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Pathophysiological Effects of Alcohol and Tobacco Consumption on Semen Parameters of Men Attending a Fertility Clinic in West Africa

Philip Vatcanarat Baysah[1], Aloysius Obinna Ikwuka[1, *], Francis Chigozie Udeh[1], Darius Popo Bleh[2], Thamara Viloria[3]

[1]College of Medicine and Health Sciences, American International University West Africa, Banjul, The Gambia

[2]Department of Laboratory Services, Medlink Clinic, Monrovia, Liberia

[3]College of Clinical Embryology and Artificial Reproduction Technology, University of Valencia, Valencia, Spain

Email address:

aloysiussweet@yahoo.com (Aloysius Obinna Ikwuka)

[*]Corresponding author

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Abstract: *Background:* Alcohol and tobacco consumption are prevalent global habits. There is existing evidence linking these habits to male infertility, although the impact they have on male fertility and reproductive outcomes are yet to be exhaustively investigated. *Aim:* This study aimed to study the pathophysiological effects of alcohol and tobacco consumption on semen parameters of men attending a fertility clinic in West Africa. *Materials and Methods:* Semen samples were collected from 196 men who attend Medlink Clinic, Monrovia, Liberia and parameters including sperm volume, count, motility, and morphology were evaluated according to the WHO criteria. The Chi-square test (χ^2) of the SPSS version 23 statistical software was used to test for hypotheses at a significance level of $p<0.05$. *Results:* The mean age of the men was 37.8±10.3 years. 20.9% of the study participants abstain from alcohol and tobacco, 38.8% consume alcohol, and 40.3% consume tobacco. Among the study participants, 36 (18.4%) had normospermia, 74 (37.8%) had oligospermia, 8 (4.1%) had cryptozoospermia, 5 (2.6%) had azoospermia, 58 (29.6%) had asthenozoospermia, and 15 (7.7%) had teratozoospermia. However, 78.9% frequent alcohol consumers, 47.4% non-frequent alcohol consumers, 77.8% non-alcohol consumers, 89.8% tobacco smokers, and 69.6% non-tobacco smokers had poor semen quality. The hypotheses tested proved that there is a significant relationship (p=0.024) between alcohol/tobacco consumption and poor semen quality, whereas there is no significant relationship (p=0.56) between non-consumption of alcohol/tobacco and good semen quality. There is also a significant relationship (p=0.0086) between alcohol consumption only and poor semen quality. *Conclusion:* Alcohol and tobacco consumption reduce male sperm quality, but abstinence from both does not guarantee optimum semen quality. Alcohol and/or tobacco consumption adversely affect the semen parameters (sperm volume, count, motility, and morphology).

Keywords: Pathophysiology, Tobacco, Alcohol Consumption, Semen Parameters, Semen Quality, Male Fertility

1. Introduction

Gametes are ova and sperm cells which are haploid and have one copy of each type of chromosome i.e. 1–22 X or 1–22 Y [34]. Spermatogenesis is the process of sperm production, occurring in the seminiferous tubules of the testes. It takes approximately 74 days for a spermatogonium to mature into a spermatozoon, with over 100 million spermatozoa produced daily [55]. Male fertility primarily relies on semen quality, encompassing parameters such as sperm volume, count, motility, and morphology [52].

Several factors including hazards linked to certain occupations (long distance driving, military, etc); previous history of genital infections (e.g. gonorrhea, orchitis, etc); previous history of surgery in the genital tract or inguinal region; lifestyle choices (sedentary lifestyle, lack of exercise, sleep deprivation, etc); environmental factors (eg. exposure to ionizing radiation, pesticides, heat from tight underwears and hot baths) can adversely affect semen parameters and lead to male infertility. Infertility is defined as the inability to achieve a clinical pregnancy after one year of regular unprotected sexual intercourse – regular sexual intercourse is 2-3 times sexual intercourse per week [80]. Infertility affects 15-30% of couples of reproductive age [55, 56, 74]. Male infertility rates surpass those of females [41], causing significant emotional distress for affected couples [78].

Alcohol and tobacco consumption are prevalent worldwide [76, 77], and are known for their addictive nature and associated health risks [8, 9, 52]. Tobacco use has been reported as teratogenic, while excessive use of both substances can be lethal [40, 63, 64].

Moderate alcohol consumption (4–7 units/week) has shown a positive correlation with sperm quality [54]. However, prolonged abuse of alcohol and tobacco has been linked to male infertility, as they negatively impact spermatogenesis through various mechanisms [4, 11, 18, 43, 59]. Firstly, alcohol consumption has been reported to be directly toxic to the Leydig and Sertoli cells in the testes. Secondly, it has also been linked with anomalies in the metabolism of testosterone [19]. Thirdly, the morphology of spermatozoa and sperm counts have also been affected by the daily use of alcohol among men [50]. Outcomes such as coil-tailed spermatozoa, immature testicular cells, spermatozoa head breakage, and distention of the mid-piece have been reported as morphological alterations [50].

Numerous studies have confirmed that tobacco is generally harmful as it contains alkaloids and other dangerous components like Tobacco-Specific Nitrosamines (TSNAs), Propionic acid, 2- Naphylamine, Choline, Tabacinine, Tabacine, Mercury (Hg), Cadmium (Cd), N-nitrosonornicotine, Tar, Pyrene, Nicotelline, Carbon monoxide and Cembrene [10, 40, 45, 63, 64, 77]. Of these alkaloids, nicotine accounts for 96-98% [10, 40], and causes high tobacco addiction, and has the most immediate pharmacological action [20]. The effects of tobacco on male fertility have been studied extensively but there is a controversy on the outcome. Some researchers identified significant adverse effects on sperm quality, while others like Halmenschlager, *et al* did not [17]. Cadmium (Cd) affects male fertility and endocrine functions by significantly reducing semen [51]. Moreover, cigarette smoking can elevate inflammatory reactions which cause leukocytosis in the testes [43, 48]. Major free radicals that are of physiological significance are superoxide anion, hydroxyl radical, and hydroperoxyl radical, while non-radical is hydrogen peroxide [33]. Cigarette smoking can also cause sperm DNA fragmentation, axonemal damage in the flagellum, and low sperm count [5, 18].

In addition, the interplay, role and effects of metabolic syndrome diseases on male fertility are still being investigated by different researchers. Metabolic syndrome diseases, MSD (Hypertension, Adiposity, Diabetes mellitus and Dyslipidemia) are interrelated diseases with very high morbidity and mortality rates [21, 22, 24, 38, 65]. Results from different studies have shown that high levels of blood pressure, glucose and lipid metabolic disorders, asymptomatic hyperuricemia, activation of systemic immune inflammation and fibrogenesis, contribute to kidney damage [25-27, 29-31, 35, 37, 39, 66-69, 73]. Adiposity, diabetes mellitus and dyslipidemia have also been linked with erectile dysfunction.

Metabolic Syndrome Diseases require new and effective treatment options. Dapagliflozin which is a Sodium-Glucose Linked Transporter 2 (SGLT-2) inhibitor and Liraglutide which is a Glucagon-like Peptide 1 Receptor Agonist (GLP-1 RA) have been found to increase the effectiveness of treatment and improve the clinical course of type 2 diabetes mellitus and hypertension in patients with such comorbidities [23, 28, 32, 36, 70-72].

The record presented in 2018, showed that the total alcohol consumption per capita (per person) among Liberian males who are ≥15 years is 6.12 liters i.e. 6.12 liters and above of pure alcohol consumed over a calendar year [61]. In 2020, tobacco smoking among Liberian men was 14.3%, a decline from 15.1% in 2018, and also a decline from 16.6% in 2015 according to the World Bank data [60]. The 15.1% rate in 2018 ranked Liberia at 134 among different countries of the world. This shows that the civil awareness made and the necessary laws passed by the 52nd Legislation banning public smoking, have contributed to the decline in tobacco smoking. With these rates of alcohol and tobacco consumption among Liberian men, it is therefore necessary to examine their impact on male fertility by evaluating semen parameters.

2. Materials and Methods

2.1. Study Area

This study is a cross-sectional study conducted from June 2020 to July 2021, at Medlink Clinic, Monrovia, Liberia, where fertility experts and clinical embryologists carry out some levels of fertility tests and treatments in patients. This clinic is a multi-faceted health institution that collaborates with other government and private agencies for the analysis of samples for fertility, and the collection of samples for DNA analysis in other tertiary healthcare facilities.

2.2. Study Population

The study population is made of an estimated four hundred (400) men who visited the clinic within a period of fourteen (14) months.

2.3. Sample Size and Sampling Technique

Krejcie and Morgan's formula was used to estimate the sample size of this study.

Below is the formula:

$$n = \frac{X^2 Np(1-p)}{e^2(N-1)+x^2p(1-p)}$$

Where:

n is the sample size;

N is the population size (400);

e is the acceptable sampling error (5% or 0.05);

X^2 is the Chi-square of the degree of freedom 1 and confidence 95% (3.841);

p is the proportion of population (if unknown, 0.5)

$$n= \frac{(3.841)\cdot(400)\cdot(0.5[1-0.5])}{0.05^2\cdot(400-1)+(3.481\cdot0.5[1-0.5])}$$

$$n= \frac{(3.841)\cdot(400)\cdot(0.5[1-0.5])}{0.05^2\cdot(400-1)+(3.481\cdot0.5[1-0.5])}$$

$$n = 196$$

Sampling Interval= $\frac{N}{n}$

N = population size (400); n = sample size (196)

$$SI= \frac{400}{196}$$

$$SI \sim 2$$

The sampling technique used was a systematic sampling technique with a sampling interval of 2, selecting a sample size of 196 from the study population of 400 men visiting the clinic during the 14 months of this study. The participants included frequent alcohol consumers, non-frequent alcohol consumers, non-alcohol consumers, tobacco smokers, and non-smokers who met the inclusion criteria. Men who had undergone surgeries on their reproductive organs, men on long-term use of fertility medication, men with congenital anomalies like varicocele, hydrocele, hypospadias, epispadias, cryptorchidism, Klinefelter syndrome, men with mumps and evident orchitis, men over 65 years of age, and men who quit alcohol and tobacco usage within three months prior to this study, were excluded. Other patients who met the inclusion criteria were requested to participate, and voluntarily consented to participate after making informed decision.

2.4. Data Collection Method

Semen samples were obtained from patients enrolled in fertility care programs for analysis. Only patients who gave written consent had their semen samples collected. Semen was collected by masturbation into a wide mouthed glass container after 3-4 days of sexual abstinence and was examined within 2 hours after each collection. After liquefaction, the semen was analyzed according to World Health Organization criteria [75]. During sample collection, the participant's age and information related to lifestyle (with attention to alcohol and tobacco consumption) were also collected. Clinical and laboratory studies were carried out in accordance with the recommendations of the manufacturers of diagnostic test kits and systems using modern laboratory technologies.

2.5. Data Analysis

Collected data were cleaned, entered, hardcoded and analyzed using Statistical Package for Social Sciences (SPSS) version 23. Summary statistics was presented using tables. Age was categorized and summarized with mean and standard deviation. Categorical variables were presented as proportions. Descriptive statistics were computed for relevant variables. The significant level of 5% (0.05) was set for all statistical procedures. Chi-square test (χ^2) was used to test the hypotheses and to compare the significance between lifestyle and its outcomes on semen quality at a level of significance set at $p<0.05$.

2.6. Ethical Consideration

Ethical clearance was obtained from the Governing Board of Medlink Clinic. This ethical clearance ensured adequate professional work ethics and confidentiality of all patients' data. Signed consent from every participant was obtained. This research was also carried out with due observance of the ethical principles of the Declaration of Helsinki (DoH) in 2013 concerning human research.

3. Results

The findings in this study are presented in tables as follows: Table 1 shows the demographic distribution of the respondents. The mean age was 37.8±10.3 years and the age bracket with the highest frequency was 28-37 years. With regards to their lifestyle, the participants were grouped into five. Frequent alcohol consumers, non-frequent alcohol consumers, non-alcohol consumers, tobacco smokers and non-smokers. Non-alcohol consumers and non-tobacco smokers accounted for 9.2% and 11.7% respectively. Alcohol consumers accounted for 38.8% of the respondents while tobacco smokers accounted for 40.3%.

Table 1. *Demographic characteristics of participants, n=196.*

Demographic characteristics	**Options**	**Frequency, *n* (%)**
Age range (years)	18-27	24 (12.2)
	28-37	80 (40.8)
	38-47	58 (29.6)
	48-57	21 (10.7)
	58-65	13 (6.6)
	Total	196 (100)
	Mean age = 37.8±10.3	
Lifestyle		
	Frequent alcohol consumers	57 (29.1)
	Non-frequent alcohol consumers	19 (9.7)
	Non-alcohol consumers	18 (9.2)

Demographic characteristics	Options	Frequency, *n* (%)
	Tobacco smokers	79 (40.3)
	Non-smokers	23 (11.7)
	Total	196 (100)

Table 2 shows the distribution of the samples analyzed with only 18.4% of the participants having normospermia after sperm volume, count, motility, and morphological assessments. On sperm count, oligospermia (sperm count <20 million per ml of semen) was evident in 37.8% of the samples, cryptozoospermia (sperm count <100,000 per ml) was seen in 4.1% of the samples, while azoospermia (sperm count 0 per ml i.e. absence of spermatozoa in semen) had the least frequency of 2.6%. On motility, 29.6% of the samples showed asthenozoospermia (<50% spermatozoa with forward progression i.e. poor sperm motility). On morphology, 7.7% showed teratozoospermia (<30% spermatozoa with normal morphology i.e. poor sperm morphology).

Table 2. *Distribution of semen parameters of the samples analyzed based on sperm volume, count, motility, and morphology.*

Semen parameters	Classification	Frequency, *n* (%)
Sperm volume, count, motility, morphology	Normospermia	36 (18.4)
Sperm count	Oligospermia	74 (37.8)
zz	Cryptozoospermia	8 (4.1)
	Azoospermia	5 (2.6)
Motility	Asthenozoospermia	58 (29.6)
Morphology	Teratozoospermia	15 (7.7)

Table 3 shows the distribution of semen qualities among the participants. Only twelve (21.1%) of the fifty-seven frequent alcohol consumers had normospermia, and asthenozoospermia accounted for the highest class of poor semen quality (77.84%). Ten (52.6%) of the non-frequent alcohol consumers were normospermic while 46.4% of them had poor semen quality. Surprisingly, 77.8% of the non-alcohol consumers had poor semen quality, while only 22.2% were normospermic. Most (89.9%) of the smokers had poor semen quality, with oligospermia accounting for the highest occurrence (81.7%), and only 10.1% were normospermic. Sixteen (69.6%) of non-smokers had poor semen quality, while 30.4% had normospermia. Irrespective of the lifestyle, 20.9% of the participants were normospermic while 79.1% had poor semen quality. Out of the poor semen qualities, the most prevalent was oligospermia (47.7%), followed by asthenozoospermia (34.2%). The occurrence of cryptozoospermia and azoospermia was low at 5.2% and 3.2% respectively.

Table 3. *Distribution of semen qualities among the study participants, n=196.*

Participants' categories	Normo-spermia	Oligo-spermia	Cryptozoo -spermia	Azoo-spermia	Astheno-zoospermia	Teratozoo-spermia	Total
Frequent alcohol consumers	12	5	1	1	35	3	57
Non-frequent alcohol consumers	10	0	1	1	5	2	19
Non-alcohol consumers	4	0	6	1	4	3	18
Smokers	8	58	0	2	6	5	79
Non-smokers	7	11	0	0	3	2	23
Total	41	74	8	5	53	15	196

3.1. Tests of Hypotheses

Three research hypotheses were tested in this study and all are displayed in Table 4. These hypotheses are to determine the relationship between lifestyle and semen quality at a level of significance $p<0.05$.

3.2. Hypothesis One

H_0: There is no significant relationship between alcohol/tobacco consumption and semen quality.

H_1: There is a significant relationship between alcohol/tobacco consumption and semen quality.

The null hypothesis (H_0) was rejected because the *p*-value is less than 0.05 ($p=0.024$), and the Chi-square test value (17.89) is greater than the critical value (5.99). This implies that there is a significant relationship between alcohol/tobacco consumption and poor semen quality (male infertility).

3.3. Hypothesis Two

H_0: There is no significant relationship between non-consumption of alcohol/tobacco and semen quality.

H_1: There is a significant relationship between non-consumption of alcohol/tobacco and semen quality.

The null hypothesis (H_0) was accepted because the *p*-value is greater than 0.05 ($p=0.56$), and the Chi-square test statistics value (0.35) is lesser than the critical value (3.84). This implies that there is no significant relationship between non-consumption of alcohol/tobacco and good semen quality (male fertility).

3.4. Hypothesis Three

H_0: There is no significant relationship between alcohol consumption and semen quality.

H_1: There is a significant relationship between alcohol consumption and semen quality.

The null hypothesis (H_0) was rejected because the *p*-value is less than 0.05 (*p*=0.0086), and the Chi-square test statistics value (6.91) is greater than the critical value (3.84). This implies that there is a significant relationship between alcohol consumption and poor semen quality (male infertility).

Table 4. *Statistical comparison between the occurrence of normospermia and poor sperm quality among the study participants based on their lifestyles.*

Participants' categories	Normo-spermia	Poor sperm quality	Normo-spermia	Poor sperm quality	Total	*p*-value	*df*	critical value	χ^2
	Actual values		Expected values						
Alcohol and tobacco consumption									
Frequent alcohol consumers	12	45	11.03	45.97	57				
Non-frequent alcohol consumers	10	9	3.68	15.32	19	0.024	2	5.99	17.89
Smokers	8	71	15.29	63.71	79				
Total	30	125	30	125	155				
Non-alcohol and tobacco consumption									
Non-alcohol consumers	4	14	4.83	13.17	18	0.56	1	3.84	0.35
Non-smokers	7	16	6.17	16.83	23				
Total	11	30	11	30	41				
Alcohol consumption									
Frequent alcohol consumers	12	45	16.5	40.5	57	0.0086	1	3.84	6.91
Non-frequent alcohol consumers	10	9	5.5	13.5	19				
Total	22	54	22	54	76				

Abbreviation and symbol: *df* = degree of freedom; χ^2 = Chi-square test

4. Discussion

Infertility is becoming a topic of concern in the society [16], and it has led to the dissolution of several marriages in African communities. Males and females could be infertile and several studies have shown that lifestyle, pollutants, diet, and psychological stress could play a role in affecting semen parameters and causing male infertility [2, 6, 7, 16]. This study examined the lifestyle (alcohol and tobacco consumption) of Liberian men visiting a fertility clinic, and the relationship between these lifestyles and semen parameters. This therefore shows that the findings of this study do not interpret the overall rate of infertility among Liberian men.

The first discovery in this study is that 18.4% of the men who visited the fertility clinic for treatment were normospermic and 81.6% had poor sperm quality. These values are similar to the findings of Ali, *et al* that showed 13.2% normospermia and 86.8% abnormal semen parameters [3], but inversely related to the findings of Raj, *et al* where patients with normospermia accounted for 79.6% and oligospermic men were just 20.4% [52]. The incidence of the classes of poor semen quality varied among the categories of the participants. Of the parameters that cause poor semen quality, low sperm count was observed to be the most prevalent (54.4%), followed by sperm motility (36.2%) and lastly, sperm morphology (9.4%). However, the overall incidence of low sperm count among the men was 44.5%, a value close to the 44% in Abdullah, *et al* study on Sudanese patients [1], and higher than the 25% in Jajoo, *et al* study on Central Indian patients [42].

Low sperm count could be classified into oligospermia, cryptozoospermia, and azoospermia. In this study, oligospermia, cryptozoospermia, and azoospermia accounted for 37.8%, 4.1%, and 2.6% respectively. The incidence of oligospermia in this study is close to the 32.1% reported by Ramya, *et al* [53], but higher than the 29.13% in Samal, *et al* [58]; 24.8% in Kalavathi, *et al* [44]; 20.4% in Raj, *et al* [52]; and 7.2% in Ali, *et al* [3] studies.

Alcohol and tobacco are globally abused and their adverse effects on health are deleterious. This study found that the category of men with the highest abnormality in semen parameters was tobacco smokers (89.9%) followed by frequent alcohol consumers (78.9%). This study also revealed that there is a relationship between the quantity of alcohol consumed and semen quality, a result similar to the findings of Amor, *et al* [4] and Raj, *et al* [52]. Raj, *et al* study analyzed the semen of 250 males attending a tertiary hospital in Maharashtra, India and found that only 8.3% frequent alcohol consumers and 36.4% non-frequent alcohol consumers were fertile. This present study found out that 21.1% frequent alcohol consumers and 52.6% non-frequent alcohol consumers were normospermic (fertile). This finding collaborates with the findings of Hansen, *et al* and Ricci, *et al* who reported that regular alcohol intake decreased semen volume and concentration of sperm [19, 54].

These effects of alcohol intake on semen quality have been reported to be caused by oxidative stress caused by an imbalance between Reactive Oxygen Species (ROS) produced by the alcohol consumed in the form of free radicals that contain one or more unpaired electrons and antioxidants [15, 62]. Frequent consumption of alcohol also stimulates lipid peroxidation that produces numerous electrophilic aldehydes, eg. malondialdehyde that can attack many cellular targets and cause DNA fragmentation [12, 15, 79, 81]. It also reduces the effects of antioxidant enzymes such as superoxide dismutase and glutathione [14].

With regards to the second category of participants of this study who are tobacco consumers, there exists a relationship between tobacco consumption and semen quality. This result is also similar to the findings of Raj, *et al* where 0% frequent tobacco smokers, 41% non-frequent tobacco smokers, and 79.7% non-smokers were fertile [52]. This present study shows that 10.1% tobacco smokers and 30.4% non-smokers were normospermic (fertile). Amor, *et al*'s study presented similar findings with semen parameters significantly better in non-tobacco smokers than in tobacco smokers [4].

In addition, tobacco smoking has been documented to also cause oxidative stress due to the production of Reactive Oxygen Species (ROS) [46, 47], and its toxic effects are evident on sperm DNA [13], on sperm motility [57], and on sperm morphology [49].

The tests of hypotheses showed that there is a significant relationship (p=0.024) between alcohol and tobacco consumption and poor semen quality (male infertility). There is no significant relationship (p=0.56) between non-consumption of alcohol/tobacco and good semen quality (male fertility). There is also a significant relationship (p=0.0086) between alcohol consumption only and poor semen quality (male infertility).

5. Conclusion

Alcohol and tobacco consumption reduce male sperm quality, but abstinence from both does not guarantee optimum semen quality. Alcohol and/or tobacco consumption adversely affect the semen parameters (sperm volume, count, motility, and morphology). Alcohol and tobacco consumption combined with bad lifestyle habits affect semen quality. Therefore, it is safer to abstain from alcohol and/or tobacco consumption since it has been proven that the adverse effects on sperm quality are directly proportional to the consumption rate of either or both substances. It is recommended that health institutions and healthcare workers should provide rigorous health education and awareness campaigns to the male populace on the negative impacts of alcohol and tobacco consumption aimed at not only improving male fertility, but also to improve life expectancy especially among the male population. The direction of future research on semen analysis should be to study other sperm abnormalities such as aspermia (no ejaculate), and asthenoteratooligozoospermia (combination of abnormal sperm motility, morphology and count).

Conflict of Interest

The authors guarantee responsibility for everything published in this manuscript, as well as the absence of a conflict of interest and the absence of their financial interest in performing this research and writing this manuscript. This manuscript was written from an original research work and has never been published, neither is it under consideration for publication elsewhere.

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