



## RESEARCH ARTICLE

# Bisphenol A as a Potential Modulator of Biochemical Markers in Children with Autism Spectrum Disorder

Renas N. Salih, Saman M. Abdulkareem

Department of Biology, College of Education, Salahaddin University-Erbil, Erbil, Kurdistan Region, Iraq

## ABSTRACT

Autism spectrum disorder (ASD) is defined as a neurodevelopmental disorder characterized by repetitive behaviors, limited interests, and difficulties with social interactions. The purpose of this study was to measure the levels of bisphenol A (BPA), Vitamin D, thyroid-stimulating hormone (TSH), body mass index (BMI), and some hematological parameters in children with and without ASD. For this study, 75 boys between the ages of 3 and 10 years were split into two groups: 40 children with ASD (ASD group) and 35 children without ASD (control group). The results of the present study show that the level of BPA is significantly higher in the ASD group, also the mean value of BMI significantly increased in the ASD group compared with the control group. Regarding the Vitamin D and calcium levels, the findings illustrate that Vitamin D and calcium significantly decline in the ASD group compared to the control group. On the other hand, the variations in the serum TSH, magnesium, and hematological parameters were insignificantly changed, except that the level of white blood cell was significantly elevated in the ASD group. BPA is the main factor lowering Vitamin D and serum calcium levels, as well as raising inflammatory cells and BMI of autistic children (children with autism).

**Keywords:** Autism disorder, autism spectrum disorder, bisphenol A, Vitamin D deficiency, thyroid-stimulating hormone

## INTRODUCTION

Autism spectrum disorder (ASD) is a developmental impairment that manifests as limited interests or repetitive activities, as well as challenges with social interaction or communication.<sup>[1]</sup> It is acknowledged that ASD is a diverse disorder, with individuals exhibiting a wide range of signs and symptoms, varying in intensity, and requiring varying degrees of support.<sup>[2]</sup> Furthermore, intellectual disabilities and epilepsy are two neurodevelopmental conditions that are commonly associated with ASD.<sup>[3]</sup> Multiple investigations show that autism-related problems are more common in males than in females. The 4:1 male-to-female ratio is among the most trustworthy findings in ASD.<sup>[4]</sup> According to Zhong *et al.*,<sup>[5]</sup> pregnant women's and children with ASD's eating habits may be modifiable factors in the development or exacerbation of autism-related symptoms.

In addition, the correlation between advanced maternal age and neurological and behavioral diseases may be influenced by cumulative exposure to environmental pollutants.<sup>[6]</sup> However, according to a number of studies, children with ASD commonly exhibit several nutritional and metabolic irregularities, such as deficiencies in sulfation and methylation, disruptions in glutathione redox balance, elevated oxidative burden, and impairments in mitochondrial activity.<sup>[7]</sup> Numerous researchers have reported the presence of inflammation in the brain and central nervous system

(CNS), marked by pronounced activation of microglial cells and increased cytokine levels in post-mortem brain samples from both younger and older individuals with ASD. Broad population-level epidemiological investigations have identified associations between ASD and abnormal concentrations of various pro-inflammatory cytokines and immune-related indicators in the bloodstream.<sup>[8]</sup> Furthermore, children with ASD have reduced amounts of micronutrients, such as iron, folic acid, magnesium, selenium, Vitamin A, Vitamin D, and Vitamin E.<sup>[9]</sup>

The production of epoxy resins and plastic items, such as toys, food can linings, drinking containers, and medical equipment, among other things, uses BPA, one of the most abundant chemicals in the world.<sup>[10]</sup> The materials used in a lot of infant bottles and milk containers also contain Bisphenol

### Corresponding Author:

Renas N. Salih, Department of Biology, College of Education, Salahaddin University-Erbil, Erbil, Kurdistan Region, Iraq.  
E-mail: renas.salih@su.edu.krd

**Received:** May 17, 2025

**Accepted:** July 7, 2025

**Published:** August 05, 2025

**DOI:** 10.24086/cuesj.v9n2y2025.pp42-47

Copyright © 2025 Renas N. Salih, Saman M. Abdulkareem. This is an open-access article distributed under the Creative Commons Attribution License.

A (BPA), an ingredient found in food packaging that may leak into the contents and endanger customers' health. Plastic bags, Tetra Pak wrapping, and infant bottles are examples of typical plastic containers used to store milk or other items that may expose users to BPA.<sup>[10]</sup> Moreover, BPA exhibits multisystem toxicity, affecting various organs, including the reproductive, nervous, hepatic, and renal systems. Notably, the CNS, particularly during its developmental stages, appears to be highly susceptible to BPA exposure.<sup>[11]</sup> A significant concern in understanding the etiology of ASD is the role of prenatal exposure to endocrine-disrupting chemicals (EDCs), such as BPA. BPA can interfere with hormonal signaling during critical periods of brain development. Increasing evidence links BPA exposure to neurodevelopmental alterations associated with ASD, including disrupted neurotransmission, immune activation, oxidative stress, and epigenetic changes. This highlights the urgent need for public health policies to regulate EDCs exposure, particularly during pregnancy, as a potential modifiable risk factor in the prevention of ASD.<sup>[12,13]</sup>

The purpose of this study was to determine the levels of BPA, some hematological parameters, Vitamin D, thyroid-stimulating hormone (TSH), and some minerals in children with ASD.

## MATERIALS AND METHODS

### Study Design

The study was performed at the Gashbin Center, a specialized center for children with ASD in Erbil, Kurdistan. Children with severe medical conditions or on medications that could affect their blood values were excluded from the study.

### Study Participants

The present study included 75 male preschoolers and school-aged children (3–10 years old) divided into two groups. The first group consists of 40 children with ASD (ASD group), and the second group consists of 35 children without ASD (control group).

### Data Collection

Children prospectively assessed eligible cases of ASD, and any subsequent cases that met the inclusion criteria were included. On a semi-structured questionnaire, information on the clinical and sociodemographic characteristics of the patients and controls was documented. Seven milliliters of blood were drawn from a vein by the butterfly venipuncture process, and following 5 mL of blood was used for serum separation for biochemical and hormonal analysis, and 2 mL for hematological study.

### Biochemical and Hormonal Analysis

The analysis of biochemical and hormonal parameters, including calcium, magnesium, TSH, and Vitamin D (25-hydroxycholecalciferol), was performed using the COBAS INTEGRA® 400 plus system (Roche Diagnostics Ltd., Rotkreuz, Switzerland) using Roche diagnostic kits (Germany). Each subject's serum BPA levels were assessed using the commercially available ELISA kits method (Sunlong Biotech CO., Ltd., China) in line with the manufacturer's protocol.

## Hematological Analysis

When the blood samples were collected, a hematological analysis was performed immediately. A fully automated Swelab Alfa Plus 3-part hematology analyzer was used to analyze complete blood counts, including total white blood cell count (WBC), lymphocyte count, granulocyte count, total red blood cell count (RBC), hemoglobin (Hb), hematocrit (HCT), and RBC indices, such as mean corpuscular volume (MCV), corpuscular Hb (MCH), and mean corpuscular Hb concentration (MCHC), RBC distribution width (RDW%), platelets count, and mean platelet volume (MPV).

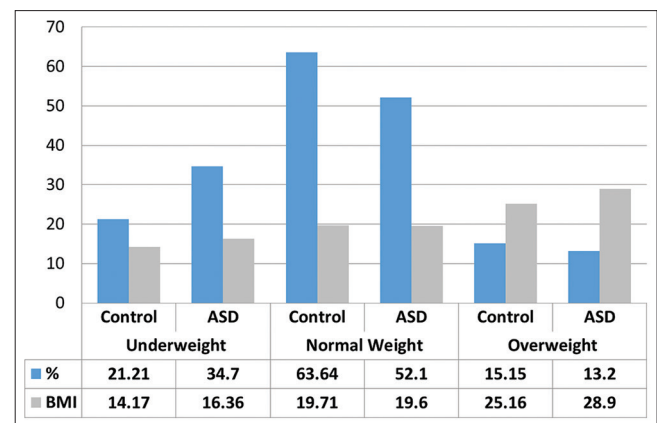
## Statistical Analysis

GraphPad Prism (GraphPad Software version 9, San Diego, CA, USA) was used to analyze the data, and the results were presented as mean  $\pm$  standard error. The Shapiro–Wilk test was used to determine whether the distribution was normal. Every variable under analysis has a normal distribution ( $P > 0.05$ ). A student *t*-test, unpaired, was used for statistical analysis to compare the groups of ASD and control children. The threshold for statistical significance was set at  $P < 0.05$ .

## RESULTS

Body mass index (BMI) is computed by dividing weight in kilograms by height in meters squared ( $\text{kg}/\text{m}^2$ ).<sup>[14]</sup> The ranges of BMI categories as underweight, normal, and overweight, for children with ASD and the control group are presented in Figure 1. The prevalence of underweight was higher in the ASD group (34.7%) than in the control group (21.21%), although the mean value of BMI was much higher in the ASD group than in the control group. The prevalence percentage of the present study showed that normal weight is higher in the control group (63.64%) than in the ASD group (52.1%), but the mean differences between the two groups were not statistically significant. On the other hand, the percentage of overweight people in the control group is slightly greater (15.15%) than in the ASD group (13.2%). However, compared to the control group, the ASD group's mean was significantly increased.

The fluctuation in BPA is shown in Figure 2. The present results illustrated that the serum BPA concentration



**Figure 1:** Percentage and mean variation of body mass index comparison between autism spectrum disorder and control groups

of children with ASD was significantly greater than that of the control group ( $19.82 \pm 1.313$  ng/mL and  $14.26 \pm 1.58$  ng/mL, respectively).

Furthermore, present findings demonstrated that the Vitamin D level in the ASD group was substantially lower than the control group. In particular, the mean Vitamin D concentration in the ASD group was  $18.91 \pm 1.01$  ng/mL, while the mean in the control group was  $23.07 \pm 0.54$  ng/mL [Figure 3]. In addition, the present study demonstrated that both groups' calcium levels varied, which showed the ASD group having a substantially lower level ( $9.35 \pm 0.11$  mg/mL) than the control group ( $9.88 \pm 0.15$  mg/mL), as seen in Figure 3.

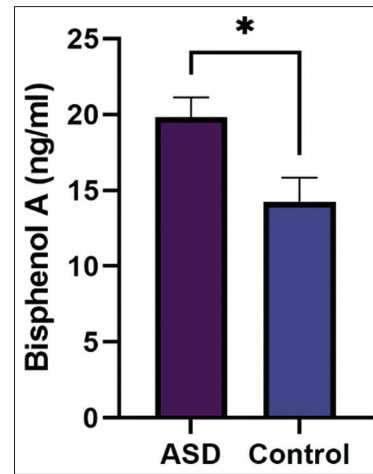
According to the findings of this study, the TSH level was insignificantly reduced in the ASD group ( $2.36 \pm 0.11$  mIU/mL) than in the control group ( $2.61 \pm 0.11$  mIU/mL), as shown in Figure 4. Furthermore, the findings in Figure 4 demonstrated that the magnesium levels in the ASD group were not significantly different from those in the control group ( $2.08 \pm 0.031$  mIU/mL vs.  $2.09 \pm 0.051$  mIU/mL).

The WBC count was significantly higher in the ASD group ( $9.54 \pm 0.53 \times 10^9/L$ ) compared to the control group ( $7.34 \pm 0.33 \times 10^9/L$ ,  $P = 0.0013$ ). The HCT percentage was also significantly elevated in the ASD group ( $37.13 \pm 0.49\%$ ) compared to the control group ( $35.44 \pm 0.35\%$ ). Furthermore, the MCHC was significantly lower in ASD children ( $34.37 \pm 0.19$  g/dL) than in the control group ( $35.71 \pm 0.18$  g/dL). A significant reduction was also observed in RDW% values in the ASD group ( $13.09 \pm 0.16\%$ ) compared to the control group ( $13.87 \pm 0.16\%$ ), suggesting lower variability in RBC size. In addition, the MPV was significantly higher in ASD children ( $9.35 \pm 0.17$  fL) than in controls ( $7.91 \pm 0.12$  fL,  $P < 0.0001$ ). The other hematological parameters of the two groups did not show any significant changes.

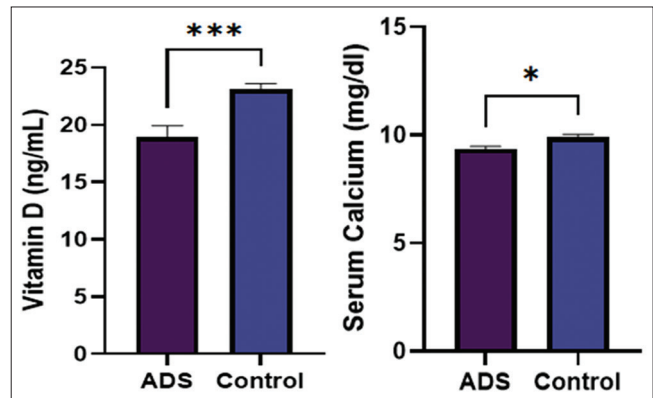
## DISCUSSION

ASD is appearing as one of the most rapidly increasing neurodevelopmental conditions globally; however, its medical management continues to encounter difficulties because of the diversity in underlying causes and variations in symptom presentation.<sup>[15]</sup> The present study illustrated that the mean of BMI significantly increases in the ASD group. The results parallel with the study of Sedgewick *et al.*,<sup>[16]</sup> who demonstrated that children with autism exhibited a higher mean BMI compared to their non-autistic children, potentially related to reduced physical activity, increased energy consumption, and a tendency toward nutrient-poor food choices. Numerous obesity-related risk factors in children with ASD are particularly related to today's environment that promotes weight gain. The use of psychiatric medications, genetic predispositions, sleep disturbances, irregular dietary habits, and difficulties in maintaining adequate physical exercise may be distinctively linked to the onset of obesity in autistic children.<sup>[14]</sup>

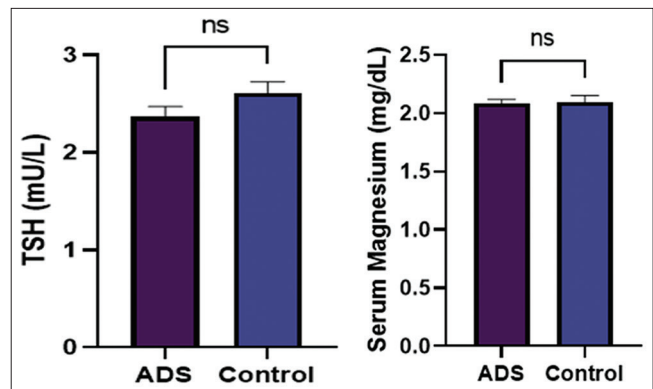
The obtained results showed that, in comparison with the control group, the children with ASD had noticeably higher serum BPA concentrations. The results agree with the study of Symeonides *et al.*,<sup>[17]</sup> which showed that prenatal



**Figure 2:** Level of serum bisphenol A in autism spectrum disorder and control groups (Mean  $\pm$  standard error)



**Figure 3:** Level of serum vitamin D and serum calcium in autism spectrum disorder and control groups (Mean  $\pm$  standard error)



**Figure 4:** Level of serum thyroid-stimulating hormone and serum magnesium in autism spectrum disorder and control groups (Mean  $\pm$  standard error)

BPA exposure is linked to male ASD-related behaviors, brain abnormalities, and reduced brain aromatase activity, and another study believed that BPA disrupts neural cell growth, movement, and specialization during brain maturation. It also affects the formation and function of synapses within the brain. As a result, BPA has been associated with the emergence of neurodevelopmental and neuropsychiatric conditions, such

**Table 1:** Some hematological parameters for ASD children and the control group (Mean±standard error)

Parameter	ASD	Control	P-value
WBC (10 <sup>9</sup> /L)	9.54±0.53	7.34±0.33	0.0013
Lymphocyte (10 <sup>9</sup> /L)	3.65±0.17	3.23±0.13	0.0587
Granulocyte (10 <sup>9</sup> /L)	4.93±0.32	4.45±0.31	0.3172
RBC (10 <sup>12</sup> /L)	4.76±0.07	4.63±0.05	0.1272
HGB (g/dL)	12.75±0.16	12.64±0.14	0.6593
HCT (%)	37.13±0.49	35.44±0.35	0.0113
mean corpuscular volume (fL)	78.22±0.95	76.46±0.91	0.1576
MCH (pg)	26.91±0.37	27.33±0.36	0.1797
MCHC (g/dL)	34.37±0.19	35.71±0.18	<0.0001
RBC distribution width (%)	13.09±0.16	13.87±0.16	0.0044
Platelet count (10 <sup>9</sup> /L)	336.15±10.44	324.82±9.69	0.4215
MPV (fL)	9.35±0.17	7.91±0.12	<0.0001

WBC: White blood cell, RBC: Red blood cell, HGB: Hemoglobin, HCT: Hematocrit, MCH: Mean corpuscular hemoglobin, MCHC: Mean corpuscular hemoglobin concentration, MPV: Mean platelet volume

as ASD, attention-deficit and hyperactivity disorders (ADHD), and schizophrenia.<sup>[18]</sup> Furthermore, BPA disrupts the usual functioning of the brain, metabolic processes, reproduction, and behavior. It also has a role in the development of some neurodevelopmental diseases, such as ADHDs and ASDs.<sup>[19]</sup> Early life exposure to EDCs, including BPA, has separately been suggested to contribute to the temporal increase in ASD prevalence.<sup>[17]</sup> Study of Meng *et al.*<sup>[20]</sup> shows how exposure to BPA alters the homeostasis of Ca<sup>2+</sup> and structural integrity of the mitochondria in hippocampus neurons. In addition, environmental BPA exposure blocks autophagic flux, inhibit the autophagic process in injured mitochondria, and negatively impacts hippocampus neurons' energy consumption through the PINK1/parkin mitophagy pathway, all of which lead to abnormal neuronal death.

The release of TSH, which regulates the release of thyroid hormones and is controlled by negative feedback.<sup>[21]</sup> Compared to the control group, the TSH level in the ASD group was non-significantly lower. The present finding agrees with the Singh *et al.*,<sup>[22]</sup> who report that TSH levels were significantly lower in ASD children. TSH production and secretion are extremely susceptible to environmental exposure.<sup>[23]</sup> Metals have been associated with differences in TSH levels in adult studies; however, it is unknown how maternal exposure to metals affects neonatal TSH and subsequent brain development.<sup>[24]</sup> However, in another study, BPA exposure can alter the level of thyroid hormone. Since thyroid hormones are crucial for fetal brain development, and maternal exposure to BPA carries sensitive clinical relevance, prenatal BPA exposure may influence thyroid hormone levels in newborns.<sup>[25]</sup>

The findings of the present study revealed that the ASD group's mean Vitamin D level was significantly lower than the control group. The results parallel with the study of Mansour *et al.*<sup>[26]</sup> demonstrated that lower serum Vitamin D levels in children with ASD could be one of the environmental variables

influencing the development of ASD. Furthermore, the inquiry of Feng *et al.*<sup>[27]</sup> found that a Vitamin D status and the overall score for behavioral abnormalities and psychiatric symptoms in kids with ASD have been linked negatively. These findings indicate that children with ASD have a higher BPA rate. According to the study of Brandi *et al.*<sup>[28]</sup> that showed BPA can raise the excretion of Vitamin D3 in the urine, which lowers blood levels. This suggests that disruption of Vitamin D3 metabolism may be connected to neurodevelopmental abnormalities caused by BPA. Moreover, Vitamin D deficiency and abnormally low serotonin levels in the brain are frequently observed in children with ASD. Neurogenesis is one of the brain processes that serotonin levels are linked to controlling.<sup>[29]</sup> Vitamin D supplementation may still be considered under medical supervision due to the high prevalence of baseline Vitamin D deficiency in children with ASD, potential effects on ASD severity, and the evidence of safety and tolerability of the supplements across all trials.<sup>[30]</sup> Calcium level in the ASD group is significantly lower than control group. The study of Omotosho *et al.*<sup>[31]</sup> showed that children with ASD were shown to have hypocalcemia and hypomagnesemia. Another study reported that children with ASD have far lower calcium levels, most likely as a result of dietary deficiencies and exposure to environmental pollutants, particularly in the early stages of development.<sup>[32]</sup> In addition, dysregulated calcium homeostasis could be the cause of the decreased serum calcium. ASD is associated with mutations in a number of voltage-gated and ligand-gated ion channels that control calcium homeostasis, which may lead to an increase in cytosolic calcium concentration and a decrease in extracellular fluid calcium concentration.<sup>[33]</sup> Furthermore, low plasma Ca<sup>2+</sup> and high brain Ca<sup>2+</sup> in autistic children can easily result in oxidative stress because elevated intracellular Ca<sup>2+</sup> stimulates mitochondrial oxygen radicals.<sup>[32]</sup>

According to the present study, the ASD group had no significantly lower magnesium level than the control group. Other studies found that magnesium is essential for the conversion of thiamine into thiamine pyrophosphate, whose absence in gastric juice is linked to autism.<sup>[32]</sup> The findings of the present study show that children with ASD frequently have iron deficiency, hypomagnesemia, and hypocalcemia. While intracellular concentrations of magnesium did not change significantly, a different investigation found that children with ASD had significantly lower plasma levels.<sup>[34]</sup>

However, the results of the present study in Table 1 showed that the ASD group had significantly higher WBC levels than the control group, which may be connected to a high inflammatory state in children with ASD. Furthermore, Arteaga-Henríquez *et al.*<sup>[35]</sup> found that in comparison to controls, ASD was characterized by a significantly higher WBC count as well as substantially greater amounts of neutrophils and monocytes. Immune system dysfunction is frequently associated with this inflamed disorder. It has been established that BPA negatively impacts biological systems.<sup>[36]</sup> BPA in the bloodstream is thought to have the potential to cause cytotoxic reactions in blood components by increasing WBC and especially monocytes.<sup>[37]</sup> Other hematological parameters did not show significant changes between the two groups. Whereas, in the Gunes *et al.*<sup>[38]</sup> study demonstrated that Hb, HCT, iron, and MCV levels of children with ASD were lower than healthy controls.

## CONCLUSION

Bisphenol A is a widely used organic compound that is considered a common pollutant due to its presence in plastic manufacturing. The production of BPA has been steadily increasing on a global scale. Exposure to BPA has been linked to various health issues, including Vitamin D deficiency, hypocalcemia, and elevated inflammatory cells, particularly in individuals with autism. In addition, individuals with autism tend to have a higher BMI.

## REFERENCES

1. K. A. Shaw, S. Williams, M. E. Patrick, M. Valencia-Prado, M. S. Durkin, E. M. Howerton, C. M. Ladd-Acosta, E. T. Pas, A. V. Bakian, P. Bartholomew, N. Nieves-Muñoz, K. Sidwell, A. Alford, D. A. Bilder,... & M. J. Maenner. Prevalence and early identification of autism spectrum disorder among children aged 4 and 8 years - Autism and developmental disabilities monitoring network, 16 sites, United States, 2022. *MMWR Surveillance Summaries*, vol. 74, no. 2, pp. 1-14, 2025.
2. A. Havdahl, M. Niarchou, A. Starnawska, M. Uddin, C. Van Der Merwe and V. Warriier. Genetic contributions to autism spectrum disorder. *Psychological medicine*, vol. 51, no. 13, pp. 2260-2273, 2021.
3. J. Xiong, S. Chen, N. Pang, X. Deng, L. Yang, F. He, L. Wu, C. Chen, F. Yin and J. Peng. Neurological diseases with autism spectrum disorder: Role of ASD risk genes. *Frontiers in Neuroscience*, vol. 13, p. 349, 2019.
4. H. E. Nag, A. Nordgren, B. M. Anderlid and T. Nærland. Reversed gender ratio of autism spectrum disorder in smith-magenis syndrome. *Molecular Autism*, vol. 9, pp. 1-9, 2018.
5. C. Zhong, J. Tessing, B. K. Lee and K. Lyall. Maternal dietary factors and the risk of autism spectrum disorders: A systematic review of existing evidence. *Autism Research*, vol. 13, no. 10, pp. 1634-1658, 2020.
6. S. Lundström, C. M. Haworth, E. Carlström, C. Gillberg, J. Mill, M. Råstam, C. M. Hultman, A. Ronald, H. Anckarsäter, R. Plomin, P. Lichtenstein and A. Reichenberg. Trajectories leading to autism spectrum disorders are affected by paternal age: Findings from two nationally representative twin studies. *Journal of Child Psychology and Psychiatry*, vol. 51, no. 7, pp. 850-856, 2010.
7. G. Björklund, M. I. Waly, Y. Al-Farsi, K. Saad, M. Dadar, M. M. Rahman, A. Elhoufey, S. Chirumbolo, J. Józwick-Pruska and J. Kałużna-Czaplińska. The role of vitamins in autism spectrum disorder: What do we know? *Journal of Molecular Neuroscience*, vol. 67, pp. 373-387, 2019.
8. B. Gesundheit, J. P. Rosenzweig, D. Naor, B. Lerer, D. A. Zachor, V. Procházka, M. Melamed, D. A. Kristt, A. Steinberg, C. Shulman, P. Hwang, G. Koren, A. Walfisch, J. R. Passweg, J. A. Snowden, R. Tamouza, M. Leboyer, D. Farge-Bancel and P. Ashwood P. Immunological and autoimmune considerations of autism spectrum disorders. *Journal of Autoimmunity*, vol. 44, pp. 1-7, 2013.
9. A. Oommen and R. S. AlOmar. Role of nutritional deficiency in the development of autism spectrum disorders. *International Journal of Research in Medical Sciences*, vol. 8, no. 5, pp. 1968-1972, 2020.
10. C. S. Uldbjerg, J. Leader, L. Minguéz-Alarcon, O. Chagnon, R. Dadd, J. Ford, E. Fleury, P. Williams, A. Juul, D. C. Bellinger, A. M. Calafat, R. Hauser and J. M. Braun. Associations of maternal and paternal preconception and maternal pregnancy urinary phthalate biomarker and bisphenol A concentrations with offspring autistic behaviors: The PEACE study. *Environmental Research*, vol. 263, p. 120253, 2024.
11. Z. H. Liu, Y. Xia, S. Ai and H. L. Wang. Health risks of bisphenol-a exposure: From wnt signaling perspective. *Environmental Research*, vol. 251, p. 118752, 2024.
12. S. A. Hafezi and W. M. Abdel-Rahman. The endocrine disruptor bisphenol A (BPA) exerts a wide range of effects in carcinogenesis and response to therapy. *Current Molecular Pharmacology*. vol. 12, no. 3, pp. 230-238, 2019.
13. O. Yesildemir and M. N. Celik. Association between pre- and postnatal exposure to endocrine-disrupting chemicals and birth and neurodevelopmental outcomes: An extensive review. *Clinical and Experimental Pediatrics*, vol. 67, no. 7, p. 328, 2023.
14. C. Curtin, M. Jojic and L. G. Bandini. Obesity in children with autism spectrum disorder. *Harvard Review of Psychiatry*, vol. 22, no. 2, pp. 93-103, 2014.
15. S. Yue, Z. Bo and H. Yuguang. Excitatory/inhibitory imbalance in autism spectrum disorder: Mechanism and treatment progress. *Medical Journal of Peking Union Medical College Hospital*, vol. 14, no. 4, pp. 844-849, 2023.
16. F. Sedgewick, J. Leppanen and K. Tchanturia. Autistic adult outcomes on weight and body mass index: A large-scale online study. *Eating and Weight Disorders*, vol. 25, no. 3, pp. 795-801, 2020.
17. C. Symeonides, K. Vacy, S. Thomson, S. Tanner, H. K. Chua, S. Dixit, T. Mansell, M. O'Hely, B. Novakovic, J. B. Herbstman, S. Wang, J. Guo, J. Chia, N. T. Tran,...& W. C. Boon. Male autism spectrum disorder is linked to brain aromatase disruption by prenatal BPA in multimodal investigations and 10HDA ameliorates the related mouse phenotype. *Nature Communications*, vol. 15, no. 1, p.6367, 2024.
18. S. A. Hyun and M. Ka. Bisphenol A (BPA) and neurological disorders: An overview. *The International Journal of Biochemistry and Cell Biology*, vol. 173, p. 106614, 2024.
19. D. Rebolledo-Solleiro, L. Y. C. Flores and H. Solleiro-Villavicencio. Impact of BPA on behavior, neurodevelopment and neurodegeneration. *Frontiers in Bioscience Landmark (Ed)*, vol. 26, no. 2, pp. 363-400, 2020.
20. L. Meng, Z. Ouyang, Y. Chen, C. Huang, Y. Yu and R. Fan. Low-dose BPA-induced neuronal energy metabolism dysfunction and apoptosis mediated by PINK1/parkin mitophagy pathway in juvenile rats. *Science of The Total Environment*, vol. 929, p. 172655, 2024.
21. S. J. K. Abad, G. K. Chir, P. Heydari, A. Fazilat, F. M. Moghadam and M. Valilo. Hormonal disorders in autism spectrum disorders. *Hormone Molecular Biology and Clinical Investigation*, vol. 46, pp. 57-66, 2025.
22. S. Singh, U. Yazdani, B. Gadad, S. Zaman, L. S. Hynan, N. Roatch, C. Schutte, C. N. Marti, L. Hewitson and D. C. German. Serum thyroid-stimulating hormone and interleukin-8 levels in boys with autism spectrum disorder. *Journal of Neuroinflammation*, vol. 14, p. 113, 2017.
23. M. Babić Leko, I. Gunjača, N. Pleić and T. Zemunik. Environmental factors affecting thyroid-stimulating hormone and thyroid hormone levels. *International journal of molecular sciences*, vol. 22, no. 12, p. 6521, 2021.
24. L. Yu, H. Zhang, J. Liu, S. Cao, S. Li, F. Li, W. Xia, S. Xu and Y. Li. Thyroid-stimulating hormone (TSH) mediates the associations between maternal metals and neurodevelopment in children: A prospective cohort study. *Environmental Pollution*, vol. 363, p. 125150, 2024.
25. M. J. Kim and Y. J. Park. Bisphenols and thyroid hormone. *Endocrinology and Metabolism*, vol. 34, no. 4, pp. 340-348, 2019.
26. A. Mansour, A. Amer, A. Sobh, M. Zaki and T. Abou-Elsaad. Vitamin D profile in autism spectrum disorder children and its relation to the disease severity. *The Egyptian Journal of Otolaryngology*, vol. 40, no. 1, p. 7, 2024.
27. J. Feng, L. Shan, L. Du, B. Wang, H. Li, W. Wang, T. Wang, H. Dong, X. Yue, Z. Xu, W. G. Staal and F. Jia. Clinical improvement following vitamin D3 supplementation in autism spectrum

- disorder. *Nutritional Neuroscience*, vol. 20, no. 5, pp. 284-290, 2017.
28. M. Brandi, S. Bandinelli, T. Iantomasi, F. Giusti, E. Talluri, G. Sini, F. Nannipieri, S. Battaglia, R. Giusti, C. G. Egan and L. Ferrucci. Association between vitamin D and bisphenol A levels in an elderly Italian population: Results from the InCHIANTI study. *Endocrine Connections*, vol. 11, no. 3, p. e210571, 2022.
29. M. J. Berridge. Vitamin D deficiency: Infertility and neurodevelopmental diseases (attention deficit hyperactivity disorder, autism, and schizophrenia). *American Journal of Physiology Cell Physiology*, vol. 314, no. 2, pp. C135-C151, 2018.
30. M. Kittana, A. Ahmadani, L. Stojanovska and A. Attlee. The role of vitamin D supplementation in children with autism spectrum disorder: A narrative review. *Nutrients*, vol. 14, no. 1, p. 26, 2021.
31. I. O. Omotosho, A. O. Akinade and I. A. Lagunju. Calcium and magnesium levels are down regulated in Nigerian children with autism spectrum disorder and cerebral palsy. *Neuroscience and Medicine*, vol. 9, no. 3, pp. 159-170, 2018.
32. S. Shahjadi, A. S. Khan, M. U. Ahmed, M. Karim, S. Parvin, U. R. Siddiqi, S. Afroz and S. N. Mahruba. Study on serum magnesium, calcium and iron in autism spectrum disorder (ASD) children. *Journal of Dhaka Medical College*, vol. 27, no. 2, pp. 199-204, 2020.
33. S. Afroz, U. R. Siddiqi, N. Mahruba, S. Shahjadi and S. Begum. Serum calcium and phosphate in children with autism spectrum disorder. *Journal of Bangladesh Society of Physiologist*, vol. 15, no. 2, pp. 72-77, 2020.
34. J. Baj, W. Flieger, M. Flieger, A. Forma, E. Sitarz, K. Skórzyńska-Dziduszko, C. Grochowski, R. Maciejewski and H. Karakuła-Juchnowicz. Autism spectrum disorder: Trace elements imbalances and the pathogenesis and severity of autistic symptoms. *Neuroscience and Biobehavioral Reviews*, vol. 129, pp. 117-132, 2021.
35. G. Arteaga-Henríquez, J. Lugo-Marín, L. Gisbert, I. Setién-Ramos, M. Martínez-Gallo, R. Pujol-Borrell and J. A. Ramos-Quiroga. Activation of the monocyte/macrophage system and abnormal blood levels of lymphocyte subpopulations in individuals with autism spectrum disorder: A systematic review and meta-analysis. *International Journal of Molecular Sciences*, vol. 23, no. 22, p. 14329, 2022.
36. O. A. Alabi, K. I. Ologbonjaye, A. A. Sorungbe, O. S. Shokunbi, O. I. Omotunwase, G. Lawanson and O. G. Ayodele. Bisphenol A-induced alterations in different stages of spermatogenesis and systemic toxicity in albino mice (*Mus musculus*). *Journal of Health and Pollution*, vol. 11, no. 29, p. 210307, 2021.
37. M. Neri, G. M. Virzi, A. Brocca, F. Garzotto, J. C. Kim, F. Ramponi, M. De Cal, A. Lorenzin, A. Brendolan, F. Nalesso, M. Zanella and C. Ronco. *In vitro* cytotoxicity of bisphenol A in monocytes cell line. *Blood Purification*, vol. 40, no. 2, pp. 180-186, 2015.
38. S. Gunes, O. Ekinci and T. Celik. Iron deficiency parameters in autism spectrum disorder: Clinical correlates and associated factors. *Italian Journal of Pediatrics*, vol. 43, p. 86, 2017.