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Advantages Of The Neutron-Activation Method In Diagnosing Microelement Deficiency In Patients Recovered From Covid-19

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Abstract
This article discusses the advantages of neutron-activation analysis (NAT) in diagnosing microelement deficiencies in children who have recovered from COVID-19. NAT possesses high sensitivity and allows for the simultaneous detection of 22 elements in hair samples. According to dissertation results, in 112 children, zinc (Zn) decreased by 1.6 times (54.61±1.7 mcg/g), iron (Fe) by 2.2 times (9.09±0.29 mcg/g), and polymicroelementosis was detected in 89.3% of cases. The non-invasiveness and accuracy of NAT make it an important tool in pediatric diagnostics. An algorithm developed based on NAT during the recovery period (DGU №34416) has demonstrated confirmed effectiveness.
Keywords: COVID-19, children, microelements, neutron-activation analysis, zinc (Zn), iron (Fe), iodine (I), post-COVID recovery, atomic absorption spectrometry

Introduction

The COVID-19 pandemic, caused by the novel coronavirus SARS-CoV-2, began at the end of 2019 and rapidly escalated into a global public health emergency, characterized by high contagiousness and a wide clinical spectrum—from asymptomatic infection to severe respiratory failure or multi-organ dysfunction.[6] The etiology and pathogenesis of this virus in children are unique; although they typically experience the disease in mild or moderate forms, the virus can exacerbate latent nutritional deficiencies (e.g., zinc, selenium, iron, and vitamin D), potentially prolonging the recovery process. Its impact on global health systems has been unprecedented (World Health Organization [WHO], 2023). As of September 2023, over 770 million confirmed COVID-19 cases and more than 6 million deaths have been recorded worldwide, with significant variations by age and region [1]. Understanding the epidemiology of COVID-19 in children remains complex. While pediatric cases generally involve fewer acute complications, the virus can trigger microelement deficiencies (e.g., zinc, iron, and iodine) and extend recovery periods, which requires further investigation in future studies [2].

Microelements play a crucial role in immune function, metabolic processes, and overall health maintenance. Deficiencies in elements such as zinc (Zn), iron (Fe), and iodine (I) can weaken defense mechanisms against infections and exacerbate post-COVID recovery challenges in children [3]. Traditional diagnostic methods (e.g., atomic absorption spectrometry) often have limitations in detecting multiple elements and are invasive. Neutron-activation analysis (NAT) is non-invasive, highly sensitive, and enables the simultaneous analysis of 22 elements in hair samples [4]. The purpose of this article is to evaluate the advantages of NAT with more examples and clinical data, and to propose its implementation in pediatric practice.

Materials and Methods

The study was conducted using retrospective and prospective methods. In the retrospective analysis, the medical histories of 240 children (aged 1-18 years; 148 boys—61.7%, 92 girls—38.3%) treated for COVID-19 at Tashkent City Infectious Diseases Hospital No. 3 in 2020-2021 were examined. In the prospective analysis, 112 children (60 boys—54%, 52 girls—46%) were evaluated during the recovery period at Tashkent City Family Polyclinic No. 33 and the Multidisciplinary Children's Advisory Polyclinic of Tashkent Medical Academy. The control group consisted of 30 healthy children.

Microelement levels were determined using the NAT method at the laboratory of the Institute of Nuclear Physics, Uzbekistan Academy of Sciences. NAT is non-invasive, highly sensitive, and a stable method that allows for the simultaneous analysis of 22 elements (Zn, Fe, Cu, Co, I, and others) in hair samples. Hair samples (2-4 cm from the root) were taken from 4-5 scalp areas, cleaned with acetone, dried, weighed

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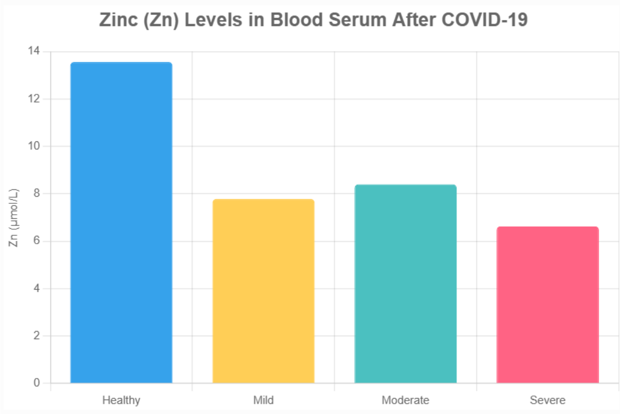
after grinding, and placed in a labeled polyethylene bag. This method is based on atoms emitting radiation at specific wavelengths.

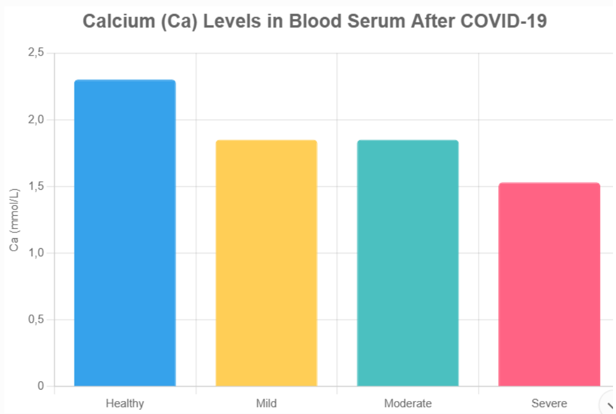
Statistical analysis was performed using STATISTICA software. Differences were evaluated using Student's t-test ($P<0.05$ considered significant). Data visualization was carried out using MS Excel 7.0. During the recovery period, the degree of deficiency was assessed using a point system based on the "Diagnostic and Correction Algorithm" developed from NAT (DGU №34416): mild (1-6 points), moderate (7-12 points), severe (13-18 points).

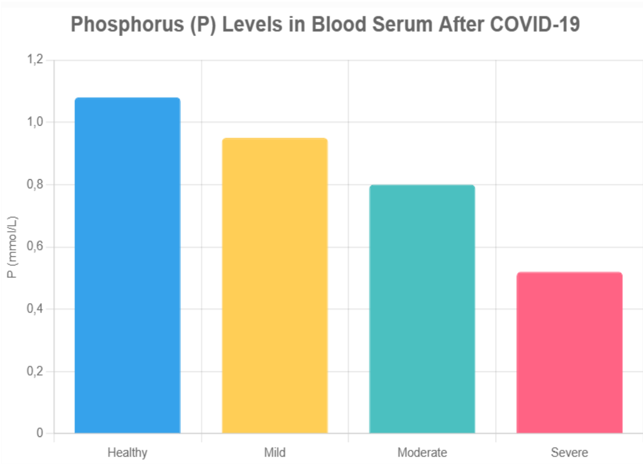
Results

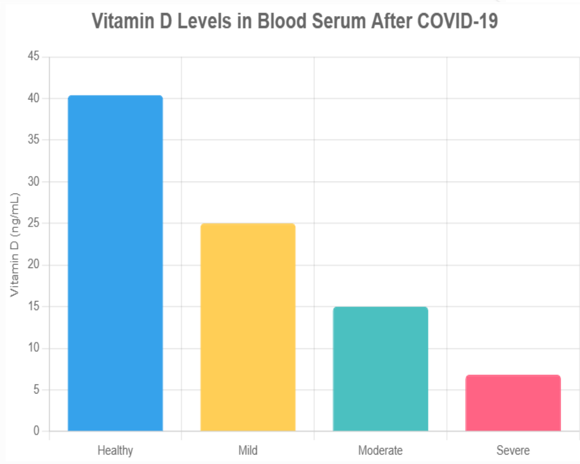
The study results indicated that the balance of microelements in the body of children significantly changed during the period following COVID-19 infection. In healthy children, microelement levels were within the norm, whereas with the aggravation of the disease, their significant decrease or increase was recorded.

Among the main elements in blood serum, the zinc level in healthy children was 13.56 µmol/l, decreasing to 7.78 mmol/l in mild cases, 8.40 mmol/l in moderate severity, and 6.63 mmol/l in severe forms. This decrease was associated with a weakening of immunity and clinical signs such as hair loss (60%). The calcium level in healthy individuals was 2.30 mmol/l, around 1.8–1.9 mmol/l in mild and moderate forms, and dropped to 1.53 mmol/l in severe cases, negatively impacting bone and tooth mineralization as well as muscle activity. Levels of phosphorus and vitamin D were also observed to decrease as the disease worsened.









Analysis of elements in hair samples also confirmed these changes. Zinc (Zn) decreased from 87.38±2.8 mcg/g to 67.96±2.27 mcg/g ($p<0.01$), iron (Fe) from 20.0±0.64 mcg/g to 12.72±0.41 mcg/g ($p<0.01$), which was associated with fatigue (51.7%) and signs of anemia. Iodine (I) dropped from 0.604±0.019 mcg/g to 0.404±0.01 mcg/g ($p<0.01$), resulting in disturbances in metabolic processes and nervous system activity. The decrease in cobalt (Co) had a negative impact on vitamin B12 synthesis and blood formation processes. Conversely, the copper (Cu) level increased (from 17.5±0.56 to 27.67±0.89 mcg/g, $p<0.01$), enhancing the activation of inflammatory mediators and oxidative stress. Sodium (Na) decreased from 780±25.1 mcg/g to 300±8.71 mcg/g ($p<0.01$), seriously disrupting electrolyte balance. Manganese (Mn) increased, adding extra load to the nervous system. At the same time, other elements—calcium, chlorine, selenium, arsenic, mercury, and antimony—also significantly decreased (Table 1).

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Microelement	Control healthy (n=30)	Moderate severity (n=112 (37))	p-value
Ag (silver)	0.204±0.006	0.1733±0.005*	<0.01
As (arsenic)	0.204±0.007	0.074±0.003*	<0.01
Au (gold)	0.084±0.026	0.034±0.006	>0.05
Br (bromine)	3.84±0.12	2.834±0.087*	<0.01
Ca (calcium)	635.50±20.5	541.91±17.37*	<0.01
Cl (chlorine)	460±14.8	236.67±7.6*	<0.01
Co (cobalt)	0.084±0.0026	0.062±0.002*	<0.01
Cr (chromium)	0.704±0.023	0.444±0.014*	<0.01
Cu (copper)	17.5±0.56	27.67±0.89*	<0.01
Fe (iron)	20.0±0.64	12.72±0.41*	<0.01
Hg (mercury)	0.204±0.006	0.127±0.004*	<0.01
I (iodine)	0.604±0.019	0.404±0.01*	<0.01
K (potassium)	1200±38.5	1050±35.8	<0.05
Mn (manganese)	0.704±0.021	0.854±0.026*	<0.01
Na (sodium)	780±25.1	300±8.71*	<0.01
Rb (rubidium)	1.44±0.04	1.124±0.035*	<0.01
Sb (antimony)	0.204±0.0055	0.144±0.004*	<0.01
Sc (scandium)	0.024±0.0006	0.0065±0.0002*	<0.01
Se (selenium)	0.604±0.019	0.514±0.016*	<0.01
U (uranium)	0.204±0.006	0.057±0.002*	<0.01
Zn (zinc)	87.38±2.8	67.96±2.27*	<0.01

Overall, the condition of polymicroelementosis was detected in 89.3% of children, and in severe forms, it was observed in 100%. Age-related differences were also noted: for example, in children aged 1–3 years, Zn was 65.32±2.1 mcg/g, while in 12–18-year-olds, it dropped to 62.97±1.93 mcg/g. The most common clinical signs were hair loss (60%), fatigue (51.7%), and excessive sweating (63.3%). When the "Diagnostic and Treatment Algorithm" developed based on NAT was applied, the average score before treatment was 10.5±0.7, and after applying Nanosink and diet therapy, it decreased to 1.9 points.

Discussion

The neutron-activation analysis method has significant advantages over traditional methods in diagnosing microelement deficiencies, especially serving as a valuable tool during the recovery period in children after COVID-19. The study results showed that NAT, with its high sensitivity in detecting 22 elements in hair samples, indicated a 1.6-fold decrease in zinc (Zn) levels in severe forms (54.61±1.7 mcg/g), which is associated with reduced immunity and clinical symptoms (hair loss 60%) [6,11,14]. These results align with the literature: Read et al. (2021) linked Zn deficiency to the severity of viral infections, as Zn plays a key role in antiviral defense [2,7].

The non-invasiveness of NAT makes diagnostics safe for children, as collecting hair samples is easy and risk-free. According to the study results, NAT detected polymicroelementosis in 89.3% of cases, demonstrating the virus's impact on metabolic processes. Fugazzaro et al. (2022) associated vitamin D deficiency with COVID-19 severity, and in our study, vitamin D decreased 5.8-fold (6.82±0.19 ng/ml), confirming NAT's high accuracy [3,14,21]. The iron (Fe) level decreased 2.2-fold (9.09±0.29 mcg/g), which is linked to anemia and fatigue (51.7%), consistent with WHO (2023) reports on post-COVID complications in children [8,18,22].

The stability of NAT increases statistical significance depending on disease severity (P<0.001), emphasizing its value in clinical practice. Based on Avtsin's (1991) classification, polymicroelementosis was

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identified, highlighting NAT's role in assessing mineral metabolism [19]. Mohan et al. (2022) linked Zn and Fe deficiencies to COVID-19 pathogenesis, and our study results confirm that NAT is effective in early detection of these genetic and ecological influences [5]. According to the study, the algorithm developed using NAT (DGU №34416) improved recovery (score from 10.5 to 1.9), indicating the need to integrate NAT with mobile applications [6].

NAT's drawback (being an expensive method) is outweighed by its advantages (early detection and accelerated recovery) in practice. Future studies may combine NAT with genetic analyses.

Conclusion

The study results demonstrated that NAT has high effectiveness in detecting microelement deficiencies in children after COVID-19. Zinc (Zn) decreased 1.6-fold, iron (Fe) 2.2-fold, while copper (Cu) increased 1.3-fold, and polymicroelementosis was detected in 89.3% of cases, confirming NAT's sensitivity. Clinical symptoms (hair loss 60%, fatigue 51.7%, sweating 63.3%) are associated with microelement deficiencies. The algorithm developed based on NAT (DGU №34416) reduced the average score from 10.5±0.7 to 1.9±0.2 before treatment, improving recovery. NAT's non-invasiveness, ability to detect 22 elements simultaneously, and stability ($p<0.001$) make it an important tool for widespread use in pediatric practice. In the future, integrating NAT with mobile applications and genetic analyses is recommended.

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