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Research Article

The Ameliorative Effects of Probiotics on the Sperm Quality and Testicular Structure After Ischemia/Reperfusion Injury Following Testicular Torsion/Detorsion

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Oxidative stress is a critical contributor to the pathophysiology of ischemia/reperfusion (I/R) injury associated with testicular torsion (TT) and detorsion (D) (TT/D). This study examines the antioxidative properties of the probiotics Lactobacillus (L.) reuteri and Lactobacillus (L.) rhamnosus in ameliorating TT/D-induced oxidative and histological damage. Male Sprague–Dawley rats ($n = 6$ per group) were allocated into five experimental groups: a sham-operated group, a torsion/detorsion (T/D) group, and three T/D groups treated with *L. reuteri* (T/D+LRe), *L. rhamnosus* (T/D+LRm), or a combination of both (T/D+LRe+LRm). TT was induced by rotating the right testis 720° clockwise for 2 h, followed by 60 days of reperfusion. The testis was then excised for further analysis. The evaluated parameters included sperm quality, hormone levels (FSH, LH, and testosterone), as well as levels of malondialdehyde (MDA) and glutathione (GSH). Additionally, the activities of myeloperoxidase (MPO) catalase (CAT), glutathione peroxidase (GPx), and superoxide dismutase (SOD), as well as histological changes, were assessed. The findings demonstrated that TT/D significantly increased the FSH and LH levels, reduced sperm quality and testosterone levels, elevated MDA levels, and enhanced MPO activity. Additionally, TT/D reduced the GSH levels and the activities of GPx, CAT, and SOD. Probiotic treatment, particularly with *L. rhamnosus*, significantly increased testicular GSH levels and the activities of antioxidant enzymes GPx and CAT while reducing MDA levels and MPO activity. Histopathological analysis revealed severe testicular damage, including reductions in spermatogenic, sertoli, and Leydig cells following TT/D, mitigated by *L. rhamnosus*. These results suggest that probiotics, especially *L. rhamnosus*, may protect against I/R injury in a rat model of testicular T/D, likely due to their antioxidant properties.

Keywords: ischemia–reperfusion; oxidative stress; probiotic; sperm quality; testicular torsion; testis

1. Introduction

Testicular torsion (TT) is a critical urological emergency predominantly affecting neonates, children, and adolescents. It arises from the spermatic cord twisting, which restricts blood flow to the testis, resulting in ischemia, and severe pain [1]. Research indicates that the degree of testicular injury is strongly correlated with both the duration and severity of the torsion. Early diagnosis and surgical correction are vital to preventing irreversible testicular damage and minimizing the risks of infertility and subfertility [2]. Damage caused by torsion can persist even after detorsion (D). Although D and reoxygenation of the testis are critical for mitigating severe testicular injury and

primarily due to increased oxidative stress and inflammation. These effects included tissue necrosis, seminiferous tubule atrophy, reduced seminiferous epithelium volume, decreased testicular cell count, impaired spermatogenesis, lower sperm quality, and diminished testosterone secretion.

Notably, *L. rhamnosus* was shown for the first time to partially mitigate these damages in a T/D rat model, demonstrating its protective role against I/R injury. The results indicated that probiotics, particularly *L. rhamnosus*, reduce oxidative stress and inflammation, thereby improving spermatogenesis and sperm quality. Furthermore, our results indicated that *L. rhamnosus* exhibited stronger antioxidant, anti-inflammatory, and tissue-protective properties compared to *L. reuteri* in reducing testicular I/R injury. In particular, *L. rhamnosus* demonstrated superior efficacy in enhancing the sperm quality, lowering oxidative stress markers, and maintaining the structural integrity of the testicular tissue. Probiotics may be a promising therapeutic option for mitigating testicular damage. However, further clinical trials are needed to optimize the dosage and evaluate the efficacy of different probiotic strains or their combinations for potential human applications

Data Availability Statement

All data used to support the findings of this study were analyzed and included in the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Zohresadat Akbari and Farhad Koohpeyma contributed to experimental investigation, data collection, and analysis. Narges Karbalaei, Saied Karbalay-Doust, Sourena Rastin, and Seyed Shahram Shekarforoush contributed to the supervision, conception, and design of the research, and interpretation of the findings. All authors read and approved the final manuscript.

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