

**STRUCTURAL AND FUNTIONAL CHARACTERISTICS OF THE TESTES UNDER
ADVERSE ENVIRONMENTAL CONDITIONS**

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Abstract

The testes are highly sensitive organs that perform both exocrine (spermatogenesis) and endocrine functions, making them essential for fertility and overall hormonal balance. Numerous studies have demonstrated that adverse environmental influences such as endocrine disorders, toxicants, temperature fluctuations, radiation, and stress factors cause significant structural and functional alterations in the testes. These changes manifest as disturbances of spermatogenesis, reduced fertility, and remodeling of endocrine structures. At the same time, adaptive mechanisms that partially compensate for negative impacts have been observed, opening perspectives for further research on prevention and therapeutic correction. The review summarizes current experimental and theoretical findings, emphasizing the importance of an integrative approach in reproductive biology and medicine.

Key words

testes; male reproductive system; environmental factors; spermatogenesis; morphometry; adaptation.

**МОРФОФУНКЦИОНАЛЬНЫЕ ОСОБЕННОСТИ СЕМЕННИКОВ ПРИ
ВОЗДЕЙСТВИИ НЕБЛАГОПРИЯТНЫХ ФАКТОРОВ ВНЕШНЕЙ СРЕДЫ**

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Аннотация

Семенники являются высокочувствительными органами, выполняющими как экзокринную функцию (сперматогенез), так и эндокринную активность, что делает их важными для обеспечения фертильности и поддержания общего гормонального баланса. Многочисленные исследования показали, что неблагоприятные воздействия внешней среды, такие как эндокринные нарушения, токсические вещества, колебания температуры, радиация и стрессовые факторы, вызывают существенные структурные и функциональные изменения в семенниках. Эти изменения проявляются в нарушениях сперматогенеза, снижении фертильности и перестройке эндокринных

структур. В то же время выявлены адаптационные механизмы, частично компенсирующие негативное воздействие, что открывает перспективы для дальнейших исследований в области профилактики и терапевтической коррекции. В обзоре обобщены современные экспериментальные и теоретические данные, подчеркивается значение интегративного подхода в репродуктивной биологии и медицине.

Ключевые слова

семенники; мужская репродуктивная система; экологические факторы; сперматогенез; морфометрия; адаптация.

**ENDOKRIN, TOKSIK VA EKOLOGIK OMILLAR TA'SIRIDA
URUG'DONLARNING MORFOFUNKSIONAL XUSUSIYATLARI**

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Buxoro davlat tibbiyot instituti

Annotatsiya

Urug'donlar juda sezgir a'zolar bo'lib, ular spermatogenez (ekzokrin) va gormonal (endokrin) faoliyatni bajaradi, bu esa ularni fertilitetni ta'minlash va umumiy gormonal muvozanatni saqlash uchun muhim qiladi. Ko'plab tadqiqotlar shuni ko'rsatadiki, endokrin buzilishlar, toksik moddalar, temperatura o'zgarishlari, radiatsiya va stress kabi noqulay tashqi omillar urug'donlarda jiddiy morfologik va funksional o'zgarishlarga olib keladi. Ushbu o'zgarishlar spermatogenez buzilishi, fertilitetning pasayishi va endokrin tuzilmalarning qayta qurilishi sifatida namoyon bo'ladi. Shu bilan birga, salbiy ta'sirlarni qisman kompensatsiya qiluvchi adaptatsion mexanizmlar aniqlangan bo'lib, bu profilaktika va terapevtik tuzatish bo'yicha yangi izlanishlar uchun istiqbollarni ochadi. Sharhda zamonaviy eksperimental va nazariy ma'lumotlar umumlashtirilib, reproduktiv biologiya va tibbiyotda integrativ yondashuvning ahamiyati ta'kidlangan.

Kalit so'zlar

urug'donlar; erkak reproduktiv tizimi; ekologik omillar; spermatogenez; morfometriya; adaptatsiya.

Introduction. The male reproductive system is one of the most sensitive to external and internal factors. The testes play a key role by combining an exocrine function (spermatogenesis) and endocrine activity, which determines their importance not only in ensuring fertility but also in regulating the overall hormonal balance of the body. Structural and functional disorders under the influence of endocrine, environmental, toxic, and stress factors lead to serious impairments in reproductive function.

In recent years, a significant body of literature has been accumulated, devoted to the study of morphofunctional characteristics of the testes under normal conditions and under various factor influences. Special attention is given to experimental models on laboratory animals, which make it possible to better understand the mechanisms of endocrine pathologies, xenobiotics, hypothermia, heat stress, and cryopreservation on the architecture and function of the testes.

This review analyzes modern articles, dissertations, and review publications devoted to the morphology and physiology of the testes, as well as their changes under the influence of adverse factors. The synthesis of these materials made it possible to identify key patterns, compare experimental and theoretical approaches, and outline promising directions for further research.

Modern directions in this field are reflected in the work of Rakhimova G.Sh. (2022), where the main morphofunctional features of the testes are considered both under normal conditions and under the influence of various exogenous factors. The author emphasizes the role of a comprehensive analysis of morphology and physiology in identifying adaptive mechanisms and pathogenetic changes [9].

The problem of endocrine regulation of reproductive function is revealed in the study by Shakirova S.M. et al. (2021), who showed that endocrine pathology in rats leads to pronounced destructive processes in the spermatogenic epithelium and impaired spermatogenesis. This study confirms the close interconnection between the endocrine and reproductive systems and the importance of hormonal balance in maintaining fertility [11].

A comparative analysis of methods for studying gonadotoxic effects was presented by Zaprivoda L.P. et al. (2015). The authors substantiated the advantages of an integrated morphological approach, including classical histology, morphometry, and immunohistochemical methods, which allow detecting even minimal changes under environmental influences [7].

Experimental studies on the toxic effects of membrane-damaging xenobiotics in mice were carried out by Bokov D.A. (2017). The author demonstrated that such compounds cause degenerative processes in the spermatogenic epithelium, a reduction in the number of mature sperm, and decreased fertility, confirming the high sensitivity of the reproductive system to xenobiotics [3].

Of particular interest are the studies of Shevlyuk N.N. et al. (2017), who examined amphibians, reptiles, and mammals living in anthropogenically transformed ecosystems of the Southern Urals. They established that the endocrine cells of the testes undergo functional restructuring under technogenic stress [13].

Vetoshkin R.V. (2016) studied the role of proteoglycans and glycosaminoglycans under chronic exposure to natural toxicants. The results showed that these compounds

serve as sensitive markers of intercellular matrix damage and reflect the degree of toxic stress on the reproductive system [4].

A number of researchers have described the functional morphology of the male reproductive system of animals, linking anatomical and histological structure with physiological reproductive features and emphasizing the importance of interdisciplinary analysis [17].

The influence of environmental factors on reproductive processes in rodents was studied by Dantas M.R.T. et al. (2021). The authors showed that ecological instability, toxicants, and climate change cause restructuring of reproductive strategies, including alterations in the morphology and functional activity of gonads [16]. Similar views were expressed by Tirpák F. et al. (2021), who examined diverse exogenous factors—stress, nutrition, toxins, and temperature—that disrupt the integrity of the reproductive system, reducing sperm quality and fertility [22].

Ion B. and Balan I. (2021) confirmed that stress factors and cryopreservation have a pronounced negative effect on the structure and function of the male gonads, noting degenerative changes in the spermatogenic epithelium and reduced fertility in experimental animals [14].

Farias et al. (2020) studied neotropical bats and demonstrated unique adaptive mechanisms—namely, the ability to retain sperm in the reproductive tract to ensure fertilization under unfavorable environmental conditions [18].

Several researchers analyzed the influence of environmental conditions and breeding technologies on the morphology of testes in beef cattle, showing that feeding and housing conditions directly affect testicular architecture and spermatogenesis quality [20].

Experiments on Nellore bulls demonstrated that heat stress causes marked morphofunctional damage to spermatozoa, although partial regeneration of reproductive structures was observed during recovery [19].

Sayapina I.Yu. et al. (2019) studied the effects of low temperatures and protective agents, demonstrating that dihydroquercetin exerts protective action, preserving testicular morphology and supporting spermatogenesis under cold stress [21].

Radiation effects on testicular morphofunctional state were analyzed by Baymuradov R.R. (2021). His research systematized data on structural and functional changes of male gonads under acute and chronic irradiation. Radiation was shown to cause spermatogenic epithelium destruction, suppression of spermatogenesis, endocrine dysfunction, and long-term reproductive consequences. Special attention was given to the dose-dependent nature of damage and differences in tissue regenerative potential [2].

In a more recent study, Baymuradov R.R. (2024) analyzed the effects of various pathogenic factors on testes, emphasizing that toxic, infectious, and stress exposures

cause complex alterations, including morphological rearrangements, reduced spermatogenesis activity, and microcirculatory disorders [1].

Age-related aspects were considered by Baymuradov R.R. and Teshaev Sh.Zh. (2021), who demonstrated that juvenile and adult rats respond differently to radiation: younger animals exhibited more pronounced destructive processes, while adults showed partial adaptation. This highlights the importance of age in assessing gonadal radiation damage [15].

The issue of spermatogenesis correction was addressed in the study by Demyashkin G.A. et al. (2021). The authors showed that corrective interventions contribute to partial restoration of seminiferous tubule architecture and normalization of spermatogenic epithelium, confirming the therapeutic potential in restoring reproductive function [6].

Poplavskaya E.A. and Poplavsky D.Yu. (2019) investigated morphological changes in rat testes on day 40 after exposure to Gram-negative bacterial lipopolysaccharides. They showed that endotoxin exposure leads to persistent destructive changes in seminiferous tubules, reduction in spermatogenic cells, and microcirculation impairment, confirming the high sensitivity of testes to infectious-inflammatory factors [8].

Sayapina I.Yu., Barannikova S.V., and Ogorodnikova T.L. (2023) studied functional morphology of Leydig cells in rat testes under cold stress, revealing restructuring of steroidogenic activity and reduced secretory potential, accompanied by impaired hormonal support of spermatogenesis [10].

Galimova E.F. (2016) conducted a fundamental study on molecular and cellular mechanisms of the male reproductive system under various stressors. The author demonstrated cascades of morphofunctional rearrangements at the level of cell metabolism, signaling pathways, and intercellular interactions, ultimately affecting spermatogenesis [5].

Sharafutdinova L.A. (2019) studied the effects of titanium dioxide (rutile) nanoparticles on nervous, immune, and reproductive systems, showing pronounced morphofunctional disorders in testes, including spermatogenic epithelium damage, immune imbalance, and decreased fertility, highlighting the importance of nanotoxicology in assessing male health risks [12].

The reviewed studies indicate that the male reproductive system is highly sensitive to endocrine, toxic, environmental, and temperature factors. These influences cause marked changes in testicular morphology and function, manifested as impaired spermatogenesis, reduced fertility, and endocrine restructuring. At the same time, some studies emphasize the existence of adaptive mechanisms that partly compensate for negative effects, opening prospects for further research on correction and prevention.

Thus, analysis of the modern literature shows that most studies focus on radiation, toxicants, stress, temperature, xenobiotics, and infectious agents. Considerable attention has been paid to endocrine regulation, adaptive mechanisms, and correction of spermatogenesis disorders. However, despite the wide range of analyzed factors, there is a noticeable lack of comprehensive studies on socially significant influences such as chronic alcohol and nicotine intoxication. Considering the high prevalence and known negative impact of these factors on reproductive health, systematic morphofunctional analysis of testicular condition under these conditions remains underdeveloped, highlighting the relevance and necessity of further experimental and clinical research in this direction.

LITERATURE:

1. Баймурадов Р. Р. Влияние патогенных факторов на состояние семенников // International Journal of Integrated Sciences. – 2024. – Т. 1. – № 1.
2. Баймурадов Р. Р. Морфофункциональное состояние семенников при остром и хроническом радиационном облучении (обзор литературы) // Биология и интегративная медицина. – 2021. – № 4 (51).
3. Боков Д. А. Морфофункциональная характеристика сперматогенного эпителия, динамика развития половых клеток и уровень фертильности мышей CBAxС57В16 при действии мембраноповреждающих ксенобиотиков в эксперименте // Оренбургский медицинский вестник. – 2017. – № 4 (20). – С. 61–69.
4. Ветошкин Р. В. Протеогликаны и гликозаминогликаны репродуктивной системы самцов крыс при хроническом воздействии природных токсикантов : дис. ... канд. биол. наук. – Рязань: Рязан. гос. мед. ун-т им. И. П. Павлова, 2016. – 154 с.
5. Галимова Э. Ф. Молекулярные и клеточные механизмы функционирования мужской репродуктивной системы в условиях экстремальных и фоновых воздействий различной природы и интенсивности. – Москва, 2016.
6. Демяшкин Г. А., и др. Морфологическая характеристика семенников в условии коррекции гипосперматогенеза (экспериментальное исследование) // Крымский журнал экспериментальной и клинической медицины. – 2021. – Т. 11. – № 2. – С. 6–10.
7. Запривода Л. П., Остапенко О. В., Яценко В. П. Сравнительная характеристика морфологических методов оценки гонадотоксичного эффекта факторов окружающей среды // Математические исследования в естественных науках. – 2015. – № 12. – С. 171–179.
8. Поплавская Е. А., Поплавский Д. Ю. Сравнительный анализ структуры семенников крыс на 40-е сутки после воздействия липополисахаридов

грамотрицательных бактерий // Вестник Смоленской государственной медицинской академии. – 2019. – Т. 18. – № 1. – С. 16–22.

9. Рахимова Г. Ш. Современные аспекты изучения особенностей морфофункциональных характеристик семенников в норме и при различных факторных воздействиях // *Central Asian Journal of Medical and Natural Science*. – 2022. – Т. 3. – № 6. – С. 15–23.

10. Саяпина И. Ю., Баранников С. В., Огородникова Т. Л. Функциональная морфология интерстициальных эндокриноцитов яичек крыс при низкотемпературном воздействии // *Крымский журнал экспериментальной и клинической медицины*. – 2023. – Т. 13. – № 4. – С. 69–76.

11. Шакирова С. М., Шакирова Г. Р., Гильдилов Д. И. Морфофункциональная характеристика семенников и придатка семенника самцов крыс при эндокринной патологии // Вестник Башкирского государственного аграрного университета. – 2021. – № 1. – С. 87–92.

12. Шарафутдинова Л. А. Морфофункциональные изменения нервной, иммунной и репродуктивной систем при воздействии наноразмерного диоксида титана в форме рутила: дис. ... докт. биол. наук. – 2019.

13. Шевлюк Н. Н., Третьякова Р. Ф., Каюмов Ф. Г. и др. Гистофизиология эндокринных структур семенников амфибий, рептилий и мелких млекопитающих, населяющих антропогенно трансформированные экосистемы Южного Урала // *Журнал анатомии и гистопатологии*. – 2017. – Т. 6. – № 3. – С. 86–90.

14. Balan I., Ion B., et al. Morphofunctional changes in the male reproductive system under the influence of stressogenic factors and cryopreservation // *Oltenia, Studii si Comunicari Seria Stiintele Naturii*. – 2021. – Vol. 37. – № 1. – P. 131–137.

15. Baymuradov R. R., Teshayev Sh. J. Characteristics of anatomical parameters of rat testes in normal conditions and under irradiation in the age aspect // *International Journal of Trend in Scientific Research and Development*. – 2021. – March. – P. 106–108.

16. Dantas M. R. T., et al. Understanding how environmental factors influence reproductive aspects of wild myomorph and hystricomorph rodents // *Animal Reproduction*. – 2021. – Vol. 18. – P. e20200213.

17. Das P. K., Mukherjee J., Banerjee D. Functional morphology of the male reproductive system // *Textbook of Veterinary Physiology*. – Singapore: Springer Nature, 2023. – P. 441–476.

18. Farias T. O., et al. Male reproductive morphofunctional evaluation of a Neotropical sperm-storing vespertilionid bat (*Myotis levis*) in an environmental context // *Cell and Tissue Research*. – 2020. – Vol. 382. – № 3. – P. 639–656.

19. Garcia-Oliveros L. N., et al. Chronological characterization of sperm morpho-functional damage and recovery after testicular heat stress in Nellore bulls // *Journal of Thermal Biology*. – 2022. – Vol. 106. – P. 103237.
20. Kayumov F. G., Tretyakova R. F., Shevlyuk N. N. Influence of environmental conditions and technology of cultivation on the morphological structure of the testes of bull calves of three breeds in beef production // *IOP Conference Series: Earth and Environmental Science*. – 2021. – Vol. 624. – № 1. – P. 012031.
21. Sayapina I. Yu., et al. Functional morphology of organs of the male reproductive system in adaptation to low temperatures and treatment by dihydroquercetin. – 2019.
22. Tirpák F., et al. Exogenous factors affecting the functional integrity of male reproduction // *Life*. – 2021. – Vol. 11. – № 3. – P. 213.