THE MORPHOFUNCTIONAL EFFECTS OF ENERGY DRINKS ON TESTICULAR TISSUE

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Abstract. Energy drinks are widely consumed for their stimulating effects, primarily due to high caffeine, taurine, and sugar content. However, emerging preclinical evidence raises concerns about their potential adverse impact on male reproductive health. This narrative review examines the morphofunctional effects of energy drinks on testicular tissue, drawing from animal studies that assess histological alterations, sperm parameters, oxidative stress markers, and apoptotic pathways. Chronic exposure to commercial energy drinks or their key components has been associated with dose-dependent testicular damage, including seminiferous tubule degeneration, reduced spermatogenesis, elevated lipid peroxidation, and impaired antioxidant defenses. Mechanisms predominantly involve oxidative stress and apoptosis, with partial reversibility observed through antioxidant supplementation. Although most data derive from rodent models, supportive human observational findings suggest reduced sperm quality with high intake. These results highlight the need for caution in frequent energy drink consumption among reproductive-age males and call for further longitudinal human studies.

Keywords: energy drinks, testicular tissue, morphofunctional effects, oxidative stress, spermatogenesis, caffeine, taurine, reproductive toxicity, apoptosis, male fertility

Introduction. Energy drinks have gained immense popularity worldwide, particularly among young adults and adolescents seeking enhanced alertness, physical performance, and concentration. These beverages typically contain high levels of caffeine, taurine, sugar, and other stimulants. While they provide short-term benefits, growing evidence from animal studies suggests potential adverse effects on reproductive health, especially in males. The testis is a sensitive organ responsible for spermatogenesis and steroidogenesis, making it vulnerable to oxidative stress and metabolic disruptions induced by these compounds. This review synthesizes findings from preclinical research on the morphofunctional impacts of energy drinks on testicular tissue, focusing on histological changes, sperm parameters, and underlying mechanisms such as oxidative damage (Schuchowsky et al., 2017; Al-Shaikh and Rajeh, 2023).

Methods. This narrative review is based on a comprehensive analysis of peer-reviewed studies retrieved from scientific databases, including PubMed and other sources. Search terms included "energy drinks," "caffeine," "taurine," "testicular tissue," "sperm parameters," "oxidative stress," and related combinations. Inclusion criteria focused on experimental studies (primarily in rodents) examining direct exposure to commercial energy drinks or their key

components. Human observational data were considered where relevant, but emphasis was placed on animal models for morphofunctional outcomes. Studies were selected for their relevance to dose-dependent effects, histological evaluations, and biochemical markers. Key publications spanned from 2015 to 2023 to reflect recent insights (Park et al., 2015; Nwakamma et al., 2023; Al-Shaikh and Rajeh, 2023).

Results. Preclinical studies consistently demonstrate that chronic exposure to energy drinks induces detrimental changes in testicular morphology and function, often in a dose-dependent manner.

In Wistar rats administered varying doses of Fearless energy drink for three weeks, higher doses led to scattered seminiferous tubules, loss of spermatogenic cells, degeneration of interstitial cells, and vascular congestion. Lower doses caused moderate spermatogenic arrest, accompanied by reduced sperm quality (Nwakamma et al., 2023).

Long-term consumption (120 days) of an unspecified commercial energy drink in adult male Wistar rats significantly decreased sperm concentration without altering motility or morphology, suggesting selective impairment of spermatogenesis (Schuchowsky et al., 2017).

Exposure to Code Red energy drink in rats resulted in elevated malondialdehyde (MDA) levels, reduced antioxidant enzymes (SOD and GSH), and increased caspase-3 expression, indicating oxidative stress and apoptosis in testicular tissue. Histologically, this manifested as disrupted seminiferous epithelium and germ cell loss, effects partially ameliorated by antioxidant-rich blueberry extract (Al-Shaikh and Rajeh, 2023).

Caffeine, a primary component, has been implicated independently. In immature male rats, doses equivalent to high human intake altered testicular microarchitecture, slowed germ cell proliferation, and reduced testosterone production via direct effects on Leydig cells (Ting et al., 2017). Peripubertal high-dose caffeine induced testicular atrophy and impaired spermatogenesis (Park et al., 2015).

Human cross-sectional data provide supportive evidence: young men with higher intake of sugar-sweetened beverages (including energy drinks) showed lower sperm concentration, total count, and inhibin-B/FSH ratios, hinting at suppressed testicular function (Nassan et al., 2021).

Mechanistically, these effects appear driven by oxidative stress from caffeine-taurine-sugar interactions, leading to lipid peroxidation, inflammation, and disrupted steroidogenesis.

Discussion. The reviewed studies highlight a pattern of morphofunctional disruption in testicular tissue due to energy drinks. Histological degeneration, reduced sperm reserves, and hormonal imbalances likely stem from excessive reactive oxygen species (ROS) overwhelming antioxidant defenses, as evidenced by elevated MDA and caspase-3 (Al-Shaikh and Rajeh, 2023). Dose dependency observed across models underscores that moderate consumption may pose lower

risks, while chronic high intake amplifies damage (Nwakamma et al., 2023; Schuchowsky et al., 2017).

Limitations include the predominance of rodent models, which may not fully translate to humans due to metabolic differences. Few studies isolate individual ingredients, complicating attribution to specific components like taurine versus caffeine. Human data remain observational and cross-sectional, precluding causality (Nassan et al., 2021). Future research should incorporate longitudinal human cohorts and explore protective interventions.

Overall, while energy drinks offer transient benefits, their potential to impair testicular integrity through oxidative and apoptotic pathways warrants caution, especially for reproductive-age males.

References

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