The American Journal of Medical Sciences and Pharmaceutical Research ISSN 2689-1026 Volume 08 - 2026

Characteristics of The Health of Children with Down Syndrome, Taking into Account Vitamin D and Trace Element Status, Development of Methodological Approaches to Correction

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Received: 31 Dec 2025 | Received Revised Version: 25 Jan 2026 | Accepted: 10 Feb 2026 | Published: 24 Feb 2026

Volume 08 Issue 02 2026 | Crossref DOI: 10.37547/tajmspr/Volume08Issue02-23

Abstract

This article provides a comprehensive analysis of the health of children with Down syndrome, taking into account vitamin D levels and trace element status, as well as the development of scientifically based methodological approaches to correcting the identified disorders. Based on data from clinical trials conducted in 2015–2024.

Conclusions. A new vibration method for removing intracerebral hematomas is proposed. Further accumulation of clinical material and determination of indications for the use of the device and method are necessary.

Keywords: Vitamin D, trace elements, osteopenia, correction, pediatrics, metabolic disorders.

Cite This Article: Zufarova Nodira Ibroxim qizi. (2026). Characteristics of The Health of Children with Down Syndrome, Taking into Account Vitamin D and Trace Element Status, Development of Methodological Approaches to Correction. The American Journal of Medical Sciences and Pharmaceutical Research, 8(2), 153–156. https://doi.org/10.37547/tajmspr/Volume08Issue02-23

1. Introduction

Down syndrome is one of the most studied, but at the same time remains clinically complex chromosomal abnormalities, which is due to the multisystem nature of the disorders affecting the somatic, endocrine and immune health of the child.

According to epidemiological reviews for 2018–2023, the frequency of births of children with trisomy 21 remains at the level of 1:700–1:900 newborns, despite the development of prenatal diagnosis. Modern studies increasingly point to the significant role of metabolic factors in the formation of secondary complications in this category of patients.

Particular attention is paid to vitamin D, which is considered not only as a regulator of calcium-phosphorus metabolism, but also as an immunomodulator and neuroprotector. Results of multicenter studies 2019–2024. demonstrate that the prevalence of vitamin D deficiency among children with Down syndrome ranges from 60 to 80%, which is significantly higher than in the general pediatric population.

At the same time, pronounced disturbances in the microelement balance are revealed, primarily in zinc, magnesium and selenium. These elements are involved in

antioxidant protection and regulation of neurotransmitter processes, which is especially important during genetically determined oxidative stress.

Accumulated data indicate the need for an integrated approach to assessing the health status of children with Down syndrome, taking into account nutritional factors. In this regard, an urgent scientific task is to develop methodologically verified approaches to correcting identified deficiency conditions.

This study was carried out using clinical, laboratory and analytical and statistical approaches that meet the requirements of evidence-based medicine. In the period from 2021 to 2024, 126 children with a confirmed diagnosis of Down syndrome aged 3 to 12 years living in urban and suburban environments were examined.

The control group consisted of 98 somatically healthy children, matched by gender and age. All study participants had their serum 25(OH)D levels determined using a chemiluminescent immunoassay, which is recognized as the "gold standard" in clinical practice.

At the same time, calcium, phosphorus, parathyroid hormone levels, as well as microelement status (zinc, magnesium, selenium) were assessed using atomic absorption spectrophotometry. Additionally, densitometry data were used to assess bone mineral density in children over 5 years of age. Statistical processing was carried out using SPSS 26.0 and R 4.2 packages, with the calculation of average values, confidence intervals and Pearson correlation coefficients.

The level of statistical significance was assumed to be $p<0.05$. The research methodology made it possible to ensure the reproducibility of the results and their comparability with data from international publications from 2017–2024.

Analysis of the data obtained showed that the average level of 25(OH)D in children with Down syndrome was 17.6±4.2 ng/ml, while in the control group this figure reached 26.9±5.1 ng/ml, which indicates a statistically significant difference. Vitamin D deficiency (<20 ng/ml) was detected in 73.8% of examined patients with trisomy 21, while among healthy children this figure did not exceed 34.7%.

A significant negative correlation was established between the level of vitamin D and the frequency of acute respiratory infections ($r = –0.62$; $p<0.01$). Trace element analysis revealed a decrease in the concentration of zinc in 59.5% of children with Down syndrome, magnesium in 51.2%, and selenium in 46.8% of those examined. At the same time, a combined deficiency of two or more microelements was observed in 38% of cases, which indicated the systemic nature of metabolic disorders. Densitometric data showed a decrease in bone mineral density in 41% of children with severe hypovitaminosis D.

During a pilot correction program, which included taking cholecalciferol and microelement complexes for 6 months, an increase in 25(OH)D levels by an average of 9.4 ng/ml and a decrease in the frequency of infectious episodes by 27% were noted. The results obtained confirm the clinical significance of monitoring vitamin and mineral status and the effectiveness of staged correction.

The data obtained during the study support the concept that children with Down syndrome develop a specific metabolic phenotype, characterized by a combination of hypovitaminosis D and an imbalance of key microelements. Comparative analysis with the results of international studies 2018–2023. demonstrates a comparable incidence of 25(OH)D deficiency, reaching 70–80% in a pediatric cohort with trisomy 21. Specifically, in a 2021 multicenter European study (n=312), the mean 25(OH)D level was 18.2 ng/mL, which is almost identical to our findings.

This indicates the systemic nature of the problem and its independence from climatic factors, since similar data were recorded both in countries with moderate insolation and in regions with high solar radiation. A likely explanation is a decrease in the activity of vitamin D receptors and metabolic characteristics caused by a genetic abnormality.

An additional pathogenetic factor may be hypothyroidism, the prevalence of which among children with Down syndrome reaches 30–40% according to 2020 data. Endocrine dysfunction reduces the efficiency of hepatic and renal hydroxylation of vitamin D, which affects its bioavailability. Thus, hypovitaminosis D in this population is not only nutritional, but also genetically mediated.

Analysis of the microelement profile revealed a stable trend towards a decrease in the concentrations of zinc, magnesium and selenium, which is consistent with the concept of increased oxidative stress in trisomy 21. It is known that the SOD1 gene, localized on chromosome 21, encodes superoxide dismutase, the overexpression of which leads to an imbalance of free radical reactions.

With a lack of selenium and zinc, the activity of glutathione peroxidase and metalloproteins is significantly reduced, increasing damage to cell membranes. A 2019 study found that selenium levels below 70 µg/L are associated with a 25–

30% increase in inflammatory markers. In our sample, a combined deficiency of two or more microelements was detected in 38% of cases, which confirms the systemic nature of metabolic disorders. Magnesium, as a cofactor in more than 300 enzymatic reactions, affects neuromuscular conduction and cognitive function.

Its decrease correlated with indicators of speech development delay in young children. Consequently, microelement disorders are not secondary, but represent a significant component of the pathogenesis of somatic and neurocognitive disorders.

The identified relationship between 25(OH)D levels and the incidence of infectious diseases deserves special attention.

The negative correlation found ($r = -0.62$; $p < 0.01$) confirms the 2022 meta-analysis, according to which increasing vitamin D levels to 30 ng/ml reduces the risk of respiratory infections by 20-35%. In children with Down syndrome, innate immune dysfunction is exacerbated by a deficiency of vitamin D, which regulates the expression of antimicrobial peptides.

In addition, hypovitaminosis D affects the regulation of the T-cell response, which increases susceptibility to viral agents. The results obtained demonstrate the need to include vitamin D in protocols for the prevention of infectious diseases. At the same time, it should be taken into account that monotherapy with cholecalciferol without correction of microelement status does not provide a complete restoration of metabolic balance. An integrated approach allows you to achieve a more pronounced clinical effect, which is confirmed by a reduction in the incidence of infections by 27% after a six-month correction.

A separate aspect of the discussion is related to the state of the skeletal system. A decrease in bone mineral density in 41% of the examined children indicates the formation of early signs of osteopenia. Data 2020–2023 indicate that children with Down syndrome have lower bone mass levels than the age norm by 10–15%. Vitamin D and magnesium deficiency worsens bone remodeling disorders. An increase in the level of parathyroid hormone with severe hypovitaminosis D confirms the development of secondary hyperparathyroidism. In the long term, this can lead to an increased risk of fractures and musculoskeletal deformities.

Thus, the correction of vitamin and mineral disorders has not only preventive, but also rehabilitation significance.

In the context of developing methodological approaches to correction, it seems appropriate to introduce a stage-by-stage monitoring model. Below is a table showing key assessment indicators and recommended monitoring intervals.

The developed algorithm ensures consistency and reproducibility of clinical decisions. It involves interdisciplinary interaction between a pediatrician, endocrinologist and rehabilitation specialist. Of particular importance is the individualization of dosage, taking into account age, body weight and concomitant pathology. The inclusion of an educational component for parents helps to increase adherence to therapy. Thus, a discussion of the results allows us to conclude that vitamin D deficiency and microelement disorders are significant modifiable risk factors that require regular monitoring and evidence-based correction.

The study made it possible to establish that the health of children with Down syndrome is largely determined by the level of vitamin D and the balance of microelement status. Analysis of clinical and laboratory indicators for the period 2021–2024. showed a high prevalence of hypovitaminosis D and combined deficiency of zinc, magnesium and selenium, which confirms the systemic nature of metabolic disorders in trisomy 21.

The identified changes correlate with an increased incidence of infectious diseases, decreased bone mineral density and slower neurocognitive development. The data obtained are consistent with the results of international studies in recent years and indicate the pathogenetic significance of nutritional factors in the formation of secondary complications.

It has been established that vitamin D deficiency in children with Down syndrome is multifactorial in nature and is caused not only by insufficient insolation and nutritional characteristics, but also by genetically determined metabolic disorders.

Microelement imbalance exacerbates oxidative stress and reduces the effectiveness of antioxidant defense, which negatively affects the functioning of the immune and nervous systems. The combination of these factors forms a stable pathological background that prevents the full social and medical rehabilitation of patients. In this regard, vitamin and mineral status should be considered as one of the key biomarkers of the health status of this category of children.

The developed methodological approaches to correction, based on stage-by-stage monitoring, individualization of therapy and interdisciplinary interaction of specialists, have

demonstrated clinical effectiveness.

The use of comprehensive programs, including correction of vitamin D, microelements and nutritional diet, helps reduce infectious morbidity, improve bone metabolism and increase the overall functional status of children. The results obtained confirm the advisability of including regular assessment of nutritional status in the standards of clinical observation of children with Down syndrome.

A promising direction for further research is to conduct multicenter prospective observations with expanded sampling and a long monitoring period. This will make it possible to clarify optimal schemes for the prevention and correction of deficiency conditions, taking into account regional and ethnocultural characteristics. The implementation of systemic nutritional support programs can become an important element in improving the quality of life and social adaptation of children with Down syndrome.

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