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Original Research Article

Sociodemographic and lifestyle factors associated with semen status among men undergoing infertility evaluation

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ABSTRACT

Background: Male infertility is multifactorial, and semen abnormalities may be associated with sociodemographic and lifestyle factors. This study evaluated associations between demographic, behavioural, lifestyle, and socioeconomic factors and distinct semen-status categories among men undergoing infertility evaluation.
Methods: An observational study was conducted among 501 men undergoing infertility evaluation at an infertility care centre, Raipur, from 2023 to 2026. Participants were classified as having normozoospermia, non-azoospermic abnormal semen parameters, or azoospermia. Sociodemographic, lifestyle, behavioural, and socioeconomic factors were assessed. Pearson's chi-square test was used for unadjusted associations, followed by multinomial logistic regression with normozoospermia as the reference outcome. The model was adjusted for age, BMI, smoking, alcohol, smokeless tobacco, education, computer use, fast-food consumption, mobile-phone use, sleep duration, physical activity, and annual family income.
Results: Among 501 men, unadjusted analyses showed significant associations with smoking (p=0.002), alcohol consumption (p=0.007), educational attainment (p<0.001), and computer use (p=0.029). The multinomial regression model was significant (χ^2=71.8, df=46, p=0.009; McFadden pseudo-R^2=0.084). Educational attainment remained significantly associated with semen status (LR χ^2=13.555, df=6, p=0.035). Low educational attainment was associated with higher adjusted odds of azoospermia compared with graduation-level education (AOR=3.617, 95% CI 1.098-11.920; p=0.035). No other individual adjusted comparison was statistically significant.
Conclusions: Smoking and alcohol consumption were significantly associated with semen status in unadjusted analyses. After adjustment, educational attainment remained significantly associated with semen status, with low education associated with higher odds of azoospermia. These findings highlight the relevance of lifestyle and sociodemographic factors in male infertility.

Keywords: Azoospermia, Education, Lifestyle factors, Male infertility, Normozoospermia, Semen analysis

INTRODUCTION

Male infertility is a major component of reproductive failure and contributes substantially to the global burden of infertility. Semen analysis remains a fundamental investigation for evaluating male reproductive function and is performed according to standardized World Health Organization (WHO) procedures.[1] Male infertility is multifactorial and may involve genetic, endocrine, anatomical, infectious, environmental, and lifestyle-related factors.[2]

Lifestyle and behavioral factors have received increasing attention because several are potentially modifiable. Smoking, alcohol consumption, and other adverse lifestyle characteristics have been associated with impaired reproductive function through mechanisms that may include oxidative stress, altered hormonal regulation, and

impaired spermatogenesis.[3-6,12] Environmental and lifestyle exposures may also contribute to sperm DNA damage, although the magnitude and consistency of these associations vary across populations and study designs.[7]

The increasing use of digital devices has generated additional interest in their potential effects on male reproductive health. Studies investigating mobile-phone exposure have reported variable associations with semen parameters, while systematic reviews have highlighted heterogeneity in the available evidence.[8,9] Recent research has also examined the combined influence of lifestyle and digital-device exposure on semen quality and sperm DNA fragmentation.[10,11] These findings suggest that male reproductive health may be influenced by multiple interacting sociodemographic, lifestyle, and environmental factors rather than by a single exposure.

Despite increasing evidence on individual lifestyle and environmental factors, the relationship between multiple sociodemographic, behavioral, and digital factors and distinct semen-status phenotypes remains incompletely characterized, particularly among men attending infertility-care services. Moreover, combining all abnormal semen findings into a single category may obscure differences between azoospermia and non-azoospermic abnormal semen profiles.

Therefore, this study aimed to evaluate the association of sociodemographic, lifestyle, behavioral, and digital-exposure factors with semen status among men undergoing infertility evaluation. Using multinomial logistic regression, we specifically assessed factors independently associated with azoospermia and non-azoospermic abnormal semen parameters, with normozoospermia as the reference category.

METHODS

Study design and setting

This observational study was conducted among men undergoing infertility evaluation at an infertility-care centre in Raipur, Chhattisgarh, India. The study period was from 2023 to 2026.

Study population

A total of 501 men undergoing infertility evaluation were included in the analysis. Participants were classified according to their semen status into three outcome categories: normozoospermia: 331 (66.1%), non-azoospermic abnormal semen parameters: 113 (22.6%), azoospermia: 57 (11.4%)

Semen status was assessed according to the criteria and laboratory procedures described in the World Health Organization (WHO) laboratory manual for the examination and processing of human semen.[1]

Data collection and study variables

Sociodemographic, lifestyle, behavioral, and digital-exposure information was collected using a structured questionnaire. The variables assessed included age, body mass index (BMI), duration of infertility, educational attainment, smoking, alcohol consumption, smokeless tobacco use, computer/laptop use, mobile-phone use, fast-food consumption, sleep duration, occupational physical activity, and annual family income.

Educational attainment was categorized as low, school education, graduation, and postgraduate or higher education. Smoking status was categorized as non-smoker, occasional smoker, and consumption of 2-5 cigarettes per day. Alcohol consumption was categorized as none, occasional, and regular weekly/daily consumption. Computer/laptop use was categorized as no use, ≤4 hours/day, and >4 hours/day. Mobile-phone use was categorized according to daily duration of use. Physical activity was classified as physically demanding, moderate, or sedentary. Annual family income was categorized into predefined income groups.

Statistical analysis

Statistical analyses were performed using jamovi software, version 2.7 (The Jamovi project, Sydney, Australia).[13] Continuous variables were assessed for normality and, as they were not normally distributed, were summarized using medians and interquartile ranges (IQRs). Categorical variables were summarized using frequencies and percentages.

Pearson's chi-square test was initially used to assess associations between categorical variables and semen-status categories. Multinomial logistic regression analysis was subsequently performed using normozoospermia as the reference outcome. The adjusted model included age, BMI, smoking status, alcohol consumption, smokeless tobacco use, educational attainment, computer/laptop use, fast-food consumption, mobile-phone use, sleep duration, physical activity, and annual family income.

Adjusted odds ratios (AORs) with corresponding 95% confidence intervals (CIs) were reported. Overall model fit was assessed using the likelihood-ratio chi-square test and McFadden's pseudo-R^2. All statistical.

Ethical approval

The study was conducted in accordance with the Declaration of Helsinki (2013). Owing to its retrospective design and use of existing clinical data, IRB approval was exempted; however, written informed consent for secondary research use of clinical data was obtained from all participants.

RESULTS

Baseline characteristics

A total of 501 men were included in the analysis. The baseline characteristics of the study population are summarized in Table 1. The median age was 35.0 (9.0) years, with a median body mass index (BMI) of 24.6 (4.80) kg/m^2 and a median (IQR) duration of infertility of 6.0 (6.0) years.

Regarding lifestyle factors, the majority of participants were non-smokers (64.1%) and reported no smokeless tobacco use (63.1%). Alcohol consumption was reported as absent by 38.1% of participants, while 38.1% reported occasional consumption.

Distribution of semen-status categories

Regarding semen-status categories, normozoospermia was observed in 331 (66.1%) participants. Non-azoospermic abnormal semen parameters were present in 113 (22.6%), while 57 (11.4%) participants had azoospermia.

Smoking and semen status

Smoking status was significantly associated with semen status [Pearson $\chi^2(4)=16.5$, p=0.002]. Normozoospermia was observed in 67.0% of non-smokers, 67.7% of occasional smokers, and 60.7% of men smoking 2-5 cigarettes per day. Notably, the proportion of non-azoospermic men with abnormal semen parameters increased from 18.4% among non-smokers to 27.1% among occasional smokers and 33.3% among those smoking 2-5 cigarettes per day (Table 2).

Table 1: Baseline characteristics of the study population.

Variables	Category	N (%)
Age, years	Median (IQR)	35.0 (9.0)
BMI, kg/m^2	Median (IQR)	24.6 (4.80)
Infertility duration, years	Median (IQR)	6.0 (6.0)
Education	Low	46 (9.2)
	School	122 (24.4)
	Graduation	159 (31.7)
	Postgraduate and above	174 (34.7)
Smoking	No	321 (64.1)
	Occasional	96 (19.2)
	2-5 cigarettes/day	84 (16.8)
Alcohol consumption	No	191 (38.1)
	Occasional	191 (38.1)
	Once weekly	97 (19.4)
	Daily	22 (4.4)
Smokeless tobacco	No	316 (63.1)
	Yes	185 (36.9)

Table 2: Association between smoking and semen status.

Semen status	No smoking, (%)	Occasional, (%)	2–5/day, (%)	Total
Normozoospermia	215 (67.0)	65 (67.7)	51 (60.7)	331
Non-azoospermic abnormal	59 (18.4)	26 (27.1)	28 (33.3)	113
Azoospermia	47 (14.6)	5 (5.2)	5 (6.0)	57
Total	321 (100)	96 (100)	84 (100)	501

Pearson χ^2 (4) =16.5, p=0.002.

Table 3: Association between alcohol consumption and semen status.

Semen status	Non-drinkers, (%)	Occasional drinkers, (%)	Regular drinkers (weekly/daily), (%)	Total
Normozoospermia	131 (68.6)	133 (69.6)	67 (56.3)	331
Non-azoospermic abnormal	32 (16.8)	45 (23.6)	36 (30.3)	113
Azoospermia	28 (14.7)	13 (6.8)	16 (13.4)	57
Total	191 (100.0)	191 (100.0)	119 (100.0)	501

Pearson $\chi^2(4)=14.1$, p=0.007.

Table 4: Association between educational attainment and semen status.

Semen status	Postgraduate and above, (%)	Graduate, (%)	School education, (%)	Low education, (%)	Total
Normozoospermia	133 (76.4)	104 (65.4)	68 (55.7)	26 (56.5)	331
Non-azoospermic abnormal	31 (17.8)	40 (25.2)	34 (27.9)	8 (17.4)	113
Azoospermia	10 (5.7)	15 (9.4)	20 (16.4)	12 (26.1)	57
Total	174 (100.0)	159 (100.0)	122 (100.0)	46 (100.0)	501

Pearson $\chi^2(6)=26.6$, $p<0.001$.

Alcohol consumption and semen status

Alcohol consumption was significantly associated with semen status in the unadjusted analysis [Pearson $\chi^2(4)=14.1$, $p=0.007$]. Normozoospermia was observed in 68.6% of non-drinkers, 69.6% of occasional drinkers, and 56.3% of regular drinkers. The proportion of men with non-azoospermic abnormal semen parameters was 16.8%, 23.6%, and 30.3%, respectively (Table 3).

Education and semen status

Educational attainment demonstrated a significant association with semen status [Pearson $\chi^2(6)=26.6$, $p<0.001$]. Normozoospermia was observed in 76.4% of participants with a postgraduate education or higher, 65.4% of graduates, 55.7% of those with a school-level education, and 56.5% of those with a low level of education. Azoospermia was observed in 5.7%, 9.4%, 16.4%, and 26.1% of participants across these respective educational groups (Table 4).

Other lifestyle and socioeconomic variables

Based on Pearson's chi-square analysis, no statistically significant associations with semen status were observed for smokeless tobacco use [$\chi^2(2)=3.48$, $p=0.176$], occupational physical activity [$\chi^2(4)=8.30$, $p=0.081$], mobile-phone use [$\chi^2(6)=5.58$, $p=0.471$], fast-food consumption [$\chi^2(2)=5.53$, $p=0.063$], sleep duration [$\chi^2(4)=4.56$, $p=0.335$], or annual family income [$\chi^2(6)=11.2$, $p=0.081$]. While computer use demonstrated a statistically significant association with semen status [$\chi^2(4)=10.8$, $p=0.029$], the magnitude of this association was exceedingly weak (Cramer's V=0.104) and was not considered significant in the overall context of the study.

Table 5: Multinomial logistic regression analysis.

Predictors	Azoospermia versus normozoospermia AOR (95% CI)	P value	Non-azoospermic abnormal versus normozoospermia AOR (95% CI)	P value
Age	0.959 (0.909-1.012)	0.128	1.019 (0.980-1.060)	0.354
BMI	0.990 (0.917-1.069)	0.798	1.006 (0.956-1.058)	0.829
Smoking				
Occasional versus no	0.460 (0.162-1.311)	0.146	1.524 (0.822-2.827)	0.181
2-5 cigarettes/day versus no	0.458 (0.151-1.387)	0.167	1.817 (0.949-3.477)	0.071
Alcohol				
Occasional versus no	0.659 (0.303-1.431)	0.292	1.184 (0.658-2.127)	0.573
Regular weekly/daily versus no	1.295 (0.522-3.211)	0.578	1.531 (0.758-3.091)	0.235
Smokeless tobacco				
Yes versus no	0.590 (0.270-1.289)	0.186	0.938 (0.543-1.619)	0.818
Education				
Postgraduate+ versus graduation	0.531 (0.217-1.294)	0.164	0.613 (0.343-1.098)	0.100
School versus graduation	2.047 (0.782-5.360)	0.145	1.393 (0.703-2.761)	0.342
Low education versus graduation	3.617 (1.098-11.920)	0.035	0.764 (0.268-2.180)	0.615
Computer use				
>4 hours/day versus ≤4 hours/day	0.624 (0.159-2.449)	0.499	0.955 (0.442-2.064)	0.906
No use versus ≤4 hours/day	1.628 (0.654-4.052)	0.295	1.157 (0.603-2.218)	0.660
Fast-food consumption				
Regular/frequent versus occasional/never	0.906 (0.456-1.798)	0.777	1.381 (0.848-2.251)	0.195
Mobile phone use				
2-4 hours versus <2 hours	1.833 (0.793-4.239)	0.157	1.371 (0.683-2.752)	0.375
4-6 hours versus <2 hours	0.949 (0.291-3.093)	0.931	1.700 (0.760-3.801)	0.196
>6 hours versus <2 hours	1.168 (0.327-4.164)	0.811	1.362 (0.544-3.406)	0.509

Continued.

Predictors	Azoospermia versus normozoospermia AOR (95% CI)	P value	Non-azoospermic abnormal versus normozoospermia AOR (95% CI)	P value
Sleep				
<6 hours versus 6-8 hours	1.600 (0.290-8.842)	0.590	1.728 (0.508-5.880)	0.381
8-10 hours versus 6-8 hours	2.230 (0.813-6.119)	0.119	1.560 (0.691-3.518)	0.284
Physical activity				
Physically demanding versus moderately active	1.098 (0.484-2.492)	0.822	1.265 (0.691-2.317)	0.446
Sedentary versus moderately active	0.946 (0.344-2.603)	0.915	1.240 (0.621-2.475)	0.542
Income				
₹1-2.5 lakh versus ₹2.5-5 lakh	0.487 (0.179-1.328)	0.160	1.187 (0.587-2.398)	0.634
<₹1 lakh versus ₹2.5-5 lakh	0.632 (0.200-1.998)	0.434	1.648 (0.657-4.133)	0.287
₹5-20 lakh versus ₹2.5-5 lakh	0.962 (0.367-2.522)	0.937	1.469 (0.771-2.797)	0.242

Model: $\chi^2(46)=71.8$, p=0.009; McFadden pseudo-R^2=0.0837; N=501. Reference outcome: Normozoospermia. Note: AOR=adjusted odds ratio; CI=confidence interval. The model was adjusted simultaneously for age, BMI, smoking, alcohol consumption, smokeless tobacco use, education, computer use, fast-food consumption, mobile-phone use, sleep duration, physical activity and income.

Multinomial logistic regression

The adjusted multinomial logistic regression model was statistically significant [$\chi^2(46)=71.8$, p=0.009], with a McFadden's pseudo-R^2 of 0.0837.

Educational attainment demonstrated a statistically significant overall likelihood-ratio association with semen status [$\chi^2(6)=13.555$, p=0.035]. Compared with participants having graduation-level education, those with low education exhibited significantly higher adjusted odds of azoospermia versus normozoospermia (aOR=3.617, 95% CI: 1.098-11.920; p=0.035). Comparisons involving postgraduate education and school education were not statistically significant.

Smoking showed a borderline overall association in the adjusted model [likelihood-ratio $\chi^2(4)=9.171$, p=0.057]. Specifically, smoking 2-5 cigarettes per day versus no smoking for non-azoospermic abnormal semen parameters approached, but did not reach, statistical significance (aOR=1.817, 95% CI: 0.949-3.477; p=0.071).

Age and BMI were not independently associated with either azoospermia or non-azoospermic abnormal semen parameters. Similarly, alcohol consumption, smokeless tobacco use, computer use, fast-food consumption, mobile-phone use, sleep duration, physical activity, and income showed no statistically significant individual adjusted associations (Table 5).

DISCUSSION

In this study of 501 men undergoing infertility evaluation, normozoospermia was the most common semen-status category, followed by non-azoospermic abnormal semen parameters and azoospermia. We evaluated the associations of sociodemographic, lifestyle, behavioral, and digital-exposure factors with semen status using unadjusted and multivariable analyses. Several factors were associated with semen status in unadjusted analyses; however, after adjustment for potential confounders, educational attainment was the only factor showing a statistically significant overall association.

Smoking was significantly associated with semen status in the unadjusted analysis ($\chi^2=16.5$, p=0.002). Non-azoospermic abnormal semen parameters were more frequent among occasional smokers and men smoking 2-5 cigarettes/day than among non-smokers. Previous studies have reported adverse associations between smoking and male reproductive health, with oxidative stress and impaired sperm function proposed as possible mechanisms.[4-6,12] However, smoking did not remain statistically significant after multivariable adjustment (overall p=0.057), suggesting that the unadjusted association may partly reflect other sociodemographic or lifestyle factors.

Alcohol consumption was also significantly associated with semen status in the unadjusted analysis ($\chi^2=14.1$, p=0.007), but neither occasional nor regular weekly/daily consumption remained statistically significant after adjustment. Lifestyle exposures frequently coexist, making it difficult to attribute observed differences in semen status to a single behavior.[3-6] Thus, the present findings indicate associations in unadjusted analyses but do not establish independent or causal effects of smoking or alcohol consumption.

Educational attainment remained significantly associated with semen status after multivariable adjustment (likelihood-ratio $\chi^2=13.555$, p=0.035). Men with low educational attainment had higher adjusted odds of azoospermia compared with those with graduation-level education (AOR=3.617; 95% CI: 1.098-11.920; p=0.035). No significant association was observed between low education and non-azoospermic abnormal semen parameters.

Education may reflect broader socioeconomic circumstances, health literacy, occupational conditions,

access to healthcare, and health-related behaviors. Previous literature has emphasized the contribution of lifestyle and environmental factors to male reproductive health.[3-6] However, the mechanism underlying the observed association cannot be determined from the present study. The relatively wide confidence interval also warrants cautious interpretation of the magnitude of the association.

Computer use was significantly associated with semen status in the unadjusted analysis (χ^2=10.8, p=0.029), although the effect size was small (Cramer's V=0.104), and the association was not significant after adjustment. Mobile-phone use was also not independently associated with semen status.

Previous studies have investigated mobile-phone exposure in relation to semen quality, with findings varying across populations and study designs.[8,9] Recent evidence has further emphasized the complex relationship between lifestyle, environmental exposures, and male reproductive health.[6,7,10,11] Differences in exposure duration, intensity, device characteristics, and semen-assessment methods may contribute to inconsistent findings.[12,13] Our results therefore do not demonstrate an independent association between digital-device use and semen status after adjustment.

Physical activity and dietary patterns have been investigated as potentially modifiable factors influencing semen quality. Previous studies have reported associations between physical activity, sedentary behavior, dietary patterns, nutrient intake, and semen parameters.[14-18] In the present study, occupational physical activity was not significantly associated with semen status in the unadjusted analysis (p=0.081) and was not independently associated after adjustment. Fast-food consumption similarly showed no significant independent association.

These findings may partly reflect the broad exposure categories used in the study. Frequency-based categories may not adequately capture dietary quality, nutritional composition, exercise intensity, or total sedentary time. Therefore, the absence of significant associations should not be interpreted as evidence that diet or physical activity has no relevance to male reproductive health.

The multinomial logistic regression model was statistically significant overall (likelihood-ratio χ^2=71.8, p=0.009), with a McFadden pseudo-R^2 of 0.084, indicating modest explanatory power. The multinomial approach allowed azoospermia and non-azoospermic abnormal semen parameters to be evaluated separately rather than combining all abnormal profiles into one outcome.

An important finding was the difference between unadjusted and adjusted analyses. Smoking, alcohol consumption, and computer use showed significant unadjusted associations but were attenuated after adjustment. In contrast, educational attainment remained significantly associated with semen status, particularly with azoospermia. These findings demonstrate the importance of multivariable analysis when evaluating multiple interrelated factors in male infertility.

Strengths include the relatively large clinical sample, assessment of multiple sociodemographic and lifestyle factors, and use of multinomial regression to distinguish azoospermia from other abnormal semen profiles. Limitations include the observational design, categorized exposure variables, relatively small subgroups with wide confidence intervals, and single-centre setting. The study also lacked comprehensive assessment of hormonal, genetic, environmental, and sperm DNA-fragmentation parameters.

Educational attainment may be a relevant sociodemographic marker when interpreting semen-status patterns among men undergoing infertility evaluation. However, the observed associations should not be interpreted as causal. Larger prospective, multicentre studies incorporating detailed clinical, socioeconomic, lifestyle, environmental, hormonal, genetic, and sperm DNA-fragmentation measures are needed to further clarify these relationships.

CONCLUSION

Our study found that smoking and alcohol consumption were significantly associated with semen status in unadjusted analyses, highlighting their potential relevance as modifiable factors in male infertility. However, after multivariable adjustment, low educational attainment remained independently associated with higher odds of azoospermia (AOR 3.617; 95% CI 1.098-11.920). These findings underscore the importance of considering lifestyle and sociodemographic factors in male infertility assessment and support further prospective studies to establish their independent and causal effects.

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