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Hair and Serum Mineral Profiles in Children Recovering From COVID-19

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ABSTRACT: Mineral measurements may help characterize nutritional and metabolic status after childhood COVID-19, but evidence combining serum and hair analyses is limited. We summarized a clinical recovery cohort of 112 children with previous mild ($n = 16$), moderate ($n = 70$) or severe ($n = 26$) COVID-19, compared with 30 healthy controls as reported in the original manuscript. Serum zinc, calcium, phosphorus and vitamin D and five reported hair-element profiles were evaluated descriptively; a separate retrospective hospital cohort of 240 children provided contextual acute-illness information only. Mean serum zinc was $13.56 \mu\text{mol/L}$ in controls and 7.78 , 6.98 and $6.63 \mu\text{mol/L}$ after mild, moderate and severe disease. Corresponding vitamin D means were 40.40 , 12.96 , 11.60 and 6.82 ng/mL . Hair zinc declined from $87.38 \mu\text{g/g}$ in controls to 80.38 , 68.89 and $54.61 \mu\text{g/g}$ across the recovered groups, whereas hair copper increased from 17.5 to 22.5 , 27.0 and $33.5 \mu\text{g/g}$. Gastrointestinal complaints (66.9%) and fatigue/autonomic symptoms (63.3%) were reported in the recovery sample. These descriptive gradients warrant prospective study but do not establish causation or the benefit of supplementation.

1. INTRODUCTION

The health of children after SARS-CoV-2 infection remains a clinical concern. Longitudinal and matched studies report persistent symptoms in some children, but their frequencies depend on case definition, follow-up and the comparison group [1–4, 11–13, 18, 20]. Symptoms can also arise for reasons unrelated to infection. The findings of a selected recovery clinic cohort cannot therefore be generalized to all infected children. European and other pediatric cohorts have recorded varied symptoms and trajectories after acute illness [5–10, 14–17]. A multidisciplinary clinical approach is advocated when symptoms affect functioning, while accurate severity classification and case ascertainment remain essential for interpretation [19, 21]. In Uzbekistan, Bobomuratov et al. examined cardiovascular involvement in a retrospective series of 88 children hospitalized with COVID-19 [44]. This local clinical work provides context for pediatric multisystem assessment, although it does not evaluate the serum and hair mineral profiles considered here.

Dietary minerals contribute to immune and metabolic function during growth [22–24]. Adult observational studies have related circulating zinc, copper and other micronutrient measures to COVID-19 severity [25–29]. These findings motivate biomarker study in children but do not establish a pediatric causal pathway. Studies of selenium, blood and urinary metals, and vitamin D in adults have yielded variable associations with COVID-19 outcomes [30–36]. Randomized trials concerning vitamin D and other respiratory infections answer a different question from observational measurement during pediatric post-COVID recovery [37, 38]. Hair can retain information about elemental exposure over its growth interval, but concentrations may be affected by external contamination, washing and hair treatment. A pediatric validation study found marked element-specific limitations, although another pediatric clinical setting reported some useful comparisons with serum measures [41, 43]. Hair-element levels alone do not establish a clinical nutritional deficiency.

2. MATERIALS AND METHODS

2.1 Study design and participants

This observational study used two separate data streams in Tashkent, Uzbekistan: a retrospective hospital series of 240 children and a recovery-phase clinical cohort of 112 children. The original article labels a further 30 children as healthy controls in its biomarker table and figure. The 240 hospital records were not combined with either biomarker group. The related dissertation describes a larger 250-record series and 50 healthy children; the present analysis is restricted to the original article's reported 240 and 30. The source documents do not identify which records were omitted from the larger dissertation samples. Recovery-cohort ages were 1–3 years ($n = 21$), 4–7 ($n = 27$), 8–11 ($n = 31$) and 12–17 ($n = 33$). The recovery cohort comprised 16 children with previously mild disease managed at home, 70 with moderate disease and 26 with severe disease. The source material does not establish case ascertainment, severity definitions, recruitment dates, time from infection to sampling, vaccination status, control matching or full exclusion criteria. Accordingly, the comparisons below describe reported groups rather than a controlled causal contrast.

2.2 Clinical and laboratory assessments

Clinical manifestations were summarized by organ system. The source article tabulates serum zinc, calcium, phosphorus and vitamin D by previous disease category. It describes neutron activation analysis for hair elements and refers to 22 measured elements; we report the five with readable values in each of its four figure groups: zinc, iron, iodine, cobalt and copper. The original records do not document a sufficiently complete assay protocol here to assess hair washing, reference materials, detection limits or assay-specific missingness.

2.3 Analysis and data presentation

Numbers were transcribed from the original manuscript and its embedded figure. The serum table identifies its $\pm$ terms as standard errors of the mean (SEM), although original analysis output was unavailable for independent confirmation. Only proportions calculated from integer counts and percentage differences calculated from displayed group means were added. We did not generate individual observations, box plots, scatter plots, P values, confidence intervals or regression estimates from summary statistics [42].

3. RESULTS AND DISCUSSION

3.1 Description of the cohorts

The retrospective hospital series comprised moderate and severe cases; its reported category percentages were recalculated from the integer counts (Table 1). Previous moderate illness predominated in the separate recovery cohort. Gastrointestinal and fatigue/autonomic complaints were frequently reported during recovery, but symptom categories could overlap. Because their specific denominators were unavailable, symptom counts were not imputed.

Table 1. Reported cohort composition and recovery-phase clinical findings

Characteristic	Reported result
Recovery cohort	112: mild 16/112 (14.3%); moderate 70/112 (62.5%); severe 26/112 (23.2%)
Age groups in recovery cohort	1–3 y: 21; 4–7 y: 27; 8–11 y: 31; 12–17 y: 33

Characteristic	Reported result
Healthy controls	30 in original article and biomarker tables; assay-specific counts unavailable
Retrospective hospital series	240: moderate 203/240 (84.6%); severe 37/240 (15.4%); separate from biomarker groups
Gastrointestinal symptoms	66.9% of recovery cohort; denominator unavailable
Fatigue/autonomic symptoms	63.3% of recovery cohort; denominator unavailable
Cardiovascular findings	23.2% of recovery cohort; denominator unavailable
Anemia	60.0% of recovery cohort; diagnostic threshold unavailable

3.2 Hair-element profiles

Hair zinc, iron, iodine and cobalt means followed a downward gradient across the control and prior-illness categories; copper showed the opposite direction (Table 2; **Figure 1**). The severe category had the greatest descriptive separation from controls. These group means do not establish within-child depletion or a clinical deficiency, and individual variation was unavailable.

Table 2. Hair-element group means transcribed from the original manuscript figure

Element (µg/g)	Controls	Mild	Moderate	Severe
Zinc	87.38	80.38	68.89	54.61
Iron	20.00	16.00	13.07	9.09
Iodine	0.60	0.54	0.36	0.31
Cobalt	0.080	0.073	0.061	0.051
Copper	17.5	22.5	27.0	33.5

Source figure labels give n = 30 controls and n = 16/70/26 mild/moderate/severe recovery groups. Assay-specific counts and individual observations were unavailable.

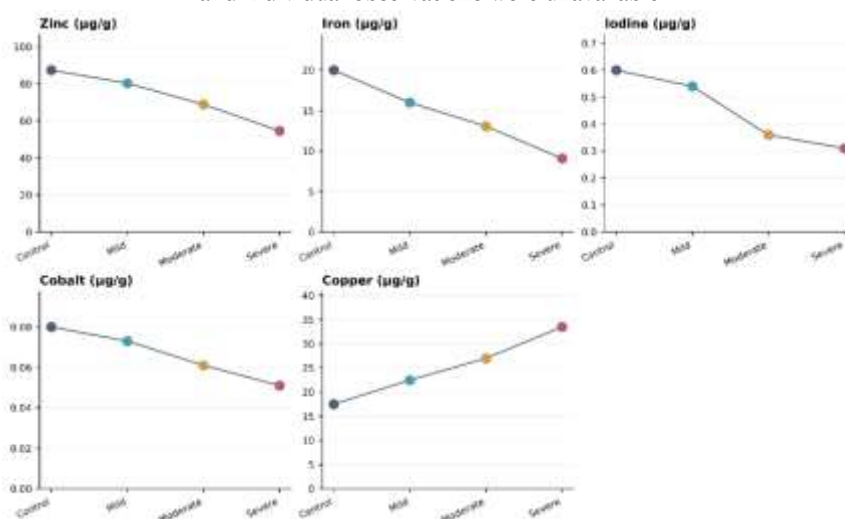


Figure 1. Mean hair zinc, iron, iodine, cobalt and copper concentrations by previous disease category. Each plotted point is a reported group mean from the source article (controls n = 30; mild n = 16; moderate n = 70; severe n = 26). Lines guide the eye. Assay-specific denominators, uncertainty intervals and individual measurements were unavailable.

3.3 Serum mineral and vitamin D profiles

Serum zinc, calcium, phosphorus and vitamin D means were lower across the recovery categories than in controls and tended to decrease with previous illness severity (Table 3; **Figure 2**). The vitamin D contrast was particularly pronounced. The reported

error terms could not be independently checked, and these aggregate results cannot establish a within-child serum–hair association.

Table 3. Serum group means and reported error terms

Marker (unit)	Controls	Mild	Moderate	Severe
Zinc ($\mu\text{mol/L}$)	13.56 ± 0.38	7.78 ± 0.41	6.98 ± 0.13	6.63 ± 0.17
Calcium (mmol/L)	2.20 ± 0.03	1.80 ± 0.07	1.65 ± 0.03	1.53 ± 0.03
Phosphorus (mmol/L)	1.08 ± 0.04	1.02 ± 0.05	0.93 ± 0.02	0.52 ± 0.02
Vitamin D (ng/mL)	40.40 ± 1.65	12.96 ± 1.39	11.60 ± 0.38	6.82 ± 0.19

The original table labels error terms SEM and gives group sizes of 30, 16, 70 and 26. Assay-specific denominators were unavailable.

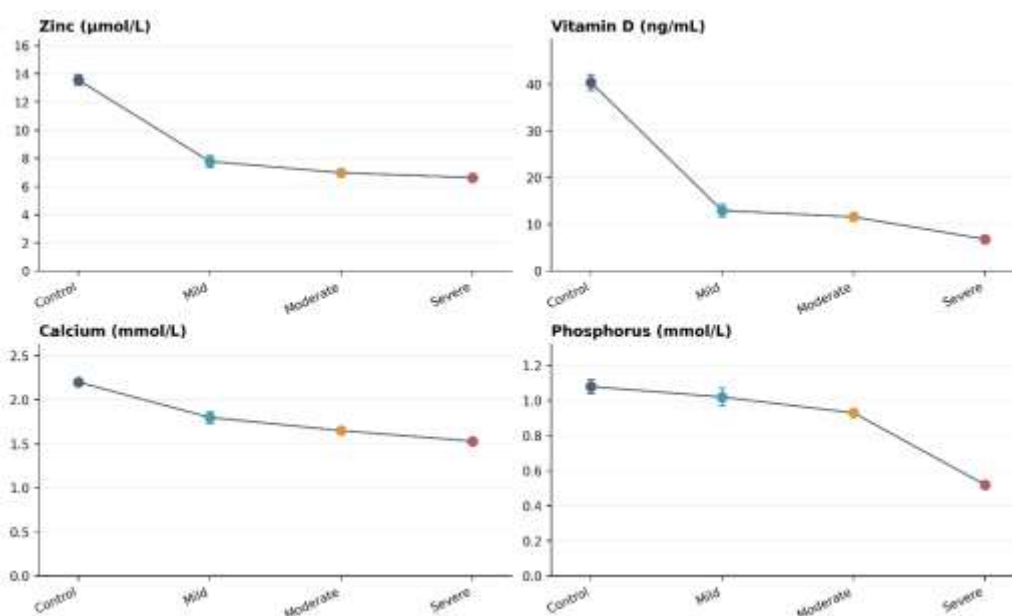


Figure 2. Reported serum zinc, calcium, phosphorus and vitamin D group means with error terms labeled SEM in the source table. Independent panels use different units and vertical scales. Laboratory output and analyte-specific sample counts were unavailable for confirmation.

3.4 Interpretation and limitations

The working hypothesis was that nutritional and inflammatory processes during and after acute illness might leave related signals in serum and hair. The concordant direction of the zinc group gradients is compatible with that idea, while the opposing copper pattern suggests that each analyte may respond differently. Adult COVID-19 studies link circulating zinc and other metals with severity [25–29], but serum concentrations can also reflect inflammation-related redistribution, dietary intake or supplementation [22–24]. Since measurements here were made after infection, pre-illness status and changes over time cannot be separated; the gradients do not show that COVID-19 caused a deficiency. The vitamin D pattern also needs cautious interpretation. Previous observational reports include both positive and null severity associations [33–36], and supplementation trials for other respiratory outcomes address an intervention question rather than the origin of these post-infection measurements [37, 38]. A future pediatric analysis would need season, age, diet, body composition, supplements and sampling interval to judge whether vitamin D contributes information beyond these factors. Similarly, hair copper and zinc may reflect longer exposure windows, but washing, external contamination and hair growth constrain individual interpretation [39–41, 43]. The two matrices should therefore be treated as complementary exploratory measures rather than interchangeable tests or a

validated multi-element deficiency score. Symptoms and biomarkers also require separate interpretation. Controlled pediatric follow-up studies have found persistent complaints in both infected and comparison children [2, 5–10, 18]; the present unlinked group summaries cannot relate a particular symptom to an analyte within a child. Age, baseline nutrition, chronic illness, inflammatory status, treatment and environmental exposure may confound the observed severity patterns. The reported 89.3% multi-element classification relied on an undocumented algorithm and cannot be used as a validated prevalence estimate. Arsenic, mercury and uranium are not essential nutrients, so their lower concentrations must not be labeled deficiencies. In addition, the dissertation's 250/50 samples cannot be reconciled with the article's 240/30 sets without original screening and laboratory logs. Participant-level measurements, analyte-specific denominators and a prespecified model are necessary before effect sizes, uncertainty intervals or diagnostic claims can be supported [41–43].

4. Conclusion

The available group summaries show lower serum zinc and vitamin D and lower hair zinc, alongside higher hair copper, with more severe prior illness. These observations support a hypothesis of altered post-infection elemental profiles, but the separate 240-child clinical series does not enlarge the 112-child recovery and 30-control biomarker comparison. Prospective research should use age-matched controls, define severity and time since infection, document diet and supplementation, report assay quality control and missing samples, and analyze individual measurements with adjustment for confounders. Until such evidence is available, these results do not justify diagnostic cutoffs or routine supplementation for post-COVID recovery.

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Author Contributions

Turdikul A. Bobomuratov: Supervision.

Dilnoza Sharipova: Conceptualization, Methodology, Writing – original draft.

Zebo Ruziyeva: Investigation, Data curation.

Nargiza Karimova: Investigation, Data curation.

Anvar Tursunbayev: Formal analysis.

Makhira Bakirova: Investigation, Methodology.

Gulruh Shodmonkulova: Writing – review & editing.

Nargiza Nurmatova: Investigation, Data curation.

Ulugbek Nurmatov: Writing – review & editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

The study was approved by the Ethics Committee of Tashkent Medical Academy, Tashkent, Uzbekistan (approval No. 218/1, dated 22 December 2023). The study was conducted in accordance with the principles of the Declaration of Helsinki.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Individual participant data are not publicly available to protect the privacy and confidentiality of the children included in the study.

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