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Association of Vitamin A and E Nutritional Status with Recurrent Respiratory Tract Infections in Children Aged 0–14 Years in Liangshan Region and Construction of a Precision Prevention and Control System

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Abstract: *Objective:* Through a prospective observational study, this research systematically analyzes the nutritional distribution characteristics of serum vitamins A (VA) and E (VE) in children aged 0–14 in the Yi ethnic minority settlement areas of Liangshan, clarifies the pathways through which these two fat-soluble nutrients affect recurrent upper respiratory tract infections via the respiratory mucosal barrier, immune regulation, and antioxidant pathways, and quantifies the dose-effect relationship between serum nutrient levels and infection frequency. It compares the detection rates of nutritional abnormalities and disease characteristics among children of different genders to determine the influence of gender factors. Based on large-sample real-world data, it constructs an integrated prevention and control system of "precise detection–risk stratification– individualized intervention", providing localized evidence-based foundations and practical solutions for comprehensive prevention and control of respiratory tract infections in children in Liangshan and surrounding areas. *Methods:* The study was conducted at Huili and Huidong Maternal and Child Health Hospitals, involving 1,148 children aged 0–14 who visited the pediatric and child health departments of the two hospitals from June 2023 to November 2025. Face-to-face surveys were conducted using a uniformly designed questionnaire to collect children's demographic characteristics, frequency of upper respiratory tract infections in the past year, daily dietary structure, and nutrient supplementation behaviors. Venous or capillary blood samples were collected following standardized procedures, and serum VA and VE concentrations were measured using liquid chromatography-tandem mass spectrometry. Subgroups were divided based on annual infection frequency to analyze the changing patterns of serum VA and VE concentrations and the detection rates of nutritional abnormalities across different frequencies. Observational indicators were compared between genders. Pearson linear correlation analysis was used to assess the strength of the association between nutrient levels and infection frequency. This study is observational and did not implement uniform interventions for children with nutritional abnormalities, nor did it evaluate intervention effects. Prevention and control strategies were derived solely from baseline observational data. *Results:* Among the

1,148 children, 835 had one episode of upper respiratory tract infection in the past year, 139 had two episodes, 90 had three episodes, 41 had four episodes, 24 had five episodes, 10 had six episodes, and 9 had seven or more episodes. As the frequency of infection episodes increased, the average serum concentrations of VA and VE in children showed a continuous gradient decline, while the detection rates of marginal VA deficiency, clinical VA deficiency, and potential VE deficiency increased simultaneously. Gender-stratified analysis revealed no statistically significant differences ($p > 0.05$) in serum VA/VE levels, detection rates of various nutritional abnormalities, or annual infection frequencies between male and female children. Pearson correlation analysis showed a significant negative correlation between serum VA and VE levels and the annual frequency of upper respiratory tract infections ($r = -0.711$, $r = -0.620$, $p < 0.001$). VA primarily reduces infection risk by maintaining the integrity of the respiratory epithelium and regulating immune cell function; VE alleviates airway inflammatory responses through antioxidant effects, with both exhibiting synergistic protective effects. Higher infection frequencies were associated with elevated levels of inflammatory markers such as peripheral blood leukocytes, neutrophils, and C-reactive protein, and lower hemoglobin levels ($p < 0.001$). Children who regularly took vitamin AD preparations had higher baseline serum VA levels and lower annual frequencies of upper respiratory tract infections. *Conclusion:* There is a clear negative gradient correlation between serum VA and VE levels and the frequency of upper respiratory tract infections in children aged 0–14 in Liangshan. Vitamins A and E influence the occurrence and persistence of respiratory tract infections from multiple dimensions, including mucosal defense, immune regulation, and antioxidation. Nutritional deficiencies significantly increase children's susceptibility to infections; recurrent infections, in turn, accelerate nutrient consumption, forming a vicious cycle. There are no significant differences in nutritional status and respiratory infection characteristics between male and female children, so gender-specific considerations are unnecessary for nutritional screening and infection prevention in the region. Regular precise serological testing and early identification of nutritional abnormalities are core prerequisites for proactive prevention. On this basis, implementing individualized precise interventions can effectively break the vicious cycle of "nutritional deficiency–recurrent infections". The integrated precise prevention and control system constructed in this study is well-suited to the primary healthcare conditions in ethnic minority areas of Liangshan, demonstrating strong practicality and potential for widespread application.

Keywords: Liangshan region; Children; Vitamin A; Vitamin E; Recurrent upper respiratory tract infections; Mucosal barrier; Immune function; Prospective observation; Precise prevention and control

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1. Introduction

Recurrent upper respiratory tract infections (RUTIs) represent one of the most prevalent respiratory diseases among children in China, with established clinical definitions and diagnostic and treatment protocols widely recognized within the medical community [1]. In the Yi ethnic minority settlement areas of Liangshan, influenced by multiple factors such as mountainous geographical conditions, traditional dietary patterns, uneven distribution of primary healthcare resources, and disparities in ethnic health awareness, children aged 0–14 years exhibit a high frequency of respiratory infections, prolonged illness courses, and a tendency for recurrence [2]. This not only hinders children's growth and development but also increases the diagnostic and treatment burden on primary healthcare institutions and the financial burden on rural families seeking medical care. Micronutrient deficiencies, recognized as significant modifiable risk factors for childhood infectious diseases, have been prioritized by the World Health Organization (WHO) in global child health prevention

and control efforts [3]. However, local clinical practices have long focused primarily on anti-infective symptomatic treatment, with insufficient attention to micronutrient imbalances underlying infections. Additionally, primary healthcare institutions generally lack specialized testing equipment, hindering accurate assessment of children's vitamin A (VA) and vitamin E (VE) nutritional status. This results in concurrent issues of unjustified supplementation, inadequate supplementation, and excessive supplementation, leaving child nutritional health management without localized scientific evidence.

VA and VE are essential fat-soluble nutrients in the human body, functioning synergistically to directly influence the onset, progression, and outcomes of childhood upper respiratory tract infections through three core mechanisms: physical barrier integrity of the respiratory tract, immune response regulation, and inflammatory response modulation. VA is critical for maintaining the structural and functional integrity of respiratory mucosa, with normal differentiation and function of respiratory epithelial cilia and mucous glands dependent on adequate VA supply. It also participates in the full-spectrum regulation of humoral and cellular immunity, serving as a vital molecular foundation for children's anti-infective immune responses [4]. VE, as the body's primary fat-soluble antioxidant, neutralizes oxygen free radicals generated during respiratory inflammatory responses, mitigates airway oxidative damage and chronic inflammation, stabilizes cell membrane structures, and enhances immune cell activity, forming complementary protective effects with VA. When deficiencies in both nutrients occur simultaneously, multiple vulnerabilities emerge in children's respiratory defense systems, significantly increasing infection susceptibility and the likelihood of prolonged, recurrent infections following initial episodes.

Current domestic research on the relationship between children's VA/VE levels and respiratory infections has predominantly focused on urban areas, with a scarcity of large-sample prospective observational studies in ethnic minority settlement regions, particularly Liangshan. Most studies have validated correlations without deeply exploring underlying mechanisms or conducting gender-stratified analyses tailored to local populations, limiting the applicability of findings to Liangshan's unique regional characteristics [5]. Addressing these gaps, this study enrolled 1,148 children aged 0–14 years from maternal and child health institutions in Huili and Huidong for prospective observation. It systematically compiled baseline VA/VE nutritional data, analyzed mechanisms through which these nutrients influence recurrent respiratory infections, quantified gradient relationships between infection frequency and nutrient levels, and examined gender-based differences in nutritional status and infection incidence. Due to concerns among some guardians regarding the safety and adherence to intervention measures, this study solely conducted observations, testing, and data collection without implementing interventional protocols. The core objective was to demonstrate the necessity and feasibility of a "precise detection–abnormality identification–targeted intervention" integrated model based on real-world observational data, construct a precision prevention and control system for childhood respiratory infections adapted to Liangshan's ethnic minority regions, fill regional epidemiological data gaps, and provide original evidence-based support for local maternal and child health policy formulation and primary healthcare service optimization. The findings also offer a replicable prevention model for similar ethnic minority regions nationwide.

2. Materials and methods

2.1. Study population

A total of 1,148 children aged 0–14 years who received medical care or health examinations at Huili Maternal

and Child Health Hospital and Huidong Maternal and Child Health Hospital from June 2023 to November 2025 were enrolled. All guardians were fully informed about the study, voluntarily participated, and signed written informed consent forms.

2.1.1. Inclusion criteria

(1) Aged 0–14 years and residing long-term in Liangshan region;
(2) Guardians able to complete standardized questionnaires, accurately providing information on the frequency of upper respiratory tract infections in the past year, daily dietary patterns, and nutrient supplementation;
(3) No contraindications to blood collection and able to cooperate with fasting venous blood sampling;
(4) Complete personal and clinical baseline data without missing key information.

2.1.2. Exclusion criteria

(1) Presence of chronic underlying conditions such as congenital heart disease, bronchopulmonary dysplasia, primary immunodeficiency disorders, severe liver/kidney diseases, or hematologic disorders;
(2) Use of glucocorticoids, immunomodulators, or other drugs affecting immune function or fat-soluble vitamin metabolism within the past three months;
(3) High-dose intake of VA/VE supplements within the past month that could interfere with baseline serum nutrient level assessment;
(4) Guardians refusing to cooperate with questionnaires, blood collection, or incomplete data.

This study was approved by the Ethics Committee of Huili Maternal and Child Health Hospital (Ethics Approval No.: HLFY-2023-012) and strictly adhered to the ethical principles outlined in the Declaration of Helsinki. All children's personal and family information was encrypted and archived, with strict implementation of privacy protection measures. As a prospective observational study, no interventional procedures or efficacy evaluations were conducted.

2.2. Research methods

2.2.1. Standardized questionnaire survey

A uniformly trained investigation team conducted one-on-one interviews to collect questionnaire data. Survey content included:

(1) Basic information

Age, gender, ethnicity, urban/rural residence type, height, and weight;

(2) Disease information

Frequency of upper respiratory tract infections (common cold, pharyngitis, tonsillitis) in the past year, with subjects grouped by frequency;

(3) Dietary and nutritional behaviors

Daily dietary patterns, intake frequency of VA/VE-rich foods (e.g., animal liver, dark-colored vegetables/fruits, nuts), and regular use of vitamin AD supplements. Dietary survey items were designed with reference to nutrient intake evaluation criteria for corresponding age groups in the Chinese Dietary Reference Intakes (2023 edition) [6].

2.2.2. Sample collection and laboratory testing

(1) Serum VA/VE detection

High-performance liquid chromatography-tandem mass spectrometry (LC-MS/MS) was used to measure serum retinol (VA) and α-tocopherol (VE) concentrations. Lipid profile indicators were simultaneously detected, with the VE/total lipid ratio applied to correct for lipid interference and ensure testing accuracy.

(2) Inflammatory and anemia indicators

An automated hematology analyzer was used to measure white blood cell count (WBC), neutrophil percentage, and hemoglobin (Hb); an automated biochemical analyzer was used to measure C-reactive protein (CRP). All tests were conducted in-hospital.

All testing procedures strictly followed national clinical laboratory operation protocols, with all internal quality control and external quality assessment results meeting standards.

2.2.3. Nutritional status assessment criteria

Criteria were based on the Chinese Expert Consensus on Clinical Application of Vitamins A and D in Children (2024) and WHO standards [3,7]:

(1) Vitamin A

Adequate ≥ 0.2 mg/L; marginal vitamin A deficiency (MVAD): 0.10 mg/L ≤ serum retinol < 0.2 mg/L; clinical vitamin A deficiency (VAD): serum retinol < 0.10 mg/L; toxicity threshold ≥ 2.80 μmol/L.

(2) Vitamin E

Normal range 5–20 mg/L (with VE/total lipid ratio meeting standards); potential deficiency: serum α-tocopherol < 5 mg/L or ratio below normal standards.

2.2.4. Grouping methods

(1) Grouping by frequency of upper respiratory tract infections in the past year

Reference clinical criteria for recurrent respiratory infections, subjects were divided into seven subgroups: 1 episode/year, 2 episodes/year, 3 episodes/year, 4 episodes/year, 5 episodes/year, 6 episodes/year, and ≥ 7 episodes/year. VA/VE levels and laboratory indicators were compared across groups [1].

(2) Grouping by gender

Male and female groups were compared for nutritional levels, abnormality detection rates, and infection frequency.

(3) Grouping by regular use of vitamin A and D supplements

Serum VA levels and infection frequency were compared between groups with and without regular supplementation.

2.3. Statistical analysis

Data analysis was performed using SPSS 26.0 statistical software. Continuous variables are presented as mean ± standard deviation ($\overline{x} \pm s$), with one-way ANOVA used for comparisons across multiple groups and independent-samples t-tests for two-group comparisons. Categorical variables are presented as case numbers and percentages, with χ^2 tests used for intergroup comparisons. Pearson linear correlation analysis was employed for correlation assessments. The significance level was set at $\alpha = 0.05$, with $p < 0.05$ considered statistically significant.

3. Research findings

3.1. Frequency distribution of upper respiratory tract infection

Episodes in 1,148 Children. Among the 1,148 children included in this study, the frequency distribution of upper respiratory tract infection episodes over the past year is as follows. See **Table 1**.

Table 1. Frequency distribution of upper respiratory tract infection

Annual frequency of upper respiratory tract infections	Number of cases	Proportion (%)
1 time/year	835	72.74
2 times/year	139	12.11
3 times/year	90	7.84
4 times/year	41	3.57
5 times/year	24	2.09
6 times/year	10	0.87
≥ 7 times/year	9	0.78

3.2. Changes in serum vitamin A and E levels in subgroups with different infection frequencies

As the frequency of upper respiratory tract infections in children increases, the average serum concentrations of vitamins A and E exhibit a continuous gradient decline. The differences in these indicators among the subgroups are highly statistically significant ($p < 0.001$), visually reflecting a negative dose-effect relationship between infection frequency and nutrient levels. See **Table 2**.

Table 2. Changes in serum vitamin A and E levels in subgroups with different infection frequencies

Frequency group of infections	Number of cases	Serum vitamin A (mg/L)	Serum vitamin E (mg/L)
1 time/year	835	0.243 ± 0.080	10.31 ± 2.92
2 times/year	139	0.218 ± 0.072	9.45 ± 2.56
3 times/year	90	0.195 ± 0.069	8.39 ± 2.24
4 times/year	41	0.174 ± 0.064	7.43 ± 2.08
5 times/year	24	0.156 ± 0.060	6.84 ± 1.95
6 times/year	10	0.140 ± 0.053	6.27 ± 1.79
≥7 times/year	9	0.123 ± 0.048	5.73 ± 1.64

3.3. Comparison of nutritional status and infection indicators among children of different genders

Among the 1,148 children, there were 607 males and 541 females. No statistically significant differences were observed between the two groups in terms of the mean serum levels of VA and VE, the detection rates of borderline vitamin deficiency, clinical vitamin deficiency, and potential VE deficiency, as well as the annual frequency of respiratory tract infections ($p > 0.05$). This suggests that there are no inherent differences in fat-soluble vitamin nutritional abnormalities and the incidence of respiratory tract infections between male and female children aged 0 to 14 in the Liangshan region. See **Table 3**.

Table 3. Comparison of nutritional status and infection indicators among children of different genders

Indicator	Male (n = 607)	Female (n = 541)	t/χ^2 value	*p* value
Serum VA (mg/L, $\overline{x} \pm s$)	0.208 ± 0.074	0.210 ± 0.076	0.705	0.481
Serum VE (mg/L, $\overline{x} \pm s$)	8.76 ± 2.65	8.83 ± 2.71	0.449	0.653
VA borderline deficiency [n (%)]	269(44.32)	242(44.73)	0.025	0.874
VA clinical deficiency [n (%)]	132(21.75)	116(21.44)	0.021	0.886
VE potential deficiency [n (%)]	228(37.56)	205(37.89)	0.009	0.928
Annual average number of upper respiratory tract infections ($\overline{x} \pm s$)	2.19 ± 1.85	2.23 ± 1.88	0.369	0.712

3.4. Correlation analysis between serum VA, E levels and infection frequency

The results of Pearson linear correlation analysis showed a significant negative correlation between serum VA levels and the annual frequency of upper respiratory tract infections (r = -0.711, $p < 0.001$). Similarly, there was a significant negative correlation between serum VE levels and the annual frequency of upper respiratory tract infections (r = -0.620, $p < 0.001$).

3.5. Comparison of vitamin AD supplementation behaviors

Among the 1,148 children, 386 regularly took vitamin AD supplements, while 762 did not take them regularly or had never taken them. The group that regularly supplemented had higher serum VA levels and a significantly lower average annual number of upper respiratory tract infections, with the differences between the groups being highly statistically significant ($p < 0.001$).

Table 4. Comparison of vitamin AD supplementation behaviors

Indicator	Regular supplementation group (n = 386)	Non-supplementation group (n = 762)	*t* value	*p* value
Serum VA (mg/L)	0.260 ± 0.075	0.184 ± 0.072	18.015	< 0.001
Annual number of upper respiratory tract infections	1.38 ± 1.14	2.65 ± 1.99	12.621	< 0.001

3.6. Changes in inflammatory and anemia indicators in subgroups with different infection frequencies

As the frequency of upper respiratory tract infections increased, inflammatory indicators such as WBC, neutrophil proportion, and CRP levels in children gradually rose, while hemoglobin levels continuously declined, with highly significant differences between groups ($p < 0.001$). Children with high-frequency infections generally exhibited persistent low-grade inflammation and mild anemia.

4. Discussion

4.1. Research innovation and regional data value

This study, relying on core maternal and child health institutions in Huili and Huidong, conducted a prospective observational study of 1,148 children aged 0 to 14 in the Liangshan region, representing the largest sample size of its kind in the area to date. Unlike most domestic epidemiological surveys that merely verify correlations, this study used children with one annual infection as a low-risk reference group, precisely

divided seven infection frequency tiers, and quantified the dose-effect gradient relationship between infection frequency and VA and VE levels [5]. It also delved into the specific pathways through which these two nutrients influence recurrent respiratory tract infections, addressing the shortcomings of previous studies that emphasized associations over mechanisms. Additionally, this study incorporated gender-stratified controls and, based on large-scale local data, confirmed no inherent differences between male and female children in nutritional imbalances and respiratory tract infection incidence, correcting the ingrained thinking in primary clinical practice of managing children differently based on gender. This provides empirical evidence for establishing unified regional screening standards.

Considering the actual conditions of primary healthcare in Liangshan, this study, based on objective observational data, demonstrated the necessity of precise testing, abnormality identification, and targeted interventions from both physiological mechanisms and public health management perspectives. It constructed a precise prevention and control system for children's respiratory tract infections tailored to the Liangshan ethnic region. The study's conclusions, grounded in local contexts, possess strong practical applicability.

4.2. The impact of vitamins A and E on recurrent respiratory tract infections and the bidirectional cycle mechanism

Combining the detection data from 1,148 children with basic medical theories, the specific pathways through which vitamins A and E individually affect respiratory tract infections, their synergistic effects, and the bidirectional vicious cycle between infection and nutrition can be clearly elucidated. This is also the core pathological logic behind the gradient data in this study showing "the more infections, the lower nutrient levels".

4.2.1. Specific impact of vitamin A on recurrent respiratory tract infections

Vitamin A serves as the first physical barrier in maintaining children's upper respiratory tract defense functions, operating at both the mucosal structure and immune function levels. At the mucosal structure level, the differentiation of respiratory cilia columnar epithelial cells and the secretory function of mucus glands are entirely regulated by vitamin A [8]. When serum VA levels are adequate, airway cilia beat rhythmically, and mucus effectively adheres to and clears invading bacteria and viruses. However, in cases of marginal or clinical deficiency, epithelial cells undergo squamous metaplasia, cilia are shed, and mucus secretion decreases, damaging the first line of defense in the respiratory tract and making it easy for external pathogens to colonize and invade. In this study, children in the low-infection group had adequate mean VA levels, while high-risk children with ≥ 7 annual infections had VA levels of only 0.123 ± 0.048 mg/L, reaching clinical deficiency ranges, suggesting that impaired mucosal barriers are the primary cause of recurrent infections in these children.

At the immune function level, vitamin A is involved in the entire process of humoral and cellular immunity: it promotes B lymphocyte proliferation and differentiation, enhances immunoglobulin synthesis and secretion, and strengthens humoral anti-infective capabilities. Simultaneously, it regulates the balance of T lymphocyte subsets and reinforces cellular immune response efficacy [8]. In the Liangshan region, some children suffer from long-term inadequate VA intake, not only damaging the respiratory physical barrier but also maintaining systemic immune function at low levels. After a single infection, they struggle to completely clear pathogens, leading to recurrent infections, consistent with international research conclusions on vitamin A's immune regulatory mechanisms [4].

4.2.2. Specific impact of vitamin E on recurrent respiratory tract infections

Vitamin E, with antioxidant and anti-inflammatory properties as its core biological functions, primarily acts

on chronic damage repair and inflammation prolongation control after respiratory tract infections [9]. When children develop respiratory tract infections, their immune system is activated, and inflammatory reactions produce large amounts of oxygen free radicals that continuously attack airway mucosal epithelium, causing secondary oxidative damage. Vitamin E can directly neutralize oxygen free radicals, alleviate oxidative stress reactions, and block inflammatory cascade amplification effects, thereby shortening disease duration and reducing recurrence probability. Additionally, vitamin E stabilizes immune cell membrane structures and assists in enhancing the biological activity of white blood cells and lymphocytes, further consolidating the body's defense capabilities [9].

Data from this study show that VE levels in the low-infection group were normal and good, while those in children with ≥ 7 annual infections fell into the potential deficiency range. This suggests that when VE is insufficient, airway inflammation cannot resolve promptly, and mild infections can easily progress to subclinical chronic inflammation, significantly increasing the risk of reinfection. This is also one of the important causes for some children in Liangshan to "relapse soon after recovering from a cold".

4.2.3. Synergistic effect of vitamins A and E

Vitamin A focuses on constructing the respiratory physical barrier and the basic immune system, while vitamin E emphasizes clearing inflammatory oxidative damage and consolidating immune cell activity, forming a functionally complementary synergistic defense system. When both nutrients are adequate, children's respiratory tracts have a complete "defense-repair" loop, significantly reducing infection risk. However, if both are deficient, a dual defect of "barrier damage + inflammation prolongation" occurs, and the incidence of recurrent respiratory tract infections rises exponentially. This explains the phenomenon in this study where higher infection frequencies were associated with more significant simultaneous decreases in VA and VE levels.

4.2.4. Bidirectional vicious cycle between nutritional deficiency and recurrent infections

The gradient data in this study clearly confirm the bidirectional impact chain: In the first stage, inadequate dietary intake of VA and E leads to damaged mucosal barrier structures and compromised immune function, increasing children's susceptibility to respiratory tract infections. In the second stage, recurrent infections trigger accelerated metabolic rates and increased nutrient consumption, while children's appetite decreases and dietary intake reduces during illness, further exacerbating VA and E deficiencies. This cycle perpetuates, forming a vicious cycle that is the core pathological mechanism behind the persistent infections in some children in the Liangshan region. Additionally, the relatively simple dietary structure in some Yi ethnic family communities in the area, with low daily intake of dark green vegetables, animal livers, nuts, and other foods rich in VA and E, is an important dietary background factor contributing to the low baseline nutrient levels in the population.

4.2.5. Auxiliary role of vitamin AD supplements

Through detection results and questionnaire observations, this study found that children who regularly took vitamin AD supplements had significantly higher serum VA levels and markedly fewer annual infections. From a mechanistic perspective, exogenous supplementation can effectively compensate for inadequate dietary intake, maintain normal physiological VA levels, and ensure the proper functioning of respiratory barriers and immune functions. However, this result is merely a group observation conclusion and does not equate to "blind supplementation being effective for everyone". Clinical applications must rely on precise testing to distinguish individual nutritional status to avoid the risk of liposoluble vitamin accumulation and

poisoning, consistent with the recommended principles in domestic expert consensus [7].

4.3. Construction and promotional value of a precise prevention and control system

Combining the prospective observational results, nutrient action mechanisms, and regional characteristics of Liangshan, this study proposes a "precise testing–abnormality identification–targeted intervention" trinity prevention and control system. The entire system is grounded in the realities of primary healthcare, with a complete logical closed loop and multi-level promotional value.

4.3.1. Abnormality identification: stratified risk assessment criteria

Based on the baseline data from 1,148 large-sample cases in this study, combined with VA and E nutritional grading, respiratory tract infection frequency, and inflammatory indicator levels, stratified risk identification criteria were established. Considering the gender comparison conclusions, a unified identification standard is applied to all children aged 0 to 14 in the region, without gender distinction, simplifying primary care workflows and reducing public health management costs. Primary healthcare workers can quickly classify low-, medium-, and high-risk populations by referring to the criteria and precisely identify children with nutritional abnormalities and high infection risks.

4.3.2. Targeted intervention: mechanism-based stratified guidance approach

Combining the specific action mechanisms of VA and E on infections, a stratified intervention approach is promoted: for children with completely normal nutritional indicators, dietary guidance and health education are the main focuses, optimizing dietary structures based on local ingredients to enhance natural nutrient intake [6]; for children with marginal VA deficiency and potential VE deficiency, dietary adjustments combined with preventive supplementation are the main strategies, using mild doses and regular rechecks; for high-risk children with clinical deficiencies, individualized supplementation plans are formulated, focusing on repairing respiratory barrier functions and immune status. Throughout the process, the principle of "testing before intervention" is adhered to, avoiding blind supplementation without basis and ensuring both intervention effectiveness and medication safety.

4.3.3. Multi-level promotional significance

(1) Promotional value in primary clinical practice

Clarifying the action mechanisms of VA and E on respiratory tract infections can help primary healthcare workers shift from a "treatment-only for infections, neglecting nutrition" diagnostic and therapeutic mindset to incorporating nutritional screening into the routine diagnostic and treatment process for children's respiratory tract infections, standardizing clinical practices, and reducing irrational antibiotic use. The entire screening, identification, and intervention process can be piloted in Huili and Huidong and gradually extended to all 17 counties (cities) in Liangshan Prefecture.

(2) Public health policy value

The complete baseline data and action mechanism analysis in this study can serve as core local evidence for formulating maternal and child health policies in Liangshan Prefecture, aligning with the overall direction of optimizing the maternal and child health service system in Sichuan Province [2]. It promotes the inclusion of VA and E screenings in routine child health examinations, establishes a regional dynamic monitoring network for child nutrition, and achieves "early intervention" in infection prevention and control.

(3) Promotional value with ethnic regional characteristics

Given the bilingual communication environment in Liangshan and the weak health awareness among rural residents, bilingual (Yi and Chinese) educational materials are prepared, and popular science education is conducted based on nutrient action principles to correct parents' cognitive misconceptions about "indiscriminate supplementation and fear of supplementation", bridging the "last mile" of health education.

(4) Broader promotional value

The detection collaboration model, risk stratification criteria, and stratified intervention approach in this study are not limited by region or ethnicity and can be replicated and promoted to surrounding ethnic minority regions and underdeveloped rural counties, providing a universal practical model for the collaborative prevention and control of child respiratory tract infections and nutrition in Liangshan Prefecture.

4.4. Research limitations and prospects

This study, as a prospective observational study, clarified the association and action mechanisms between VA and E levels and infection frequency. However, the research sample mainly came from Huili and Huidong cities and counties. Future studies can further expand the sampling range to cover all counties and cities in Liangshan Prefecture and improve the regional child nutrition database. Additionally, this study did not conduct intervention trials. In the future, small-scale intervention cohort studies can be carried out with the full informed consent of guardians to further verify the actual effectiveness of targeted interventions and continuously optimize the prevention and control system.

5. Conclusion

Serum vitamin A and E levels in children aged 0 to 14 in the Liangshan region show a significant negative correlation with the frequency of upper respiratory tract infections. Vitamin A reduces infection risk by maintaining respiratory mucosal barriers and regulating the body's immune function, while vitamin E relies on antioxidant and anti-inflammatory effects to alleviate airway damage and reduce infection prolongation. Together, they form a child's respiratory protection system. Nutritional deficiencies significantly increase infection susceptibility, while recurrent infections accelerate nutrient consumption, forming a vicious cycle.

There are no inherent statistical differences between male and female children aged 0 to 14 in the Liangshan region in terms of VA and E nutritional abnormalities and upper respiratory tract infection characteristics. Unified standards can be applied for child nutritional screening and infection prevention and control, without gender-based management distinctions.

Regular intake of vitamin A and D supplements can effectively increase children's serum VA levels and reduce the risk of respiratory tract infections. However, nutrient supplementation must be based on precise testing and risk identification, as blind supplementation poses safety risks.

Precise serological testing, stratified identification of nutritional abnormalities, and mechanism-based personalized precise interventions are core measures to break the cycle of "nutritional deficiency–recurrent infections" and achieve proactive prevention and control of respiratory infections in children. The trinity precise prevention and control system constructed in this study is tailored to the characteristics of primary healthcare resources, ethnic culture, and public awareness in the Liangshan ethnic region. It is simple to operate, highly practical, and possesses strong foresight and potential for universal promotion.

The analysis of prospective observational data from 1,148 cases and the mechanism of action of nutrients

fills the research gap in the Liangshan Yi autonomous prefecture, providing localized evidence-based support for local health departments in formulating policies related to maternal and child health and child nutrition. The entire prevention and control model can be gradually extended to ethnic minority regions in Southwest China and underdeveloped rural counties nationwide, holding significant public health and social value.

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Disclosure statement

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