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Original Research Article

Impact of lifestyle factors and digital device exposure on semen quality and sperm DNA fragmentation in infertile men

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ABSTRACT

Background: Lifestyle and environmental factors may influence semen quality and sperm DNA integrity. This study evaluated the associations of lifestyle habits, digital device use, substance use, abstinence duration, and socioeconomic factors with semen parameters and sperm DNA fragmentation index (DFI) in infertile men.

Methods: This retrospective observational study included 195 infertile men attending the Infertility Clinic at Ashirwad Hospital, Raipur India, between 2022 and 2024. Participants were categorized according to physical activity, occupation, dietary habits, digital device use, substance use, abstinence duration, and annual income. Semen analysis and DFI assessment were performed according to WHO 2021 recommendations. Factors associated with DFI were evaluated using a multivariable generalized linear model adjusted for major confounders.

Results: Active smoking was independently associated with increased DFI and was the strongest predictor of sperm DNA fragmentation ($p<0.001$). High daily mobile phone use (6-12 hours/day) was also associated with elevated DFI ($p=0.030$), whereas laptop use and total screen exposure showed no significant association. Prolonged abstinence (>2 days) was associated with increased sperm DNA fragmentation. Vegetarians had significantly higher normal sperm morphology ($p=0.004$), although dietary pattern was not independently associated with DFI. Physical activity, occupational activity, and annual income showed no independent associations with DFI.

Conclusions: Active smoking, prolonged mobile phone use, and extended abstinence duration were independently associated with increased sperm DNA fragmentation in infertile men. These findings highlight the importance of modifiable lifestyle factors in male reproductive health and support lifestyle counselling during infertility evaluation to improve sperm genomic integrity.

Keywords: Male infertility, Sperm DNA fragmentation, Semen quality, Lifestyle factors, Mobile phone use, Smoking

INTRODUCTION

Infertility affects nearly 15% of couples worldwide, with male factors contributing to approximately half of all cases.[1] Conventional semen analysis remains the cornerstone of male fertility assessment; however, normal semen parameters do not always reflect reproductive potential.[2,3] Therefore, additional biomarkers are needed to improve the evaluation of male infertility.

Sperm DFI has emerged as an important marker of sperm chromatin integrity and reproductive competence. Elevated DFI is associated with oxidative stress, defective chromatin packaging, and apoptosis during spermatogenesis and has been linked to reduced fertilization rates, impaired embryo development, recurrent implantation failure, and pregnancy loss.[4-6] Recent evidence suggests that DFI assessment provides valuable information beyond conventional semen analysis,

particularly in infertile men with otherwise normal semen parameters.[18-20]

Lifestyle and environmental factors play an important role in male reproductive health. Prolonged use of mobile phones and computers, sedentary behaviour, poor dietary habits, and prolonged abstinence have been associated with impaired semen quality and increased sperm DNA damage through mechanisms involving oxidative stress and reactive oxygen species production.[7-17] Conversely, regular physical activity and antioxidant-rich diets may help preserve sperm function and DNA integrity.[13,16] Recent systematic reviews further support the contribution of modifiable lifestyle and environmental factors to sperm DNA fragmentation.[22]

In addition to lifestyle habits, socioeconomic factors such as annual income may indirectly influence reproductive health through their effects on diet, occupational exposure, stress levels, and access to healthcare. However, most previous studies have evaluated these factors individually, and data regarding their combined impact on semen quality and sperm DNA fragmentation remain limited.

Therefore, the present study aimed to evaluate the integrated effects of digital device exposure, physical activity, dietary patterns, abstinence duration, and annual income on semen parameters and sperm DNA fragmentation in infertile men. Understanding these modifiable factors may help identify potential targets for lifestyle-based interventions and improve the management of male infertility.

METHODS

Study design, ethical approval, and study population

This retrospective observational study was conducted at Ashirwad Hospital and ICSI Test Tube Baby Centre, Raipur, Chhattisgarh, India, between 2022 and 2024. The study adhered to the ethical principles outlined in the Declaration of Helsinki (2013).[23] Given the retrospective design and the use of pre-existing clinical data, formal Institutional Review Board (IRB) approval was deemed exempt; however, written informed consent for the secondary research use of clinical data was obtained from all participants prior to enrolment.

Initially, 200 male partners of infertile couples attending the clinic during this period were evaluated for eligibility. Men presenting with primary or secondary infertility were included. To capture a comprehensive profile of lifestyle and environmental factors, individuals with a history of smoking, tobacco use, and alcohol consumption were explicitly included in the study cohort. However, to mitigate major clinical confounders, strict exclusion criteria were applied. Participants were excluded if they presented with clinically palpable varicocele, recent genital infections or inflammation, chronic systemic diseases (e.g., diabetes mellitus, metabolic syndrome), or if they were currently taking medications known to impair spermatogenesis.

After applying these criteria and excluding five men diagnosed with azoospermia, a final cohort of 195 participants was included in the analysis. To minimise recall and selection bias inherent in observational designs, patient histories were cross-verified with their electronic medical records wherever possible, and data extraction was performed by trained, blinded clinical staff.

Data collection and variable categorisation

Demographic, clinical, and lifestyle data were collected using a standardised, pretested questionnaire administered by trained personnel. Information included age, body mass index (BMI), marital duration, duration of infertility, occupation, dietary habits, physical activity, digital device use, and abstinence duration before semen collection. To ensure clinical relevance, variables were categorised as follows:

Occupational activity

Categorised based on daily physical demand and occupational hazard exposure into highly active (e.g., drivers, farmers, labourers), moderately active (e.g., teachers, doctors, service staff), and sedentary/inactive (e.g., office workers, IT professionals, bankers).

Dietary habits

Broadly classified as vegetarian, occasional non-vegetarian, or regular non-vegetarian. While limited by the absence of a quantitative food frequency questionnaire, this classification was utilised to reflect standard, regional dietary patterns.

Physical activity

Grouped into highly active, moderately active, or sedentary. This categorisation was based on self-reported frequency and intensity, adapted from the principles of the International Physical Activity Questionnaire (IPAQ).

Digital device use

Assessed through structured interviews. Mobile phone use was categorised as low (<4 hours/day), moderate (4–6 hours/day), or high (6-12 hours/day). Crucially, to account for exposure proximity and potential thermal/radiation effects, participants were also queried on whether devices were predominantly kept in trouser pockets or on the lap (close to the testes).

Laptop/computer use was classified as non-use, ≤6 hours/day, or >6 hours/day. Total daily screen exposure was calculated by aggregating mobile and computer usage times, stratifying participants into low, moderate, and high exposure groups.

Semen collection and analysis

Semen samples were collected by masturbation after 2-7 days of sexual abstinence. Each sample was obtained in a sterile, wide-mouthed container in a private collection room within the clinic. After liquefaction at 37°C for 20–60 minutes, analyses were performed according to the World Health Organisation (WHO) Laboratory Manual for the Examination and Processing of Human Semen, 6th Edition (2021).[24]

To ensure the reliability and rigour of the semen analysis, strict quality control measures were implemented. All assessments were performed by two independent, trained, and certified andrology technicians. Intra- and inter-observer variability were routinely monitored and maintained at <10%. Furthermore, all primary measurements (sperm concentration and motility) were performed in duplicate, and the average values were recorded. Semen pH was measured using pH indicator paper. Sperm concentration and motility were determined using a Makler counting chamber under light microscopy, and motility was classified according to WHO guidelines. Sperm morphology was evaluated using pre-stained QwikCheck™ morphology slides following WHO strict criteria. A 3-4 µL aliquot of well-mixed semen was placed on the pre-stained slide, allowed to fix for 15-20 minutes, and examined microscopically to determine the percentage of morphologically normal spermatozoa.

Percentage of normal sperm = (Number of normal forms / Total number of cells counted) × 100

Sperm vitality was assessed using the Eosin-Nigrosine staining method (QwikCheck™ 1-Step Vitality Stain, MES India). Equal volumes (10 µL) of semen and 0.5% aqueous eosin Y solution were mixed, covered with a coverslip, and examined under a phase-contrast microscope after 3-5 minutes. Two hundred spermatozoa were evaluated per slide; live sperm remained unstained, whereas dead sperm appeared red.

Assessment of sperm DFI

Sperm DNA fragmentation was assessed using the sperm chromatin dispersion (SCD) assay with the Sperm 360 DNA fragmentation kit (Sperm Processor Pvt. Ltd., India) according to the manufacturer's instructions.

A minimum of 200 spermatozoa per sample were evaluated and classified according to halo morphology as having intact DNA, fragmented DNA, or degraded DNA. The DFI was calculated as the percentage of sperm exhibiting fragmented or degraded DNA among all sperm counted.

DFI = [(Number of sperm with fragmented DNA + Number of sperm with degraded sperm)/Total number of sperm evaluated] × 100

Statistical analysis

Data were entered and managed using Microsoft Excel (Microsoft Corporation, USA). All statistical analyses were performed using Jamovi software (Version 2.7).[25] The normality of continuous variables was assessed using the Shapiro-Wilk test. Because the data were not normally distributed, continuous variables were summarised as median with interquartile range (IQR), while categorical variables were expressed as frequencies and percentages.

For comparisons between two independent groups, the Mann-Whitney U test was used. For comparisons among more than two groups, the Kruskal-Wallis test was applied. When the Kruskal-Wallis test yielded a statistically significant result, post-hoc pairwise comparisons were conducted using the Dwass-Steel-Critchlow-Fligner test, which intrinsically adjusts for multiple comparisons. Associations between categorical variables were evaluated using the Chi-square test. The association between DFI and study variables was assessed using a generalised linear model. All statistical tests were two-tailed, and a $p<0.05$ was considered statistically significant.

RESULTS

Baseline characteristics

A total of 195 infertile men were included in the study. Baseline demographic and clinical characteristics are presented in Table 1. The mean age was 35.13±8.77 years, and the mean BMI was 23.63±2.67 kg/m². Primary infertility was the predominant diagnosis (82.6%), with a male factor identified in 36.9% of cases. Lifestyle and occupational factors are summarised in Table 2. Office work was the most common occupation (32.3%). Notably, there was a high prevalence of self-reported addictions (73.3%), primarily alcohol consumption (50.8%) and smoking (44.6%), and nearly half of the participants (48.7%) were taking antioxidant supplements.

Effect of physical and occupational activity on semen parameters

Semen parameters were compared across three physical activity groups (no exercise, 1-2 hours daily, and moderate activity <1 h/day) using the Kruskal-Wallis test (Table 3). No statistically significant differences were observed in age, sperm count, concentration, motility, vitality, morphology, semen volume, or DFI (all $p>0.05$).

Similarly, semen parameters were compared across three occupational activity categories (highly active, inactive, and moderately active). No significant differences were observed for any of the measured semen parameters or DFI (all $p>0.05$). Overall, unadjusted physical and occupational activity levels were not significantly associated with semen quality in this cohort.

Digital device exposure: computer, mobile, and total screen time

Semen parameters were evaluated across groups based on daily laptop/computer usage (Table 4). No significant differences were observed in any semen parameters or DFI across non-users, ≤6 hours, and >6 hours of use (all p>0.05).

Conversely, when stratifying participants by daily mobile phone use (<4 h/day, 4-6 h/day, and 6-12 h/day), significant differences were observed in total sperm count, total and progressive motility, vitality, semen volume, and DFI (all p<0.05) (Table 4). Post-hoc pairwise comparisons revealed that the 6-12 h/day group had significantly lower sperm parameters compared to the <4 h/day group. DFI demonstrated the strongest association (p<0.001), with markedly higher fragmentation in the highest exposure group. Sperm concentration and morphology were not significantly affected.

Interestingly, when assessing total digital exposure time (the cumulative duration of mobile and computer usage), no statistically significant differences were observed across usage categories for any measured semen parameters or DFI (all p>0.05) (Table 4).

This discrepancy between mobile phone usage and total screen exposure highlights a critical biological plausibility: the deleterious effects may be tied to device proximity rather than cumulative screen time.

Mobile phones are frequently kept in trouser pockets in close proximity to the testes, potentially exposing them to local thermal effects and radiofrequency electromagnetic radiation, whereas laptops/computers are typically situated on desks further from the body.

Dietary patterns

Analysis of dietary patterns using the Mann-Whitney U test (Table 5) demonstrated significantly higher normal sperm morphology in pure vegetarians compared to non-vegetarians (p=0.004). This finding remained consistent across the three-tier dietary subgroup analysis (Kruskal-Wallis test, p=0.017).

DFI values were lower in vegetarians (15.0%) compared to non-vegetarians (18.8%), though this difference did not reach statistical significance (p=0.089). No significant differences were observed in sperm count, motility, or semen volume (all p>0.05).

Effect of duration of abstinence

Participants were categorised into three abstinence groups: 2 days (n=35), 3-4 days (n=107), and 5-7 days (n=53) (Table 6). There were no statistically significant differences in total sperm count, sperm concentration, motility, vitality, morphology, or semen volume (all p>0.05). However, DFI differed significantly among the groups (p=0.003), with the lowest median DFI observed in the 2-day abstinence group.

Annual income and semen parameters

Participants were categorised into low-income (n=110) and middle/higher-income (n=85) groups (Table 7). Total motility was significantly lower in the middle/higher-income group compared with the low-income group (45.0% vs 55.0%, p=0.034). Conversely, DFI was significantly higher in the middle/higher-income group (19.38% vs 15.63%, p=0.020). Other parameters did not differ significantly.

Multivariable analysis for factors associated with DFI

A generalised linear model was performed to comprehensively assess factors associated with the DFI. To rigorously control for potential confounding, the model adjusted for digital device use, lifestyle factors, age, BMI, and prevalent addiction variables (smoking, alcohol, and tobacco use) (Table 8). The overall model was highly significant and explained a substantial portion of the variance (R^2=0.284, p<0.001).

Importantly, even after adjusting for lifestyle and addiction confounders, high daily mobile phone use (>6–12 hours/day) remained an independent predictor of sperm DNA damage, associated with a 21.5% higher DFI compared to those using mobile phones for <4 hours/day (Exp(B)=1.215, 95% CI: 1.02-1.45; p=0.030). Among the addiction variables, smoking emerged as the strongest independent risk factor in the cohort, associated with a 33.3% increase in DFI (Exp(B)=1.333, 95% CI: 1.16-1.53; p<0.001). Alcohol and tobacco use showed positive trends toward higher DFI but did not reach statistical significance in the adjusted model (p=0.079 and p=0.066, respectively). Furthermore, prolonged abstinence durations of 3-4 days and 5-7 days remained significantly associated with higher DFI compared to a 2-day abstinence period (p=0.013 and p=0.017, respectively). Laptop/computer use, physical activity, dietary patterns, annual income, age, and BMI did not demonstrate independent associations with DFI in this comprehensive model.

Table 1: Baseline demographic and clinical characteristics of study participants.

Parameters	Category/subgroup	N/Mean±SD
Age (in years)		35.13±8.77
BMI (kg/m²)		23.63±2.67
Married life (in years)		5.63±3.49
Duration of infertility (in years)		4.22±3.05

Continued.

Parameters	Category/subgroup	N/Mean±SD
Type of infertility	Primary	161 (82.6%)
	Secondary	34 (17.4%)
Infertility factor	Male factor	72 (36.9%)
	Female factor	27 (13.8%)
	Both factors	62 (31.8%)
	Unexplained	34 (17.4%)

Table 2: Lifestyle and occupational characteristics.

Parameter	Category/subgroup	N
Occupation	Office work	63 (32.3%)
	Driver	12 (6.2%)
	Industry/factory worker	20 (10.3%)
	Business	20 (10.3%)
	Teacher	14 (7.2%)
	Computer/IT	18 (9.2%)
	Others	48 (24.6%)
Dietary habits	Pure vegetarian	80 (41.0%)
	Non-vegetarian (occasional)	87 (44.6%)
	Non-vegetarian (2-3 times/week)	9 (4.6%)
	Non-vegetarian (daily)	19 (9.7%)
Addiction status	Any addiction	143 (73.3%)
	No addiction	52 (26.7%)
Specific addictions	Alcohol intake	99 (50.8%)
	Smoking	87 (44.6%)
	Tobacco use	64 (32.8%)

Table 3: Effect of physical activity and occupational activity on semen parameters.

Activities	No exercise (n=108)	1–2 h/day (n=35)	Moderate activity (n=52)	χ^2	P values
Physical activity					
Age (in years)	35.0 (7.0)	34.0 (9.0)	35.0 (7.25)	0.808	0.668
Total count (10^6)	52.0 (90.4)	46.8 (92.2)	65.0 (74.0)	0.550	0.759
Sperm concentration (10^6/ml)	25.5 (32.0)	22.0 (33.6)	30.0 (31.5)	1.281	0.527
Total motility (%)	49.5 (33.3)	45.0 (41.5)	60.0 (30.5)	5.448	0.066
Vitality (%)	48.0 (31.3)	46.0 (32.0)	62.0 (29.5)	5.791	0.055
Morphology (% normal)	4.0 (2.0)	4.0 (1.5)	4.0 (1.25)	1.445	0.485
Semen volume (ml)	2.0 (0.83)	2.1 (1.0)	2.0 (1.0)	1.900	0.387
DFI (%)	18.8 (11.3)	18.8 (9.38)	15.6 (11.6)	4.211	0.122
Occupational activity	**Highly active (n=50)**	**Inactive (n=74)**	**Moderately active (n=71)**	χ^2	**P value**
Total count (10^6)	36.0 (84.3)	64.0 (86.9)	64.0 (90.8)	0.943	0.624
Sperm concentration (10^6/ml)	18.0 (36.8)	28.5 (28.3)	29.0 (35.1)	1.734	0.420
Total motility (%)	54.0 (35.5)	50.5 (35.0)	47.0 (42.5)	0.027	0.986
Vitality (%)	48.0 (39.5)	54.5 (27.8)	52.0 (32.5)	0.315	0.855
Morphology (% normal)	4.0 (2.0)	4.0 (2.0)	4.0 (2.0)	2.822	0.244
Semen volume (ml)	2.00 (1.00)	2.00 (0.95)	2.00 (1.05)	1.061	0.588
DFI (%)	17.5 (14.2)	19.4 (10.9)	17.5 (11.3)	2.040	0.361

Table 4: Comparison of semen parameters and DFI across digital device exposure.

Parameters	Low use	Moderate use	High usage	P value	ε^2
Computer use	**Not use**	**≤6 h**	**>6 h**		
Total count (10^6)	64.0 (88.7)	24.0 (75.0)	64.0 (81.6)	0.131	0.021
Sperm concentration (10^6/ml)	26.0 (39.0)	12.0 (30.0)	29.0 (22.0)	0.211	0.016
Total motility (%)	52.0 (35.0)	42.0 (40.0)	50.0 (35.0)	0.256	0.014
Progressive motility (%)	30.0 (43.0)	10.0 (25.0)	20.0 (45.0)	0.153	0.019
Vitality (%)	52.0 (38.0)	39.0 (36.0)	55.0 (24.0)	0.067	0.028
Morphology (%)	4.0 (2.0)	4.0 (1.0)	4.0 (1.0)	0.531	0.007
Semen volume (ml)	2.0 (1.0)	2.0 (0.70)	2.0 (1.0)	0.275	0.013
DFI (%)	17.5 (11.9)	21.3 (8.75)	20.0 (12.5)	0.154	0.019

Continued.

Parameters	Low use	Moderate use	High usage	P value	ε^2
Mobile use	**<4 h/day, (n=86)**	**4-6 h/day, (n=60)**	**6-12 h/day, (n=49)**		
Total count (10^6)	73.0 (104.0)[a]	50.0 (74.2)[ab]	28.8 (76.9)[b]	0.042*	0.033
Sperm concentration (10^6/ml)	30.0 (37.0)[a]	25.0 (34.25)[a]	18.0 (26.0)[a]	0.206	0.016
Total motility (%)	54.0 (30.75)[a]	55.0 (32.50)[a]	40.0 (30.0)[b]	0.018*	0.041
Progressive motility (%)	30.0 (41.50)[a]	30.0 (40.00)[a]	10.0 (25.0)[b]	0.023*	0.039
Vitality (%)	55.5 (36.00)[a]	55.5 (27.25)[a]	41.0 (22.0)[b]	0.006*	0.053
Morphology (%)	4.0 (2.00)[a]	4.0 (2.25)[a]	4.0 (1.00)[a]	0.414	0.009
Semen volume (ml)	2.05 (1.00)[a]	2.00 (1.00)[a]	2.00 (0.30)[b]	0.001*	0.071
DFI (%)	15.63 (12.19)[a]	15.63 (12.03)[a]	21.88 (12.50)[b]	<0.001*	0.102
Total digital exposure	**Low, (n=97)**	**Moderate, (n=44)**	**High, (n=54)**	**χ^2**	**P**
Total count (10^6)	58.0 (99.0)	68.0 (94.8)	44.4 (73.2)	1.999	0.368
Sperm concentration (10^6/ml)	26.0 (38.0)	33.0 (41.0)	24.0 (24.5)	1.936	0.380
Motility (%)	54.0 (30.0)	51.5 (38.5)	44.0 (38.8)	3.507	0.173
Vitality (%)	52.0 (28.0)	58.5 (41.0)	46.5 (30.0)	2.531	0.282
Morphology (%)	4.00 (2.00)	4.00 (3.00)	4.00 (1.00)	1.029	0.598
Volume (ml)	2.00 (0.89)	2.04 (1.00)	2.00 (0.97)	0.673	0.714
DFI (%)	17.5 (12.5)	15.6 (10.9)	20.0 (39.7)	3.107	0.211

*Values expressed as Median (IQR). ε^2 = effect size for Kruskal–Wallis test. Different superscript letters (a, b) indicate significant pairwise differences by Dwass–Steel–Critchlow–Fligner test (p<0.05).

Table 5: Semen parameters and DFI by dietary pattern.

Parameters	Pure veg (n=80)	Non-veg total (n=115)	P value (2-group)	Non-veg occasional (n=87)	Non-veg daily/2–3x (n=28)	P value (3-group)
Total count	52.0 (101)	58.0 (89.0)	0.731	58.0 (86.7)	56.0 (87.5)	0.883
Sperm concentration	27.0 (34.8)	25.0 (33.0)	0.492	24.0 (31.0)	29.5 (31.3)	0.779
Total motility (%)	54.0 (37.3)	50.0 (34.0)	0.390	51.0 (33.5)	42.5 (33.3)	0.669
Progressive motility (%)	30.0 (44.3)	20.0 (40.0)	0.307	20.0 (40.0)	26.5 (39.8)	0.451
Vitality (%)	56.5 (39.8)	48.0 (28.5)	0.218	51.0 (32.5)	45.5 (23.8)	0.462
Semen volume (ml)	2.00 (0.80)	2.00 (1.00)	0.196	2.00 (1.00)	2.00 (1.00)	0.397
Morphology (%)	4.00 (2.00)	4.00 (2.00)	0.004*	4.00 (2.00)	4.00 (1.00)	0.017*
DFI (%)	15.0 (13.3)	18.8 (10.9)	0.089	19.4 (10.9)	17.5 (10.6)	0.234

*Values are Median (IQR). 2-group p-value from Mann-Whitney U test; 3-group p-value from Kruskal-Wallis test. p<0.05.

Table 6: Comparison of semen parameters according to abstinence duration.

Parameters	2 days (n=35)	3–4 days (n=107)	5–7 days (n=53)	χ^2 (df=2)	P value
Age (in years)	35.0 (8.00)	35.0 (7.50)	34.0 (8.00)	0.722	0.697
Total sperm count	32.0 (59.0)	68.4 (100)	57.0 (88.0)	4.067	0.131
Sperm concentration	20.5 (23.0)	30.0 (37.5)	24.0 (32.0)	3.255	0.196
Total motility (%)	49.0 (33.0)	53.0 (35.0)	45.0 (36.0)	0.951	0.621
Progressive motility (%)	20.0 (43.0)	28.0 (40.5)	25.0 (45.0)	0.697	0.706
Vitality (%)	46.0 (35.5)	55.0 (31.5)	51.0 (34.0)	0.392	0.822
Morphology (%)	4.00 (2.00)	4.00 (2.00)	4.00 (1.00)	0.173	0.917
Semen volume (ml)	2.00 (0.60)	2.00 (1.00)	2.00 (1.00)	1.407	0.495
DFI (%)	13.1 (9.38)	20.0 (12.5)	18.8 (10.0)	11.312	0.003*

*Values are presented as Median (IQR). Kruskal–Wallis test used for comparison.

Table 7: Comparison of annual income with semen parameters and DFI.

Parameters	Low income (n=110)	Middle/higher income (n=85)	Mann-Whitney U	P value	Effect size (r)
Total sperm count	67.0 (87.6)	48.0 (97.0)	4565	0.779	-0.023
Sperm concentration	29.0 (37.0)	22.0 (30.0)	4388	0.463	-0.061
Total motility (%)	55.0 (34.75)	45.0 (35.0)	3847	0.034*	-0.177

Continued.

Parameters	Low income (n=110)	Middle/higher income (n=85)	Mann-Whitney U	P value	Effect size (r)
Progressive motility (%)	30.0 (44.75)	20.0 (34.0)	3977	0.073	-0.149
Vitality (%)	55.0 (36.0)	48.0 (30.0)	3950	0.064	-0.155
Morphology (%)	4.0 (2.0)	4.0 (2.0)	4044	0.098	-0.135
Semen volume (ml)	2.0 (1.0)	2.0 (1.0)	4596	0.836	0.017
DFI (%)	15.63 (12.97)	19.38 (10.0)	3769	0.020*	0.194

*Values are Median (IQR). Effect size reported as rank biserial correlation (r).

Table 8: Multivariable gamma regression analysis for factors associated with DFI.

Variables	Comparison	Exp(B)	95% CI	P value
Mobile phone use	4–6 h/day vs <4 h/day	0.896	0.764-1.050	0.174
	>6-12 h/day vs <4 h/day	1.215	1.018-1.452	0.030*
Laptop/computer use	≤6 h/day vs non-user	1.147	0.917-1.431	0.225
	>6 h/day vs non-user	1.013	0.865-1.190	0.870
Smoking	Yes vs No	1.333	1.161-1.534	<0.001*
Alcohol use	Yes vs No	1.137	0.984-1.311	0.079
Tobacco use	Yes vs No	1.142	0.991-1.321	0.066
Annual income	Middle/higher vs low	1.131	0.983-1.301	0.083
Abstinence duration	3-4 days vs 2 days	1.252	1.048-1.502	0.013*
	5-7 days vs 2 days	1.276	1.044-1.562	0.017*
Physical activity	Moderate vs Active	0.891	0.762-1.040	0.147
	Inactive vs Active	1.077	0.815-1.420	0.599
Dietary pattern	Pure veg vs non-veg occasional	0.914	0.791-1.060	0.220
	Non-veg daily vs non-veg occas.	0.920	0.752-1.130	0.417
Age (in years)	Per year increase	1.010	0.997-1.020	0.143
BMI (kg/m^2)	Per unit increase	1.021	0.995-1.050	0.118

*Results expressed as Exp(B) (Odds Ratios) with 95% Confidence Intervals from a Generalised Linear Model (Gamma Distribution). Model R^2=0.284, $p<0.001$. Statistically significant ($p<0.05$).

DISCUSSION

The present study evaluated the influence of lifestyle, behavioural, and socioeconomic factors on semen quality and sperm DNA fragmentation in infertile men. Following adjustment for age, BMI, smoking, alcohol consumption, and tobacco use, high daily mobile phone use, active smoking, and prolonged abstinence emerged as independent predictors of elevated sperm DFI. These findings suggest that sperm DNA integrity may be particularly sensitive to modifiable lifestyle factors and support the growing role of DFI as an adjunct marker in the assessment of male infertility, particularly in men with unexplained infertility or normal conventional semen parameters.

A notable finding was the independent association between prolonged mobile phone use and increased DFI. Previous studies have suggested that prolonged exposure to mobile phones may contribute to oxidative stress, mitochondrial dysfunction, and impaired sperm chromatin integrity through thermal and radiofrequency-related effects.[10,11] Interestingly, laptop use and total screen exposure were not significantly associated with DFI, indicating that device proximity to the reproductive organs may be more relevant than overall screen time. However, because exposure duration was self-reported and biological markers of oxidative stress were not measured; these findings should be interpreted cautiously.

Smoking demonstrated the strongest association with elevated DFI in our cohort. This observation is consistent with previous evidence demonstrating that cigarette smoke induces oxidative stress, lipid peroxidation, and DNA damage in spermatozoa.[21] Smoking therefore represents an important and potentially reversible risk factor that should be routinely addressed during fertility counselling and treatment.

The present study also identified a significant association between abstinence duration and sperm DNA fragmentation. Men with shorter abstinence periods exhibited lower DFI values, whereas prolonged abstinence was associated with increased DNA damage. This finding is biologically plausible because prolonged epididymal storage may increase sperm exposure to reactive oxygen species, thereby compromising DNA integrity.[2-5] These observations suggest that optimizing abstinence duration may improve sperm genomic quality without substantially affecting conventional semen parameters.

Dietary patterns influenced selected semen characteristics, particularly sperm morphology. Vegetarians demonstrated a higher percentage of morphologically normal sperm than

non-vegetarians, although DFI differences were not statistically significant. Plant-based diets are generally rich in antioxidants, folate, and micronutrients that may help protect spermatozoa against oxidative damage.[15-17,22] However, detailed nutritional assessment was not performed, limiting further interpretation.

Contrary to expectations, physical activity and occupational activity were not independently associated with DFI after adjustment for confounding factors. Previous investigations have reported mixed findings, with moderate exercise generally showing beneficial effects and excessive exercise potentially impairing reproductive function.[12-14] The absence of a significant association in our cohort suggests that physical activity may exert a smaller influence on sperm DNA integrity than smoking, abstinence duration, or mobile phone exposure.

Socioeconomic status was associated with DFI; however, the observed effect size was small and its clinical relevance remains uncertain. Higher-income participants exhibited slightly increased DFI values, potentially reflecting occupational stress, sedentary work patterns, or greater digital device use. Because these intermediary variables were not directly assessed, the underlying mechanisms remain speculative.

The principal strength of this study lies in its comprehensive assessment of multiple lifestyle, behavioural, and socioeconomic factors within a single infertile population. By evaluating several exposures simultaneously and adjusting for major confounders, the study provides a broader understanding of the multifactorial nature of male infertility.

Several limitations should be acknowledged. The retrospective cross-sectional design precludes causal inference, lifestyle exposures were self-reported and may be subject to recall bias, and biomarkers of oxidative stress or direct measures of electromagnetic exposure were not assessed. Furthermore, the study was conducted in infertile men attending a single tertiary fertility centre, which may limit the generalizability of the findings.

Overall, the present study demonstrates that prolonged mobile phone use, active smoking, and extended abstinence are independently associated with increased sperm DNA fragmentation in infertile men. These findings reinforce the importance of lifestyle modification as a potentially valuable component of infertility management. Assessment of sperm DNA fragmentation may provide additional clinical information beyond conventional semen analysis in identifying men at risk of impaired reproductive outcomes. Future prospective multicentre studies incorporating objective exposure measurements and oxidative stress biomarkers are required to further clarify these associations and determine whether targeted lifestyle interventions can improve the reproductive outcomes.

CONCLUSION

In conclusion, this study demonstrates that active smoking, prolonged mobile phone use (>6-12 hours/day), and extended abstinence duration (>2 days) are independently associated with increased sperm DNA fragmentation among infertile men. These findings highlight the potential influence of modifiable lifestyle factors on sperm DNA integrity and support the value of DFI assessment as an adjunct to conventional semen analysis in the evaluation of male infertility. However, owing to the retrospective design, reliance on self-reported exposure data, and the single-centre study population, the observed associations should not be interpreted as causal relationships. Further prospective, multicentre studies incorporating objective exposure measurements and biological markers of oxidative stress are warranted to confirm these findings and clarify the underlying mechanisms.

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