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Application Research on Intelligent Screening System for Adolescent Scoliosis with Orientation of School Health Monitoring System Optimization

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Abstract: To address the core challenges of current adolescent scoliosis screening in school health monitoring systems—low manual efficiency, high missed diagnosis rates, and incomplete closed-loop monitoring—this study aims to empower school health monitoring systems with intelligent screening solutions. We developed an AI-powered scoliosis screening system integrating image recognition and 3D posture scanning technologies, piloting it in three middle schools to explore practical implementation pathways. Through analyzing the system's technical framework ("data collection → intelligent analysis → result feedback → intervention tracking") and standardized workflow ("semester-wide screening → focused follow-up → record updates"), we validated system optimization using pilot data: average screening efficiency per grade level increased by 40%, missed diagnosis rates dropped below 3%, and intervention follow-up rates rose from 35% to 82%. The study also identified challenges, including high hardware costs, data compatibility issues, and limited parental awareness, proposing targeted strategies like "tiered equipment configuration," "standardized interface protocols," and "home-school collaborative education." These findings provide practical references for improving health monitoring systems in primary and secondary schools, while offering theoretical support for integrating smart technologies with school public health services.

Keywords: School health monitoring system; Adolescent scoliosis; Intelligent screening system; AI image recognition; Health management closed loop

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1. Introduction

1.1. Research background

The incidence of adolescent scoliosis continues to rise (according to the *China Adolescent Spinal Health Blue Book*, the detection rate of adolescent scoliosis in China reached 12.5% in 2024), which has become an important public health issue affecting adolescent health [1]. Traditional school scoliosis screening relies on "manual visual inspection + protractor measurement," which has low efficiency (it takes 3–5 days to screen all grades in a single school), high subjectivity (the missed diagnosis rate exceeds 15%), and lacks long-term follow-up management. The national *"Healthy China 2030" Plan Outline* explicitly requires "promoting intelligent health monitoring in schools and building a health service system covering the entire life cycle" [2]. However, most schools currently lack intelligent technology support for their health monitoring systems, making it difficult to meet the needs of "early detection and early intervention" [3].

1.2. Domestic and foreign research status

In international research, Western countries have explored 3D scanning technology for adolescent spinal screening (e.g., Germany's Diers 3D Spinal Measurement System), though its clinical applications remain limited and lack integration with school health monitoring systems. Domestically, scholars have focused on optimizing screening accuracy through AI-powered image recognition (e.g., automated measurement of scoliosis angles via smartphone imaging), yet most studies remain in laboratory settings without large-scale validation in school environments [4].

1.3. Research significance

Theoretical significance: Enrich the interdisciplinary research field of "intelligent technology + school public health," improve the theoretical framework of the school health monitoring system, promote the system from "single screening" to "screening-intervention-tracking" closed loop extension.

Practical significance: Provide schools with a practical intelligent screening solution, solve the pain points of traditional screening, and help the health monitoring system transform from "extensive" to "precise."

2. Related concepts and theoretical basis

2.1. Definition of core concepts

School health monitoring system: A routine health management mechanism primarily implemented in primary and secondary schools, comprising four key components: health screening, risk assessment, intervention guidance, and medical record management, with the core objective of preventing adolescent health issues.

Smart adolescent scoliosis screening system: An integrated system combining hardware collection (portable 3D scanner/mobile camera), software analysis (AI algorithm model), and data management (school health platform integration), which automatically identifies key indicators such as Cobb angle and vertebral rotation [5].

Key indicators for scoliosis screening: As per the "Youth Spinal Health Screening Guidelines," these include Cobb angle (to assess curvature severity), vertebral rotation grade, and trunk tilt.

2.2. Theoretical support

Public health surveillance theory: Provides guidance for the systematic design of a closed-loop monitoring system of "data collection, analysis, feedback, and intervention," ensuring that it is consistent with the core objectives of the school health monitoring system.

Technology acceptance model (TAM): Analyzes the acceptance of the intelligent screening system among school teachers, students, and parents, providing a theoretical basis for its promotion.

Precision health management theory: The system is designed to support "personalized screening reports + targeted intervention suggestions," upgrading health monitoring from "group coverage" to "individual precision."

3. Design and development of an intelligent screening system for adolescent scoliosis

3.1. System architecture

The system adopts a “three-tier architecture” design, with clear functions and coordinated linkage at each level:

Hardware layer: includes a portable 3D scanner (accuracy ≤0.5 mm, weight ≤2 kg, suitable for mobile screening in schools) and a mobile app (supporting iOS/Android systems, compatible with smartphone rear camera image capture) [6];

Software layer: Includes data acquisition module (supporting 3D point cloud and 2D image data input), AI analysis module (Cobb angle recognition model trained on ResNet50 network with accuracy ≥92%), report generation module (automatically generating screening reports with Cobb angle and health recommendations), and data integration module (supporting API integration with the school’s existing health management platform).

Application layer: Provides role-specific interfaces—School administrators (data analytics and export), teachers (class screening and organization), and parents (child progress reports and intervention tracking).

3.2. Core functions and technical advantages of the system

See **Table 1**.

Table 1. Core functions and technical advantages of the system

Functional module	Core content	Technical advantages (compared to traditional manual screening)
Smart data collection	3D scanners automatically capture trunk morphology data, or take standing posture images with a smartphone (no professional medical background required)	The screening threshold is low, and the time for single screening is reduced from 5 minutes to 1 minute
Auto Metric Analysis	The AI model calculates Cobb angle and vertebral rotation in real time, and automatically labels scoliosis type (such as S-shaped/L-shaped)	With strong objectivity, the missed diagnosis rate dropped from 15% to less than 3%, with no subjective errors.
Generate personalized reports	Develop tailored intervention plans for mild (Cobb angle <20°), moderate (20°≤ Cobb angle <40°), and severe (Cobb angle ≥40°) scoliosis cases, including posture correction exercises and medical referrals.	The intervention provides strong guidance and avoids the one-size-fits-all approach of traditional screening.
Long-term data tracking	Store students’ screening data over the years, generate spinal health change curves, and support follow-up reminders for key groups (moderate or severe scoliosis)	The “screening-tracking” closed loop is difficult to achieve long-term data preservation and comparison with the traditional manual mode

3.3. Key technical difficulties and solutions in system development

Difficulty 1: There are differences in image recognition accuracy between adolescents with different body types (such as obese and thin groups).

Solution: Expand the training data set (covering more than 100,000 samples of adolescents with different body types aged 8–18), and optimize the model feature extraction algorithm to improve the recognition adaptability to samples with special body types.

Difficulty 2: School scenarios require high portability and battery life of devices.

Solution: The scanner uses Type-C fast charging technology, enabling 8 hours of continuous screening with a single charge. It adapts to mobile scenarios like classrooms and playgrounds, reducing venue limitations.

4. Application practice of the system in the school health monitoring system

4.1. Application scenarios and process design

4.1.1. Core application scenarios

a. Conduct a grade-wide screening at the start of the semester (covering students aged 8–15);

b. Follow-up of key groups during the semester (light scoliosis students will be reviewed every two months);

c. Annual health record update (automatically enter screening data into students' electronic health records).

4.1.2. Standardized application process

a. School preparation: Determine the screening period (using after-class service time, not occupying normal teaching time), and train 1–2 teachers to master the operation of equipment;

b. Data collection: Organize students to complete 3D scanning/mobile phone image collection by class (about 30 minutes per class);

c. Intelligent analysis: The system generates screening reports in real time and marks the results as "normal/light/medium/severe" in four categories;

d. Result feedback: Mild scoliosis → Correction training videos will be sent via the parent app; Moderate/severe scoliosis → The school will proactively contact parents and refer them to an orthopedic hospital for further diagnosis.

e. Intervention tracking: Teachers can check the progress of intervention for students in the class through the system, and remind students with mild scoliosis to complete the training check-in every month to ensure the continuity of intervention.

4.2. Application cases of pilot schools: Taking Minquan County No.1 Junior Middle School as an example

4.2.1. Pilot foundation

The school has screened more than 3,600 people. Under the traditional screening mode, it takes 5 school doctors and 10 teachers to cooperate for 4 days, and the missed diagnosis rate is about 18%.

4.2.2. System application effect

a. Screening efficiency: 2 teachers operate the equipment, and the screening of the whole grade is completed in 3 days, which is 33% higher than the traditional mode;

b. Screening accuracy: After hospital re-examination, the system's missed diagnosis rate was reduced to 2.8%, the accuracy rate was 93.5%, and the subjective error was significantly reduced;

c. Intervention effect: Among 86 students with mild scoliosis, 32 achieved Cobb angle reduction of ≥3° after two months of corrective training, with an intervention effectiveness rate of 37.2%.

5. Optimization effect of system application on the school health monitoring system

5.1. Screening module: From "extensive" to "efficient"

Efficiency improvement: The annual screening time of a single school is reduced from 3–5 days to 2–3 days, and the manpower demand is reduced from 15 to 2–3 people, effectively reducing the school operation cost;

Expanded coverage: Pilot schools upgraded from "one annual general screening" to "one general screening +

two key follow-ups," optimizing the frequency of health monitoring and reducing the risk of missed diagnosis.

5.2. Management module: From "fragmentation" to "closed loop"

Archive management: The system automatically connects with the school's electronic health records, avoiding the traditional problems of "paper archives are easy to lose and difficult to collect," and realizing the "one life one file" management of spinal health data;

Intervention tracking: Establishing a complete closed-loop system of "screening-feedback-intervention-follow-up" has increased the intervention follow-up rate from 35% to 82%, compared with traditional screening (which only informs results without follow-up).

5.3. Decision-making module: From "experience-driven" to "data-driven"

Micro-level data support: The system generates multidimensional scoliosis incidence reports by grade, gender, and class (e.g., 14.2% in Grade 7 compared to 9.8% in Grade 9), providing data-driven support for schools to develop targeted health education plans for key grades.

Macro policy reference: After compiling data from the three pilot schools, the findings can be reported to the municipal education department to assess the current state of adolescent spinal health in the region, thereby informing the optimization of relevant policies (such as introducing spinal health courses).

6. Problems and optimization strategies in system application

6.1. Existing problems

High hardware cost: the purchase cost of a single portable 3D scanner is about 50,000 yuan, which is difficult for some rural schools to bear due to limited funds;

Inadequate data compatibility: Some schools' existing health management platforms are outdated versions, creating technical barriers to API integration with smart systems, resulting in data incompatibility.

Parents' lack of awareness: According to the pilot survey data, about 25% of parents believe that "mild scoliosis does not need intervention," and the implementation of the correction suggestions pushed by the system is low, which affects the effectiveness of the intervention.

6.2. Optimization strategies

Cost control: Develop the "basic version system" (only supports mobile phone image acquisition function, no 3D scanning module), reduce the cost to less than 5,000 yuan, suitable for rural school needs;

Technical adaptation: Cooperate with platform developers to formulate "school health monitoring system data interface standards," provide free technical upgrade services for schools, and solve data docking obstacles;

Cognitive enhancement: Through school WeChat official accounts, parent-teacher meetings, and other channels, combined with the system-generated "scoliosis progression simulation animation" for education, to visually demonstrate the hazards of scoliosis and enhance parents' awareness of spinal health.

7. Conclusion and prospect

7.1. Research conclusions

The intelligent adolescent scoliosis screening system effectively addresses the core challenges of traditional school screenings—low efficiency, poor accuracy, and lack of follow-up. Its technical architecture and application process align with the essential requirements of school health monitoring systems. By optimizing three key modules: screening, management, and decision-making, the system drives the transformation from “single-service” to “precision and closed-loop” approaches, providing robust support for adolescent spinal health protection.

7.2. Future outlook

Feature enhancements: Introduce “Spine Health Course Recommendations” and “Correction Training Progress Tracking” features to strengthen the system’s integration with school health education initiatives.

Scenario extension: Expand the application of the system from primary and secondary schools to kindergartens (for monitoring the development of children’s spines) and universities (for spinal problems caused by sitting for a long time among college students), so as to achieve coverage of all ages;

Technological iteration: Integrate wearable device data (e.g., sitting posture monitoring from smart wristbands) to develop a comprehensive spinal health management model combining “static screening and dynamic monitoring,” thereby enhancing monitoring comprehensiveness.

Disclosure statement

The authors declare no conflict of interest.

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