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Association Between Blood Nanoplastic Exposure and Reproductive Hormone Levels in Healthy Young Adults: A Cross-Sectional Study

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Abstract

Background: Nanoparticles constitute one of the most serious pollutants in the environment because of their prevalence and endocrine-disrupting nature. Various experimental researches had proposed that nanoparticles could affect reproductive health via inducing oxidative stress, causing inflammation, and interfering with the synthesis and signaling of hormones. There is little data on the relationship between the exposure to nanoparticles and reproductive hormones levels in humans. Objective of this study is to analyze the relationship between the exposure to nanoparticles and serum levels of progesterone and testosterone. Methods: Cross-sectional research was carried out in Baghdad, Iraq, from November 2025 to March 2026. It involved 67 healthy volunteers, comprising 35 women and 32 men aged between 18 and 35 years. Blood samples were obtained and tested under identical conditions for serum progesterone and testosterone content, as well as the quantity of nanoplastic particles in the blood. Data analysis was performed, with statistical significance established at $p < 0.05$. Results: However, no statistically significant association was found between nanoparticle exposure and absolute levels of progesterone and testosterone. Likewise, no statistically significant difference was found among the means of hormone levels between the exposure groups. On the other hand, all abnormal hormone levels fell under the medium and high exposure groups. There is a statistically significant association between the highest exposure group and abnormal testosterone levels but there is no statistically significant association with abnormal progesterone levels. Conclusion: In this study, no relation was found between exposure to plastic nanoparticles and alteration in the level of blood progesterone and testosterone. Nevertheless, there were instances of irregular hormone level in people who have been exposed moderately and heavily to plastic nanoparticles. This could mean that plastic nanoparticles have the possibility of being an early agent of endocrine disruption. Future studies on this topic should be conducted to confirm the findings.

Keywords

Progesterone;
Testosterone;
Nanoplastic;
Reproductive hormones

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INTRODUCTION

Progesterone and Testosterone are two very important steroid hormones which help in the regulation of reproduction and reproductive potential in both males and females. Progesterone is involved in controlling the menstrual cycle, fertilization, implantation of the fertilized ovum, and maintenance of pregnancy. Testosterone is involved in the development and maintenance of the male reproductive system and muscles. Thus, any difference in the concentrations of these hormones causes reproductive and physiological abnormalities (Baker & Katsu, 2020).

Recently, many pollutants that may interfere with the functions of the endocrine system have gained attention.In these pollutants, one which is gaining much importance is the plastic nanoparticle, described as plastic particles less than 1 micrometer in size. The small size of this pollutant helps it penetrate biological barriers and accumulate in different body organs including the endocrine and reproductive organs (Leso *et al.*, 2023).

Several pieces of evidence exist to indicate that the plastic nanoparticles might function as endocrine disruptors via several possible pathways such as generating oxidative stress and inflammation, programmed cell death, as well as hormonal signaling interference and disruption of hormone receptors. The exposure to micro- and nanoplastics has been found to affect the hypothalamus-pituitary-gonad system and ovarian and testicular functions (Leso *et al.*, 2023; Tyc *et al.*, 2025). For instance, exposure to nanoplastics was shown to lower the ovarian functions, causing the reduction of the progesterone concentration. Moreover, adverse effects on the testicular tissues have been shown to be connected with the problems with the reproductive function. In addition to that, recent research has shown the ability of nanoplastics to interact with the pathways of androgen and estrogen receptors, indicating their ability to affect the hormones even when exposed at lower concentrations (Peranić *et al.*, 2026). New evidence has confirmed the fears regarding the possible effect of plastics on human health. Plastic particles have been found in many tissues. Plastics have been identified in human biological fluids, such as blood, placenta, breast milk, and reproductive organs, confirming the ability of these contaminants to penetrate the biological membranes and accumulate in the human body. Recent findings have shown that this accumulation is connected with hormonal disturbances, reproductive problems, oxidative stress, and inflammation, and that there is a need to conduct additional human biomonitoring to examine the effect of these particles on reproductive hormones (Galgani *et al.*, 2024; Galloway, 2024; Ragusa *et al.*, 2021).

Although there is an increasing amount of data on the endocrine disruptive effects of plastic nanoparticles, the connection between accumulation of plastic nanoparticles in the body and levels of progesterone and testosterone is yet to be thoroughly researched. Hence, research into the possible correlation between the presence of an increased nanoplastic load in the body and decreases in these hormones will be highly important from both scientific and public health perspectives.

METHODOLOGY

Study Design and Setting;

This cross-sectional analytical study was conducted in the laboratories of the College of Health and Medical Technologies at Uruk University, Additional hormonal and biochemical analyses were conducted in accredited external clinical laboratories equipped with specialized diagnostic facilities, Baghdad, Iraq. The study was carried out over a five-month period extending from November 2025 to March 2026.The study aimed to investigate the association between nanoplastic exposure and serum levels of progesterone and testosterone among the study population.

Study Population:

The study population consisted of male and female participants aged between 18 and 35 years. Participants were recruited from the working population and were selected based on their regular exposure to potential sources of plastic-derived

contaminants through the consumption of packaged foods and beverages. Such exposure included the frequent use of plastic-containing food packaging materials, tea bags, instant food products requiring the addition of hot water, and other consumer products that may contribute to nanoplastic exposure. Blood samples were collected under standardized conditions to minimize potential variations in hormone measurements. For both males and females, blood samples were collected from a vein between 9:00 and 10:00 AM following standardized sampling procedures. To minimize hormonal and physiological effects, blood was collected on the third day of the menstrual cycle for females. All participants were in good health. Demographic and exposure information were obtained. Prior to sample collection, serum was separated to assess hormonal status, and remaining blood components were collected for plastic nanoparticle analysis.

Blood Sample Collection and Processing:

After collecting blood samples under standardized conditions, the serum was separated using a centrifuge. The serum was transferred to Eppendorf tubes and appropriately stored until hormonal analysis. Serum progesterone and testosterone levels were measured using a Cobas C303 analyzer, according to the manufacturer's instructions and standard laboratory procedures.

The rest of the blood samples were kept for the measurement and identification of the plastic particles (plastic nanoparticles). This process was conducted using Fourier transform infrared spectroscopy (FTIR) to measure and identify plastic nanoparticles in the blood samples. All the processes involved in sample handling were conducted in controlled laboratory conditions.

RESULTS

Participant Characteristic:

Seventy individuals participated in this study. Three participants were excluded due to accidental errors. Therefore, the final number of participants was 67, divided into 32 males and 35 females. Based on the nanoplastic particle exposure scores obtained from the questionnaire, participants were classified into three exposure categories: low exposure (n = 42), moderate exposure (n = 17), and high exposure (n = 8). Table 1 shows the distribution of participants across the exposure groups. The distribution of participants across exposure groups is presented in Table (1).

Table (1): Distribution of participants according to nanoplastic exposure category

Exposure rate	Number
Low	42= (65.5) %
Moderate	17= (25.5) %
High	8= (9.0) %

Testosterone Levels Across Exposure Categories:

The descriptive statistics for testosterone concentration in the male participants are explained as shown in Table (2). The mean testosterone concentration was 4.85 ± 1.69 ng/mL in the low-exposure group, compared with 5.54 ± 5.40 ng/mL and 5.61 ± 2.52 ng/mL in the moderate- and high-exposure groups, respectively. High average testosterone concentrations were observed among participants with medium and high exposure, but significant variability within the group was evident, particularly in the medium exposure group.

Table (2): Testosterone concentrations according to exposure category

Exposure	n	Mean ± SD	Median	Range
Low	18	4.85 ± 1.69	4.42	2.77–8.23
Moderate	9	5.54 ± 5.40	4.25	0.20–15.96
High	5	5.61 ± 2.52	4.46	3.88–8.50

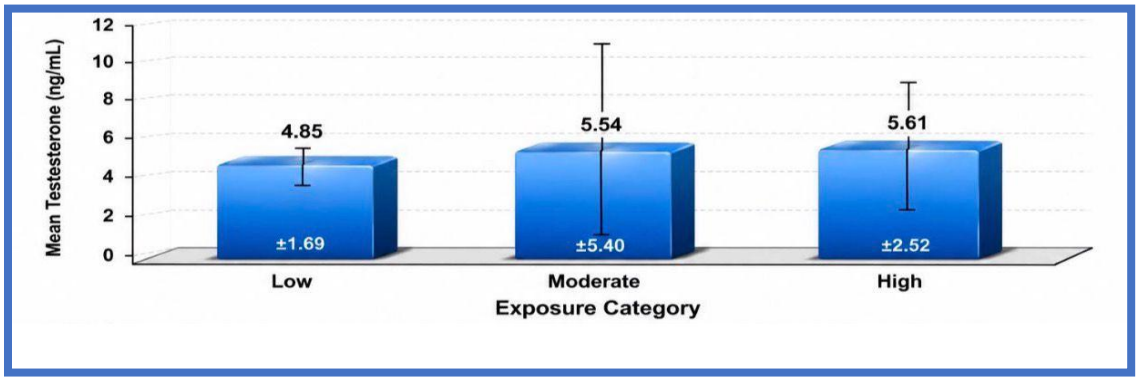

Figure (1): Mean testosterone concentration according to nanoplastic category

Progesterone Levels Across Exposure Categories

Table (3) shows the statistical results for progesterone hormone in female participants. Mean progesterone concentrations were 8.43 ± 8.39 nmol/L, 6.98 ± 9.22 nmol/L, and 21.72 ± 23.21 nmol/L in the low-, moderate-, and high-exposure groups, respectively. Despite the small number of participants in the high-exposure group, it showed the highest average progesterone concentration; however, this should be interpreted with caution due to the small number of participants in this category.

Table (3): Progesterone concentrations according to exposure category

Exposure	n	Mean ± SD	Median	Range
Low	21	8.43 ± 8.39	3.69	2.36–30.27
Moderate	9	6.98 ± 9.22	3.16	2.93–29.45
High	5	21.72 ± 23.21	21.72	5.31–38.13

Correlation Between Nanoplastic Exposure and Hormone Levels

Correlation analysis was performed to investigate the relationship between plastic nanoparticle exposure and hormone concentrations. No statistically significant correlation was found between exposure and testosterone concentration (Spearman's rank correlation coefficient $\rho = 0.028$, $p = 0.893$). Similarly, no statistically significant correlation was observed between exposure and progesterone concentration (Spearman's rank correlation coefficient $\rho = 0.061$, $p = 0.748$).

Pearson's correlation analysis also yielded similar results, indicating the absence of a statistically significant linear relationship between exposure and hormone concentrations.

Table (4): Correlation analysis between plastic nanoparticle exposure and hormone concentrations

Hormone	Spearman's ρ	p-value
Testosterone	0.028	0.893
Progesterone	0.061	0.748

Comparison of Hormone Levels Among Exposure Groups

Comparisons between the groups were performed using parametric and non-parametric statistical methods. Kruskal-Walli's analysis revealed no statistically significant differences in testosterone concentration between the exposure groups (H = 0.45, p = 0.798).

Similarly, progesterone levels did not differ significantly between the exposure groups (H = 3.17, p = 0.205). One-way ANOVA also showed the same results, confirming the absence of statistically significant variation in hormone concentrations with respect to exposure.

Table (5): Comparison between the exposure groups and their hormone concentrations.

Hormone	Test	Statistic	p-value
Testosterone	Kruskal-Wallis	H=0.45	0.798
Progesterone	Kruskal-Wallis	H=3.17	0.205

Abnormal Hormone Results According to Exposure Category:

The frequency of hormone measurements outside of established clinical reference settings was then confirmed and examined. No abnormal values for these hormones were observed in participants in the low-exposure group. On the other hand, all abnormal hormones observed in this study were measured in participants in the high and medium-exposure groups. Among males, abnormal testosterone levels were detected in 3 out of 9 participants (33.3%) in both the high and medium-exposure groups. No abnormal or suspicious results were observed in the low-exposure group.

Fisher's exact test showed a statistically significant correlation (p = 0.037).

Among females, one abnormal progesterone result was detected in both the medium and high-exposure groups. No abnormal results were observed among participants in the low-exposure group. This difference did not reach statistical significance (p = 0.333).

Table (6): Frequency of Abnormal Hormone Measurements According to Exposure Groups

Hormone	Low Exposure	Moderate/High Exposure	p-value
Testosterone	0/16 (0%)	3/9 (33.3%)	0.037*
Progesterone	0/20 (0%)	1/10 (10%)	0.333

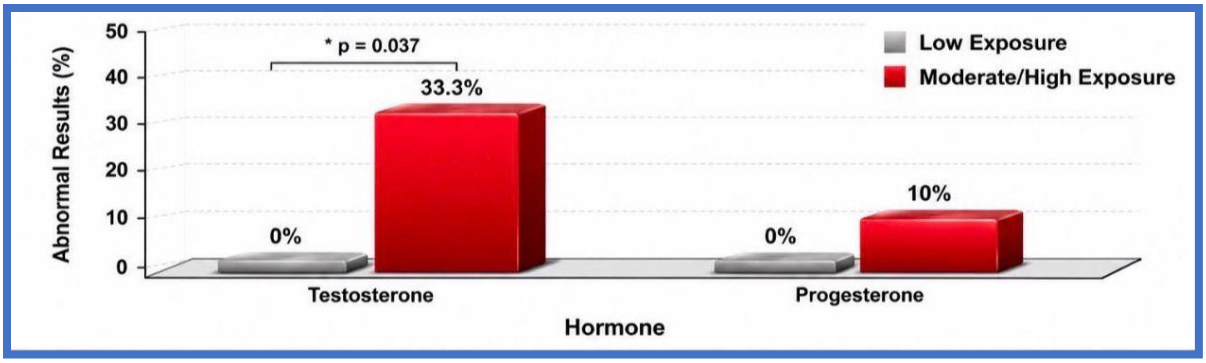

Figure (2): Frequency of abnormal hormone measurements according to exposure category

Overall Hormonal Deviation from Clinical Reference Ranges:

To facilitate comparison between male and female participants, hormone concentrations were normalized relative to their respective clinical reference ranges. Visual inspection demonstrated a tendency toward greater deviation from normal hormonal ranges among participants classified within the high-exposure category compared with low- and moderate-exposure groups. Although this interpretation did not reach the level of statistical significance, it suggests the possibility that the greater the exposure to plastic nanoparticles, the greater the likelihood of hormonal imbalance.

DISCUSSION

This study aimed to investigate the relationship between exposure to plastic nanoparticles and serum progesterone and testosterone levels in healthy young men. No statistically significant relationship was observed between plastic nanoparticle exposure levels and hormone levels. However, all abnormal hormonal values were found only in participants exposed to moderate or high levels of nanoplastics. This suggests that increased exposure may cause hormonal imbalances in individuals, rather than uniform changes in circulating hormone levels. These findings are consistent with recent human studies indicating that environmental plastics may disrupt hormonal balance without causing significant changes in average hormone concentrations. placental exposure to microplastics was related to changes in steroid hormones, such as androgens, indicating that plastics can disrupt hormonal regulations via various biological mechanisms (Liu *et al.*, 2025). Likewise, there were significant correlations between the placental exposure to microplastics and changes in thyroid hormone levels in infants (Zhang *et al.*, 2025).

Several reasons can justify the absence of statistically significant results in this research:

First, the effect of endocrine-disruptors is usually minimal, and it cannot be reflected in hormone levels of a population, especially a smaller one (Leso *et al.*, 2023).

Second, the balance of hormones is regulated by compensation mechanism.

Considering the pituitary-hypothalamic-gonadal axis, physiological hormone levels can be maintained within normal limits because of early hormone disturbance (Tyc *et al.*, 2025; Zhang *et al.*, 2025). There is recent evidence based on experimental research, according to which plastic nanoparticles change androgen and estrogen receptors' function without influencing steroid hormone synthesis (Peranić *et al.*, 2026). Additional biological evidence has been received from animal studies. Chronic and continuous exposure to plastic nanoparticles decreases testosterone synthesis due to Leydig cells impairment and suppression of steroidogenesis pathway (Han *et al.*, 2024; Jin *et al.*, 2024). It is established that ovarian endocrine disorders and androgen excess take place after polystyrene microplastic particles exposure. It

proves reproductive endocrine tissues sensitivity to plastic toxicity (Adhikari *et al.*, 2024).

One of the most important results obtained in this study was that hormone levels were found to be abnormal only in the case of medium and high exposure to plastic nanoparticles; even though there was no significant difference in the average hormone levels, the conclusion one can make from this is that exposure to plastic nanoparticles might lead to hormonal imbalance rather than to hormonal change for the whole population, which is something that has been observed in other studies as well (Leso *et al.*, 2023).

Despite its multiple advantages such as the use of consistent blood sampling techniques, sampling of hormones in a controlled physiological setting, and measuring plastic nanoparticles directly in blood using FTIR, this study was also accompanied by some limitations. Such limitations include small sample sizes as well as possible confounding variables that could have affected the study's results.

CONCLUSION

The above findings indicate that exposure to plastic nanoparticles does not lead to any significant changes in blood progesterone or testosterone levels in healthy adults. Nevertheless, the presence of abnormal hormone levels only in those people who have been exposed to plastic nanoparticles suggests the theory that plastic nanoparticles can lead to endocrine disruption. Prospective studies are needed to confirm this effect.

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