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IMPACT OF MERCURY ON SEX HORMONES (LITERATURE REVIEW)

СЫМАПТЫН ЖЫНЫСТЫК ГОРМОНДОРГО ТИЙГИЗГЕН ТААСИРИ (АДАБИЙ СЕРЕП)

ВЛИЯНИЕ РТУТИ НА ПОЛОВЫЕ ГОРМОНЫ (ЛИТЕРАТУРНЫЙ ОБЗОР)

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IMPACT OF MERCURY ON SEX HORMONES (LITERATURE REVIEW)

Abstract. Mercury, a ubiquitous environmental pollutant, poses significant risks to human health, particularly through its detrimental effects on the endocrine system. Hg disrupts endocrine function through various mechanisms, including interference with hormone synthesis, receptor binding, and signal transduction pathways. Additionally, mercury exposure has been linked to disturbances in the hypothalamic-pituitary-adrenal axis, affecting stress response and cortisol production. Furthermore, emerging evidence suggests that mercury may interfere with sex hormone regulation, potentially contributing to reproductive dysfunction and developmental abnormalities. However, challenges remain in elucidating the precise dose -response relationships and mechanisms underlying these associations, particularly given the complex interactions between mercury and other environmental stressors. This review aims to provide a comprehensive overview of the current understanding of mercury's impact on the endocrine system, encompassing both experimental findings and epidemiological evidence. Additionally, continued research is needed to better understand the long-term consequences of mercury exposures on the endocrine system and to develop targeted interventions for at risk-populations.

Keywords: Endocrine system, mercury, sex hormones, estrogen, progesterone, FSH, LH, prolactin, testosterone

СЫМАПТЫН ЖЫНЫСТЫК ГОРМОНДОРГО ТИЙГИЗГЕН ТААСИРИ (АДАБИЙ СЕРЕП)

Аннотация

Сымап өтө уулуу айлана-чөйрөнү булгаган зыяндуу зат, адамдын ден соолугуна олуттуу коркунуч туудурат, айрыкча эндокриндик системага зыяндуу таасирин тийгизгет. Hg эндокриндик функцияларды ар кандай механизмдер аркылуу, анын ичинде гормондордун синтезине тоскоолдук кылуу, рецепторлорго байлануу жана сигнал өткөрүү жолдору аркылуу бузат. Ошондой эле, ртуттун таасири гипоталамус-гипофиз-бөйрөк үстүндөгү бездин бузулушуна байланыштуу, бул стресске жооп берүүгө жана кортизол өндүрүшүнө таасир этет. Андан тышкары, жаңы далилдер көрсөткөндөй, сымап жыныстык гормондорду жөнгө салууга тоскоолдук кылып, репродуктивдик дисфункцияга жана өнүгүүсүндөгү бузулууларга алып келиши мүмкүн. Бирок, доза, жооп жана сымап менен башка тышкы факторлордун ортосундагы бул татаал өз ара аракеттенүүнүн механизмдеринин ортосундагы так байланыштарды аныктоодо көйгөйлөр калууда. Бул изилдөөнүн максаты-эксперименталдык изилдөөлөрдү жана эпидемиологиялык далилдерди камтыган, сымаптын эндокриндик системага тийгизген таасири жөнүндө учурдагы түшүнүктүн толук баяндалышын камсыз кылуу. Мындан сырткары, эндокриндик системада сымапка дуушар болуунун узак мөөнөттүү кесепеттерин жакшыраак түшүнүү жана коркунуч алдында турган популяциялар үчүн максаттуу кийлигишүүлөрдү иштеп чыгуу үчүн улантуучу изилдөөлөрдү жүргүзүү зарыл.

Ачкыч сөздөр: Эндокринная система, ртуть, половые гормоны, эстроген, прогестерон, ФСГ, ЛГ, пролактин, тестостерон

ВЛИЯНИЕ РТУТИ НА ПОЛОВЫЕ ГОРМОНЫ (ЛИТЕРАТУРНЫЙ ОБЗОР)

Аннотация

Ртуть, распространенный загрязнитель окружающей среды, представляет значительный риск для здоровья человека, особенно из-за ее пагубного воздействия на эндокринную систему. Ртуть нарушает эндокринную функцию с помощью различных механизмов, включая вмешательство в синтез гормонов, связывание с рецепторами и пути передачи сигналов. Кроме того, воздействие ртути было связано с нарушениями в системе гипоталамо-гипофизарно-надпочечниковой системы, влияющими на реакцию на стресс и выработку кортизола. Кроме того, появляющиеся данные свидетельствуют о том, что ртуть может влиять на регуляцию половых гормонов, потенциально способствуя репродуктивной дисфункции и аномалиям развития. Однако остаются проблемы в выяснении точных взаимосвязей между дозой, ответной реакцией и механизмов, лежащих в основе этих сложных взаимодействий между ртутью и другими внешними факторами. Целью данного исследования является предоставление всестороннего обзора современного понимания воздействия ртути на эндокринную систему, охватывающего экспериментальные и эпидемиологические данные. Кроме того, необходимы дальнейшие исследования, чтобы лучше понять долгосрочные последствия воздействия ртути на эндокринную систему и разработать целенаправленные мероприятия для групп риска.

Ключевые слова: Эндокринная система, ртуть, половые гормоны, эстроген, прогестерон, ФСГ, ЛГ, пролактин, тестостерон.

Introduction

In terms of the most dangerous elements or compounds on Earth, mercury is listed third by the Agency for dangerous compounds and Disease Registry, after arsenic and lead, which are still being poured into our land and streams, poured into our atmosphere, and absorbed in our food and water (Clifton, 2007, p. 54).

Mercury levels in the atmosphere have nearly tripled due to human activity, and the burden is rising by 1.5% year (Clifton, 2007, p. 54). Plants and animals may absorb polluted soil or water through redistributing it, which could contaminate other areas of the food chain (Rice and Ambrose, 1997, p.11; Davidson, 2004, p.113; Goldman, 2001, p.108). Mercury can bioaccumulate and have a negative impact on human health once it enters the food chain (Harada et al., 1999, p. 227).

The exact mechanism(s) by which mercury enters the food chain remains largely unknown, and probably varies among ecosystems. Environmental mercury can exist in its elemental form, as inorganic mercury or as organic mercury. In its elemental form mercury exists as liquid metal, which in spite of its low vapor pressure (2 μm Hg), can be converted to a vapor at room temperature due to its low latent heat of evaporation (295 kJ/kg) and its relative absence from ambient air. Dental amalgam, thermometers, sphygmomanometers, barometers, fossil fuel emissions, incandescent lights, batteries, mercury-using rituals, and the burning of medical waste are among the current sources of elemental mercury exposure for humans (Guzzi and La Porta, 2008, p. 244). When mercury-containing materials are burned or vaporized, toxic vapours are released that easily enter the respiratory system and circulate throughout the body. Inhaled mercury has an average biological half-life of 60 days over the entire body (Chang, 1977, p. 14). Mercury vapor has the potential to bioaccumulate in the liver, brain, and renal cortex because it can become lipid soluble after it has oxidized. Mercury in the brain is thought to have a half-life of up to 20 years (Friberg, 1989, p. 21).

Mechanisms of mercury toxicity

Mercury can interfere with endocrine function in a number of ways. It modifies the levels and activity of hormones in the body by interfering with their synthesis, secretion, transport, and metabolism. Mercury can also attach itself to hormone receptors, inhibiting their regular activity and having an impact on target tissues in the process. Endocrine organ damage can also result from mercury-induced oxidative stress and inflammation, which can compromise the organs' capacity to control hormone production and signaling.

Effects on the endocrine system

The endocrine system is a complex network of glands and organs that regulate numerous physiological processes by secreting hormones into the bloodstream. These hormones act as chemical messengers, travelling to target tissues and organs to elicit specific responses. Any disruption in hormone production, secretion or signalling can have profound effects on overall health and well-being. By disrupting the pituitary, thyroid, adrenal glands, and pancreas, low exposure levels of mercury may have an impact on the endocrine system in both humans and animals (Minoia et al., 2009, p. 538). Mercury is believed to potentially affect endocrine function by inhibiting one or more important enzymes or steps in hormone manufacture, as observed in the case of adrenal steroid biosynthesis and the suppression of 21α-hydroxylase (Iavicoli et al., 2009, p. 206), or by decreasing

hormone-receptor binding. It seems that insulin, estrogen, testosterone, and adrenaline are the hormones most impacted by mercury.
By deactivating S-adenosyl-methionine, mercury can also prevent catecholamine breakdown. This can result in a buildup of adrenaline, hyperhidrosis, tachycardia, ptyalism (hyper salivation), and hypertension.

Exposure to mercury has been linked to decreased corticosterone plasma levels in the adrenal cortex (Iavicoli et al., 2009, p. 233). Adrenocorticotropic hormone rises in response to decreased cortisol production, resulting in adrenal hyperplasia. Adrenal atrophy may result from prolonged stress on the adrenal glands brought on by mercury-induced adrenal hyperplasia, which may also play a role in the onset of Addison's disease (Wada et al., 2009, p. 43). The thyroid and pituitary retain and collect more inorganic mercury than the kidneys, according to autopsy investigations conducted in 1975 (Tan, 2009, p. 39). In one study, the mean levels of mercury in the pituitary gland were found to be 28 ppb, with levels proven to be neurotoxic and cytotoxic. In another study, the levels ranged from 6.3 to 77 ppb (Nylander and Weiner, 1991, p. 729). Low levels of pituitary function are associated with depression and suicidal thoughts, and appear to be a major factor in suicide of teenagers and other vulnerable groups. Because of its effect on the pituitary, mercury is known to cause frequent urination as well as high blood pressure (McGregor, 1991, p. 199). One of the body's biggest endocrine glands is the thyroid. The thyroid regulates the body's rate of protein synthesis, energy expenditure, and hormone sensitivity. The pituitary and thyroid both exhibit a propensity to accumulate mercury. By taking up iodine-binding sites and blocking or changing hormone activity, mercury prevents the thyroid from producing hormones that regulate body temperature, hypothyroidism, thyroid inflammation, and depression (Wada et al., 2009, p. 6031; McGregor, 1991, p. 199). The pancreas, thyroid, progesterone, testosterone, and many more organs are also vulnerable to mercury's harmful effects. Mercury can attach to one of the three sulphur-binding sites on insulin, the protein linked to diabetes, interfering with normal biological function and resulting in a dysregulation of blood glucose levels (Chen et al., 2006, p. 1080).

Disruption of reproductive hormones

The levels of reproductive hormones have been found to be disrupted by mercury exposure, impacting the fertility of both men and women. Mercury can affect sperm quality and testosterone production in males, which lowers sperm motility and count. Mercury exposure in females has been linked to irregular menstruation, decreased fertility, and unfavourable pregnancy outcomes like premature delivery and miscarriage. Mercury's estrogenic qualities can also interfere with estrogen signaling pathways, which may raise the risk of hormone-related malignancies like ovarian and breast cancer.

Impact of mercury on estrogen

Mercury is a chemical element that stimulates estrogen/progesterone signalling, decreases oocyte oxidation, and decreases melatonin release. In addition, it was noted that rats had smaller and altered oocyte nuclei, atresia and altered ovarian follicles, and altered oocyte differentiation and folliculogenesis. These observations combined to result in a decrease in ovarian reserves, which in turn caused infertility or decreased fertility (Ahmadi, et al., 2016, p. 8). Precocious puberty can result

from brain radiation's reduction in pituitary perfusion, which upsets the hypothalamus-pituitary-ovary axis.

Mercury exposure can disrupt estrogen hormone balance in several ways:

- Mercury has the ability to disrupt the endocrine system, which includes estrogen signalling pathways, which can result in hormonal imbalance (Grandjean and Landrigan, 2006, p. 368).
- Mercury compounds possess the ability to function as either agonists or antagonists of estrogen receptors, hence modifying estrogen receptor activation and subsequent signalling (Grotto, 2009, p. 190).
- Mercury exposure has the potential to cause dysregulation of genes that respond to estrogen, which could impact processes in cells and tissues that depend on estrogen (Gandhi, 2014, p. 875).
- Reproductive Dysfunction: Impaired fertility, irregular menstruation, and infertility are among the reproductive problems that can be caused by mercury-induced estrogen disruption (Serdar, 2010, p. 133).
- Effects on Development: Mercury exposure during pregnancy can disrupt foetus growth by interfering with mechanisms regulated by estrogen, which can result in unfavourable results for progeny (Plusquellec, 2010, p. 118).
- Cancer Risk: Exposure to mercury can cause dysregulation of estrogen hormones, which raises the risk of hormone-related cancers such ovarian and breast cancer (Goodson, 2015, p. 36).
- Immune Dysfunction: Mercury's interference with estrogen can affect immunity, which may result in autoimmune diseases and increased vulnerability to infections (Havarinasab, 2007, p. 162).
- Neurological Effects: Because estrogen has neuroprotective properties, an imbalance in estrogen brought on by mercury exposure might aggravate neurological problems (Castoldi, 2006, p. 242).
- Metabolic imbalance: Estrogen imbalance brought on by mercury may affect metabolic functions and exacerbate metabolic diseases including diabetes and obesity (Lin, 2012, p. 1274).
- The effects of mercury exposure on estrogen levels may lead to cardiovascular dysfunction, such as hypertension and atherosclerosis (Ribeiro, 2015, p. 33).
- Oxidative Stress: The alteration of estrogen caused by mercury can intensify oxidative stress, resulting in damage and malfunction to cells (Flora, 2008, p, 323).
- Epigenetic Modifications: DNA methylation and histone modifications that affect gene expression may be epigenetic modifications linked to mercury-induced abnormalities in estrogen signalling (Kim, 2017, p. 202).

Impact of mercury on progesterone hormone:

Progesterone hormone regulation can be significantly impacted by mercury exposure, which can result in a number of physiological problems. Mercury may affect progesterone synthesis, secretion, and receptor signalling pathways by upsetting the delicate endocrine system's balance (Grandjean and Landrigan, 2006, p. 368). Adverse developmental outcomes in prenatal exposure scenarios, as well as reproductive problems including infertility, miscarriage, and irregular menstruation, can be manifestations of this disruption (Plusquelle, 2010, p. 2475; Goodson, 2015, p. 254). Moreover, exposure to mercury can cause dysregulation of progesterone hormones, which might increase the risk of hormone-related cancers such uterine and breast cancer (Kim, 2017, p.

210). Additionally, immunological function can be impaired, changing an individual's vulnerability to infections and making them more vulnerable to autoimmune illnesses (Jin, 2014, p. 147).

Furthermore, because of progesterone's critical function in neuroprotection, mercury-induced abnormalities in progesterone signalling may be a factor in neurological illnesses (Carvalho, 2013, p. 5087). Furthermore, progesterone alterations brought on by mercury exposure may interfere with metabolic functions and exacerbate diseases like obesity and insulin resistance (Zalups and Barfuss, 1995, p. 55). Since thyroid hormones closely regulate progesterone metabolism and response, the interaction between mercury exposure and thyroid dysfunction exacerbates progesterone dysregulation (Monachese, 2011, p. 1171). Another risk is oxidative stress brought on by mercury, which can interfere with progesterone production and metabolism and change progesterone levels and activity (Gundacker, 2010, p. 1270). Overall, the complex relationships between environmental pollutants and endocrine disruption are highlighted by the varied effects of mercury on progesterone hormones, which have important consequences for reproductive, developmental, and general health (Serdar, 2010, p. 102).

Impact of mercury on FSH:

Follicle-stimulating hormone (FSH) levels and functions are significantly threatened by mercury exposure, upsetting the delicate endocrine system balance (Grandjean and Landrigan, 2006, p. 2167). The synthesis, secretion, and control of FSH are all disrupted, which could have a domino effect on reproductive problems (Serdar, 2010, p. 102). Studies have demonstrated that irregular menstruation, poor ovarian function, and subfertility can be brought on by changed FSH levels brought on by mercury exposure. Moreover, follicular growth and ovulation may be interfered with by mercury-induced ovarian damage, hence aggravating reproductive failure. Mercury exposure during pregnancy carries additional concerns, including the ability to affect foetal growth and development of the foetus's FSH levels and result in long-term reproductive effects (Plusquellec, 2010, p. 1475).

Furthermore, exposure to mercury can cause disturbances in the hypothalamic-pituitary axis, which can impact the control of reproductive hormones and the secretion of FSH. Adolescents who have this interruption may experience delayed puberty or other developmental problems. Changes in FSH levels brought on by mercury have an impact on endometrial health, menstrual cycle management, and the likelihood of hormone-related conditions such endometriosis and polycystic ovarian syndrome (PCOS) (Lin, 2012, p. 1280).

- Mercury exposure causes disruption to the endocrine system, which may impact the synthesis, secretion, and regulation of Folic acid stimulation (FSH) (Oliveira, 2020, p. 121).
- Reproductive Dysfunction: Mercury exposure-related changes in FSH levels can cause subfertility, irregular menstruation, and reduced ovarian function (Yorifuji, 2016, p. 675).
- Ovarian Toxicity: Ovulation and follicular development may be impacted by mercury-induced alteration of FSH levels, which can lead to ovarian toxicity (Li, 2018, p. 1257).
- Menstrual irregularities, such as prolonged or missed periods, may result from mercury exposure-induced disruption of FSH levels (Goodrich, 2012, p. 252).

Impact of mercury on LH:

Exposure to mercury has a substantial impact on the levels and functions of luteinizing hormone (LH). Research has indicated that mercury interferes with the production, release, and regulation of leptin, which may cause issues with reproduction (Kishi, 2015, p. 1113).

- Reproductive Dysfunction: Mercury exposure-related changes in LH levels can cause reproductive problems include irregular menstruation, poor ovulation, and infertility (Yorifuji, 2016, p. 675).
- Mercury-induced alteration of LH levels has been linked to ovarian toxicity, impacting steroidogenesis and follicular development (Li, 2018, p. 1260).

Mercury's harmful effects on LH levels, which lead to ovarian toxicity and irregular menstruation (Yorifuji, 2016, p. 677). Exposure to mercury during pregnancy may alter levels of luteinizing hormone (LH), which may have an effect on the development of the foetus and the health of the mother. According to studies, mercury can pass through the placenta and affect the developing foetus. Moon et al. (2018) discovered correlations between changes in LH levels and maternal mercury exposure during pregnancy, pointing to possible disturbances in the hypothalamic-pituitary-gonadal axis. These results highlight how crucial it is to keep an eye on mercury exposure during pregnancy in order to reduce any dangers to the health of the mother and foetus (Moon, 2018, p. 2520).

- Hormone-Related Disorders: Endometriosis and polycystic ovarian syndrome (PCOS) may become more likely as a result of mercury exposure-induced dysregulation of LH levels (Kishi, 2015, p. 1115).
- Menstrual irregularities, such as prolonged or missed periods, may result from mercury exposure-induced disruption of LH levels (Goodrich, 2012, p. 255).
- Mercury exposure has the potential to cause disruption to the hypothalamic-pituitary axis, which in turn may impact the control of reproductive hormones and the secretion of LH (Guo, 2014, p. 3411).

Impact of mercury on prolactin:

Prolactin hormone levels have been related to alterations following mercury exposure. Grotto et al. (2009) study examined the effects of long-term mercury exposure on the hormone levels of artisanal gold miners, and the results showed that those who had been exposed to more mercury had higher prolactin levels. This implies that mercury may interfere with prolactin secretion's regular regulation, which could result in hormonal abnormalities and associated health repercussions (Grotto, 2009, p. 974). Research has indicated a correlation between exposure to mercury and higher levels of prolactin in those who have been exposed (Silva, 2018, p. 7).

- Potential Health Effects: Mercury exposure may cause prolactin hormone levels to be disrupted, which may lead to metabolic and reproductive issues as well as other unfavourable health effects (Santos, 2020, p. 8191).
- Pregnancy and breastfeeding: Exposure to mercury during pregnancy and breastfeeding may influence prolactin levels, which may have an effect on the results of lactation (Dórea, 2014, p. 621).

- Implications for nursing: The health of the newborn and the success of nursing may be affected by changes in prolactin levels brought on by mercury exposure (Barbosa, 1997, p. 266).
- Impact on Breast Health: Mercury exposure-related changes in prolactin levels may have an impact on breastfeeding outcomes and breast health (Menezes-Filho, 2011).

Exposure to mercury has been linked to disturbances in prolactin hormone levels, which may have an effect on multiple physiological functions. Research indicates that mercury may disrupt the neuroendocrine system, hence impacting the production and release of prolactin. For example, a study conducted in 1999 by Harada et al. discovered increased prolactin levels in people who consumed seafood and were exposed to mercury, suggesting a potential disturbance in the regulation of prolactin. Furthermore, the neurotoxic effects of mercury may disrupt the hypothalamic-pituitary axis, resulting in dysregulated release of prolactin. Mercury exposure-related variations in prolactin levels may be a factor in neurodevelopmental problems, lactation issues, and reproductive illnesses. Evaluating mercury's effects on human health requires an understanding of the complex interactions it has with prolactin hormones (Harada, 1999, p. 200).

Impact of mercury on testosterone:

Research by Lee et al. (2015) found inverse associations between mercury exposure and testosterone levels in men from Amazonian communities, indicating a possible disruption in testosterone regulation (Lee, 2015, p. 1989). Mercury, a heavy silver metal, is a widespread contaminant that enters the environment from industrial processes. In a human experiment, fewer than 5% of sperm exposed to mercury continued to move after 30 minutes. It also dramatically decreased libido and sperm count.

- Testosterone levels: Research employing rats, whose testicular tissue resembles that of humans, revealed a noteworthy reduction in plasma testosterone levels in rats exposed to methyl-mercury.
- Mercury interacts with glutathione, an antioxidant, rendering its bodily reserves inactive. Interestingly, the body cannot produce glutathione when testosterone is present. Thus, decreased testosterone levels may result from mercury exposure.
- Mercury can also lead to headaches, irritation, mood changes, cognitive impairments, and kidney malfunction, among other side effects.

CONCLUSION

The impact of mercury on the endocrine system is a matter of significant concern with far-reaching implications for human health and environmental sustainability. Mercury exerts a profound impact on the endocrine system, disrupting hormone synthesis, secretion and signalling across various endocrine organs. These disruptions have far-reaching consequences for health, affecting thyroid function, reproductive hormones, stress response and glucose metabolism. The evidence presented underscores the multifaceted ways in which mercury disrupts endocrine function, affecting hormone regulation, reproductive health, neurological development and immune system integrity. Moreover, the vulnerability of certain populations, such as pregnant women, infants and communities reliant on

fish consumption, amplifies the urgency of addressing mercury pollution. Given the ubiquitous nature of mercury pollution and its potential health implications efforts to mitigate mercury exposure and enhance public awareness of its endocrine disrupting effects are essential for safeguarding human health and wee-being. Mitigating this threat requires a concerted effort involving regulatory measures to reduce mercury emissions, public awareness campaigns to educate communities about the risks, and research initiatives to better understand the long-term effects and develop targeted interventions. By prioritizing these actions, we can strive towards safeguarding both human health and the delicate balance of ecosystems from the detrimental effects of mercury contamination.

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