91%; Data error rate decreased from 22% to 7%; Timeliness of updates improved, with 90% of test results uploaded within 24 hours.

3.3. Improved Patient Outcomes

Acute exacerbation referral rates dropped from 49% to 12%; Patient satisfaction scores increased from 62 to 87 (100-point scale). Disease-Specific Metrics: Diabetes: Glycemic control rate improved from 52% to 76%; CAD: Monthly angina episodes reduced by 2.3.

3.4. Public Health Examinations and Health Screening

Residents' routine physical examination data were automatically uploaded to the Nyingchi Municipal Hospital Health Management Platform, enabling real-time monitoring of residents' health status and facilitating personalized health management services. The chronic disease management platform automatically identified high-risk populations (including priority groups and clinically vulnerable individuals), allowing care providers to promptly initiate interventions and optimize care coordination through the platform, and therefore, significantly improve patients' quality of life and health outcomes.

3.5. Teleconsultation and Referral Services

Residents could receive on-site primary care services, including basic physical examinations, with data automatically uploaded to the platform. For complex cases, healthcare providers could initiate teleconsultations with specialists at Nyingchi

People's Hospital and facilitate two-way referrals when necessary. This innovative service model improved healthcare accessibility for remote populations and optimized resource allocation through tiered medical collaboration.

3.6. Data-Driven Health Assessment and Intervention

The big data analytics and risk assessment models enabled comprehensive evaluation and targeted interventions for residents' health conditions, thereby enhancing health awareness and treatment adherence. This approach assisted healthcare institutions in better understanding patients' health status, early identification of potential risks, and delivery of personalized health management plans. Furthermore, it facilitated the development of healthy behaviors among residents and contributed to disease prevention.

4. Discussion

4.1. Advantages of Chronic Disease Management System in High-Altitude Regions

4.1.1. Overcoming Geographic Barriers

The integrated "health kiosk + telemedicine" model effectively addressed transportation challenges in high-altitude regions. Residents could complete basic examinations at township health centers, while severe cases received prompt specialist guidance via teleconsultation, reducing unnecessary referrals.

4.1.2. Enhancing Primary Care Capacity

The system provided standardized diagnostic tools and evidence-based intervention prompts (e.g., automated hyperglycemia alerts), effectively compensating for primary care providers' limited clinical expertise. Meanwhile, electronic health record management significantly reduced manual documentation errors and enhanced data utilization efficiency.

4.1.3. Precision Chronic Disease Management

For altitude-prevalent conditions (e.g., diabetes, CAD), the system enabled early warning through longitudinal data tracking (e.g., seasonal blood pressure fluctuation alerts) and reduced complication risk by optimizing treatment via remote specialist guidance.

4.2. System Implementation Challenges

Equipment maintenance difficulties: The extreme high-altitude conditions (low temperature, hypoxia) increased device failure rates compared to lowland areas, requiring frequent technical maintenance that raised operational costs.

Elderly user barriers: Data collection efficiency was reduced due to the dependence of some elderly patients from Xizang on staff assistance for operating digital devices.

Data security risks: Unstable network connectivity in high-altitude areas created potential data leakage risks during transmission, requiring enhanced encryption.

tion measures.

4.3. Improvement Recommendations

For equipment maintenance, collaborate with manufacturers to develop devices adapted to high-altitude conditions and train primary care staff in basic maintenance to reduce repair time.

For elderly patients in Xizang, create bilingual, instruction manuals and station bilingual volunteers at health kiosks to assist with examination.

For data security, implement blockchain technology for secure data transfer and conduct regular cybersecurity training.

5. Conclusion

This study demonstrates that the implemented chronic disease care management system, integrating a “three-tier network + digital health technology” approach, effectively addressed local challenges of limited medical resources and geographical barriers. The system significantly improved primary care capacity, health record quality, and clinical outcomes for chronic disease patients. The findings confirm that information technology represents a viable solution for healthcare delivery improvement in high-altitude regions, though continued optimization of equipment, workflows, and data security measures remains necessary to accommodate unique environmental conditions. The system enables real-time data sharing and telemedicine services to improve healthcare accessibility, enhances primary care capabilities, standardizes health record management, reduces complication rates and improves quality of life for chronic disease patients. Future directions include expanding system coverage to additional chronic conditions and exploring integration with health insurance systems to establish a comprehensive chronic disease prevention and management framework.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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