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HIIT vs MICT on Male Reproductive Function in a Diabetic Model: A Review of the Benefit-to-Volume Ratio

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Abstract

Diabetes mellitus impairs male reproductive function through hyperglycemia-induced oxidative stress, hormonal disruption, and testicular damage. This structured literature review evaluated the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on reproductive outcomes in streptozotocin-induced diabetic rodents. Studies reporting sperm quality, testosterone, oxidative stress markers, and testicular morphology after exercise interventions were synthesized narratively. Across the included studies, HIIT was associated with rapid increases in testosterone and sperm motility, alongside reductions in lipid peroxidation and apoptosis, mainly through acute metabolic stimulation and enhanced Leydig cell responsiveness. In contrast, MICT produced slower but more stable improvements, characterized by better spermatogenesis and sustained enhancement of antioxidant capacity, consistent with exercise-induced hormesis and improved insulin sensitivity. These findings suggest that HIIT and MICT act through distinct yet complementary physiological pathways and can be tailored to therapeutic goals and disease severity. Nevertheless, conclusions should be interpreted cautiously due to heterogeneity in streptozotocin dose, training intensity, and intervention duration.

Key words: *high-intensity interval training; moderate-intensity continuous training; diabetes mellitus; male reproductive function; streptozotocin*

INTRODUCTION

Diabetes mellitus is a chronic metabolic disease that has a broad impact on the male reproductive system, primarily through increased oxidative stress and hormonal dysfunction due to prolonged hyperglycemia (Saremi et al., 2022) . This condition reduces sperm quality, damages testicular structure, and suppresses testosterone levels through increased free radicals, disruption of the hypothalamic-pituitary-gonadal axis, and excessive apoptosis in germ cells (Bagheri et al., 2023). The accumulation of this damage leads to decreased fertility in an animal model of streptozotocin (STZ)-induced diabetes, necessitating non-pharmacological interventions capable of restoring the biochemical environment and hormonal function.

Physical exercise is one of the non-pharmacological interventions consistently reported to play a role in improving reproductive complications caused by diabetes. Physical activity is known to increase insulin sensitivity, reduce oxidative stress, improve tissue perfusion, and support testicular function recovery through hormonal modulation and antioxidant mechanisms (Odetayo et al., 2024; Zańko et al., 2025). In experimental diabetes models, physical exercise has been shown to improve sperm quality, reproductive hormone balance, and reduce the activation of inflammatory and apoptotic pathways that contribute to testicular damage. However, the magnitude of the benefits is strongly influenced by the type, intensity, and volume of exercise. The two most frequently used exercise models in experimental studies are high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT), which, despite their different physiological characteristics, both show potential in improving sperm quality, hormonal balance, and metabolic health related to male fertility.

HIIT consists of a series of high-intensity intervals interspersed with recovery phases and produces rapid metabolic stimulation, including increased antioxidant capacity, improved glucose metabolism, and potent endocrine activation (Fayyazian et al., 2025). Several studies have shown that HIIT can increase testosterone more rapidly than moderate-intensity exercise by increasing Luteinizing Hormone (LH) sensitivity and optimizing leydig cell mitochondrial function. However, high intensity training can potentially trigger excessive oxidative stress if training volume is not controlled, which can exacerbate testicular germinal damage (Nazanin et al., 2022).

Unlike HIIT, MICT emphasizes moderate-intensity activity over a longer duration and produces more stable adaptations. MICT has been reported to lower blood glucose, increase antioxidant capacity, and protect testicular tissue from oxidative damage (Bagheri et al., 2023). Furthermore, MICT improves sperm motility and germ cell morphology in various models of metabolic disorders, with a more gradual but sustained increase in testosterone (Saremi et al., 2022) . This more stable benefit profile makes MICT a relatively safe intervention for testicular tissue in chronic diabetes.

The differences in adaptation characteristics between HIIT and MICT raise the need to compare their biological efficacy in diabetes models. One relevant approach is the benefit-to-volume ratio, which is the ratio of the magnitude of biological benefits obtained to the total volume of exercise required. This concept aligns with the finding that low-volume high-intensity interval training (LV-HIIT) can produce cardiometabolic health improvements comparable to moderate-intensity continuous exercise despite requiring a significantly lower time commitment, suggesting that the effectiveness of physiological adaptations does not necessarily depend on increased training volume, but rather on the quality of the intensity stimulus delivered (Yin et al., 2024). A study by Zahmatkesh & Rostamkhani (2023) showed that HIIT has a higher ratio through rapid hormonal changes, while MICT provides gradual benefits with a lower risk of oxidative stress (Zahmatkesh & Rostamkhani, 2023). However, direct comparative evidence in diabetic animals, particularly regarding primary reproductive parameters such as sperm quality and testosterone levels, is still limited.

Recent literature also indicates significant heterogeneity in exercise protocols, STZ doses, intervention durations, and measured reproductive parameters (Parastesh et al., 2019). Some studies even assessed non-diabetic conditions such as testicular damage due to hepatic steatosis or morphine exposure (Zahmatkesh & Rostamkhani, 2023); (Azarrang et al., 2024). These studies still provide insight into the underlying biological mechanisms, but are not the primary focus of the STZ diabetes model. This methodological variation leads to inconsistent interpretation of the relative benefits across exercise protocols and underscores the need for narrative synthesis rather than quantitative meta-analysis. Based on this background, this study aims to provide a critical review of the effects of HIIT and MICT on sperm quality and testosterone levels in diabetic rats, while evaluating exercise efficiency through a benefit-to-volume ratio approach.

METHODS

This study was conducted as a structured narrative literature review employing a systematic search strategy to identify and synthesize evidence regarding the effects of high-intensity interval training (HIIT) and moderate-intensity continuous training (MICT) on male reproductive function in diabetic animal models. A narrative review approach was selected because it allows integration of heterogeneous experimental findings and supports conceptual interpretation based on biological mechanisms, which is commonly performed through qualitative synthesis without pooled statistical analysis

(Basheer, 2022). Within evidence synthesis frameworks, narrative reviews aim to provide a comprehensive overview of a topic and identify research gaps, particularly when substantial variability in study design, intervention protocols, and outcome measurements precludes quantitative meta-analysis (Ghosh & Choudhury, 2025). Accordingly, this study was not designed as a systematic review or meta-analysis but as a structured narrative synthesis focusing on physiological interpretation of exercise responses.

The literature search followed PRISMA reporting principles to enhance transparency and traceability of the study selection process. The PRISMA framework was applied solely to describe identification, screening, and eligibility procedures and was not intended to imply a formal systematic review, as no standardized risk-of-bias assessment or quantitative quality appraisal was performed (Ringo, 2025). This approach was considered appropriate because the primary objective was evidence mapping and mechanistic interpretation rather than effect size estimation.

Literature searches were conducted in PubMed and Google Scholar databases for studies published between 2010 and 2025. Search terms included combinations of "high-intensity interval training," "HIIT," "moderate-intensity continuous training," "MICT," "streptozotocin-induced diabetic rats," "testosterone," and "sperm quality," combined using Boolean operators to improve search precision. The initial search identified 337 records, consisting of 126 articles from PubMed and 211 from Google Scholar. After removal of 11 duplicates, 145 articles were automatically excluded for not meeting baseline criteria, and 21 records were removed for technical reasons such as unavailable full text or incompatible publication format. A total of 326 articles underwent title and abstract screening, of which 306 were excluded because they were not related to STZ-induced diabetes, did not evaluate male reproductive outcomes, or were unrelated to exercise interventions. Twenty-six full-text articles were assessed for eligibility, and six could not be accessed, resulting in 20 studies included in the final synthesis. The overall selection process is illustrated in **Figure 1**.

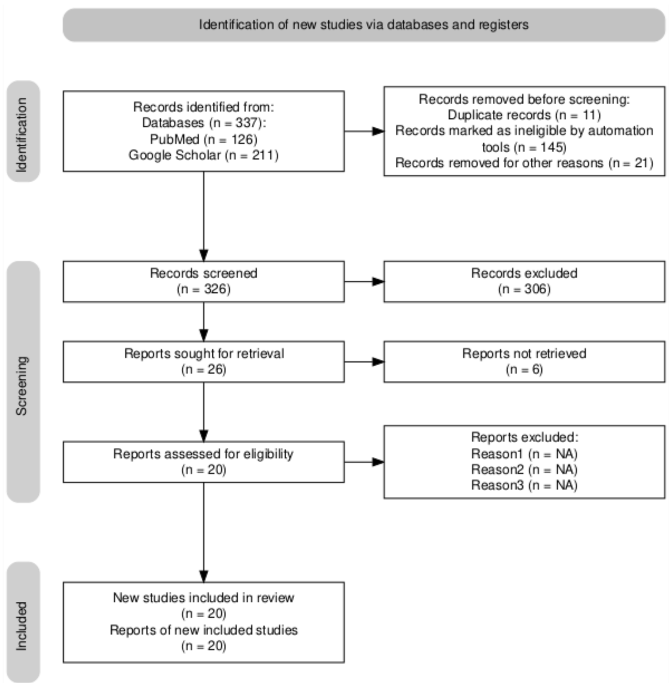

Figure 1. PSRISMA flowchart

The primary inclusion criteria consisted of studies using male rats or mice with streptozotocin-induced diabetes, implementation of exercise protocols categorized as HIIT or MICT, and reporting of reproductive outcomes such as sperm quality, testosterone levels, or testicular histological changes. Studies involving human participants, non-diabetic experimental models, or review articles were retained only in a limited capacity as supporting mechanistic evidence to strengthen physiological interpretation. These supporting studies were clearly distinguished from the primary dataset and were not included in the main comparative synthesis or proportional outcome calculations, ensuring that the analytical focus remained on STZ-induced diabetic rodent models.

Data extraction was performed systematically by recording the diabetes model, exercise protocol characteristics (duration, frequency, and intensity), STZ dosage, reproductive outcomes, and oxidative or antioxidant biomarkers. To support interpretation of the benefit-to-volume concept, session duration, relative intensity, and weekly training frequency were documented whenever reported. Data synthesis was conducted narratively due to substantial heterogeneity among studies, including differences in exercise protocols, disease induction methods, intervention duration, and biological outcome measures, which prevented valid quantitative meta-analysis. The findings were therefore integrated to identify general response patterns between high-intensity and moderate-intensity exercise with emphasis on physiological relevance to male reproductive function. Non-diabetic studies, including hepatic steatosis or drug-exposure models, were retained exclusively as mechanistic support and were not used as the primary basis for comparative conclusions.the basis for the main conclusion, so the focus of the review remains on STZ-induced diabetes.

RESULTS

A total of 20 studies met the inclusion criteria and were analyzed in this review. Of these, 14 studies directly used STZ-induced male diabetes models, while the other 6 studies used non-diabetic models such as hepatic steatosis , morphine exposure, or ketamine-induced testicular damage and were included as supporting evidence for biological mechanisms, not as the basis for primary conclusions (Ehsanifar et al., 2025); (Zahmatkesh & Rostamkhani, 2023). Studies using the STZ model showed dose variations between 40–65 mg/kg with an induction interval that generally lasted 5–10 days before the exercise intervention began (Hamidi et al., 2023); (Saremi et al., 2022); (Xu et al., 2022). Exercise protocols were also highly heterogeneous, with intervention durations ranging from 4 to 12 weeks, a frequency of 3–5 sessions per week, and a clear difference in intensity between HIIT, which ranges from 80–100% VO_2max, and MICT, which ranges from 60–70% VO_2max (Didani, 2024); (Paramita et al., 2022); (Samadian et al., 2020). This high heterogeneity in exercise duration, frequency, and intensity meant that a quantitative meta-analysis could not be conducted validly, so narrative synthesis was chosen as the primary approach in presenting the review results.

Of the total studies analyzed, 10 explicitly evaluated testosterone levels as a primary reproductive parameter in male animals with STZ-induced diabetes. Seven studies using HIIT protocols reported significant increases in testosterone levels, particularly in interval protocols with peak intensities ≥85% VO_2max or speeds approaching the animal's maximal capacity (Didani, 2024); (Olojede et al., 2022); (Xu et al., 2022). In more complex diabetes models, such as the combination of a high-fat diet with STZ induction, HIIT still demonstrated the ability to increase testosterone and fertility capacity, especially when combined with antioxidant agents such as nanocurcumin (Didani, 2024). Meanwhile, three studies using MICT protocols also reported testosterone increases, but with a more gradual and stable adaptation pattern, along with improved insulin sensitivity and a more controlled metabolic environment (Nadi et al., 2021); (Samadian et al., 2020); (Saremi et al., 2022). Comparatively, the synthesis results showed that HIIT consistently provided a faster and greater testosterone-increasing response, while MICT tended to produce a more moderate but sustained hormonal increase.

A total of 12 studies in this review evaluated sperm quality through parameters such as count, motility, morphology, viability, or spermatogenesis score. In the HIIT group, the majority of studies reported significant increases in sperm count and motility within the 4–8-week intervention period, accompanied by improved morphology and a decrease in the proportion of abnormal sperm (Didani, 2024); (Paramita et al., 2022); (Xu et al., 2022). However, one study evaluating excessive-volume swimming in non-diabetic models showed that uncontrolled high-intensity training can actually decrease sperm count and motility, possibly due to increased free radicals and overtraining (Dewangga et al., 2021). In the MICT protocol, improvements in sperm quality occurred more gradually but consistently, especially in studies with a duration of at least eight weeks and stable moderate intensity (Hamidi et al., 2023); (Samadian et al., 2020); (Saremi et al., 2022). This pattern suggests that HIIT tends to provide rapid improvements in sperm quality when training volume remains within adaptive limits, while MICT is superior in maintaining long-term stability of spermatogenesis and sperm quality.

Nearly all included studies assessed oxidative stress as a mechanism for both damage and improvement in male reproductive function. In HIIT protocols, several studies reported significant decreases in malondialdehyde (MDA) levels, a marker of lipid peroxidation, accompanied by increases in the activity of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and total antioxidant capacity (TAC), particularly with training durations of 6–8 weeks with a frequency of 3–5 sessions per week (Didani, 2024); (Khoramipour et al., 2024); (Xu et al., 2022). However, the highly intense metabolic nature of HIIT makes this response highly dependent on the total training volume; if the duration and frequency are too high, increased free radical production can offset or even exceed antioxidant adaptive capacity, potentially leading to secondary oxidative stress (Abedpoor et al., 2024); (Dewangga et al., 2021). In contrast, studies employing MICT have shown a more consistent pattern of decreasing MDA and increasing TAC, GPx, SOD, and CAT in testicular tissue of diabetic rats, including in models combined with morphine exposure or other stress factors (Azarrang et al., 2024); (Hamidi et al., 2023); (Saremi et al., 2022) . These findings indicate that MICT provides a more stable and reliable antioxidant protection profile, while HIIT offers rapid redox improvements but is more sensitive to training volume regulation.

Eight studies specifically evaluated histological changes in the testis, including seminiferous tubule diameter, germinal epithelial thickness, spermatogenesis index, and expression of apoptosis markers. In HIIT protocols, reports indicate rapid structural improvements in the form of increased tubule diameter, repair of the germ cell layer, and a decrease in the number of apoptotic cells through modulation of the expression of proteins such as Bcl-2, Bax, p53, and PARP-1 (Paramita et al., 2022); (Zahmatkesh & Rostamkhani, 2023). These changes are consistent with increased testicular perfusion and improved mitochondrial function due to high-intensity metabolic stimuli. Meanwhile, studies applying MICT documented a more gradual but stable recovery of testicular structure, including normalization of the Johnsen score, a decrease in the apoptosis index, and increased expression of trophic factors such as GDNF in STZ-induced type 1 diabetes models (Hamidi et al., 2023); (Samadian et al., 2020). This pattern suggests that HIIT is more effective in inducing rapid structural repair in the testes, but MICT provides safer and more sustained restoration of tissue architecture, especially in chronic diabetic conditions with severe tissue damage.

To provide a more structured overview of each study, the main characteristics of the studies included in this review are systematically summarized in **Table 1**.

Table 1. Outcome HIIT and MICT

Outcome Category	Main Findings in HIIT	Main Findings in MICT	Synthesized Interpretation	References
Hormonal response (testosterone, LH, FSH)	Faster and greater increases in testosterone driven by intense metabolic stimulation	Gradual hormonal improvement associated with enhanced insulin sensitivity	HIIT promotes rapid hormonal responses, whereas MICT supports more stable endocrine adaptation	(Xu et al., 2022) (Didani, 2024); (Olojede et al., 2022); (Nadi et al., 2021); (Parastesh et al., 2019)
Sperm quality and spermatogenesis	Rapid improvements in sperm count and motility, typically observed within 4–8 weeks	Consistent enhancement of spermatogenesis during longer intervention periods	HIIT induces early improvements, while MICT contributes to sustained reproductive stability	(Paramita et al., 2022); (Hamidi et al., 2023); (Samadian et al., 2020); (Saremi et al., 2022); (Lee et al., 2018)
Oxidative stress and antioxidant response	Reduced lipid peroxidation (MDA) and increased antioxidant enzymes (SOD, CAT), but sensitive to excessive training volume	More stable reduction of oxidative stress with consistent increases in TAC, GPx, and SOD	MICT provides more consistent redox protection, whereas HIIT effects depend on controlled training volume	(Toprak et al., 2023); (Azarrang et al., 2024); (Nazanin et al., 2022); (Bagheri et al., 2023); (Fayyazian et al., 2025)
Testicular histology and apoptosis	Rapid structural recovery of seminiferous tubules and reduced apoptotic markers	Gradual but stable tissue recovery and structural normalization	HIIT accelerates regeneration, whereas MICT favors safer long-term tissue adaptation	(Zheng et al., 2012); (Khoramipour et al., 2024); (Xu et al., 2022); (Mogaddami et al., 2018); (Seo et al., 2018); (Parastesh et al., 2019)

Several non-diabetic studies were included in this review as supporting evidence to help explain the biological mechanisms underlying exercise-induced adaptations; however, they were not used as the primary basis for conclusions regarding exercise effects in streptozotocin (STZ)-induced diabetic models. For instance, in a ketamine-induced testicular injury model, MICT was reported to suppress ferroptosis through reductions in iron and MDA levels together with increases in GSH, GPx, Fpn, Fth, and SLC7A11 expression (Ehsanifar et al., 2025). Another study using a tetracycline-induced hepatic steatosis model demonstrated that HIIT reduced Bax and p53 expression while increasing Bcl-2 and PARP-1, indicating decreased apoptosis in testicular tissue (Zahmatkesh & Rostamkhani, 2023). In addition, moderate-intensity exercise improved antioxidant capacity in a combined STZ and morphine exposure model through increased TAC, GPx, and SOD activity (Azarrang et al., 2024). Although mechanistically relevant, these studies were treated as supporting evidence and were not included in the proportional analysis of primary outcomes.

Table 2. HIIT and MICT parameters

Parameter	HIIT	MICT
Testosterone increases	7 /7 (100%)	3/5 (60%)
Sperm quality increases	6/7 (86%)	7/8 (87%)
Antioxidants increase	6/8 (75%)	9/9 (100%)
Histological repair	5/6 (83%)	4/4 (100%)
Risk of excess ROS	High when volume is large	Very low
Response speed	Fast (4–8 weeks)	Stable & gradual

The proportions presented in **Table 2** were calculated exclusively from rodent studies using STZ-induced diabetes that directly evaluated male reproductive parameters. Human studies, non-diabetic models, and review articles were excluded from the denominator of the analysis. Therefore, the reported proportions are intended to illustrate overall reporting trends across studies rather than to represent quantitative comparisons or statistical meta-analytic estimates. This approach was used to provide a descriptive overview of consistency in findings while acknowledging methodological heterogeneity among studies.

Based on the narrative synthesis summarized in **Table 1** and **Table 2**, HIIT studies tended to report earlier improvements in testosterone levels and sperm motility, commonly observed within 4–8 weeks of intervention, particularly when high intensity was balanced with controlled training volume (Didani, 2024; Olojede et al., 2022; Xu et al., 2022). In contrast, studies applying MICT more frequently demonstrated gradual improvements in antioxidant capacity and sustained enhancement of spermatogenesis, especially in protocols lasting ≥8 weeks with stable moderate intensity (Azarrang et al., 2024; Hamidi et al., 2023; Samadian et al., 2020). Accordingly, HIIT appears to induce faster hormonal and metabolic adaptations, whereas MICT is more commonly associated with stable long-term adaptation and oxidative protection of testicular tissue. These interpretations are derived from consistency of reporting patterns rather than direct statistical comparisons of effect size.

In this review, the concept of the benefit-to-volume ratio is applied as a conceptual framework to compare the relative biological efficiency of HIIT and MICT rather than as a quantitative mathematical calculation. Most included studies did not report standardized total training volume, making numerical comparison infeasible. Consequently, this concept was interpreted physiologically based on the temporal pattern and stability of biological adaptations described across studies. Heterogeneity in exercise protocols, disease models, and measured biological parameters remains a major limitation that restricts generalization. Nevertheless, the recurring pattern of relatively rapid responses following HIIT and more stable adaptations following MICT provides a conceptual basis for understanding exercise efficiency in the context of reproductive health under diabetic conditions.

DISCUSSION

This study demonstrated that both HIIT and MICT exercise significantly improved male reproductive function in a model of STZ-induced diabetes. However, the two types of exercise produced distinct biological response profiles. These differences reflect variations in physiological adaptation mechanisms influenced by exercise intensity, duration, and volume (Bagheri et al., 2023; Saremi et al., 2022). Non-diabetic studies, such as those using hepatic steatosis models or morphine exposure, were not included as the basis for the main conclusions but remain supporting evidence for understanding relevant antioxidant and anti-apoptotic mechanisms (Azarrang et al., 2024; Zahmatkesh & Rostamkhani, 2023). Furthermore, the high heterogeneity of exercise protocols including differences in STZ dosage, intervention duration, exercise frequency, and intensity prevented quantitative meta-analysis, and narrative synthesis was chosen as the most appropriate approach.

Rapid Response: Hormonal and Metabolic Adaptations to HIIT

HIIT stimulates a more rapid endocrine response than MICT. The metabolic surge resulting from high-intensity intervals increases activation of the hypothalamic-pituitary-gonadal axis, increasing Leydig cell sensitivity to luteinizing hormone. This leads to accelerated testosterone secretion (Fayyazian et al., 2025). This effect is further enhanced by increased mitochondrial activity, as testosterone biosynthesis occurs in the mitochondrial membrane of Leydig cells (Xu et al., 2022). Other studies have shown that high-intensity intervals can improve sperm quality and reduce apoptosis by modulating the expression of Bcl-2, Bax, and p53 in a relatively short time (Paramita et al., 2022; Olojede et al., 2022).

In terms of redox parameters, HIIT reduces MDA and increases antioxidant enzymes such as SOD and CAT. However, these effects are volume-dependent. When training volume is too high, ROS production increases drastically, which can cause secondary oxidative stress and even damage testicular tissue (Abedpoor et al., 2024). Therefore, although HIIT offers a high benefit-to-volume ratio, these benefits are only achieved when high intensity is balanced with training volume that remains within adaptive limits (Zahmatkesh & Rostamkhani, 2023).

Stable Response: Gradual Recovery through MICT

Unlike HIIT, MICT produces slower but more stable hormonal improvements. Moderate-intensity activity provides a sustained metabolic stimulus, improves insulin sensitivity, and increases testicular tissue perfusion without causing a surge in free radicals (Nazanin et al., 2022). In diabetes models, insulin resistance is one of the causes of testosterone decline; therefore, improving insulin sensitivity through moderate-intensity exercise supports the restoration of androgen biosynthesis (Samadian et al., 2020).

MICT also demonstrates stronger consistency in enhancing antioxidant capacity. Moderate intensity triggers low and stable levels of ROS, sufficient to activate the exercise-induced hormesis mechanism without causing oxidative damage (Saremi et al., 2022). These findings are confirmed by various studies showing increases in TAC, GPx, and SOD, as well as testicular structural improvements including normalization of spermatogenesis and decreased apoptosis (Azarrang et al., 2024; Hamidi et al., 2023). Thus, MICT has a better physiological safety profile for long-term interventions and chronic diabetic conditions with severe tissue damage.

Comparison of HIIT and MICT Adaptation Patterns

In addition to differences in mechanisms, the adaptation patterns of the two also differ. Based on a study synthesis, most studies report that HIIT is more effective in triggering testosterone increases and improving sperm quality within 4–8 weeks. MICT, in contrast, shows a gradual but consistent pattern of improvements in antioxidant capacity and testicular structure. A synthesis of available studies suggests that HIIT tends to be associated with testosterone increases and sperm quality improvements over shorter intervention periods, while MICT more often shows a stable, gradual pattern of adaptation in antioxidant capacity and testicular structure. Several studies showed that 100% of the HIIT studies in this review reported testosterone increases, while MICT showed increases in approximately 60% of the studies. For antioxidant parameters, MICT was more consistent with improvements across almost all studies, while HIIT showed variation depending on training volume. Physiologically, this pattern confirms that HIIT produces rapid responses, while MICT provides more sustained responses.

Benefit-to-volume ratio becomes relevant when comparing the two types of training. HIIT provides substantial benefits in a short time per unit of training volume, but its effects are highly sensitive to overload, potentially leading to excess ROS generation. MICT provides more moderate but stable benefits, with minimal risk of increased oxidative stress. Studies evaluating duration, intensity, and frequency indicate that HIIT benefits are typically achieved with protocols of 3–5 sessions per week at high intensity, whereas MICT requires durations of ≥8 weeks to achieve optimal improvements. Therefore, protocol selection should consider therapeutic goals, diabetes severity, and the risk of increased ROS from high-intensity training.

Unlike previous reviews that generally evaluated the effects of physical exercise on metabolic parameters or reproductive health separately, this review specifically compares two exercise paradigms, HIIT and MICT, in the context of male reproductive function in a streptozotocin-induced diabetes model. The main contribution of this study lies in the development of a physiological synthesis that highlights the differences in biological adaptation patterns between the rapid response associated with intense metabolic stimulation in HIIT and the stable response associated with oxidative regulation in MICT. Furthermore, this review introduces the benefit-to-volume conceptual framework as an interpretive approach to understanding the biological efficiency of exercise, not solely based on intensity, but on the relationship between the magnitude of the physiological response and the required training volume. This approach allows the integration of hormonal, oxidative, and histological findings into a more comprehensive interpretive model, thus providing new perspectives in designing non-pharmacological interventions for diabetes-induced reproductive disorders.

Overall, the study results address the research objectives by demonstrating that HIIT and MICT are not contradictory, but rather complementary. HIIT excels in rapid hormonal stimulation and intensive metabolic adaptation, while MICT provides long-term stability through oxidative regulation and structural restoration of testicular tissue. These implications are important for designing effective non-pharmacological interventions to mitigate reproductive damage in diabetes, particularly considering the heterogeneity of physiological responses between individuals. With the right approach, both types of exercise can be integrated or selectively chosen according to therapeutic needs.

CONCLUSION

This literature review indicates that HIIT and MICT have the potential to improve male reproductive function in an animal model of STZ-induced diabetes through different physiological adaptation mechanisms. HIIT is generally associated with more rapid improvements in testosterone levels, sperm motility, and reduced oxidative stress through intense metabolic stimulation and acute hormonal responses, whereas MICT tends to be associated with more gradual and sustained improvements in spermatogenesis and antioxidant capacity through hormesis and increased insulin sensitivity.

This review provides a conceptual synthesis of the relative efficacy of both forms of exercise in terms of benefit-to-volume ratio and emphasizes that the choice of exercise protocol should be considered according to therapeutic goals and diabetes severity. However, these findings should be interpreted with caution given the heterogeneity of exercise protocols, variations in STZ dosage, differences in intervention duration, and the inclusion of several non-diabetic studies as supporting evidence, thus limiting the generalizability of the results. Nevertheless, this review adds to the understanding of the mechanistic differences between HIIT and MICT in mitigating hyperglycemia-induced reproductive damage and provides a more structured physiological basis for the development of more effective, relatively safe, and evidence-based non-pharmacological interventions to maintain reproductive health in diabetes.

Several limitations should be considered when interpreting the results of this review. First, there is significant heterogeneity in diabetes induction protocols, including variations in streptozotocin dosage, induction methods, and differences in animal strain and age, potentially influencing reproductive responses and adaptations to exercise. Second, most studies used surrogate parameters such as testosterone levels, sperm quality, and oxidative biomarkers without direct evaluation of fertility success or long-term functional reproductive outcomes. Third, variations in exercise protocols, including differences in intervention duration, weekly frequency, and relative intensity, limit the possibility of quantitative comparisons between studies. Furthermore, most studies did not report long-term follow-up after exercise cessation, thus the sustainability of reproductive adaptation effects remains uncertain. Finally, the inclusion of non-diabetic studies as supporting mechanistic evidence has the potential to broaden biological interpretations, but caution is still required in generalizing to the pure STZ diabetes model.

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