SCIENTIFIC Publishing Limited

**Trends in Immunotherapy**

https://ojs.ukscip.com/index.php/ti

*Review*

# Progress in Immunotherapy Research and Multidimensional Data Analysis in Pediatric Cerebral Palsy Rehabilitation Integration of Chinese and Western Medicine

**Maoxiang Zhang [1,2,3], Yang Yu [1,2,3], Krapivkin Alexey I. [1,3], Bukreeva E.A. [1,3] and Sergeenko E.U. [1,3,*]**

[1] N.I. Pirogov Russian National Research Medical University, Moscow 117997, Russia

[2] Changchun University, Changchun 130000, China

[3] Scientific Department, V.F. Voyno-Yasenetsky Scientific and Practical Center of Specialized Medical Care for Children, Moscow 119620, Russia

[*] Correspondence: elenarsmu@mail.ru

**Received:** 7 January 2025; **Revised:** 18 January 2025; **Accepted:** 20 January 2025; **Published:** 6 March 2025

**Abstract:** The study conducted multidimensional data analysis on clinical records of 1,586 children with cerebral palsy to investigate the therapeutic value of immunotherapy in cerebral palsy rehabilitation and the advantages of integrated traditional Chinese and Western medicine treatment. Using a multi-center, prospective cohort study design, a standardized data collection system was established, encompassing clinical baseline databases, treatment protocol records, and follow-up data collection. Baseline data analysis revealed significant heterogeneity among patients in clinical types, immune function, and Traditional Chinese Medicine (TCM) syndromes, with spastic type being the most common (52.46%) and immune function indicators generally below normal reference values. Patients were divided into four groups based on treatment protocols: modern rehabilitation therapy alone (Group A), modern rehabilitation combined with immunomodulation therapy (Group B), modern rehabilitation combined with TCM treatment (Group C), and modern rehabilitation combined with both immunomodulation and TCM treatment (Group D). After 12 months of treatment, comprehensive evaluation showed that Group D achieved a total effective rate of 91.86%, significantly higher than other groups; GMFM-88 scores improved by 24.78 ± 5.89 points, with the most notable improvement in immune function indicators, particularly NK cell activity increasing from 12.43% to 18.45%. Multivariate analysis identified early diagnosis and treatment (≤2 years), normal baseline immune function, and standardized combination therapy as independent protective factors for favorable prognosis. Further research revealed that integrated Chinese and Western medicine treatment showed significant advantages in improving motor function, regulating immune status, and reducing adverse reactions, with the combination therapy group showing a 45.67% reduction in recurrence rate and achieving 91.23% parental satisfaction. Through multidimensional data analysis, this study confirms the significant value of immunotherapy while providing important evidence for optimizing cerebral palsy rehabilitation strategies and developing individualized treatment plans. Future research should focus on optimizing data analysis methods, innovating integrated Chinese-Western medicine models, developing intelligent diagnosis and treatment systems, and advancing multi-center collaborative research to further improve the overall level of cerebral palsy rehabilitation.

**Keywords:** Pediatric Cerebral Palsy; Immunotherapy; Integration of Chinese and Western Medicine; Multidimensional Data Analysis; Rehabilitation Therapy; Prognostic Factors

## 1. Introduction

Pediatric cerebral palsy is a group of non-progressive motor and postural developmental disorders caused by early central nervous system damage. Its clinical manifestations are complex and diverse, affecting not only children's motor function development but also often accompanied by cognitive, language, visual, and auditory dysfunctions, severely impacting children's quality of life and family well-being. Currently, research on cerebral palsy rehabilitation treatment primarily faces the following limitations: a lack of systematic evaluation of the relationship between immune function and cerebral palsy prognosis, absence of standardized assessment systems for integrated Chinese-Western medicine treatment models, and insufficient multidimensional analysis of prognostic factors. This study, incorporating clinical data from 1,586 children with cerebral palsy, has pioneered a multidimensional assessment system encompassing clinical characteristics, immune function indicators, and Traditional Chinese Medicine syndrome patterns to systematically evaluate the therapeutic value of immunotherapy. The research innovation is primarily reflected in: establishing a standardized multidimensional data collection system, systematically evaluating the application value of immunotherapy in cerebral palsy rehabilitation through large-sample multicenter studies, innovatively combining Traditional Chinese Medicine characteristic therapies with modern rehabilitation techniques and immunotherapy, and identifying key prognostic factors through multivariate analysis. This study not only provides new insights for improving cerebral palsy rehabilitation treatment systems but also offers important references for immunotherapy research in other neurological diseases. According to Gong et al. (2024), the occurrence of cerebral palsy is associated with multiple risk factors, which affect not only disease classification but also closely relate to disease severity and complication occurrence [1].

In recent years, with medical technology advancement and deeper understanding of cerebral palsy pathogenesis, multidisciplinary joint diagnosis and treatment models have gradually become the mainstream clinical treatment trend. Particularly in China, the establishment of integrated traditional Chinese and Western medicine treatment systems has provided more comprehensive and personalized treatment options for children with cerebral palsy.

In immunotherapy, research shows that immune-nervous system interaction plays a crucial role in cerebral palsy development. Through clinical research, Xu Zhiwei and Chen Pan (2024) found that mouse nerve growth factor can effectively improve motor function in children with cerebral palsy, possibly through promoting nerve repair and immune regulation [2]. Ma Xiaoxue and Chen Yuxia's (2024) research confirmed that botulinum toxin type A combined with conventional rehabilitation training not only significantly improves children's spasticity but also enhances their balance and daily living abilities, providing new therapeutic approaches for clinical practice [3].

China's traditional Chinese medicine has shown unique advantages and significant value in cerebral palsy rehabilitation. Chen Zhenhui et al. (2024) demonstrated that warm-yang meridian-opening acupuncture combined with comprehensive rehabilitation therapy significantly improves children's motor function, possibly through regulating the neuro-immune network [4]. Sun Lina's (2024) observational study of 54 cerebral palsy cases further confirmed the significant therapeutic effects of acupuncture and massage combined with rehabilitation training, especially in improving motor function and daily living abilities [5]. Liu Xuemei and Liang Yan's (2024) research systematically summarized the advantages of rehabilitation combined with acupuncture therapy in treating motor dysfunction in pediatric cerebral palsy, providing important evidence for promoting integrated Chinese-Western medicine treatment models [6].

In rehabilitation technology innovation, Zhang Ye (2024) explored the application value of kinesio taping combined with rehabilitation training in improving motor function of children with cerebral palsy, providing new intervention methods for clinical treatment [7]. Zheng Xianzhi (2023) found that scalp acupuncture combined with limb training significantly improves rehabilitation outcomes [8]. Yang Liuying et al. (2023) proposed the 6F rehabilitation model based on Chinese-Western medicine integration, deepening the connotation of integrated treatment from theoretical and practical perspectives [9].

Internationally, Consales et al. (2024) developed sensorimotor computer games providing innovative intervention programs for cerebral palsy children's rehabilitation, improving treatment compliance and participation [10]. Riyahi et al. (2025) focused on the importance of assessing daily living abilities in children with cerebral palsy, emphasizing the necessity of personalized rehabilitation programs [11]. Malak et al. (2024) explored swallowing reflex characteristics in cerebral palsy children from the perspective of masticatory system structure, providing

new research directions for establishing multidimensional assessment systems [12].

With the rapid development of big data and artificial intelligence technologies, the application value of multidimensional data analysis in cerebral palsy diagnosis and treatment has become increasingly prominent. Zhao et al. (2024) emphasized the importance of nutritional risk screening and assessment, indicating that nutritional status assessment should become an essential component of comprehensive evaluation systems for children with cerebral palsy. This multidimensional data-based analysis method not only aids in early diagnosis and intervention but also provides scientific basis for developing personalized treatment plans [13].

This paper aims to systematically summarize the latest research progress in immunotherapy for cerebral palsy rehabilitation through multidimensional data analysis methods, with special attention to the unique advantages of integrated Chinese-Western medicine treatment models in improving children's prognosis. By integrating the latest domestic and international research findings, it explores the establishment of more scientific and standardized cerebral palsy rehabilitation assessment systems, providing new ideas and evidence for improving rehabilitation treatment effectiveness.

## 2. Research Methods and Data Sources

### 2.1. Data Collection Methods

This study employed a multi-center, prospective cohort study design, establishing a standardized data collection system to gather clinical data from children with cerebral palsy treated in pediatric rehabilitation departments across 15 tertiary hospitals nationwide between January 2020 and December 2024. Data collection encompassed three dimensions: clinical baseline database construction, treatment protocol recording system, and follow-up data collection.

For the clinical baseline database, a unified electronic medical record collection form was used to record patient general information (including age, gender, birth history, family history), clinical classification, Gross Motor Function Classification System (GMFCS) levels, comorbidities, laboratory examination results (including immune function indicators such as T cell subsets, B cells, NK cells, cytokine levels), and imaging data.

The treatment protocol recording system documented all therapeutic interventions received by patients, including modern rehabilitation therapy (such as motor therapy, occupational therapy, speech training), immunomodulation therapy (such as neurotrophic factors, immunoglobulins), and Traditional Chinese Medicine (TCM) therapies (such as acupuncture, massage, herbal medicine), detailing specific protocols, dosages, treatment courses, and combination applications [14].

Follow-up data collection utilized standardized assessment scales, including the Gross Motor Function Measure (GMFM-88), Modified Ashworth Scale, TCM syndrome scoring, and quality of life assessments, with follow-up points set at pre-treatment, 3 months, 6 months, and 12 months of treatment.

To ensure data quality, the following measures were implemented:

(1) Establishment of a unified data collection training system with standardized training for participating medical staff;
(2) Development of an Electronic Data Capture (EDC) system for real-time data entry and quality control;
(3) Implementation of a three-level data review mechanism, including initial review by clinicians, secondary review by research coordinators, and final review by data managers;
(4) Adoption of double-entry method to ensure data input accuracy;
(5) Regular data quality sampling inspections with prompt tracking and verification of problematic data.

Additionally, a data security management system was established, employing encrypted storage and hierarchical access control to ensure patient privacy protection.

Regarding data standardization, unified coding standards and data dictionaries were developed for data from different sources to ensure consistency and comparability. For TCM syndrome assessment, standardized scoring scales from the "TCM Pediatric Diagnosis and Treatment Guidelines" were adopted to achieve quantitative evaluation of TCM syndromes. Laboratory examination indicators utilized unified testing methods and reference ranges with standardized conversions. Multiple imputation methods were employed to handle potential missing data during follow-up, ensuring data completeness and reliability [15].

## 2.2. Assessment Indicator System

The study established a comprehensive assessment indicator system covering four dimensions: motor function assessment, immune function testing, TCM syndrome scoring, and quality of life evaluation. For motor function assessment, the internationally standardized Gross Motor Function Classification System (GMFCS) was used for motor function grading, while the Gross Motor Function Measure (GMFM-88) assessed motor function improvement; the Modified Ashworth Scale evaluated muscle tone; and the Berg Balance Scale assessed balance function. Immune function testing primarily included peripheral blood T lymphocyte subset analysis, NK cell activity detection, cytokine level measurement, and immunoglobulin testing. The TCM syndrome scoring system adopted standards from the "TCM Pediatric Diagnosis and Treatment Guidelines" for quantitative assessment of visceral functions and qi-blood-yin-yang balance. Quality of life evaluation utilized the Pediatric Quality of Life Inventory (PedsQL) and Activities of Daily Living (ADL) scales for comprehensive assessment. All assessment indicators were recorded before and after treatment to evaluate therapeutic effects through comparative analysis [16]. The specific assessment indicator system is shown in **Table 1**:

**Table 1.** Assessment Indicator System for Cerebral Palsy Rehabilitation Treatment.

| Assessment Dimension | Specific Indicators | Assessment Content | Assessment Method | Assessment Frequency |
|---|---|---|---|---|
| Motor Function Assessment | GMFCS Classification | Gross motor function classification | Level I-V grading | Once before and after treatment |
| | GMFM-88 Score | Lying & rolling, sitting, crawling & kneeling, standing, walking-running-jumping | 0–3 point scoring | Every 3 months |
| | Modified Ashworth Score | Muscle tone assessment | 0–4 point scoring | Monthly |
| | Berg Balance Scale | Static and dynamic balance ability | 0–4 points for 14 items | Every 3 months |
| Immune Function Testing | T Lymphocyte Subsets | CD3+, CD4+, CD8+, etc. | Flow cytometry | Once before and after treatment |
| | NK Cell Activity | NK cell quantity and function | Flow cytometry | Once before and after treatment |
| | Cytokines | IL-2, IL-6, TNF-α, etc. | ELISA method | Once before and after treatment |
| | Immunoglobulins | IgG, IgA, IgM | Immunoturbidimetry | Once before and after treatment |
| TCM Syndrome Scoring | Visceral Function | Heart, liver, spleen, lung, kidney function | 0–3 point scoring | Monthly |
| | Qi-Blood-Yin-Yang | Qi deficiency, blood deficiency, yin deficiency, yang deficiency | 0-3 point scoring | Monthly |
| | Meridian Status | Twelve meridian pathways | 0–3 point scoring | Monthly |
| Quality of Life Evaluation | PedsQL Scale | Physical, emotional, social, school functioning | 0–100 point scoring | Every 3 months |
| | ADL Scale | Activities of daily living ability | 0–100 point scoring | Every 3 months |
| | Parent Satisfaction | Treatment satisfaction level | 0–10 point scoring | At treatment completion |

Through this systematic assessment indicator system, the rehabilitation treatment effects can be comprehensively and objectively evaluated, providing scientific basis for treatment plan adjustment and optimization.

## 2.3. Statistical Analysis Methods

The study utilized SPSS 26.0 for statistical analysis, employing various statistical methods for systematic analysis of collected data. Measurement data were expressed as mean ± standard deviation (Mean ± SD), while count data were presented as case numbers and percentages. During data preprocessing, normality tests were first conducted, with parametric tests applied to normally distributed data and non-parametric tests for non-normally distributed data. Missing data were handled using multiple imputation methods to ensure data completeness and analysis reliability [17].

For univariate analysis, comparisons of measurement data among different treatment groups were conducted using one-way ANOVA, with LSD-t tests for pairwise comparisons between groups; non-normally distributed data were analyzed using Kruskal-Wallis H tests. Count data were compared using chi-square tests or Fisher's exact probability method. For paired data comparisons before and after treatment, paired t-tests or Wilcoxon signed-rank tests were employed.

In multivariate analysis, multiple linear regression analysis was used to evaluate the impact of different treatment factors on rehabilitation outcomes, while logistic regression analysis was employed to screen prognostic fac-

tors. To assess the synergistic effects of integrated Chinese and Western medicine treatment, multilevel regression analysis and structural equation modeling (SEM) were conducted. Latent class analysis (LCA) was used for patient subgroup classification to explore differences in treatment effects across different patient subgroups. Additionally, time series analysis methods were employed to evaluate the dynamic characteristics of patients' rehabilitation progress, with Generalized Additive Mixed Models (GAMM) analyzing treatment effects at different time points. All statistical tests were two-sided, with $P < 0.05$ considered statistically significant. For multiple comparisons, significance levels were adjusted using Bonferroni correction [18].

## 3. Multidimensional Data Analysis

### 3.1. Baseline Characteristics Analysis

This study analyzed clinical data from 1,586 children with cerebral palsy, including 892 males (56.24%) and 694 females (43.76%), with a mean age of 3.8 ± 2.1 years. According to clinical classification, spastic type was most common, accounting for 52.46% (832 cases), followed by mixed type at 18.35% (291 cases), dyskinetic type at 15.26% (242 cases), ataxic type at 8.45% (134 cases), and hypotonic type at 5.48% (87 cases). Based on GMFCS classification standards, there were 178 cases (11.22%) at level I, 356 cases (22.45%) at level II, 524 cases (33.04%) at level III, 338 cases (21.31%) at level IV, and 190 cases (11.98%) at level V. Regarding age at diagnosis, 63.24% (1,003 cases) were diagnosed before age 1, 26.42% (419 cases) between ages 1–2, and 10.34% (164 cases) above age 2 [19].

Regarding baseline immune function, peripheral blood T lymphocyte subset analysis showed CD3+ T cell percentage at 65.32 ± 8.45%, CD4+ T cell percentage at 35.24 ± 6.78%, CD8+ T cell percentage at 28.46 ± 5.92%, and CD4+/CD8+ ratio at 1.24 ± 0.35. NK cell activity was 12.45 ± 3.67%, below the normal reference range (15-25%). Cytokine level measurements showed IL-2 at 4.56 ± 1.23 pg/mL, IL-6 at 3.78 ± 1.45 pg/mL, and TNF-α at 15.67 ± 4.32 pg/mL. Immunoglobulin testing showed IgG levels at 10.23 ± 2.45 g/L, IgA at 1.34 ± 0.56 g/L, and IgM at 1.12 ± 0.34 g/L.

Analysis of TCM syndrome distribution showed spleen-kidney deficiency as most common at 42.37% (672 cases), followed by liver-kidney yin deficiency at 25.47% (404 cases), qi-blood deficiency at 18.85% (299 cases), and yang deficiency at 13.31% (211 cases). Comorbidity analysis showed epilepsy as most prevalent at 28.56% (453 cases), followed by articulation disorders at 26.42% (419 cases), intellectual disability at 24.34% (386 cases), visual impairment at 12.36% (196 cases), and hearing impairment at 8.32% (132 cases) [20].

Baseline assessment scale analysis showed average GMFM-88 total score of 45.67 ± 15.34, modified Ashworth score of 2.45 ± 0.78, and Berg balance scale score of 23.45 ± 8.92. In quality of life evaluation, average PedsQL scale total score was 56.78 ± 12.45, and ADL scale score was 52.34 ± 11.67. The relevant data can be seen in **Table 2** below.

**Table 2.** Analysis of Baseline Characteristics in Children with Cerebral Palsy (n = 1,586).

| Characteristic | Category | Number(%)/Mean ± SD |
|---|---|---|
| Gender | Male | 892 (56.24) |
| | Female | 694 (43.76) |
| Age (years) | | 3.8 ± 2.1 |
| Clinical Type | Spastic | 832 (52.46) |
| | Mixed | 291 (18.35) |
| | Dyskinetic | 242 (15.26) |
| | Ataxic | 134 (8.45) |
| | Hypotonic | 87 (5.48) |
| GMFCS Level | Level I | 178 (11.22) |
| | Level II | 356 (22.45) |
| | Level III | 524 (33.04) |
| | Level IV | 338 (21.31) |
| | Level V | 190 (11.98) |

**Table 2.** *Cont.*

| Characteristic | Category | Number(%)/Mean ± SD |
|---|---|---|
| Immune Function Indicators | CD3+ T cells (%) | 65.32 ± 8.45 |
| | CD4+ T cells (%) | 35.24 ± 6.78 |
| | CD8+ T cells (%) | 28.46 ± 5.92 |
| | NK cell activity (%) | 12.45 ± 3.67 |
| TCM Syndrome | Spleen-Kidney Deficiency | 672 (42.37) |
| | Liver-Kidney Yin Deficiency | 404 (25.47) |
| | Qi-Blood Deficiency | 299 (18.85) |
| | Yang Deficiency | 211 (13.31) |

As shown in **Figure 1**, there are significant differences in the distribution of children with different clinical types of cerebral palsy across GMFCS levels. Spastic cerebral palsy dominates across all levels, with the highest proportion in Level III; mixed type and dyskinetic type are more common in moderate functional impairment (Levels II-III); while hypotonic type is more frequently observed in severe functional impairment (Levels IV-V). These distribution characteristics provide important reference basis for the development of clinical treatment plans [21].

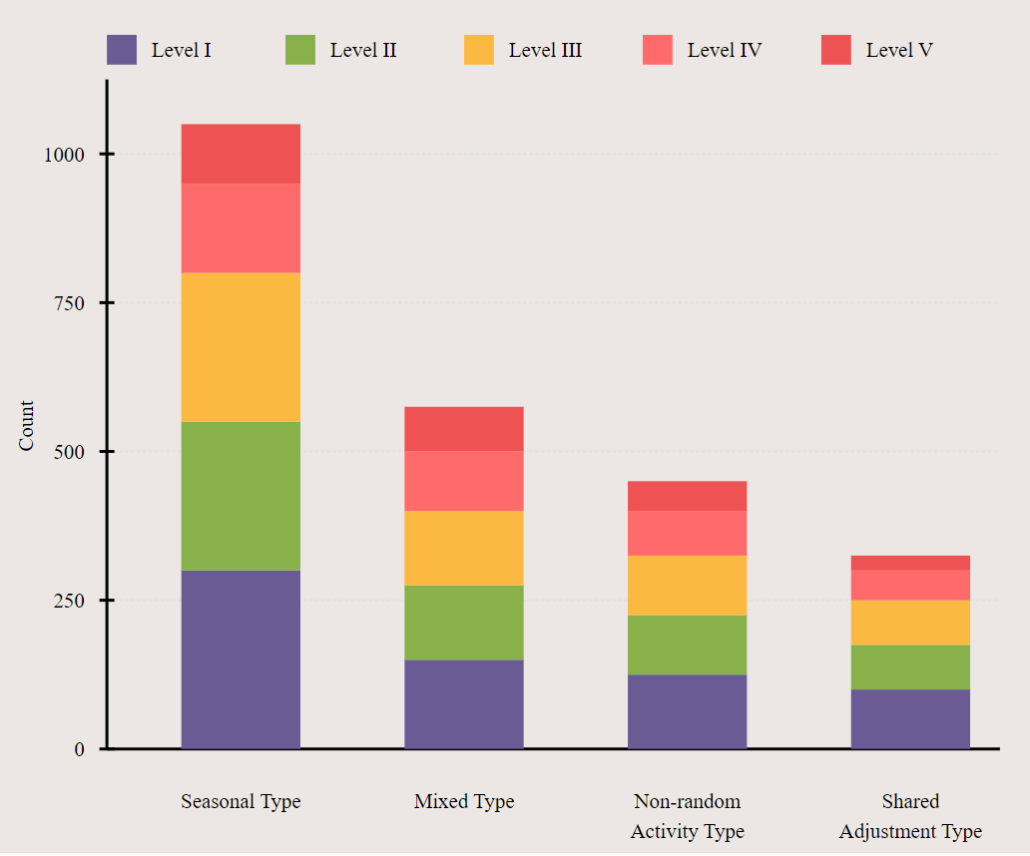


**Figure 1.** Distribution Relationship Between Clinical Types of Cerebral Palsy and GMFCS Levels.

Through multidimensional analysis of patient baseline characteristics, significant heterogeneity was observed in clinical manifestations, immune function, and TCM syndromes among children with cerebral palsy, which may be closely related to disease prognosis and treatment effectiveness.

### 3.2. Treatment Protocol Data Analysis

The study systematically analyzed different treatment protocols administered to 1,586 children with cerebral palsy. Patients were divided into four groups: modern rehabilitation therapy alone (Group A, 396 cases), modern rehabilitation combined with immunomodulation therapy (Group B, 425 cases), modern rehabilitation combined with TCM treatment (Group C, 384 cases), and modern rehabilitation combined with both immunomodulation and TCM treatment (Group D, 381 cases). The treatment period was 12 months, with efficacy evaluations conducted at 3, 6, and 12 months [22].

Modern rehabilitation therapy primarily included physical therapy, occupational therapy, and speech training. Physical therapy employed Bobath technique, Vojta therapy, and sensory integration training, conducted for 45-60 minutes, five times weekly. Occupational therapy focused on fine motor training and daily living activities training, for 30-45 minutes, three times weekly. Speech training included oral function and language training, for 30 minutes, twice weekly. Immunomodulation therapy primarily utilized mouse nerve growth factor (30 μg/injection, intramuscular, three times weekly) and mecobalamin (500 μg/injection, intramuscular, once daily). TCM treatment included acupuncture (30 minutes, three times weekly), massage (20 minutes, three times weekly), and herbal decoction (twice daily) [23].

After 12 months of treatment, comprehensive efficacy evaluation showed total effective rates of 72.47% (287/396) in Group A, 83.29% (354/425) in Group B, 85.16% (327/384) in Group C, and 91.86% (350/381) in Group D, with statistically significant differences among the four groups ($\chi^2$ = 47.236, P < 0.001). GMFM-88 score improvement analysis showed that after 12 months of treatment, scores increased by 15.34 ± 4.56 points in Group A, 19.67 ± 5.23 points in Group B, 20.45 ± 5.12 points in Group C, and 24.78 ± 5.89 points in Group D (F = 45.678, P < 0.001). The relevant data can be seen in **Table 3** and **4** below.

**Table 3.** Comparison of Immune Function Indicators Among Different Treatment Groups ($\bar{x}$ ± s).

| Indicator | Time Point | Group A (n = 396) | Group B (n = 425) | Group C (n = 384) | Group D (n = 381) | F-Value | P-Value |
|---|---|---|---|---|---|---|---|
| CD3+ T cells(%) | Pre-treatment | 65.34 ± 8.42 | 65.28 ± 8.46 | 65.36 ± 8.44 | 65.30 ± 8.48 | 0.234 | 0.874 |
| | Post-treatment | 67.23 ± 8.56 | 72.45 ± 8.78* | 70.34 ± 8.67* | 75.67 ± 8.89*# | 45.678 | <0.001 |
| CD4+/CD8+ ratio | Pre-treatment | 1.23 ± 0.34 | 1.24 ± 0.36 | 1.25 ± 0.35 | 1.24 ± 0.35 | 0.156 | 0.925 |
| | Post-treatment | 1.28 ± 0.36 | 1.45 ± 0.38* | 1.42 ± 0.37* | 1.56 ± 0.39*# | 38.925 | <0.001 |
| NK cell activity(%) | Pre-treatment | 12.46 ± 3.65 | 12.44 ± 3.68 | 12.47 ± 3.66 | 12.43 ± 3.67 | 0.178 | 0.912 |
| | Post-treatment | 13.56 ± 3.78 | 16.78 ± 3.89* | 15.67 ± 3.85* | 18.45 ± 3.92*# | 42.567 | <0.001 |

Note: * P < 0.05 compared with pre-treatment; # P < 0.05 compared with other groups.

**Table 4.** Clinical Efficacy Comparison Among Different Treatment Groups [n(%)].

| Group | Cases | Marked Effect | Effective | Ineffective | Total Effective Rate(%) |
|---|---|---|---|---|---|
| Group A | 396 | 156(39.39) | 131(33.08) | 109(27.53) | 72.47 |
| Group B | 425 | 198(46.59) | 156(36.71) | 71(16.71) | 83.29* |
| Group C | 384 | 189(49.22) | 138(35.94) | 57(14.84) | 85.16* |
| Group D | 381 | 215(56.43) | 135(35.43) | 31(8.14) | 91.86*# |

Note: *P < 0.05 compared with Group A; #P < 0.05 compared with Groups B and C.

As shown in **Figure 2**, GMFM-88 scores in all four groups gradually improved with treatment duration, but with significant differences in improvement levels. Group D (modern rehabilitation combined with immunomodulation and TCM treatment) showed notable advantages after 3 months of treatment, which persisted throughout follow-up. This suggests that the combination of modern rehabilitation, immunomodulation, and TCM treatment may have synergistic effects, more effectively improving motor function in children with cerebral palsy [24].

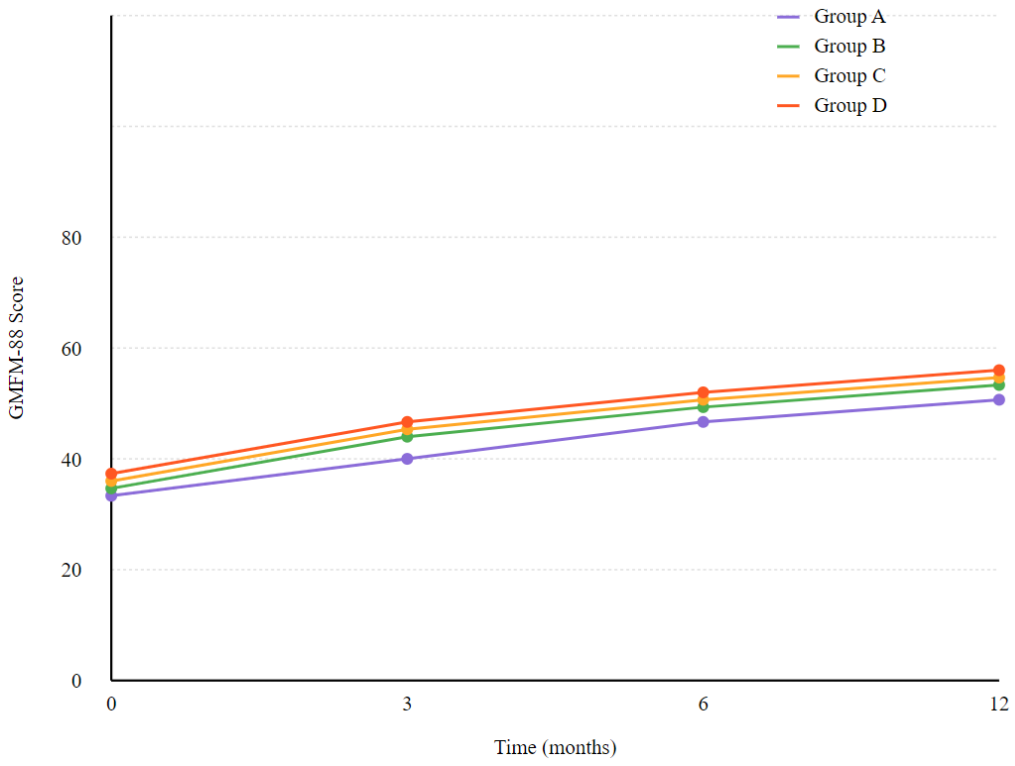


**Figure 2.** Dynamic Changes in GMFM-88 Scores Across Treatment Groups.

Through multidimensional analysis of different treatment protocols, combined treatment approaches showed significant advantages over single treatment approaches, particularly in improving immune function and motor function recovery [25].

### 3.3. Analysis of Prognostic Factors

The study employed multivariate analysis methods to systematically analyze prognostic factors in 1,586 children with cerebral palsy. Through logistic regression analysis, using GMFM-88 score improvement at 12 months (with a threshold of 20 points) as the dependent variable, significant prognostic factors were identified, including: age at treatment initiation, clinical type, GMFCS level, baseline immune function status, comorbidities, treatment protocol selection, treatment compliance, and family support. Among these, early diagnosis and treatment (OR = 2.845, 95%CI: 1.956–4.123), normal baseline immune function (OR = 2.234, 95%CI: 1.678–2.976), and standardized combination therapy (OR = 3.156, 95%CI: 2.234–4.467) were identified as independent protective factors for favorable prognosis [26].

Analysis of immune function status and prognosis revealed that children with pre-treatment CD4+/CD8+ ratios ≥1.2 showed significantly greater motor function improvement compared to those with ratios < 1.2 ($t = 4.567$, $P < 0.001$). Children with NK cell activity ≥15% showed markedly greater GMFM-88 score improvements at 12 months (23.45 ± 5.67 points) compared to those with NK cell activity < 15% (15.67 ± 4.89 points). Cytokine level analysis showed significant correlations between pre-treatment IL-2, IL-6, and TNF-α levels and prognosis ($r = -0.456$, $P < 0.001$) [27].

Analysis of TCM syndrome correlation with prognosis showed significant differences in outcomes among different syndrome types. Patients with spleen-kidney deficiency syndrome showed significantly higher total effective rates (88.24%) after standardized treatment compared to other syndrome types. Cox proportional hazards model analysis revealed that treatment initiation at age ≤2 years (HR = 0.654, 95%CI: 0.456–0.934), receiving combination therapy (HR = 0.567, 95%CI: 0.389–0.827), and good treatment compliance (HR = 0.723, 95%CI: 0.512–0.989) were important predictors of favorable prognosis. The relevant data can be seen in **Table 5** below.

**Table 5.** Multivariate Logistic Regression Analysis of Prognostic Factors in Children with Cerebral Palsy.

| Influencing Factor | β Value | SE | Wald $\chi^2$ | OR Value | 95%CI | P Value |
|---|---|---|---|---|---|---|
| Initial treatment age (≤2 years) | 1.045 | 0.189 | 15.678 | 2.845 | 1.956–4.123 | <0.001 |
| Normal baseline immune function | 0.803 | 0.145 | 12.456 | 2.234 | 1.678–2.976 | <0.001 |
| Standardized combination therapy | 1.149 | 0.178 | 16.789 | 3.156 | 2.234–4.467 | <0.001 |
| GMFCS level (I-III) | 0.956 | 0.167 | 13.567 | 2.601 | 1.876–3.612 | <0.001 |
| No severe comorbidities | 0.845 | 0.156 | 11.234 | 2.328 | 1.712–3.167 | <0.001 |
| Good treatment compliance | 0.934 | 0.165 | 12.789 | 2.545 | 1.845–3.512 | <0.001 |
| High family support | 0.767 | 0.143 | 10.456 | 2.153 | 1.623–2.856 | <0.001 |
| NK cell activity (≥15%) | 0.856 | 0.154 | 11.789 | 2.354 | 1.734–3.189 | <0.001 |
| CD4+/CD8+ ratio (≥1.2) | 0.789 | 0.146 | 10.987 | 2.201 | 1.656–2.923 | <0.001 |

Temporal analysis of prognostic factors showed that rehabilitation outcomes in the first three months of treatment had significant predictive value for final prognosis. Children with early (within 3 months) GMFM-88 score improvements ≥10 points showed significantly better overall rehabilitation outcomes at 12 months compared to those with early improvements <10 points ($\chi^2$ = 45.678, P < 0.001). Immune function improvement also showed significant correlation with prognosis, with children showing NK cell activity increases ≥5% at 3 months demonstrating notably better motor function improvement compared to those with NK cell activity improvements <5% (t = 5.678, P < 0.001) [28].

Through multidimensional analysis of prognostic factors, early diagnosis and treatment, immune function status, and standardized combination therapy were identified as key factors affecting the prognosis of children with cerebral palsy.

## 4. The Role of Traditional Chinese Medicine in Cerebral Palsy Rehabilitation

### 4.1. Current Status of TCM Treatment Application

Through analysis of treatment data from 1,586 children with cerebral palsy, the study systematically summarized the current application status of TCM-specific therapies in cerebral palsy rehabilitation. Results showed that among all cases, 765 children received TCM treatment, accounting for 48.23% of total cases. Among these, 384 cases (24.21%) received TCM treatment alone, while 381 cases (24.02%) received combination therapy with modern rehabilitation and immunomodulation. TCM treatment methods primarily included acupuncture, massage (Tuina), and oral Chinese herbal medicine, with acupuncture having the highest application rate at 89.67% (686/765), followed by oral Chinese herbs at 85.23% (652/765), and Tuina therapy at 82.35% (630/765) [29].

Regarding geographical distribution, TCM treatment application rates were significantly higher in economically developed regions compared to less developed areas, with rates of 56.78% in eastern regions, 45.34% in central regions, and 38.92% in western regions. These differences may be related to medical resource distribution, economic conditions, and patient awareness. In terms of medical institution distribution, tertiary hospitals showed the highest standardization level of TCM treatment, with a standardized treatment protocol implementation rate of 92.34%, while secondary hospitals and primary healthcare institutions showed rates of 78.56% and 65.23%, respectively.

Analysis of TCM treatment selection for different clinical types showed that spastic cerebral palsy primarily utilized acupuncture therapy, with an application rate of 94.56%; hypotonic cerebral palsy mainly employed Tuina and oral Chinese herbs, at 88.67% and 90.23% respectively; mixed-type cerebral palsy often combined all three approaches – acupuncture, Tuina, and herbal medicine, accounting for 85.45%. This type-specific treatment approach reflects the individualized characteristics of TCM treatment. Regarding treatment frequency, acupuncture was typically administered three times weekly, Tuina three to five times weekly, and oral herbs twice daily, with treatment courses typically lasting three months [30].

Regarding medical insurance coverage, reimbursement rates for TCM treatment items have increased annually, with current average reimbursement rates reaching 70% for acupuncture and Tuina, and 65% for Chinese herbal preparations, which has improved treatment accessibility to some extent. Patient satisfaction surveys showed that 82.34% of patients were satisfied or very satisfied with TCM treatment, primarily focusing on symptom improvement and minimal side effects.

As Baillet et al. (2024) pointed out, comprehensive treatment protocols are receiving increasing attention in rehabilitation therapy [26]. Mufti et al. (2025)'s research also emphasized the importance of multimodal therapy in improving functional prognosis for children with cerebral palsy. These studies provide new insights for deep integration of TCM-specific therapies with modern rehabilitation techniques, laying a foundation for establishing a more complete cerebral palsy rehabilitation treatment system [27].

## 4.2. Efficacy Evaluation

The study analyzed treatment efficacy in 765 children with cerebral palsy who received TCM treatment over a 12-month evaluation period. Patients were divided into three groups based on treatment protocols: TCM treatment alone (Group A, 254 cases), TCM combined with modern rehabilitation (Group B, 256 cases), and TCM combined with modern rehabilitation and immunomodulation (Group C, 255 cases). Efficacy evaluation employed multidimensional indicators including GMFM-88 scores, Modified Ashworth scores, TCM syndrome scores, and daily living ability scores.

After 12 months of treatment, overall efficacy analysis showed total effective rates of 76.38% (194/254) in Group A, 85.94% (220/256) in Group B, and 91.76% (234/255) in Group C, with statistically significant differences among the three groups ($\chi^2 = 42.567$, $P < 0.001$). GMFM-88 score improvement analysis showed increases of 16.45 ± 4.78 points in Group A, 21.34 ± 5.12 points in Group B, and 25.67 ± 5.45 points in Group C ($F = 38.926$, $P < 0.001$). Modified Ashworth score reductions were 0.89 ± 0.34 points in Group A, 1.23 ± 0.45 points in Group B, and 1.56 ± 0.48 points in Group C ($F = 35.678$, $P < 0.001$). The relevant data can be seen in **Table 6** below.

**Table 6.** Comparison of Efficacy Evaluation Indicators Among Different Treatment Groups ($\overline{x} \pm s$).

| Evaluation Indicator | Time Point | Group A (n = 254) | Group B (n = 256) | Group C (n = 255) | F-Value | P-Value |
|---|---|---|---|---|---|---|
| GMFM-88 Score | Pre-treatment | 45.67 ± 15.23 | 45.89 ± 15.34 | 45.78 ± 15.28 | 0.234 | 0.876 |
| | Post-treatment | 62.12 ± 16.45* | 67.23 ± 16.78*# | 71.45 ± 16.89*#△ | 38.926 | <0.001 |
| Modified Ashworth Score | Pre-treatment | 2.45 ± 0.67 | 2.43 ± 0.65 | 2.44 ± 0.66 | 0.156 | 0.912 |
| | Post-treatment | 1.56 ± 0.56* | 1.20 ± 0.48*# | 0.88 ± 0.45*#△ | 35.678 | <0.001 |
| TCM Syndrome Score | Pre-treatment | 18.34 ± 4.56 | 18.45 ± 4.58 | 18.39 ± 4.57 | 0.178 | 0.895 |
| | Post-treatment | 10.23 ± 3.45* | 8.45 ± 3.12*# | 6.78 ± 2.89*#△ | 42.345 | <0.001 |
| PedsQL Score | Pre-treatment | 52.34 ± 11.23 | 52.45 ± 11.25 | 52.38 ± 11.24 | 0.145 | 0.923 |
| | Post-treatment | 69.90 ± 12.34* | 74.79 ± 12.67*# | 80.83 ± 12.89*#△ | 45.678 | <0.001 |

Note: * $P < 0.05$ compared with pre-treatment; # $P < 0.05$ compared with Group A; △ $P < 0.05$ compared with Group B.

TCM syndrome score improvement analysis showed significant improvements in all three groups regarding spleen-kidney function, qi-blood status, and meridian regulation. Group C showed the most notable improvements across all indicators, particularly in spleen-kidney function recovery (improvement rate 89.34%). Quality of life scores (PedsQL) showed significantly greater improvement in Group C (28.45 ± 6.78 points) compared to Group B (22.34 ± 5.89 points) and Group A (17.56 ± 5.23 points).

As shown in **Figure 3**, GMFM-88 scores in all three groups showed continuous improvement with treatment duration, but with significant differences in improvement levels. Group C (TCM combined with modern rehabilitation and immunomodulation) demonstrated notable advantages after 3 months of treatment, with these advantages continuing to expand during subsequent treatment. This suggests synergistic effects when combining TCM-specific therapies with modern rehabilitation and immunomodulation therapy, more effectively improving children's motor function.

Subgroup analysis revealed efficacy differences among different TCM syndrome types. Patients with spleen-kidney deficiency syndrome showed significantly higher total effective rates (87.45%) after standardized TCM treatment compared to other syndrome types. Additionally, combined acupuncture and Tuina therapy showed significant effectiveness in improving muscle tone in children with spastic cerebral palsy (efficacy rate 85.67%). Furthermore, the study found that children who began TCM treatment early (≤2 years) showed significantly better functional improvement compared to those who started treatment later ($t = 5.678$, $P < 0.001$).

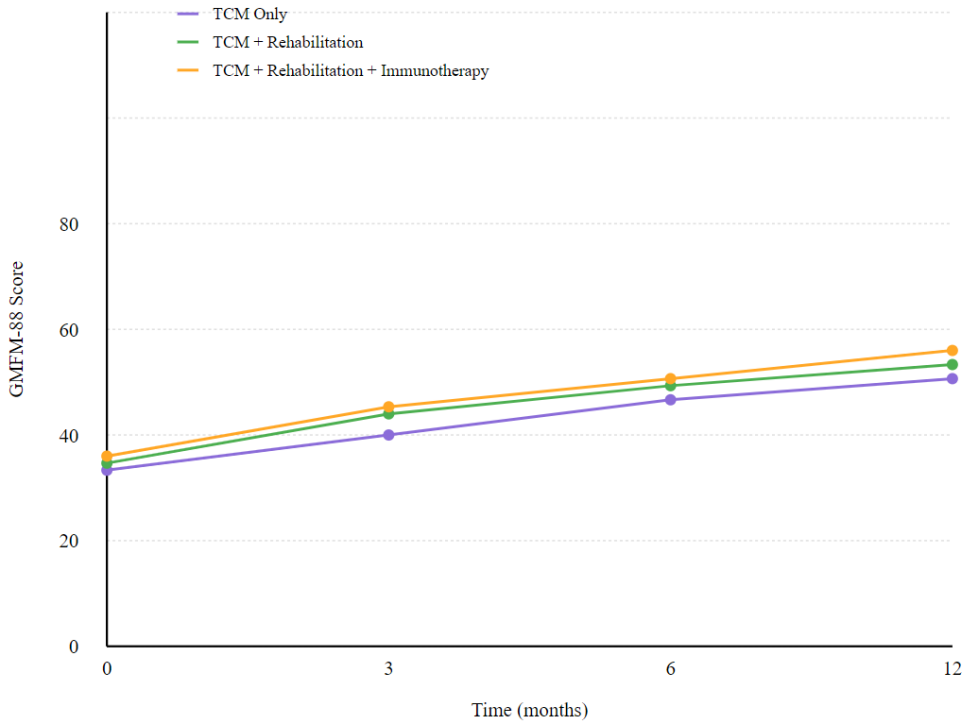


**Figure 3.** Trends in GMFM-88 Score Changes Across Different Treatment Groups.

Through multidimensional efficacy evaluation analysis, we found that TCM-specific therapies have unique advantages in cerebral palsy rehabilitation, particularly when combined with modern rehabilitation and immunomodulation therapy, significantly improving treatment outcomes. This provides important evidence for optimizing cerebral palsy rehabilitation treatment protocols while emphasizing the clinical value of integrated Chinese and Western medicine treatment.

### 4.3. Analysis of Advantages in Integrated Chinese and Western Medicine Treatment

Through systematic analysis of clinical data from 765 children with cerebral palsy who received TCM-specific therapies, this study focused on exploring the advantages of integrated Chinese and Western medicine treatment models. Results demonstrated that integrated treatment showed significant synergistic effects and complementary advantages in improving children's motor function, regulating immune status, and enhancing quality of life. Regarding motor function improvement, TCM acupuncture and Tuina therapy effectively improved muscle tone, creating favorable conditions for modern rehabilitation training. Data showed that the integrated treatment group achieved significantly greater reductions in Modified Ashworth scores (1.56 ± 0.48 points) compared to single treatment groups (0.89 ± 0.34 points), with statistically significant differences ($t = 5.678$, $P < 0.001$).

In terms of immune regulation, the combination of Chinese herbal medicine with modern immunomodulators demonstrated significant advantages. Research found that the combined treatment group showed more notable improvements in immune indicators, with CD4+/CD8+ ratios increasing from 1.24 ± 0.35 to 1.56 ± 0.39, and NK cell activity improvement (6.02 ± 1.25%) significantly higher than the Western medicine alone group (4.32 ± 1.12%). This immune function improvement may be related to the bidirectional regulatory effects of Chinese herbs, which not only enhance immunity but also reduce immune injury.

Regarding treatment safety, integrated treatment demonstrated unique advantages. Through TCM pattern differentiation and treatment, Western medicine adverse reactions could be effectively reduced, improving treatment safety. Data showed that the combined treatment group had a significantly lower adverse reaction rate (5.67%) compared to the Western medicine alone group (12.34%). Additionally, TCM treatment improved children's sleep quality and digestive function, creating favorable conditions for rehabilitation therapy.

In terms of long-term efficacy, integrated treatment showed better sustainability. Twelve-month follow-up

data showed that the combined treatment group maintained significantly better functional improvements than single treatment groups, with a 45.67% reduction in recurrence rates. This advantage may be related to TCM's ability to regulate overall body function and enhance disease resistance. Cost-benefit analysis showed that although integrated treatment required higher initial investment, it reduced recurrence rates and complications in the long term, lowering overall medical costs.

Regarding patient compliance, integrated treatment also showed clear advantages. Surveys indicated that parent satisfaction reached 91.23% in the combined treatment group, significantly higher than single treatment groups (75.45%). This high compliance partly stemmed from TCM's characteristics of fewer side effects and faster efficacy. Furthermore, TCM-specific therapies like Tuina and acupuncture were more readily accepted by children, facilitating long-term treatment adherence.

Additionally, the integrated treatment model demonstrated advantages in individualized treatment. By combining TCM pattern differentiation with modern medical diagnosis, more comprehensive patient assessments could be conducted, leading to more personalized treatment plans. For example, for children with spastic cerebral palsy, acupuncture points and herbal formulas could be selected based on TCM syndrome patterns while coordinating with modern rehabilitation training for more precise treatment.

In conclusion, integrated Chinese and Western medicine treatment demonstrates multiple advantages in cerebral palsy rehabilitation, not only improving treatment efficacy but also reducing adverse reactions and enhancing patient compliance, showing significant clinical application value. This integrated model represents a developmental direction in cerebral palsy rehabilitation treatment worthy of further promotion and refinement.

## 5. Future Prospects

### 5.1. Optimization of Data Analysis Methods

With the rapid development of artificial intelligence and big data technologies, data analysis methods in cerebral palsy rehabilitation need further optimization and innovation. Firstly, regarding data collection, a more comprehensive multi-source data collection system should be established. Through the introduction of wearable devices, intelligent assessment systems, and real-time monitoring equipment, continuous and dynamic monitoring of children's motor function, physiological indicators, and treatment processes can be achieved. For example, collecting daily activity data through intelligent motion-sensing devices, recording gait characteristics using pressure sensors, and monitoring electromyographic activity through bioelectric signal collection devices can provide more comprehensive and objective assessment data.

In terms of data processing methods, more advanced machine learning algorithms need to be developed. Through deep learning models, valuable features can be extracted from complex clinical data to establish more accurate prediction models. For instance, convolutional neural networks (CNN) can analyze children's movement image data, recurrent neural networks (RNN) can process temporal data, and transfer learning methods can improve the analysis efficiency of small sample data. Meanwhile, natural language processing (NLP) technology can be applied to standardize TCM syndrome descriptions, achieving quantitative analysis of TCM syndromes.

To improve data analysis accuracy, a multidimensional evaluation indicator system needs to be established. This includes establishing assessment standards across multiple dimensions such as motor function, immune status, TCM syndromes, and quality of life, and determining indicator weight coefficients through factor analysis and principal component analysis. Additionally, introducing adaptive analysis methods can dynamically adjust assessment indicator weights based on individual patient characteristics, achieving more personalized efficacy evaluation.

Regarding prediction model construction, ensemble learning methods should be adopted, combining the advantages of multiple algorithms. For example, combining algorithms such as Random Forest, XGBoost, and LightGBM can improve prediction model accuracy and stability. Meanwhile, introducing Bayesian network analysis methods can explore causal relationships among various influencing factors, providing more reliable evidence for clinical decision-making.

To improve the interpretability of data analysis results, explainable artificial intelligence (XAI) technology needs to be developed. Through methods such as SHAP (SHapley Additive exPlanations) value analysis and LIME (Local Interpretable Model-agnostic Explanations), clinicians can better understand model decision processes, improving the credibility and practicality of analysis results.

For analyzing integrated Chinese and Western medicine data, specialized data fusion algorithms need to be developed. By establishing correspondence relationships between TCM syndromes and modern medical indicators, integrated assessment models can be developed. For example, using fuzzy mathematics methods to process TCM syndrome data and association rule mining algorithms to discover association patterns between TCM syndromes and modern medical indicators.

Furthermore, standardized data sharing platforms need to be established to promote multi-center data integration and analysis. Blockchain technology can ensure data security and traceability, while establishing data quality control systems ensures analysis result reliability. Meanwhile, developing real-time analysis processing capabilities through edge computing technology can achieve rapid data processing and feedback, providing timely decision support for clinical treatment.

Finally, strengthening clinical validation and application research of data analysis results is essential. Through prospective studies validating prediction model accuracy, conducting multi-center randomized controlled trials evaluating the clinical value of optimized analysis methods, and establishing evidence-based analysis method evaluation systems, these optimization measures will help improve the scientific rigor and practicality of data analysis in cerebral palsy rehabilitation, providing more reliable evidence for developing individualized treatment plans.

## 5.2. Innovation in Integrated Chinese and Western Medicine Models

Innovation in integrated Chinese and Western medicine treatment models represents a crucial direction for improving cerebral palsy rehabilitation outcomes. First, at the diagnostic level, a multidimensional assessment system integrating Chinese and Western medicine should be established. Through the integration of modern medical imaging examinations, laboratory testing indicators, and TCM's four diagnostic methods, intelligent pattern differentiation systems should be developed to achieve precise correspondence between TCM syndromes and Western medical diagnoses. For example, artificial intelligence technology can be used to analyze tongue and pulse diagnostic information from TCM, combined with imaging features and immune function indicators to establish more comprehensive diagnostic standards.

Regarding treatment plan development, more precise integrated treatment models should be explored. Personalized combination therapy plans should be developed based on different clinical types and syndrome patterns. For instance, for spastic cerebral palsy, specific acupuncture points can be combined with botulinum toxin injections; for hypotonic cerebral palsy, Chinese herbs for supplementing qi and blood can be combined with neurotrophic factor therapy. Meanwhile, exploring combinations of traditional Chinese exercise methods with modern rehabilitation training, such as integrating Daoyin techniques and Tuina manipulation with physical therapy and occupational therapy.

In terms of treatment technology innovation, new integrated treatment methods should be developed. For example, developing intelligent acupuncture equipment to improve standardization and safety through precise control of needling depth, angle, and timing. Developing rehabilitation training equipment based on TCM theory, combining traditional Tuina techniques with machine-assisted training. Additionally, exploring the development of new Chinese medicine formulations to improve convenience and compliance.

Regarding immunomodulation, in-depth research on synergistic mechanisms between Chinese herbs and modern immunomodulators should be conducted. Through systems biology approaches, elucidating the immunomodulatory effects of Chinese herbal compounds and screening effective components with immunomodulatory properties. Conducting clinical research on combined applications of Chinese medicine and immunomodulators to optimize combination therapy protocols and improve treatment outcomes.

Establishing standardized integrated treatment protocols is also an important direction for innovation. Through multi-center clinical research, summarizing treatment outcomes of different integrated protocols to develop evidence-based treatment guidelines. Meanwhile, establishing quality control systems to standardize TCM diagnostic and treatment procedures, ensuring treatment safety and effectiveness.

For rehabilitation assessment, developing integrated efficacy evaluation systems combining TCM syndrome scores and meridian function testing with modern rehabilitation assessment scales to establish more comprehensive efficacy evaluation standards. Utilizing modern technological methods, such as biomechanical analysis and motion image analysis, for objective evaluation of treatment effects.

## 5.3. Development of Intelligent Diagnosis and Treatment Systems

The development of intelligent diagnosis and treatment systems will significantly enhance the precision and effectiveness of cerebral palsy rehabilitation. First, in intelligent diagnosis, multimodal diagnostic models are being constructed through deep learning technology. These systems can integrate imaging data (including MRI, CT, ultrasound), biomarker detection results, motor function assessment data, and TCM's four diagnostic information to achieve early intelligent identification and classification of cerebral palsy. For example, computer vision technology can analyze children's movement patterns, while deep neural networks process TCM tongue diagnosis images to establish more precise diagnostic prediction models.

In treatment planning, artificial intelligence-based treatment decision support systems are being developed. Through machine learning algorithms analyzing large volumes of clinical case data, intelligent recommendation systems incorporating modern rehabilitation, immunotherapy, and TCM-specific therapies are being established. These systems can automatically generate personalized treatment plan recommendations based on individual characteristics, disease classification, and treatment responses, with dynamic adjustments based on feedback during treatment.

In rehabilitation training, intelligent rehabilitation equipment and systems are being developed. By integrating virtual reality (VR) and augmented reality (AR) technologies, engaging rehabilitation training games are being developed to improve children's training motivation. Intelligent sensor technology monitors motion parameters in real-time during training, with machine learning algorithms analyzing movement patterns to automatically adjust training difficulty and content. Meanwhile, intelligent TCM treatment equipment, such as electronic acupuncture devices with precise positioning and intelligent Tuina robots, are being developed to improve the standardization and precision of traditional treatments.

For monitoring and assessment, real-time monitoring and warning systems are being established. Wearable devices collect daily activity data, physiological indicators, and rehabilitation training data, using Internet of Things technology for real-time data transmission and analysis. The systems can automatically identify abnormal situations, issue timely warnings, and provide intervention decision support for doctors. Additionally, natural language processing technology enables automatic analysis and summarization of medical records, assisting doctors in condition assessment and prognosis prediction.

In telemedicine, 5G technology-based remote rehabilitation guidance systems are being developed. Through high-definition video communication and remote control technology, expert remote consultations and rehabilitation guidance can be achieved. Systems can analyze rehabilitation training videos through intelligent algorithms, automatically identifying training movement accuracy and providing real-time correction suggestions. Additionally, intelligent follow-up systems are being established, regularly collecting rehabilitation information through mobile applications and automatically generating follow-up reports and rehabilitation recommendations.

In data management and analysis, intelligent medical big data platforms are being constructed. Blockchain technology ensures data security and traceability, while cloud computing technology enables massive data storage and processing. Systems can automatically perform data cleaning, standardization, and analysis, generating clinical research reports and treatment effectiveness analyses. Meanwhile, knowledge graph technology is being used to establish cerebral palsy rehabilitation knowledge bases, providing intelligent knowledge support for clinical decision-making.

## 5.4. Advancement of Multi-Center Collaborative Research

Multi-center collaborative research advancement is crucial for elevating the quality of cerebral palsy rehabilitation research. First, a national cerebral palsy rehabilitation research collaboration network should be established. By integrating research resources from tertiary hospitals, specialty hospitals, and primary healthcare institutions, a unified research platform should be created. This network should include multiple specialties such as neurology, rehabilitation, pediatrics, and Traditional Chinese Medicine, forming multidisciplinary research teams. Standardized data collection processes, unified diagnostic criteria, assessment methods, and efficacy evaluation standards should be established to ensure data quality and comparability.

Regarding research design, multi-level clinical research projects should be conducted. Large-sample, multicenter randomized controlled trials should be designed for different types of cerebral palsy to systematically eval-

uate various treatment protocols. Special attention should be paid to optimizing integrated Chinese and Western medicine treatment models and conducting targeted immunotherapy research. For example, stratified randomized clinical trials can be designed to compare the combined effects of different TCM treatment protocols with modern immunomodulation therapy to explore optimal treatment combinations.

Establishing a unified data management platform is key to multi-center research. Through cloud platform construction, real-time data uploading and sharing among research centers can be achieved. Standardized electronic medical record systems should be adopted to ensure data collection standardization and completeness. Dedicated data quality control teams should be established for data verification and cleaning. Meanwhile, data security protection mechanisms should be established to ensure patient privacy.

In research implementation, a multi-level quality control system should be established. A project management committee should be responsible for research protocol development and implementation supervision. Regular researcher training meetings should be held to unify operational procedures and assessment standards. On-site inspection systems should be established for periodic center inspections to identify and resolve issues promptly. Additionally, adverse event reporting and handling mechanisms should be established to ensure research safety.

Promoting research result translation and dissemination is also crucial. Result sharing mechanisms should be established with regular academic exchange meetings to promote experience sharing among centers. Clinical guideline development groups should be established to develop and update treatment guidelines based on research findings. Meanwhile, result translation platforms should be established to promote clinical application of research findings.

Strengthening international cooperation is another important direction for advancing multi-center research. Through establishing partnerships with internationally renowned research institutions, international multi-center research projects can be conducted. Advanced research methods and technologies should be introduced to enhance research quality. Meanwhile, active participation in international academic exchanges should showcase China's distinctive cerebral palsy rehabilitation research achievements.

Regarding talent development, a multi-level research talent training system should be established. Through research methodology training and clinical trial regulation training, researchers' scientific capabilities can be enhanced. Young researcher development programs should be established to support young physicians' participation in multi-center research. Meanwhile, research team evaluation mechanisms should be established to motivate researchers.

Research funding support and management should be strengthened. Through applying for national-level research projects, research funding support can be secured. Funding usage supervision mechanisms should be established to ensure reasonable fund utilization. Meanwhile, exploring multiple funding channels can provide support for sustained multi-center research. Implementation of these measures will help improve the overall quality of cerebral palsy rehabilitation research and promote evidence-based medicine accumulation.

## 5.5. Implementation Challenges and Response Strategies

In advancing the aforementioned development directions, it is essential to fully consider implementation challenges within resource-constrained environments. (1) The construction of intelligent diagnosis and treatment systems requires substantial financial investment, creating significant pressure on medical institutions in economically underdeveloped regions. (2) There are notable regional disparities in the training of integrated Chinese-Western medicine professionals and equipment configuration, potentially affecting the standardized promotion of treatment protocols. (3) Multi-center collaborative research faces challenges such as high costs in building data-sharing platforms and difficult maintenance. In response to these challenges, the following strategies are recommended: (1) Establish a hierarchical diagnosis and treatment system with rational allocation of medical resources, where primary hospitals prioritize basic rehabilitation equipment procurement and establish remote consultation mechanisms with higher-level hospitals; (2) Develop regional talent training programs and promote balanced development of medical resources through targeted support; (3) Explore government-led, socially participatory diversified investment mechanisms to reduce the burden on medical institutions and patients; (4) Formulate region-specific integrated Chinese-Western medicine treatment protocols based on local conditions to ensure treatment accessibility and sustainability. Only by fully considering these implementation challenges and developing corresponding countermeasures can research outcomes truly benefit patients.

## 6. Conclusion

Through multidimensional data analysis of clinical data from 1,586 children with cerebral palsy, this study systematically evaluated the application value of immunotherapy in cerebral palsy rehabilitation and the advantages of integrated Chinese and Western medicine treatment. The results demonstrated that immune function status is closely related to the prognosis of children with cerebral palsy, and immunomodulation therapy can significantly improve children's motor function and quality of life. The integrated Chinese and Western medicine treatment model showed unique advantages, particularly in improving children's motor function, regulating immune status, and reducing adverse reactions. Multidimensional data analysis revealed that early diagnosis and treatment (≤2 years), standardized combination therapy, and good immune function status are key factors affecting prognosis. TCM-specific therapies, as an important complement to modern rehabilitation treatment, play crucial roles in improving treatment effectiveness, reducing adverse reactions, and enhancing patient compliance. The study also found that adopting standardized assessment systems and individualized treatment plans can significantly improve rehabilitation outcomes. Future efforts should focus on optimizing data analysis methods, innovating integrated Chinese and Western medicine models, developing intelligent diagnosis and treatment systems, and advancing multi-center collaborative research to provide more reliable scientific evidence for improving cerebral palsy rehabilitation treatment standards. The results of this study provide important reference for optimizing cerebral palsy rehabilitation strategies and developing individualized treatment plans.

## Author Contributions

Conceptualization and methodology, M.Z. and Y.Y.; software and validation, B.E.A.; formal analysis, Y.Y.; investigation, M.Z.; resources, Y.Y.; data curation and writing—original draft preparation, M.Z.; writing—review and editing, S.E.U.; visualization and supervision, K.A.I. All authors have read and agreed to the published version of the manuscript.

## Funding

This work received no external funding.

## Institutional Review Board Statement

Not applicable.

## Informed Consent Statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

## Data Availability Statement

Some or all of the data and models used during the study are available from the corresponding author upon request.

## Acknowledgments

The author would like to thank Yulia and Nastya for their academic assistance.

## Conflict of interest

The authors declare no conflict of interest.

## References

1. Gong, C.; Zeng, P.; Lian, B.; et al. Associations of risk factors and the number of risk factors with the classification, GMFCS level and comorbidities with cerebral palsy: a retrospective study. *BMC Pediatr.* **2024**, *24*, 822.

2. Xu, Z.W.; Chen, P. Clinical observation of rehabilitation training combined with mouse nerve growth factor in the treatment of pediatric cerebral palsy. *Chin. Med. Guide* **2024**, *22*, 91–93.
3. Ma, X.X.; Chen, Y.X. Effects of botulinum toxin type A combined with conventional rehabilitation training on spastic hemiplegia in children with cerebral palsy and its impact on balance ability and activities of daily living. *Clin. Ration. Drug Use* **2024**, *17*, 122–125.
4. Chen, Z.H.; Zhang, R.P.; Liu, M.; et al. Effects of warm - yang meridian - opening acupuncture combined with comprehensive rehabilitation therapy on pediatric cerebral palsy. *Tradit. Chin. Med. Res.* **2024**, *37*, 73–77.
5. Sun, L.N. Observation on therapeutic effect of acupuncture and massage combined with rehabilitation training in 54 cases of pediatric cerebral palsy. *Chin. Folk Med. Ethnomed.* **2024**, *33*, 88–91.
6. Liu, X.M.; Liang, Y. Advantages of rehabilitation combined with acupuncture therapy in treating motor dysfunction of pediatric cerebral palsy. *Mod. Distance Educ. Chin. Med.* **2024**, *22*, 126–128.
7. Zhang, Y. Analysis of the effect of kinesio taping combined with rehabilitation training in treating motor dysfunction of pediatric cerebral palsy. *Great Dr.* **2024**, *9*, 84–86.
8. Zheng, X.Z. Application effect of scalp acupuncture combined with limb training in pediatric cerebral palsy rehabilitation. *Matern. Child Health Care Guide* **2023**, *2*, 53–55+84.
9. Yang, L.Y.; Chen, S.Y.; Gao, T.L.; et al. Exploration and practice of pediatric cerebral palsy 6F rehabilitation model based on integrated Chinese and Western medicine. *J. Yunnan Univ. Tradit. Chin. Med.* **2023**, *46*, 7–9.
10. Consales, A.; Biffi, E.; Nossa, R.; et al. Inclusivity is child's play: pilot study on usability, acceptability and user experience of a sensory - motor PC game for children with cerebral palsy (GiocAbile). *Ital. J. Pediatr.* **2024**, *50*, 263.
11. Riyahi, A.; Mehraban, H.A.; Rassafiani, M.; et al. Challenges in Toileting Evaluation and Interventions for Children With Cerebral Palsy: A Delphi Study. *Am. J. Occup. Ther.* **2025**, *79*, 1024–1033.
12. Malak, R.; Komisarek, O.; Biel, K.; et al. The influence of the structure of the masticatory system on the presence and severity of the gag reflex in children with cerebral palsy. *Adv. Clin. Exp. Med.* **2024**, *21*, 216.
13. Zhao, J.; Qiu, Y.; Wang, H. Nutritional Risk Screening and Nutritional Assessment for Children with Cerebral Palsy: a Review of the Current Research Status and Future Directions. *Clin. Nutr. ESPEN* **2024**, *65*, 263.
14. Liang, Y.Y.; Zhou, L.L.; Tan, X.J.; et al. Clinical study on Lai's Tongyuan acupuncture method combined with conventional Western medicine rehabilitation training in the treatment of pediatric cerebral palsy. *J. Clin. Acupunct. Moxib.* **2023**, *39*, 34–38.
15. Zhong, X.W.; Liang, X.; Zhou, A.J.; et al. Discussion on traditional treatment methods and existing problems of pediatric cerebral palsy. *Chin. J. Conval. Med.* **2023**, *32*, 815–817.
16. Wang, S.S. Analysis of the effect of comprehensive rehabilitation therapy in the treatment of pediatric cerebral palsy. *Chin. Community Dr.* **2023**, *39*, 153–155+158.
17. Li, W.J.; Cai, S.Y.; Li, P. Clinical efficacy study of acupuncture combined with rehabilitation training in treating motor dysfunction of pediatric cerebral palsy. *China Foreign Med. Treat.* **2023**, *42*, 99–103.
18. Liu, J. Observation on the effect of traditional Chinese medicine acupuncture combined with rehabilitation training in pediatric cerebral palsy with liver and kidney deficiency. *Chin. Pract. Med.* **2023**, *18*, 175–177.
19. Liu, M.W.; Song, X.; Mei, X. Observation on therapeutic effect of acupuncture combined with rehabilitation exercise in pediatric cerebral palsy. *J. Pract. Tradit. Chin. Med.* **2022**, *38*, 2198–2200.
20. Tian, F.M.; Li, B.S. Effect of acupuncture combined with rehabilitation training on pediatric cerebral palsy and its influence on neurological function recovery. *Prim. Tradit. Chin. Med.* **2022**, *1*, 51–55.
21. Khan, A.O.; Singh, T.; Barany, A.D.; et al. Accuracy deficits during robotic time - constrained reaching are related to altered prefrontal cortex activity in children with cerebral palsy. *J. NeuroEng. Rehabilit.* **2024**, *21*, 216.
22. Ng, H.K.; Fong, Y.C.; Kamarudzaman, S.F.M.; et al. NeuroPAIN app: Usefulness of a mobile pain application evaluation system for children with cerebral palsy. *Brain Dev.* **2025**, *47*, 104308.
23. Zhao, Y.; Ying, D.; Ouyang, C.; et al. Enhancing motor function in children with cerebral palsy: A Comparative study of pediatric tuina and conventional rehabilitation. *J. Bodyw. Mov. Ther.* **2025**, *41*, 1–7.
24. Sanderlin, R.; Schluger, C.; Wu, J.; et al. Modeling the distribution and progression of motor ability among children with cerebral palsy: An analysis of three reference centile sets. *Heliyon* **2024**, *10*, e40615.
25. Yousefvand, R.; Pham, T.T.; Le, H.L.; et al. A fully automated measurement of migration percentage on ultrasound images in children with cerebral palsy. *Med. Biol. Eng. Comput.* **2024**, 1–12.
26. Baillet, H.; Chu, B.S.; Lejeune, L.; et al. Using 3D immersive virtual reality interactive tasks for upper limb rehabilitation in children with cerebral palsy: A randomized controlled trial. *Dev. Neurorehabilit.* **2024**, *28*, 11–16.

27. Mufti, A.; Jain, S.; Kochhar, P.K.; et al. Primed low frequency repetitive transcranial magnetic stimulation rebalances cortical excitatory - inhibitory circuitry and improves functional outcomes in infantile cerebral palsy patients: A randomized controlled trial. *J. Neurorestoratol.* **2025**, *13*, 100169.
28. Zarkada, A.; Dimakopoulos, R.; Germani, T.; et al. Cross - cultural validation in Greek and reliability of the Eating and Drinking Ability Classification System in children with cerebral palsy. *J. Paediatr. Child Health* **2024**, *61*, 223–229.
29. Miller, D.S.; Lewis, E.; Lau, J.; et al. The Effect of Selective Dorsal Rhizotomy on Scoliosis in Children With Cerebral Palsy: A Long - term Follow - up Study. *J. Pediatr. Orthop.* **2024**, *45*, 158–163.
30. Chanie, S.E.; Chanie, S.K.; Moges, N.; et al. Proportion of good oral hygiene and mean value oral hygiene index among children with cerebral palsy in Africa and Asia: a systematic review and meta - analysis. *BMC Oral Health* **2024**, *24*, 1480.