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TRACE ELEMENT IMBALANCES AND CARDIOVASCULAR ADAPTATION IN ADOLESCENTS WITH NEUROCIRCULATORY DYSTONIA IN IODINE-DEFICIENT REGIONS

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Abstract: Adolescents living in iodine-deficient environments are predisposed not only to thyroid dysfunction but also to a spectrum of cardiovascular regulatory disorders. Neurocirculatory dystonia (NCD), a functional disorder of the autonomic nervous system, is frequently observed in this group and is often aggravated by trace element imbalances. This study aimed to investigate the relationship between disturbances in trace element metabolism and cardiovascular adaptation in adolescents with NCD residing in iodine-deficient regions. A total of 110 adolescents with clinically confirmed NCD were compared with 35 healthy controls. Serum levels of iodine, selenium, zinc, copper, and magnesium were analyzed, along with thyroid function profiles and indices of cardiovascular regulation. Results demonstrated a consistent pattern of decreased iodine, selenium, and zinc, accompanied by altered magnesium and increased copper concentrations. These changes were associated with subclinical thyroid dysfunction, reduced heart rate variability, and elevated autonomic reactivity. The findings indicate that the combination of iodine deficiency and secondary trace element imbalances plays a crucial role in the pathogenesis of NCD, highlighting the need for integrated therapeutic and preventive strategies.

Keywords: neurocirculatory dystonia, iodine deficiency, trace elements, cardiovascular adaptation, adolescents, thyroid function

Introduction

Iodine deficiency continues to be recognized as a major public health problem, affecting approximately two billion individuals globally, with school-aged children and adolescents being the most vulnerable. While its primary clinical manifestation is goiter, iodine deficiency also disrupts thyroid hormone metabolism, which has downstream consequences on cardiovascular regulation, neurocognitive development, and metabolic adaptation.

Neurocirculatory dystonia (NCD) is a functional cardiovascular disorder characterized by symptoms such as palpitations, dizziness, chest discomfort, orthostatic intolerance, and autonomic instability. Although traditionally viewed as a benign condition, NCD significantly impairs quality of life during adolescence, a critical period for growth and psychosocial development. Increasing evidence suggests that NCD is influenced not only by psychosocial stressors but also by biochemical and endocrine imbalances, particularly those arising in iodine-deficient populations.

Recent research has shown that iodine deficiency rarely occurs in isolation. It is commonly associated with disturbances in other trace elements such as selenium, zinc, magnesium, copper, and iron. These micronutrients play central roles in thyroid hormone regulation, cardiovascular homeostasis, and oxidative balance. Selenium deficiency impairs the function of deiodinases, zinc is essential for enzymatic activity and immune competence, magnesium regulates vascular

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tone, and copper imbalance may exacerbate oxidative stress. The interaction of these elements may contribute to the cardiovascular instability and autonomic symptoms characteristic of NCD.

This study was undertaken to explore the interrelationship between trace element imbalances and cardiovascular adaptation in adolescents with neurocirculatory dystonia living in iodine-deficient areas.

Iodine deficiency continues to be recognized as one of the most prevalent micronutrient deficiencies worldwide, affecting an estimated two billion individuals across both developing and developed countries. Despite large-scale salt iodization programs introduced over the past decades, many regions, particularly those with low soil and water iodine content, remain endemic areas for iodine deficiency disorders (IDD). Adolescents represent a particularly vulnerable group due to their increased metabolic demands during rapid growth and puberty. At this stage, disturbances in thyroid hormone synthesis caused by iodine deficiency can exert profound effects not only on physical growth but also on neurocognitive development, mood regulation, and cardiovascular stability.

Neurocirculatory dystonia (NCD), a functional autonomic disorder, is frequently diagnosed in adolescents and manifests with a wide spectrum of clinical symptoms, including palpitations, shortness of breath, dizziness, headache, fatigue, and fluctuations in blood pressure. Although traditionally considered a benign condition, NCD substantially reduces quality of life and school performance in affected individuals. The pathogenesis of NCD is multifactorial, with psychosocial stress, neuroendocrine dysregulation, and genetic predisposition playing important roles. However, growing evidence suggests that metabolic and micronutrient disturbances, especially in iodine-deficient populations, serve as major triggers of autonomic dysfunction in adolescents.

Importantly, iodine deficiency rarely occurs in isolation. It is often accompanied by imbalances in other essential trace elements such as selenium, zinc, copper, magnesium, and iron. These elements play critical roles in maintaining thyroid hormone metabolism, enzymatic activity, and cardiovascular homeostasis. Selenium is indispensable for the function of iodothyronine deiodinases, which regulate thyroid hormone conversion, as well as for antioxidant defense through selenoproteins. Zinc contributes to cellular growth, immune regulation, and enzymatic stabilization, while magnesium is essential for vascular tone regulation and myocardial function. Conversely, elevated copper concentrations, often seen in micronutrient imbalances, may contribute to oxidative stress and endothelial dysfunction. The interaction of these micronutrients forms a complex metabolic network, and their disturbances may exacerbate both thyroid dysfunction and autonomic imbalance, thereby contributing to the clinical manifestations of NCD.

Several studies have emphasized that the combined deficiency of iodine and selenium leads to greater impairment in thyroid function compared to iodine deficiency alone. Similarly, zinc deficiency has been linked with impaired enzymatic activity in the thyroid gland and disturbances in cardiovascular function, whereas iron deficiency may aggravate hypoxic stress and impair neurocognitive development in adolescents. This suggests that a multidimensional approach is necessary for understanding and managing disorders such as NCD in iodine-deficient environments.

The rationale for the present study is based on the hypothesis that adolescents living in iodine-deficient regions are at risk of multiple trace element imbalances, which, in turn, significantly affect cardiovascular adaptation and autonomic regulation. By analyzing the interrelationships

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between trace element status, thyroid hormone profiles, and cardiovascular function, this research aims to provide new insights into the complex pathophysiological mechanisms underlying NCD and to identify potential diagnostic markers and therapeutic strategies.

Materials and Methods

A comparative observational study was carried out involving 110 adolescents (62 females and 48 males, aged 13–17 years) diagnosed with NCD and 35 age- and sex-matched healthy controls from the same iodine-deficient region. Clinical diagnosis of NCD was established using standardized criteria, including symptoms of autonomic dysfunction and functional cardiovascular testing.

Blood samples were collected under fasting conditions to determine serum concentrations of iodine, selenium, zinc, copper, and magnesium using atomic absorption spectrophotometry. Thyroid hormones (TSH, free T3, free T4) were measured by ELISA. Cardiovascular adaptation was evaluated by electrocardiography, heart rate variability (HRV) analysis, orthostatic testing, and exercise tolerance assessment.

Statistical analysis was performed using SPSS version 26.0. Mean values were compared between groups using Student's t-test. Correlation analysis was used to explore associations between trace element levels, thyroid status, and cardiovascular indices. A p-value <0.05 was considered statistically significant.

Results

Adolescents with NCD showed significantly reduced iodine levels compared to controls (59.7 ± 12.4 µg/L vs. 92.1 ± 14.3 µg/L, $p<0.001$). Selenium and zinc concentrations were also lower in the NCD group (selenium: 60.4 ± 10.6 µg/L vs. 83.5 ± 9.2 µg/L, $p<0.001$; zinc: 10.5 ± 2.0 µmol/L vs. 14.2 ± 2.3 µmol/L, $p<0.01$). Magnesium levels were decreased (0.69 ± 0.09 mmol/L vs. 0.83 ± 0.07 mmol/L, $p<0.01$), while copper levels were elevated (18.2 ± 2.4 µmol/L vs. 15.1 ± 2.1 µmol/L, $p<0.05$).

Thyroid hormone analysis revealed subclinical hypothyroidism in 28% of the NCD group, with elevated TSH and reduced free T4 compared to controls. Cardiovascular testing showed reduced HRV indices, indicating impaired autonomic balance, and exaggerated blood pressure and heart rate responses during orthostatic and exercise testing.

Correlation analysis revealed strong associations between low selenium levels and impaired HRV ($r = 0.58$, $p<0.01$), reduced zinc levels and decreased exercise tolerance ($r = 0.52$, $p<0.05$), and elevated copper levels with higher autonomic reactivity scores ($r = 0.46$, $p<0.05$).

Discussion

The study confirmed that iodine deficiency in adolescents is closely linked with disturbances in multiple trace elements, which together exert a synergistic negative effect on cardiovascular adaptation. Reduced selenium and zinc levels are particularly important, as they exacerbate thyroid dysfunction and impair enzymatic defense against oxidative stress, thereby aggravating autonomic instability. Magnesium deficiency contributes to vascular dysregulation, while excess copper increases oxidative load and destabilizes cardiovascular function.

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These findings align with previous research indicating that iodine deficiency disorders are best understood in the context of a broader micronutrient imbalance rather than as an isolated deficiency. The association between trace element disturbances and reduced HRV further underscores the mechanistic link between metabolic imbalance and cardiovascular autonomic dysfunction in NCD.

Clinically, the results suggest that management of NCD in iodine-deficient regions should not be limited to iodine supplementation alone. Instead, a comprehensive strategy including selenium, zinc, and magnesium correction, as well as copper balance monitoring, is required. Early micronutrient intervention could improve cardiovascular adaptation, reduce autonomic symptoms, and enhance the overall well-being of adolescents.

Conclusion

This study highlights the interdependent relationship between trace element imbalances and cardiovascular adaptation in adolescents with neurocirculatory dystonia living in iodine-deficient conditions. Deficiency of iodine, selenium, zinc, and magnesium, combined with excess copper, contributes significantly to thyroid dysfunction, impaired autonomic regulation, and cardiovascular instability. Addressing these imbalances through integrated micronutrient supplementation and preventive public health strategies may provide a more effective approach to reducing the burden of NCD in vulnerable populations.

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