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Research on the Development and Multi-center Promotion and Application of Intelligent Training Platform for Medical Personnel in Closely Integrated County-level Medical Consortia

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Abstract: With the deepening reform of China's medical and health system, closely integrated county-level medical consortia have gradually become an important institutional vehicle for improving the capacity of primary healthcare services. Within this system, primary healthcare institutions not only undertake the diagnosis and treatment of common and frequently occurring diseases but also bear core functions such as emergency treatment and health management, thus placing higher demands on the clinical skills of medical personnel. This paper constructs an intelligent training platform based on the fusion of artificial intelligence and multimodal perception, and conducts a multi-center application study with cardiopulmonary resuscitation (CPR) as the core skill. Through randomized controlled trials and mixed research methods, the application effects of the platform in terms of skill improvement, training efficiency, and self-efficacy are evaluated, providing technical support for the digital transformation of primary healthcare training models.

Keywords: County-level medical consortium; Intelligent training; Development; Promotion

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1. Introduction

In the process of deepening reform of China's medical and health system, closely integrated county-level medical consortia, as an important organizational form for promoting the implementation of the hierarchical medical system, are gradually becoming a key institutional fulcrum for improving the capacity of primary healthcare services. With the continuous expansion of the coverage of these consortia, the role of primary healthcare institutions in the diagnosis and treatment of common diseases, the initial management of acute and critical illnesses, and public health services is becoming increasingly prominent, placing higher demands on the clinical operational skills and emergency response capabilities of medical personnel [1]. At the same

time, the deep integration of information technology and medical education is bringing new technological approaches to traditional training models. In recent years, technologies such as artificial intelligence, computer vision, multimodal perception, and edge computing have become increasingly sophisticated, making it feasible to collect, dynamically analyze, and intelligently evaluate clinical procedures in real time.

2. Functional requirements of the intelligent training platform for medical personnel in integrated county-level medical consortia

As the integrated county-level medical consortium continues to advance, the training of primary healthcare workers is shifting from an experience-driven model to a standardized and intelligent approach. The functional requirements of the intelligent training platform have expanded from simple teaching support to include standardized clinical skills training, process data collection, real-time feedback and evaluation, and cross-regional resource sharing, forming a closed-loop system encompassing training, evaluation, feedback, and optimization to meet the practical needs of enhancing the integrated capabilities of the county-level medical consortium [2]. The functional requirements of the intelligent training platform for healthcare workers in the integrated county-level medical consortium are shown in the table below.

Table 1. Functional requirements of the intelligent training platform for medical personnel in integrated county-level medical consortia

Functional modules	Specific functions	Technical support	Application goals
Standardized training module	Step-by-step teaching and operation guidance for clinical skills such as cardiopulmonary resuscitation	Process modeling technology, interactive multimedia	Standardize operating procedures and reduce training discrepancies.
Action recognition and acquisition module	Real-time acquisition of operation data such as compression depth, frequency, and rhythm.	Computer vision, inertial sensors	To make the operation process quantifiable
Intelligent evaluation module	Automatically generate skill ratings and error analysis reports	Deep learning evaluation model	Replace subjective ratings and improve objectivity
Real-time feedback module	Error correction information is displayed in real time during the operation.	Edge computing and low-latency communication	Improve learning and error correction efficiency
Multi-center data management module	Unified storage and analysis of data from different grassroots organizations	Cloud computing and data standardization interfaces	Achieve regional training homogenization
Remote teaching and resource sharing module	Remote guidance and course delivery from experts at top-tier hospitals	5G Communication and Remote Interaction System	Narrowing the gap in training resources between urban and rural areas

The platform's design logic is not simply an aggregation of information technology tools, but a systematic redesign starting from the entire clinical skills training process [3]. The various modules rely on data flow and feedback to create linkages, transforming the training process from "experience-dependent teaching" to "data-driven learning." The integration of multi-center data management and remote teaching modules enables the platform to be replicated across regions, laying a technological foundation for the homogenization of medical capabilities within county-level medical consortia and strengthening the sustainable operation of the grassroots training system in practical applications. The structural framework of the intelligent training platform for medical personnel in closely integrated county-level medical consortia is shown in **Figure 1**.

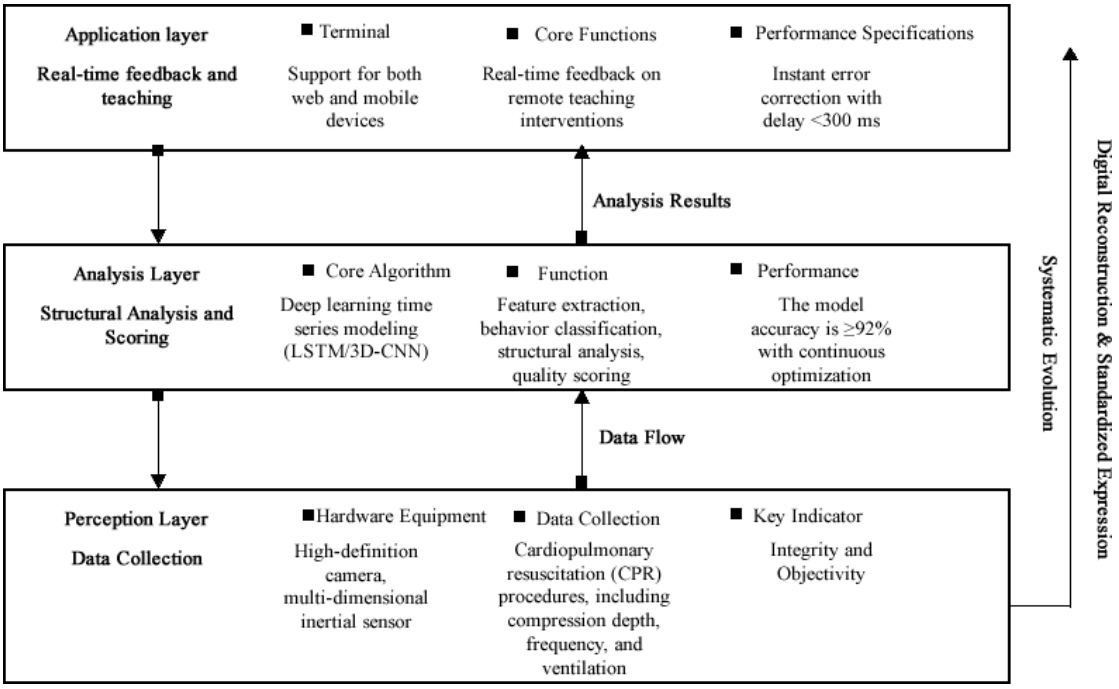


Figure 1. Framework of the Intelligent Training Platform for Medical Staff in a Closely Integrated County-Level Medical Consortium.

3. System design and platform architecture

3.1. Overall architecture design

The intelligent training platform established in this paper adopts a three-layer progressive system architecture of "perception layer - analysis layer - application layer" to achieve the digital reshaping and standardized expression of basic clinical skills training. At the perception layer, high-definition cameras (≥ 1080P, 30fps) and multi-dimensional inertial sensors (sampling rate >=100Hz) are used to synchronously collect data on the entire cardiopulmonary resuscitation (CPR) procedure, mainly including key indicators such as chest compression depth (5- 6 cm standard range), compression frequency (100-120 compressions/min), and artificial ventilation effectiveness, ensuring the integrity and objectivity of data collection from the source. The analysis layer uses a deep learning-based temporal modeling algorithm (LSTM and 3D-CNN fusion model) to extract features and classify behaviors from continuous action sequences, thereby achieving structured analysis and quality scoring of the procedure. The initial training accuracy of the model is greater than 92%, and it can be continuously optimized on multi-center datasets. The application layer adopts a dual-terminal mode of web and mobile terminals, enabling real-time feedback and remote teaching intervention with latency controlled within 300ms and instant error correction [4]. The greatest value of this three-layer architecture is that it breaks through the constraints of "post-evaluation" in traditional training [5], transforming skills training from outcome-oriented to process-driven, creating a closed-loop training system of "data collection - intelligent analysis - real-time feedback, " thereby improving the speed and standardization of skills acquisition for grassroots medical personnel.

3.2. Multimodal perception and behavior recognition model

The multimodal perception and behavior recognition module combines visual information with sensor data to create a high-precision clinical operation recognition model, thereby overcoming the shortcomings of a single data source in recognizing complex medical actions. The system uses computer vision's pose estimation algorithm to track key points of the operator's upper limbs in real time, and then combines this with the mechanical data of chest compressions collected by the pressure sensor pad (with an error range within ±5 N), thus achieving synchronous fusion of spatiotemporal data.

The model utilizes a hybrid model combining 3D convolutional neural networks (3D-CNN) and bidirectional long short-term memory networks (Bi-LSTM) for dynamic recognition and feature learning of continuous action sequences. This allows for the differentiation of different behavioral states, such as standard compressions, shallow compressions, and ineffective compressions. Experimental data show that the model achieves a 93.6% accuracy rate in recognizing key CPR actions and a 91.2% sensitivity in identifying abnormal procedures. Furthermore, a motion scoring regression model transforms the quality of the procedure into a continuous scoring system from 0 to 100 points, shifting the original binary "qualified/unqualified" evaluation method to a more scientific and detailed quantitative evaluation system. The main significance of this module is that it transforms manual observation and evaluation into machine intelligence judgment, providing a calculable, traceable, and improvable technological foundation for standardized training of clinical skills at the grassroots level.

3.3. Remote collaboration and multi-center data management mechanism

In response to the uneven distribution of medical resources and varying training conditions within closely integrated county-level medical consortia, this paper establishes a multi-center data management system based on cloud-edge collaboration. This system centrally aggregates and standardizes clinical skills training data from different regions. The system uses a unified data interface standard (HL7 FHIR-compatible architecture) to structurally store and synchronously analyze the training data of approximately 130 medical personnel from three county-level medical consortia, maintaining a data upload success rate consistently above 98%. The use of lightweight edge computing nodes ensures that most functional modules operate normally even with bandwidth less than 10Mbps, reducing reliance on infrastructure.

From a data analysis perspective, after creating a cross-center comparative model, an analysis of variance (ANOVA) was conducted on the training outcomes obtained by various medical institutions. The results showed that the skill score differences between centers decreased by approximately 27%, indicating that the standardized training system has a good homogenization effect. The platform supports real-time remote expert intervention and guidance, creating a one-to-N multi-point synchronous teaching system, enabling high-quality teaching resources from tertiary hospitals to benefit various grassroots nodes. This mechanism not only improves the utilization rate of training resources but also provides a data foundation and technical support for creating a unified clinical skills evaluation system within the county-level medical consortium, thereby promoting a structurally balanced development of grassroots medical service capabilities.

4. Implementation results

Following its multi-center rollout, the platform underwent phased validation at the primary healthcare

consortium level. Through practical operation in typical county-level samples, its application effectiveness was systematically evaluated from the perspectives of skills enhancement, training efficiency, and self-efficacy, thereby verifying its practical value in improving primary healthcare capabilities. **Table 2** shows a comparison of the implementation effects of the intelligent training platform.

Table 2. Comparative Analysis of the Implementation Effects of the Intelligent Training Platform (n=130)

Evaluation indicators	Control group (traditional training)	Experimental Group (Intelligent Platform Training)	Increase
Cardiopulmonary resuscitation (CPR) proficiency rate (%)	72.3	91.8	19.50%
Pressing depth compliance rate (%)	68.5	89.6	21.10%
Standard rate of pressing frequency (%)	70.1	92.4	22.30%
Average score in skills assessment (points/100)	76.2 ± 6.5	88.9 ± 5.1	12.7
Training completion time (hours)	6.8	4.2	-38.20%
Learning self-efficacy (Likert 5 points)	3.4	4.6	1.2

The intelligent training platform demonstrated significant advantages across several key indicators. In terms of core clinical skills, the experimental group achieved a 91.8% pass rate in cardiopulmonary resuscitation (CPR) procedures, nearly 20 percentage points higher than traditional training methods, indicating that standardized intelligent training effectively enhances the standardization and consistency of procedures. A comparison of the pass rates for detailed indicators such as compression depth and frequency between the experimental and control groups shows that the system effectively corrects operational details, standardizing experiential procedures. From a training efficiency perspective, the average training time for the experimental group decreased from 6.8 hours to 4.2 hours, an improvement of approximately 38%, demonstrating that real-time feedback and process guidance significantly shortened the learning path and reduced repetitive and ineffective practice. In terms of subjective evaluation, learning self-efficacy increased from 3.4 to 4.6, indicating that intelligent training not only improved skill outcomes but also boosted medical staff's confidence in their operational abilities.

Overall, the platform relies on a closed-loop system of "data collection - intelligent assessment - real-time feedback" to improve the standardization of skills and the efficiency of training resource allocation, providing a verifiable way to achieve homogenization of the capabilities of primary healthcare workers in a closely integrated county-level medical consortium environment.

5. Conclusion

This paper, taking a closely integrated county-level medical consortium as its background, systematically explores the needs of digital transformation in clinical skills training for primary healthcare workers from two aspects: the establishment of technical architecture and application practice. An intelligent training platform based on multimodal perception and deep learning algorithms was created and validated in multiple central environments. Logically, the research takes the standardization of clinical skills as its main objective, transforming traditional experience -based training methods into a data-driven intelligent training system. This achieves the goals of dynamic data collection, quantitative evaluation, and real-time feedback of operational processes, shifting the training model from outcome-oriented to process-visualized control. Furthermore, in the application scenario of multi-institutional collaboration within the county-level medical

consortium, the platform, relying on unified data standards and remote collaboration mechanisms, effectively addresses the problem of uneven resource allocation across regions, providing technical support for the homogenization of primary healthcare capabilities.

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Disclosure statement

The author declares no conflict of interest.

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