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Impact of type 2 diabetes mellitus on semen quality in Sudanese males: a case-control study

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Abstract

***Background & Aims*:** Infertility affects a significant proportion of couples, with male factors contributing to many cases. Diabetes mellitus (DM) is a major risk factor for male infertility, potentially affecting semen quality. To evaluate the impact of type 2 diabetes mellitus on semen parameters in Sudanese males.

***Materials & Methods*:** The study included 600 Sudanese men, consisting of 300 individuals diagnosed with type 2 diabetes mellitus (T2DM) and 300 non-diabetic individuals serving as controls. Anthropometric measurements and semen analysis, including semen volume, sperm count, motility, and morphology, were assessed.

***Results*:** The mean ages of the diabetic and non-diabetic groups were 35 ± 1.5 years and 34 ± 1.7 years, respectively (P = 0.60). Significant differences were observed in body mass index (BMI), waist circumference, and waist-to-hip ratio (WHR). Diabetic patients had a higher BMI (31.5 ± 0.5 kg/m²) compared to non-diabetic controls (24.0 ± 0.3 kg/m², P = 0.01). Semen volume was significantly lower in diabetic patients (2.46 ± 1.18 mL) than in non-diabetic controls (2.75 ± 1.19 mL, P = 0.047). Sperm count showed no significant difference (67.3 ± 33.1 million/mL in diabetics vs. 68.3 ± 40 million/mL in controls, P = 0.3). However, 30% of diabetic patients exhibited abnormal sperm motility compared to 20% in controls, with odds ratios (ORs) of 1.7 for motility and 5.1 for abnormal morphology.

***Conclusion*:** The study highlights significant impairments in semen quality among Sudanese males with type 2 diabetes mellitus, emphasizing the need for further research into the underlying mechanisms and implications for male fertility.

***Keywords*:** Male infertility, Semen quality, Sperm morphology, Sperm motility, Type 2 diabetes mellitus

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Introduction

Millions of people throughout the world suffer with diabetes mellitus (DM), a dangerous metabolic disease. Its prevalence is rising, and more individuals are being diagnosed at a younger age (1). The condition occurs when the body either doesn't produce enough insulin (INS) or becomes resistant to it, leading to problems with insulin utilization and overall metabolism. Over

time, high blood sugar levels can cause nerve damage and vascular complications. Additionally, diabetes-related metabolic imbalances, including oxidative stress and disruptions in zinc metabolism, can negatively impact male fertility and reproductive health. Research suggests that nearly half of men with diabetes experience a decline in semen quality and reproductive function (1).

DM can impact male reproductive health in several ways. It is linked to erectile dysfunction, issues with ejaculation, structural abnormalities in reproductive organs, and a decline in semen quality. These complications can significantly affect fertility and overall well-being in men with diabetes (2).

Male infertility specifically denotes a man's incapacity to impregnate a fertile female. Male infertility contributes to 40-50% of all infertility cases and impacts around 7% of men (3). Male infertility is commonly caused by abnormalities in sperm production or function, which can stem from factors such as undescended testicles, genetic disorders, or underlying health conditions like DM (4).

Given that most DM patients are diagnosed during their reproductive years, the prevalence of male fertility issues associated with DM is expected to rise in tandem with the increasing number of DM cases (5). Male reproductive function may be impacted by DM in several ways, including impairments in spermatogenesis, and potentially affecting penile erection and ejaculation (5, 6).

Numerous studies have examined the impact of diabetes on sperm parameters. Delfino et al. (7) assessed patients with both type 1 and type 2 DM, finding qualitative alterations in semen, particularly in kinetic properties such as progressive motility, though sperm morphology was significantly compromised, and sperm concentration remained largely unchanged. Conversely, La Vignera et al. (8) reported that patients with both type 1 and 2 DM exhibited a notable increase in total sperm count and concentration; However, as compared to people without diabetes, their sperm motility and semen volume were lower. Meanwhile, Sperm motility quality and morphology, however, did not change significantly. In a more recent study by Ali et al. (9), found that diabetic patients had lower levels of all semen parameters (volume, sperm count, motility, and morphology) than non-diabetics, indicating a significant impact of DM on semen quality.

In this context, total antioxidant capacity (TAC) has emerged as a critical factor in male fertility. TAC refers to the cumulative ability of antioxidants present in biological fluids to scavenge free radicals and mitigate oxidative stress. Oxidative stress is characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's ability to neutralize them, leading to potential damage to spermatozoa and impairments in sperm function (10). Research suggests that high levels of oxidative stress can adversely affect sperm motility and morphology, further complicating male infertility issues (11). In diabetic patients, oxidative stress may be exacerbated due to elevated glucose levels, resulting in increased ROS production (12). Thus, monitoring TAC in diabetic individuals may provide valuable insights into the relationship between oxidative stress and male fertility.

Given these findings, our study aims to evaluate the effects of DM on basic semen parameters and total antioxidant capacity among Sudanese patients with DM.

Materials & Methods

This retrospective case control study was conducted from January 2017 to February 2023 at Dr. Elsir Abu-Elhassan Fertility Center in Khartoum, Sudan. The study included 300 males diagnosed with type 2 diabetes mellitus (patients) and 300 non-diabetic, apparently healthy males (controls) who attended the laboratory for routine investigations. The diagnosis of diabetes was confirmed by an endocrinologist following the criteria set by WHO and the American Diabetes Association (13). Age matching was performed between the two groups to control the potential confounding variables.

Prior to registration, each subject gave their informed consent. Each participant was given a unique identification code, and subjects were assured of confidentiality as well as the study's goals and methods. Patients with Type 2 diabetes who consented to participate in the trial met the inclusion criteria. Patients with Type 2 diabetes who were receiving or undergoing therapy for infertility, had a family history of infertility or had other medical disorders that potentially impact

Informed verbal consent was obtained from all participants, who were briefed on the study's significance and procedures. Body Mass Index (BMI) was determined using the formula: weight in kilograms divided by height in meters squared (kg/m²). Waist and hip circumferences were measured to the nearest 0.1 cm using a flexible metric tape while participants were in a standing position. Waist circumference was measured at the level of the umbilicus, and the Waist-to-Hip Ratio (WHR) was calculated by dividing waist circumference (cm) by hip circumference (cm).

Semen analysis was performed to evaluate volume, sperm count, motility, and morphology, adhering to WHO criteria. WHO criteria for the objective assessment of semen quality for diagnostic purposes were adhered to in this investigation.

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 21. Descriptive statistics, including mean and standard deviation, were utilized to summarize the data. Independent t-tests were employed to compare semen parameters between the diabetic and control groups, while chi-square tests assessed associations between sperm motility and morphology among the groups. A *P-value* of ≤ 0.05 was considered statistically significant, with all tests conducted at a 95% confidence interval.

Results

Table 1 presents the anthropometric parameters of diabetic patients and non-diabetic controls. Values are expressed as mean ± standard deviation (SD). *P-values* indicate significant differences between diabetic patients and non-diabetic controls, with $P < 0.05$ considered statistically significant. The mean age of both groups was comparable, with diabetic patients averaging 35 years (± 1.5) and non-diabetic controls at 34 years (± 1.7), resulting in a non-significant P-value of 0.60. However, significant differences were observed in BMI, waist circumference, and WHR between the two groups. Diabetic patients exhibited a higher mean BMI of 31.5 kg/m² (± 0.5) compared to 24.0 kg/m² (± 0.3) in non-diabetic controls ($P = 0.01$). Waist circumference was also significantly greater in diabetic patients at 95 cm (± 1.2) versus 87 cm (± 1.0) in controls ($P = 0.03$). Furthermore, the WHR was higher in diabetic patients, averaging 0.95 (± 0.03), compared to 0.85 (± 0.02) in the non-diabetic group ($P = 0.02$). These findings suggest a distinct anthropometric profile in diabetic patients, potentially reflecting increased obesity-related health risks.

Table 1. Comparison of anthropometric parameters between diabetic patients and non-diabetic controls

Parameter	Diabetic patients (n = 300)	Non-Diabetic controls (n = 300)	*P-value*
Mean age (years)	35 ± 1.5	34 ± 1.7	0.60
BMI (kg/m²)	31.5 ± 0.5	24.0 ± 0.3	0.01
Waist circumference (cm)	95 ± 1.2	87 ± 1.0	0.03
WHR	0.95 ± 0.03	0.85 ± 0.02	0.02

BMI: Body Mass Index, WC: Waist Circumference, WHR: Waist-to-Hip Ratio. Values are expressed as mean ± standard deviation (SD). P-values indicate significant differences between diabetic patients and non-diabetic controls, with P < 0.05 considered statistically significant.

Figure 1 presents the frequency distribution of semen parameters among diabetic patients (n = 300) and non-diabetic controls (n = 300). Normozoospermia was observed in 80% of diabetic patients, compared to 93% in non-diabetic controls. Asthenoteratozoospermia was more prevalent in diabetic patients (15%) than in controls (5%). Oligoasthenoteratozoospermia was recorded in 4% of diabetic patients and 2% of controls. Azoospermia was identified in 1% of diabetic patients, while it was absent in the non-diabetic group.

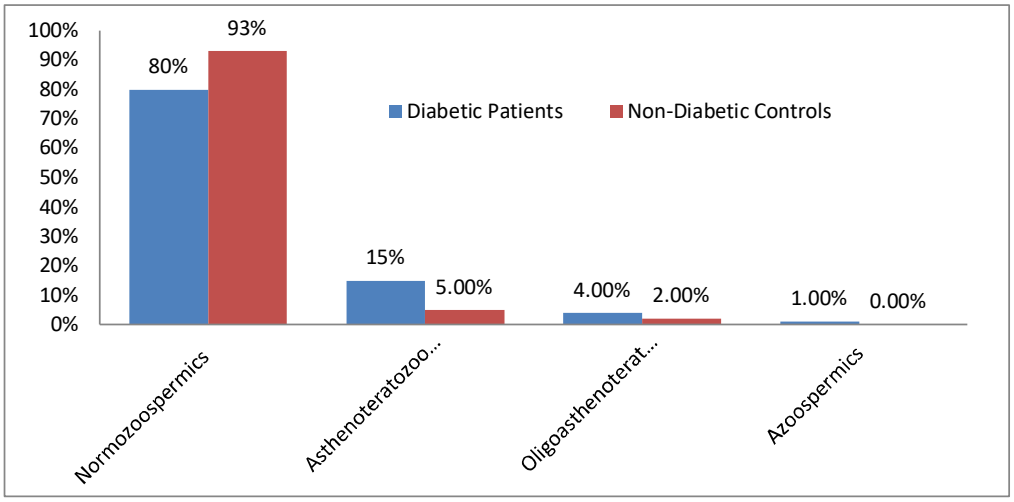

Fig. 1. Frequency distribution of semen parameters between diabetic patients and non-diabetic controls

Table 2 compares key semen parameters and total antioxidant capacity between diabetic patients and non-diabetic controls. Semen volume was significantly lower in diabetic patients (2.46 ± 1.18 mL) than in non-diabetic controls (2.75 ± 1.19 mL; $p = 0.047$). While sperm count did not differ significantly between the groups (67.3 ± 33.1 million/mL in diabetics vs. 68.3 ± 40 million/mL in controls; $p = 0.3$), total antioxidant capacity was markedly reduced in diabetic patients (1760 ± 165 µmol/L) compared to controls (1910 ± 236 µmol/L; $p = 0.02$). These findings underscore potential alterations in semen quality and antioxidant defenses associated with diabetes.

Table 2. Comparison of semen parameters and total antioxidant capacity between diabetic patients and non-diabetic controls

Parameter	Diabetic patients (n = 300)	Non-diabetic Controls (n = 300)	*P-value*
Semen volume (mL)	2.46 ± 1.18	2.75 ± 1.19	0.047
Sperm count (million/mL)	67.3 ± 33.1	68.3 ± 40	0.3
Total antioxidant capacity (µmol/L)	1760 ± 165	1910 ± 236	0.02

Within the non-diabetic control group, 32% of people have abnormal sperm morphology, 68% have normal sperm morphology, 35% have abnormal sperm motility, and 65% have normal sperm motility (Figure 2).

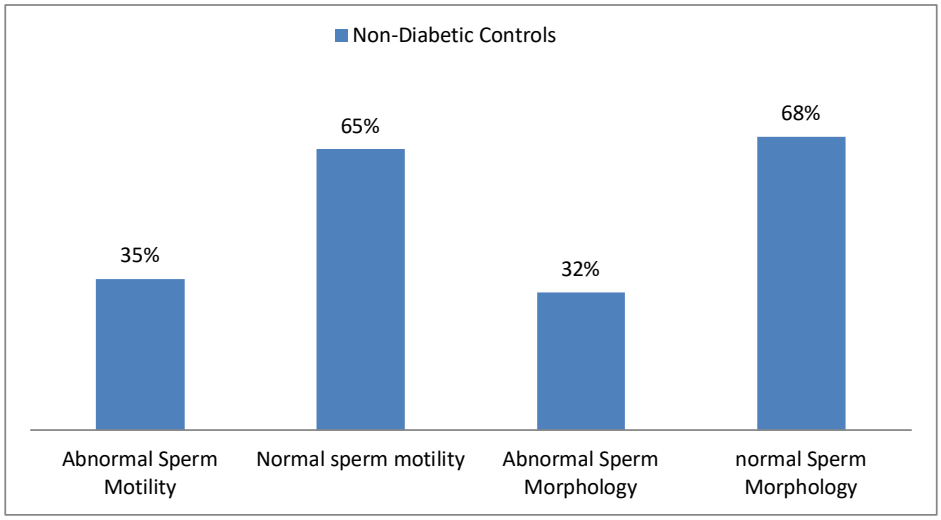

Fig. 2. Frequency distribution of sperm motility and morphology among non-diabetic controls

Table 3 highlights the association between sperm motility and morphology in diabetic patients and non-diabetic controls. Abnormal sperm motility was significantly more frequent among diabetic patients (65%) compared to non-diabetic controls (35%), with an OR of 1.7 and a *P-value* of 0.003. Conversely, normal sperm motility was observed in only 35% of diabetic patients, compared to 65% in the control group.

Similarly, abnormal sperm morphology was higher in diabetic patients (68%) than in controls (32%), with an OR of 5.1 and a statistically significant *P-value* of 0.002. In contrast, normal sperm morphology was observed in 32% of diabetic patients and 68% of non-diabetic controls. These findings suggest a strong association between diabetes and compromised sperm motility and morphology.

Table 3. Association between sperm motility and morphology among diabetic patients and non-diabetic controls

Parameter	Diabetic patients (n = 300)	Non-diabetic controls (n = 300)	Odds ratio (OR)	*P- value*
Abnormal sperm motility (%)	65%	35%	1.7	0.003
Normal sperm motility (%)	35%	65%		
Abnormal sperm morphology (%)	68%	32%	5.1	0.002
Normal sperm morphology (%)	32%	68%		

Table 4 displays the TAC levels (µmol/L) in seminal plasma for diabetic and non-diabetic individuals stratified by semen parameters.

Normozoospermic individuals in the non-diabetic group exhibited significantly higher TAC (1890 ± 150 µmol/L) than their diabetic counterparts (1782 ± 160 µmol/L; $p = 0.02$).

Among asthenoteratozoospermic individuals, TAC was significantly lower in diabetics (1570 ± 139 µmol/L) compared with non-diabetics (1676 ± 133 µmol/L; *p = 0.002*).

Similarly, among oligoasthenoteratozoospermic individuals, diabetics demonstrated lower TAC (1180 ± 142 µmol/L) than non-diabetic counterparts (1290 ± 107 µmol/L; *p = 0.012*).

The most pronounced reduction was observed in azoospermic individuals, with diabetic patients exhibiting markedly lower TAC (1020 ± 105 µmol/L) compared with non-diabetic subjects (1610 ± 97 µmol/L; *p = 0.03*).

Collectively, these results indicate that diabetic patients exhibit a consistent reduction in TAC across all semen parameters, underscoring a significant association between diabetes, diminished antioxidant capacity, and compromised semen quality.

Table 4. Total antioxidant capacity in relation to semen parameters among diabetic and non-diabetic participants

Semen parameter	**Total antioxidant capacity (µmol/L)**		***P-value***
	Diabetics	**Non-diabetics**	
Normozoospermics	1782 ± 160	1890 ± 150	0.02
Asthenoteratozoospermics	1570 ± 139	1676 ± 133	0.002
Oligoasthenoteratozoospermics	1180 ± 142	1290 ± 107	0.012
Azoospermics	1020 ± 105	1610 ± 97	0.03

Discussion

Infertility affects approximately 10-25% of couples of reproductive age, with 10-30% of these cases attributable solely to male factors (14). DM has been identified as a significant contributor to declining male fertility, potentially impairing male sexual function and reproductive health (14). Our study demonstrated significant reductions in semen parameters, specifically in semen volume, sperm motility, and morphology, among Sudanese males with DM compared to non-diabetic controls. The reduction in semen quality may result from hormonal imbalances or structural changes in the testes, including increased interstitial collagen, thickening of seminiferous tubules, peritubular and intertubular fibrosis, or gonadal dysfunction caused by circulatory impairments associated with DM. These findings are consistent with previous reports of a high prevalence of abnormal sperm motility and morphology in diabetic patients (1).

Delfino et al. (7) reported a significant reduction in the percentages of normal sperm morphology and motility among diabetic patients compared to non-diabetic controls, which is consistent with our findings. The rapid proliferation of sperm cells makes them particularly vulnerable to oxidative stress induced by diabetes, which can lead to abnormal sperm morphology (15). While the assessment of sperm morphology can present challenges, we ensured that our analysis adhered to WHO criteria, enhancing reliability. Future studies with larger sample sizes would be beneficial to further validate these findings in Sudanese populations.

In contrast to our results, Zhu et al. (16) reported a reduction in semen volume among diabetic men but noted no significant differences in other semen parameters. Furthermore, greater DNA damage has been linked to diabetes, which may further reduce one's capacity for reproduction (17). Consistent with Delfino et al. (7), The sperm counts of the diabetes and non-diabetic groups did not differ significantly, according to our study, diverging from findings by Ali et al. (9), who observed an increase in total sperm count among diabetic patients.

Our results showed a statistically significant reduction in semen volume among diabetic patients, with a mean volume of 2.46 mL compared to 2.75 mL in non-diabetic controls (P = 0.047). Furthermore, the higher prevalence of abnormal sperm motility and morphology observed in diabetic patients suggests a concerning trend for male reproductive health. Notably, 30% of diabetic patients exhibited abnormal sperm motility compared to 20% in the control group, with Ors indicating an increased risk: 1.7 for motility and 5.1 for morphology. These findings collectively underscore the association between diabetes and impaired semen quality, potentially contributing to male infertility.

Additionally, a study conducted on Sudanese males reported significant declines in all semen parameters among diabetic patients compared to their non-diabetic counterparts (18). The elevated rates of abnormal sperm motility and morphology observed in our study could be attributed to factors such as inadequate metabolic control, neuropathy, oxidative stress, and diabetes-induced damage to both nuclear and mitochondrial sperm DNA. While this study provides meaningful insights, some limitations should be considered. Firstly, the case-control design may introduce selection bias, which could impact the generalizability of our findings. Secondly, variations in semen analysis methodologies across studies may affect comparability.

Conclusion

In conclusion, our study highlights the detrimental impact of diabetes mellitus on male reproductive health, particularly in Sudanese males. These findings underscore the importance of further research into the mechanisms underlying these associations and emphasize the need for clinicians to consider reproductive health assessments in men with diabetes.

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Ethical statement

The study design was approved by the Ethics and Research Committee with the Code of Ethics 000-013-2022 by the fertility center.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest regarding the publication of this manuscript.

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Authors agreement:

The authors of this article have agreed to the publication of the present article.

Author contributions

AbdElkarim Abobakr Abdrabo participated in data collection, supervision, and writing. Sara Abdelmahmoud Omer participated in data analysis and writing. Walid Ahmed H. Eldaif participated in supervision, revision, and editing.

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