

An Investigation on Sperm Parameter Profiles among Men Seeking Infertility Treatment: A Cross-Sectional Retrospective Study about 2608 Cases

Michèle Eve Toukam^{1,2*}, Siméon Tchakonté^{1,3}, Modeste Wankeu-Nya⁴, Marius Etoundi Nkoma^{1,4}, Ruphine Nkuida^{1,2}, Kati Leuga Djiambi^{1,2}, Dominique Djomo Tamchom^{5,6}, Felix Lekefack⁷, Jacques Kamgaing Tsingaing⁸, Charlotte Tchenté Nguefack^{9,10}

¹Plenitude Scientific Research Group, Douala, Cameroon

²Assisted Reproductive Technology Laboratory, Kouam Samuel Clinic, Douala, Cameroon

³Faculty of Science, University of Buea, Buea, Cameroon

⁴Department of Animal Biology, Faculty of Science, University of Douala, Douala, Cameroon

⁵Department of Anesthesiology and Intensive Care, Douala Gynaeco-Obstetric and Pediatric Hospital, Douala, Cameroon

⁶Faculty of Health Sciences, University of Buea, Buea, Cameroon

⁷Louis Pasteur Laboratory, Douala, Cameroon

⁸Uro-Gyn Clinic, Douala, Cameroon

⁹Department of Obstetrics and Gynecology, General Hospital of Douala, Douala, Cameroon

¹⁰Faculty of Medicine and Pharmaceutical Sciences, University of Douala, Douala, Cameroon

Email: *michele.toukam@psrgresearch.com

How to cite this paper: Toukam, M.E., Tchakonté, S., Wankeu-Nya, M., Nkoma, M.E., Nkuida, R., Djiambi, K.L., Tamchom, D.D., Lekefack, F., Tsingaing, J.K. and Nguefack, C.T. (2025) An Investigation on Sperm Parameter Profiles among Men Seeking Infertility Treatment: A Cross-Sectional Retrospective Study about 2608 Cases. *Advances in Reproductive Sciences*, 13, 123-139.

<https://doi.org/10.4236/arsci.2025.133011>

Received: June 6, 2025

Accepted: July 27, 2025

Published: July 30, 2025

Abstract

Background: The emerging evidence of the global decline in sperm counts worldwide has intensified concerns about male infertility. This widespread interest is increasingly accentuated in sub-Saharan Africa, where women have long been blamed for couple infertility. Indeed, there is a lack of comprehensive studies and accurate statistics on rates of male infertility in Cameroon. This study aimed to investigate the trends of sperm parameters and determine the overall sperm quality of infertile men across age groups. **Methods:** This retrospective study analyzed the semen parameters of 2608 men aged at least 21 years who consulted for couple infertility in Douala between January 2019 and August 2024. For each medical booklet or records retrieved, the variables assessed were age, ejaculate volume, sperm motility, concentration, vitality, morphology, sperm culture, and leukocytospermia. To understand the trend of semen parameters and determine the most vulnerable age group, binary logistic regression and discriminant factor analysis were performed. **Results:** The research findings revealed a significantly high prevalence of impaired

Copyright © 2025 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

sperm parameters, with 92.2% of Asthenozoospermia, 79.3% of Teratozoospermia, 52.7% of abnormal sperm concentration, and 32.2% of Necrozoospermia. The overall sperm quality showed a proportion of 26.4% of patients suffering from Oligoasthenoteratozoospermia. Semen cultured indicated that 10.1% of patients were tested positive to infection by pathogenic microorganisms, whereas leukocytospermia was reported in 2.3% of cases. Considering the overall sperm characteristics, results depicted that just 2.8% of patients recorded normal values for the combined sperm parameters analyzed, and that sperm quality was significantly damaged in men aged between 31 - 40 years. Binary logistic regression model revealed that sperm morphology ($p = 0.000$) was the major significant influential predictor of sperm motility. **Conclusion:** The findings of this study showed an alarming deterioration of the overall sperm quality particularly among young men, with a specific emphasis on sperm morphology and motility relationship. Further research in other localities with more diverse populations is needed to validate these findings. Also, in addition to clinical determinants, other potential risks factors such as socio-ethnological traits, lifestyle and occupational exposures, dietary habit, environmental, infectious and genetic factors that might impact male fertility should be explored.

Keywords

Male Reproductive Health, Infertility Prevalence, Asthenozoospermia, Teratozoospermia, Young Men, Cameroon

1. Introduction

Infertility is the failure to achieve a clinical pregnancy after 12 months or more of regular unprotected sexual intercourse [1]. Male factor is known so far for being responsible for about 30% of infertility cases and an additional 20% as a contributing cause [2]. Semen analysis is usually the first and often the only test used to evaluate the reproductive function of a male partner in couples seeking infertility counselling [3]. Semen analysis is therefore the corner stone of the evaluation of male fertility and the effect of any treatment intake. Semen parameters including semen volume, sperm concentration, total sperm count, sperm motility, total progressive motile sperm count (TPMSC), sperm morphology, and sperm culture are essential diagnostic tools for assessing the reproductive health and fertility status of men [4].

Despite the conflicting reports on trends of semen parameters from different parts of the globe, several epidemiological studies and the World Health Organization (WHO) manual for human semen assessment have recently reported an unrelenting decline in sperm parameters in the last few decades [5]-[9]. However, human sperm production is widely believed to be declining over time, though evidence from the scientific literature is less clear as far as semen disorder and fertility, *i.e.*, the capacity of poor quality spermatozoa to fertilize the oocyte, is con-

cerned [10]. According to recent studies [11]-[13], the global prevalence of male infertility has worsened significantly between 1990 and 2021 to surpass 56 million men affected worldwide in 2021, reflecting a substantial 76.9% increase since 1990, with projections indicating an upward trend for the next 15 years. This burden is not evenly distributed since the highest prevalence of male infertility is reported in developing countries globally, where values have often exceeded the global average. In contrast, China and the Russian Federation as well as the Eastern Europe and High-income Asia Pacific have experienced a decline in their disease burden in the recent decades [11]-[13]. Semen quality represents a compelling factor for fertility, and delineating the normal values has been proven difficult. While semen disorders may significantly impact a man's fertility and his ability to conceive naturally, patients with poor sperm quality can still father a child. Indeed, a conventional semen analysis cannot reliably predict the chance of pregnancy or accurately differentiate between fertile and infertile men, except in the most extreme cases [2] [6]. Semen analysis thus appears as the primary tool to assess the severity of infertility and estimate the effects and response of possible therapies. Therefore, an understanding of the clinical causes of male infertility is crucial in order to reduce incidences of infertility and improve the clinical management of human reproductive health.

Though infertility has significant negative social impacts on the lives of infertile couples in the developing world, it is still relatively neglected as an international health problem and a topic of social, scientific and epidemiological inquiries. In Africa moreover, the recognition of the male factor involvement in couple infertility is still difficult to acknowledge in many couples, and women are particularly blamed for the problem [14] [15]. Furthermore, accurate and easily comparable data on male infertility in Africa is still lacking, especially semen parameter patterns and epidemiological data on the associated factors. In recent times, there is dearth of information on trends of sperm parameters in Sub-Saharan Africa countries.

Although there are few and scarce data on male infertility in other Sub-Saharan Africa countries [5] [16]-[21], to the best of our knowledge, just a single study has focused primarily on sperm parameters of male infertility in West region of Cameroon [22]. The few available studies have so far solely addressed the issue of female infertility in Cameroon [14] [23]-[29]. Indeed, there is a lack of comprehensive studies and accurate statistics on the rates of male infertility in Cameroon. Moreover, none is known about the trends of sperm parameters across age groups, as well as the underlying causes and determinants of male infertility in Cameroon. The present study therefore aimed at determining the trends of sperm parameters and the overall sperm quality across age groups of men seeking for infertility treatment in Douala town. Douala is the economic capital and the most densely populated township in Cameroon with a cosmopolitan population estimated at 4.34 million inhabitants [30]. Additionally, this city is poorly urbanized and dwellings/industrial buildings are blended in the same place with consequently, severe prom-

iscuities and omnipresence of pollution sources [31]-[33]. Based on clinical records and field observation, we predicted that high rate of poor sperm quality will be reported and that young men will be more affected. We equally conjectured that semen culture will reveal a significantly high number of patients with sexually infectious diseases, particularly among young men.

2. Materials and Methods

2.1. Study Framework, Design and Participants

This is a retrospective cross-sectional study spanning from January 2019 to August 2024 and involving 2608 adult men aged at least 21 years in whom semen examination was performed. These patients have consulted gynaecologists, urologists, andrologists or general practitioners for couple infertility, in the reference hospitals of the city of Douala (Laquintinie Hospital and General Hospital), in a private Laboratory (Louis Pasteur Laboratory) and some private hospitals practicing medically assisted reproduction and *in vitro* fertilization (IVF) in Douala (Kouam Samuel Clinic and Uro-Gyn Clinic).

2.2. Data Collection Tools and Methods

For each medical record consulted, the variables assessed were patient's age (in years), ejaculate volume (ml), sperm count (million sperm cells/ml), one hour progressive motility (%), vitality (%), sperm normal form (%), sperm culture, and Leukocytospermia. Sperm analyses were performed following standard medical laboratory methods [4] [34]-[36], whereas the cut-off values used to classify sperm quality were determined according to WHO 5th edition [34]. In addition, the semen analysis methodology checklist developed by Björndahl *et al.* [36] were used to assess the compliance of laboratory practices with the WHO [34] standard methods. Therefore, the ejaculated sperms were obtained by masturbation into a sterile glass container after 3 - 5 days of sexual abstinence. The volume of the ejaculate was measured using a wide-bore volumetric pipette, whereas sperm counts were performed in a haemocytometer under contrast light microscope at 400x, after dilution at 1:20 with sodium bicarbonate and formalin solution, and 10 - 15 minutes of sedimentation. Sperm motility was assessed 30 - 60 minutes after collection using a phase contrast light microscope at 400x magnification, and results after one hour progressive motility were considered for this study. The sperm vitality was determined by supravital staining technique using 2% Eosin dye, under high magnification (1000x) bright light microscope. Concerning sperm culture, it was carried out on specific, selective and non-selective media to promote the growth of potential pathogenic microorganisms that might cause infection.

2.3. Data Analysis

Prior to statistical analysis, the normality of the distribution of all quantitative data was tested (Kolmogorov-Smirnov test) and since the normality and homo-

scedasticity were not satisfied, the non-parametric Kruskal-Wallis and multiple comparisons post hoc tests were subsequently applied to verify significant differences in sperm characteristics among the age groups. Chi-Square test of independence was applied to check for relationship between sperm characteristics and patients' age groups. The extent of the influence of sperm concentration, vitality, and morphology on sperm motility was determined using odds ratio (OR) testing. Furthermore, Discriminant Factor Analysis (DFA) based on Spearman canonical correlation, generalized quadratic distances and recursive algorithm was used to segregate age groups based on sperm quality. Cross-validation was used to evaluate the predictive performance of the DFA model, whereas the overall quality and the accuracy of the classification prediction for the samples of each age group were evaluated using Wilks' Lambda test. Afterward, we applied a binary logistic regression (BLR) model analysis to investigate the effect of sperm count, vitality and morphology on the likelihood of sperm motility. We implemented a step-by-step forward Wald method to enhance the explanatory model. For each case, statistical significance was assessed at $p < 0.05$. These analyses were performed using XLSTAT 2024 software packages.

2.4. Data Quality Assurance and Ethical Consideration

Table 1. Completeness rate (%) of the collected data for each variable included in the study.

Variables	Healthcare facilities					Total valid cases	Total missing value	Completeness rate of data (%)
	LPL (n = 1961)	DGH (n = 234)	DLH (n = 158)	KSC (n = 204)	UGC (n = 51)			
Age	1923	194	156	183	50	2506	102	96.09
Volume (ml)	1952	234	158	121	51	2516	92	96.47
Sperm count (x10 ⁶)	1957	233	156	203	51	2600	8	99.69
Motility (%)	1961	75	67	197	50	2350	258	90.11
Vitality (%)	1960	185	142	120	48	2455	153	94.13
Normal forms (%)	1812	234	149	172	46	2413	195	92.52
Sperm culture	1961	0	158	178	51	2348	260	90.03
Leukocytospermia	1961	234	158	0	2	2355	253	90.30

LPL: Louis Pasteur Laboratory; DGH: Douala General Hospital; DLH: Douala Laquintinie Hospital; KSC: Kouam Samuel Clinic; UGC: Uro-Gyn Clinic; n: total number of patients in each healthcare facility.

Only patients with medical results obtained from accredited laboratories and healthcare facilities were considered, for measurements of sperm parameters were performed by trained and qualified medical personnel using updated standard methods. During the retrieving process of medical booklets or records, only patients with not more than two missing data within the targeted variables were included, and only variables with a completeness rate greater than 90% were finally retained (**Table 1**). Out of the 2608 patients included in this study, the semen analysis of 1961 (*i.e.*, 75.19%) was performed at Louis Pasteur Laboratory (LPL)

in Douala. LPL is one of the most sophisticated medical analysis laboratory in Cameroon with an ISO 9001 vs. 2015 certification and a yearly quality management assurance audit. Ethical clearance (N° 4514CEI-UDo/08/2024/M) was obtained from the Institutional Ethics Committee for Research on Human Health of the Faculty of Science of the University of Douala. Before data collection, authorization was obtained from the General Manager of the targeted healthcare facilities. Patients' privacy and confidentiality were maintained.

3. Results and Discussion

3.1. Results

3.1.1. Semen Profile across Patient's Age Groups

Table 2. Sperm characteristics across patient's age groups (in year).

Sperm characteristics	[21 - 30]	[31 - 40]	[41 - 50]	>50	All patients	Chi-Square test
	n (%)	n (%)	n (%)	n (%)	n (%)	
Volume (ml) (n = 2434)						
≥1.5 ml	319 (13.1)	1100 (45.2)	491 (20.2)	147 (6)	2057 (84.5)	p = 0.000
<1.5 ml	41 (1.7)	159 (6.5)	119 (4.9)	58 (2.4)	377 (15.5)	
Concentration (x10⁶/ml) (n = 2498)						
Azoospermia	23 (0.9)	69 (2.8)	29 (1.2)	11 (0.4)	132 (5.3)	p = 0.166
Cryptozoospermia	75 (3)	222 (8.9)	105 (4.2)	36 (1.4)	438 (17.5)	
Severe Oligozoospermia	79 (3.2)	254 (10.2)	121 (4.8)	33 (1.3)	487 (19.5)	
Moderate Oligozoospermia	41 (1.7)	138 (5.5)	58 (2.3)	23 (0.9)	260 (10.4)	
Normal sperm count	144 (5.8)	598 (23.9)	322 (12.9)	117(4.7)	1181 (47.3)	
One hour progressive motility (%) (n = 2272)						
Asthenozoospermia	291 (12.8)	1083 (47.7)	535 (23.6)	185 (8.1)	2094 (92.2)	p = 0.041
Normal sperm motility	23 (1)	75 (3.3)	59 (2.6)	21 (0.9)	178 (7.8)	
Vitality (%) (n = 2378)						
Necrozoospermia	103 (4.3)	360 (15.2)	212 (8.9)	91 (3.8)	766 (32.2)	p = 0.000
Normal sperm vitality	243 (10.2)	879 (37)	383 (16.1)	107 (4.5)	1612 (67.8)	
Morphology (%) (n = 2319)						
Teratozoospermia	263 (11.4)	963 (41.5)	457 (19.7)	156 (6.7)	1839 (79.3)	p = 0.198
Normal sperm form	72 (3.1)	226 (9.8)	138 (5.9)	44 (1.9)	480 (20.7)	
OATS (n = 2156)	88 (4.08)	306 (14.19)	137 (6.35)	38 (1.76)	569 (26.39)	
OANS (n = 2203)	17 (0.77)	65 (2.95)	53 (2.41)	20 (0.91)	155 (7.04)	
Overall normal sperm (n=2040)	3 (0.15)	21 (1.03)	26 (1.27)	7 (0.34)	57 (2.79)	

n: number of patients; OATS: Oligoasthenoteratozoospermia; OANS: Oligoasthenonecrozoospermia.

The trends of sperm parameters across age groups are presented in **Table 2**. Re-

sults revealed that 84.5% of patients have a normal sperm volume (≥ 1.5 ml) whereas 15.5% registered low sperm volume, with the age group 31 - 40 years recording the highest number of patients (6.5%) with a sperm volume below normal value. Concerning sperm count, just 47.3% of men have a normal sperm concentration, against 52.7% of abnormal cases including Azoospermia (5.3%), Cryptozoospermia (17.5%), severe Oligozoospermia (19.5%), and moderate Oligozoospermia (10.4%). The highest number of men with abnormal sperm count was registered in age group 31 - 40 years, as well as 52.3% of the cases of Azoospermia were reported in this age group (69 patients out of 132). Results of sperm motility showed that 92.2% of semen analyzed fell under Asthenozoospermia, with the highest number of patients (47.7%) observed in age group 31 - 40 years. Of the 2378 semen analyzed for sperm vitality, 67.8% showed normal vitality while 32.2% fell under Necrozoospermia. With regards to the sperm morphology, results depicted that 79.3% of semen studied have abnormal form (Teratozoospermia) with the highest number of impaired sperm form (41.5%) recorded in age group 31 - 40 years. To assess the overall sperm quality, the proportions of patients with Oligoasthenoteratozoospermia (OATS) and Oligoasthenonecrozoospermia (OANS) were determined out of the number of individuals with complete values of sperm parameters. Results revealed that 26.39% of patients were OATS and 7.04% were OANS. The highest number of OATS (14.19%) and OANS (2.95%) patients was still observed in age group 31 - 40 years. Considering the overall sperm characteristics, just 2.79% of patients recorded normal values in all the five sperm parameters analyzed, with the lowest proportion of patients (0.15%) observed in the age group 21 - 30 years, followed by the age groups >50 years (0.34%), and 31 - 40 years (1.03%), respectively.

The Chi-Square test of independency revealed that patients' age was significantly ($p < 0.05$) associated with sperm volume, motility and vitality, and showed no significant relationship ($p > 0.05$) with sperm concentration and morphology (**Table 2**).

Discriminant Factor Analysis (DFA) was applied to segregate age groups based on sperm characteristics (**Figure 1**). Results revealed that the Wilks' Lambda test on generalized quadratic distances among age group of patients was highly significant ($p < 0.0001$) and the predictive reliability for the age groups 21 - 30 years, 31 - 40 years, 41 - 50 years and >50 years were 0, 0.96, 0.1 and 0, respectively. The factorial axes F1 and F2 explained 88.20% and 8.32% of the cumulative total variance, respectively. The age groups 21 - 30 years and 31 - 40 years were positively related to axis F1 (Barycenter = 0.21 and 0.12, respectively), whereas the age groups 41 - 50 years and >50 years were negatively associated with axis F1 (Barycenter = 3.26 and 2.42, respectively) (**Figure 1(A)**). The DFA clearly highlighted that patients between 31 - 40 years have the most impaired sperm quality. The main sperm parameters discriminating age groups 21 - 30 and 31 - 40 from 41 - 50 years and >50 years were Necrozoospermia, Teratozoospermia, Asthenozoospermia, normal sperm vitality, forms and motility (**Figure 1(B)**).

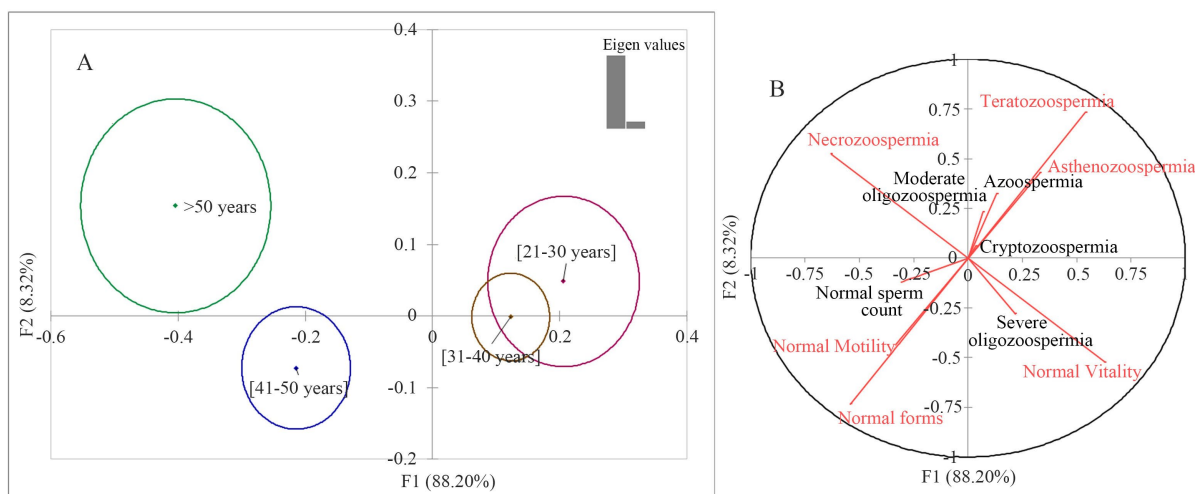


Figure 1. Centroid display of the factor analysis of sperm characteristics discriminating the patients’ age groups along the first two axes F1 and F2 (A), and correlations between sperm parameters and the corresponding axes (B). The six most influential sperm characteristics on the segregation of age groups are indicated in red.

3.1.2. Relationship between Sperm Parameters

The results of the odds ratio (OR) testing presented in **Table 3** revealed significant relationship between Asthenozoospermia and abnormal sperm concentration (OR = 3.445; p = 0.000), Necrozoospermia (OR = 2.778; p = 0.000), and Teratozoospermia (OR = 136.92; p = 0.000).

Table 3. Bivariate analysis examining the influence of sperm concentration, vitality, and morphology on sperm motility.

Sperm characteristics	Motility			Statistic metrics		
	Astheno-zoospermia	Normo-zoospermia	Total	Odds Ratio (OR)	95% CI (OR)	p-value
Concentration						
Abnormal sperm count	1185	53	1238	3.445	[2.488 - 4.771]	p = 0.000
Normal sperm count	954	147	1101			
Vitality						
Necrozoospermia	668	14	682	2.778	[1.566 - 4.927]	p = 0.000
Normal sperm vitality	1443	84	1527			
Morphology						
Teratozoospermia	1848	17	1865	136.92	[80.61 - 232.61]	p = 0.000
Normal sperm form	131	165	296			

OR: Odds Ratio; CI: Confidence Interval.

The explanatory variables of the ultimate binary logistic regression (BLR) model accounted for 59.50% of the total variation in the predictor variables, as noted by the Nagelkerke R Square. The Hosmer-Lemeshow goodness-of-fit test used to evaluate the prediction performance of the BLR model indicated a fairly-good model fit (p = 0.014) and showed a correct classification rate of 97.30% at the final step of the classification procedure. The Omnibus test of model coeffi-

cients indicated that the overall model was statistically significant ($p = 0.000$) and that all the predictor variables were significantly associated with the binary outcome (Abnormal motility, *i.e.*, Asthenozoospermia). Based on this model, we concluded that sperm morphology was the major significant influential predictor of sperm motility (Coeff. = 0.83; OR = 1.086; Wald = 222.81; $p = 0.000$), with an increase in Teratozoospermia associated with more than 108% increase in the odds of having Asthenozoospermia (**Table 4**).

Table 4. Final fitted binary logistic regression model for sperm motility, $n = 2015$ valid cases.

	Coeff.	Odds Ratio (OR)	Std. Error	Wald statistics	p-value	95% CI (OR)
Concentration	0.008	1.008	0.002	24.086	0.000	[1.005, 1.011]
Vitality	0.034	1.035	0.010	12.203	0.000	[1.015, 1.055]
Morphology	0.83	1.086	0.006	222.81	0.000	[1.075, 1.098]

3.1.3. Semen Culture and Leukocytospermia

Of the 2249 semen cultured to search for potential pathogenic microorganisms, 89.9% were tested negative while 10.1% were positive, with the age group 31 - 40 years recording the highest contamination rate (4.4%) (Supplemental **Table 2**, available online). Concerning white blood cells count, leukocytospermia was reported in 2.3% of men studied (**Table 5**). The Chi-Square test of independency revealed that patients' age was significantly ($p < 0.05$) associated with sperm culture and leukocytospermia (**Table 5**).

Table 5. Sperm culture and leukocytospermia across age groups (in year).

Sperm characteristics	[21 - 30]	[31 - 40]	[41 - 50]	>50	All patients	Chi-Square test
	n (%)	n (%)	n (%)	n (%)	n (%)	
Sperm culture (n = 2249)						
Negative	275 (12.2)	1073 (47.7)	497 (22.1)	177 (7.9)	2022 (89.9)	p = 0.009
Positive	35 (1.6)	98 (4.4)	77 (3.4)	17 (0.8)	227 (10.1)	
Leukocytospermia (n = 2275)						
No	343 (15.1)	1177(51.7)	526 (23.1)	176 (7.7)	2222 (97.7)	p = 0.008
Yes	17 (0.75)	25 (1.1)	7 (0.31)	4 (0.18)	53 (2.3)	

3.2. Discussion

In Cameroon, the prevalence of male infertility has so far been estimated based on few reports that predominantly rely on data collected from female partners of infertile couples. However, relevant data on semen parameters of infertile men in Douala and Cameroon at large is scarce. In this pioneer study, we investigated the trends of sperm parameters and determined the overall sperm quality of infertile men across age groups. This study highlighted the massive deterioration and declining trends of sperm parameters among men consulting for infertility in Douala, Cameroon. Not surprising, our results are in line with several other authors'

findings who reported a noticeable decline in sperm parameters in Africa [5] [16] [37], Europe [6] [38], America [9] [39], and Asia [7] [8] [40]-[42]. Our results revealed that sperm motility and morphology were the most impaired parameters with 92.2% and 79.3% cases of Asthenozoospermia and Teratozoospermia, respectively. In addition, sperm count was significantly low with 47.4% of Oligozoospermia and 5.3% of Azoospermia. These findings are similar to those of Ugwuja *et al.* [18] and Ibitoye *et al.* [20] who documented that Asthenozoospermia and Teratozoospermia were the major abnormal sperm parameters recorded in Nigeria. In the same vein Ikechebelu *et al.* [16] and Momo Tetsatsi *et al.* [22] revealed that Oligozoospermia and Asthenozoospermia were the most common etiological factors responsible for male infertility in South-eastern Nigeria and in West Cameroon, respectively. Similar declines in semen quality in Sub-Saharan Africa have been reported in Sudan [17], in South Africa and Nigeria [19], in Democratic Republic of Congo [21], and in some East and Southern Africa countries [43]. However, in the current study, the rates of deterioration of sperm parameters observed were incredibly high compared to those reported in the above mentioned studies in Sub-Saharan Africa. This findings highlight the urgent need for further in-depth research to explore the potential confounding factors. In this study, the BLR model showed that sperm morphology was the major significant influential predictor of sperm motility; and it is well known that sperm motility is considered as one of the strongest predictive marker of male fertility [19] [44] [45].

Moreover, this investigation revealed high rates of OATS (26.39%) and OANS (7.04%), and only 2.79% of patients scoring normal values in all the five sperm parameters analyzed (*i.e.*, 97.21% of spermogram were abnormal); with the 31 - 40 year age group being the most affected. Our results are in line with the findings by Huang *et al.* [11] which revealed that the prevalence and the years of life lived with disability related to male infertility peaked in the 30 - 34 year age group worldwide. Similar study conducted by Momo Tetsatsi *et al.* [22] in the West region of Cameroon revealed that 83.91% of patients had abnormal spermogram, but with men older than 50 years being the most affected. The significant impaired of sperm quality among young men as observed in this study is unprecedented and of great concern worldwide. Although the reasons behind these decreasing trends are complex, numerous insights indicate that environmental factors and lifestyle are important players [9] [46]. Our results align with those of Ugwuja *et al.* [18] who previously reported high prevalence of poor sperm quality in the age-group 31 - 40 years in Nigeria. Similar historical results have been documented by Van Waeleghem [47] in young healthy Belgian men aged between 20 and 40 years who presented themselves as candidate sperm donors. In the same vein, findings by Rahban *et al.* [48] revealed that the median sperm concentration measured in Swiss young men was among the lowest observed in Europe, and nearly 62% of men displayed suboptimal semen quality with sperm parameter values falling out of the WHO semen reference criteria [4]. Adolescence and emerging adulthood are specific periods in which men avoid seeking reproductive health care and take sexual and other health-related risks; they are also reluctant to admit sexual ill

health [43] [49] [50]. In line with our findings which revealed an alarmingly high prevalence of impaired sperm parameters, particularly among men aged 31 - 40 years, it is crucial to adjust the infertility screening protocols and prevention policies in Cameroon, which should be implemented with a focus on young men not older than 40 years. If decision-makers and the public are not aware of the scale of the problem, they will not be able to make it a priority to define specific and contextualized infertility screening and prevention policies for this target population.

Although the underlying causes of the deterioration of sperm quality observed in the current study were not investigated, there is a strong evidence to suggest that lifestyle factors such as alcohol [51], tobacco smoking [52], drugs abuse [53], high body mass index [54], high meat intake frequency [55], lack of sleep [56], intense physical activity [57], prolonged laptop and cell phone usage [58] [59] and other environmental factors contribute considerably to semen disorders and lead to male infertility. Moreover, promiscuity, pollution and poor sanitation and cleansing conditions in most of the neighborhoods in Douala would have exacerbated the impairment of sperm quality among the studied patients. Indeed, several studies have documented that water, air, and soil pollution, as well as electromagnetic fields and ionizing radiation are among the environmental factors for which the adverse effect on male fertility has been proven [9] [46] [60]. For instance, some studies have confirmed that air pollution affects sperm morphology and decreases sperm motility [61] [62].

Furthermore, semen culture in this study revealed that 10.1% of our patients' sperms were contaminated by pathogenic microorganisms, and that leukocytospermia was found in 2.3% of the cases analyzed. Though these infection rates are surprisingly low, it is well documented that sexually transmitted diseases and infections, particularly by *Chlamydia trachomatis* and *Ureaplasma* sp. which are widespread in our populations [18] are known to play an important role in the decrease of sperm motility. Ikechebelu *et al.* [16] revealed that genital tract infections resulting from sexual promiscuity and poorly treated sexual transmitted diseases were responsible for sperm abnormalities

4. Conclusion

Samples taken from male patients seeking fertility treatment in Douala displayed an alarming decline in sperm quality in terms of concentration, motility, vitality and morphology compared with most data from Sub-Saharan Africa. Overall, these findings revealed a high proportion of OATS among patients studied (more than 1/4) and a very low rate of total normal sperm quality (less than 3%), with significantly impaired sperm quality in men aged 31 to 40 years. One of the most challenging aspects of male infertility is its lack of visibility and the complex network of potential causes. This study suggests that the number of infertile males in Douala is grossly underestimated and that in-depth epidemiological studies are essential to determine the scale of the problem, to address the underlying causes to improve understanding of the downward trend in sperm quality, particularly

in young men. Although the underlying causes of these observed clinical determinants were not investigated, factors such as genetic makeup, socio-ethnological traits, lifestyle, dietary habits, infectious diseases, occupational exposures, and environmental conditions may have contributed to these outcomes. It is therefore crucial to analyze these confounding factors to accurately assess the observed semen trends and adapt diagnostic tools in order to improve the clinical management of the reproductive health and reduce incidences of male infertility. It is suggested that diagnosis at the first steps of suspicious couple infertility should involve both women and men because in our sociocultural and ethnological context, women are the first and most often the only ones to seek for medical care in case of couple infertility. There is an urgent need for public authorities and stakeholders to invest in the modernization of healthcare facilities and medical laboratories to improve the diagnosis and detection techniques of pathogens in semen. They should also invest in research and capacity-building initiatives to educate and raise awareness among young people about reproductive health and the risks associated with sexuality.

Acknowledgements

We are grateful to all the medical health practitioners of the various healthcare facilities studied, who assisted us in data collection.

Data availability

The data used in this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- [1] Zegers-Hochschild F., Adamson, G.D., de Mouzon, J., Ishihara, O., Mansour, R., Nygren, K., *et al.* (2009) The International Committee for Monitoring Assisted Reproductive Technology (ICMART) and the World Health Organization (WHO) Revised Glossary on ART Terminology, 2009. *Human Reproduction*, **24**, 2683-2687. <https://doi.org/10.1093/humrep/dep343>
- [2] Agarwal, A., Mulgund, A., Hamada, A. and Chyatte, M.R. (2015) A Unique View on Male Infertility around the Globe. *Reproductive Biology and Endocrinology*, **13**, Article No. 37. <https://doi.org/10.1186/s12958-015-0032-1>
- [3] Practice Committee of the American Society for Reproductive Medicine (2015) Diagnostic Evaluation of the Infertile Male: A Committee Opinion. *Fertility and Sterility*, **3**, 18-25. <https://doi.org/10.1016/j.fertnstert.2014.12.103>
- [4] World Health Organization (2021) WHO Laboratory Manual for the Examination and Processing of Human Semen. 6th Edition, WHO.
- [5] Legese, N., Tura, A.K., Roba, K.T. and Demeke, H. (2023) The Prevalence of Infertil-

- ity and Factors Associated with Infertility in Ethiopia: Analysis of Ethiopian Demographic and Health Survey (EDHS). *PLOS ONE*, **18**, e0291912. <https://doi.org/10.1371/journal.pone.0291912>
- [6] Levine, H., Jørgensen, N., Martino-Andrade, A., Mendiola, J., Weksler-Derri, D., Jolles, M., *et al.* (2022) Temporal Trends in Sperm Count: A Systematic Review and Meta-Regression Analysis of Samples Collected Globally in the 20th and 21st Centuries. *Human Reproduction Update*, **29**, 157-176. <https://doi.org/10.1093/humupd/dmac035>
- [7] Luo, X., Yin, C., Shi, Y., Du, C. and Pan, X. (2023) Global Trends in Semen Quality of Young Men: A Systematic Review and Regression Analysis. *Journal of Assisted Reproduction and Genetics*, **40**, 1807-1816. <https://doi.org/10.1007/s10815-023-02859-z>
- [8] Omolaoye, T.S., Lakshmanan, J., Aslam, I. and Du Plessis, S.S. (2024) A Retrospective Study Investigating Semen Parameter Profiles among Male Patients Attending a Fertility Center in the UAE: Insights from a Nationality Perspective. *Heliyon*, **10**, e40288. <https://doi.org/10.1016/j.heliyon.2024.e40288>
- [9] Sciorio, R., Tramontano, L., Adel, M. and Fleming, S. (2024) Decrease in Sperm Parameters in the 21st Century: Obesity, Lifestyle, or Environmental Factors? An Updated Narrative Review. *Journal of Personalized Medicine*, **14**, Article 198. <https://doi.org/10.3390/jpm14020198>
- [10] Auger, J., Eustache, F., Chevrier, C. and Jégou, B. (2022) Spatiotemporal Trends in Human Semen Quality. *Nature Reviews Urology*, **19**, 597-626. <https://doi.org/10.1038/s41585-022-00626-w>
- [11] Huang, B., Wang, Z., Kong, Y., Jin, M. and Ma, L. (2023) Global, Regional and National Burden of Male Infertility in 204 Countries and Territories between 1990 and 2019: An Analysis of Global Burden of Disease Study. *BMC Public Health*, **23**, Article No. 2195. <https://doi.org/10.1186/s12889-023-16793-3>
- [12] Xu, R., Wang, X., Lin, Q., Zhuang, Y., Zhou, Q., Xu, N., *et al.* (2025) Temporal Trends in the Burden of Disease for Male Infertility from 1990 to 2021 in the BRICS. *Risk Management and Healthcare Policy*, **18**, 1721-1733. <https://doi.org/10.2147/rmhp.s506211>
- [13] Shan, Z., Chen, S., Zhou, W., Yang, Y., Zhang, G. and Zhao, J. (2025) Analysis of the Burden of Disease for Male Infertility Globally and in China from 1990 to 2021. *Translational Andrology and Urology*, **14**, 1363-1378. <https://doi.org/10.21037/tau-2025-44>
- [14] Nana, P.N., Wandji, J.C., Fomulu, J.N., Mbu, R.E., Leke, R.J.I. and Woubinwou, M.J. (2011) Aspects Psycho-Sociaux chez Patients Infertiles à la Maternite Principale de l'Hopital Central de Yaoundé, Cameroun. *Clinics in Mother and Child Health*, **8**, 1-5. <https://doi.org/10.4303/cmch/c100601>
- [15] Anokye, R., Acheampong, E., Mprah, W.K., Ope, J.O. and Barivure, T.N. (2017) Psychosocial Effects of Infertility among Couples Attending St. Michael's Hospital, Jachie-Pramso in the Ashanti Region of Ghana. *BMC Research Notes*, **10**, Article No. 690. <https://doi.org/10.1186/s13104-017-3008-8>
- [16] Ikechebelu, J., Adinma, J., Orié, E. and Ikegwuonu, S. (2003) High Prevalence of Male Infertility in Southeastern Nigeria. *Journal of Obstetrics and Gynaecology*, **23**, 657-659. <https://doi.org/10.1080/01443610310001604475>
- [17] Elussein, E.A., Magid, Y.M., Omer, M.M. and Adam, I. (2008) Clinical Patterns and Major Causes of Infertility among Sudanese Couples. *Tropical Doctor*, **38**, 243-244. <https://doi.org/10.1258/td.2007.070125>

- [18] Ugwuja, E.I., Ugwu, N.C. and Ejikeme, B.N. (2008) Prevalence of Low Sperm Count and Abnormal Semen Parameters in Male Partners of Women Consulting at Infertility Clinic in Abakaliki, Nigeria. *African Journal of Reproductive Health*, **12**, 67-73. <https://www.ajol.info/index.php/ajrh/article/view/7955>
- [19] Akang, E.N., Opuwari, C.S., Enyioma-Alozie, S., Mounkala, L.W., Amatu, T.E., Wada, I., *et al.* (2023) Trends in Semen Parameters of Infertile Men in South Africa and Nigeria. *Scientific Reports*, **13**, Article No. 6819. <https://doi.org/10.1038/s41598-023-33648-4>
- [20] Ibitoye, B.O., Fasasi, A.O., Imosemi, I.O., Alabi, O., Olaniyan, O.T., Ibitoye, F.O., *et al.* (2023) The Spermogram and Correlation of Seminal Fluid Parameters in Patient Attending Fertility Centre in Lagos, South West Nigeria. *Morphologie*, **107**, Article ID: 100606. <https://doi.org/10.1016/j.morpho.2023.05.004>
- [21] Mukuku, O., Mwamba, J.J.K., Kasongo, K., Tamubango, H.K., Kibwe, C.M., Tshikala, I.N., *et al.* (2023) Profil épidémiologique et séminal de l'homme consultant pour désir de procréation: État des lieux à Lubumbashi, en République Démocratique du Congo. *The Pan African Medical Journal*, **45**, Article 177. <https://doi.org/10.11604/pamj.2023.45.177.36977>
- [22] Césaire Momo Tetsatsi, A., Alumeti Munyali, D., Romeo Bonsou Fozin, G., Ngadjui, E., Wankeu-Nya, M. and Watcho, P. (2020) Semen Quality among Men Attending Urology Services in the Dschang Health District, West Cameroon: A Retrospective Study on 379 Cases. *International Journal of Reproductive BioMedicine (IJRM)*, **18**, 121-128. <https://doi.org/10.18502/ijrm.v18i2.6419>
- [23] Belley Priso, E., Nguéfac, C.T., Nguemgne, C., Njamen, T.N., Taila, W. and Banag, E. (2015) L'infertilité féminine à l'Hôpital Général de Douala: Aspects épidémiologiques et radiologiques (à propos de 658 cas). *Journal Africain de l'Imagerie Médicale*, **2**, 16-23. <https://pesquisa.bvsalud.org/portal/resource/pt/afr-198224>
- [24] Kasia, J.M., Belinga, E., Noa Ndoua, C.C., Bella, A., Voundi Voundi, E., Metogo Ntsama, J. and Toukam, M. (2019) Facteurs prédictifs de grossesse chez les femmes âgées de plus de 38 Ans en Assistance Médicale à la Procréation au Centre Hospitalier de Recherche et d'Application en Chirurgie Endoscopique et Reproduction Humaine. *Health Sciences and Disease*, **21**, 11-14.
- [25] Kasia, J.M., Ngowa, J.D.K., Mimboe, Y.S., Toukam, M., Ngassam, A., Noa Ndoua, C.C., Belinga, E. and Medou, A. (2016) Laparoscopic Fimbrioplasty and Neosalpingostomy in Female Infertility: A Review of 402 Cases at the Gynecological Endoscopic Surgery and Human Reproductive Teaching Hospital in Yaounde-Cameroon. *Journal of Reproduction and Infertility*, **17**, 104-109. <https://pubmed.ncbi.nlm.nih.gov/27141465/>
- [26] Neossi, G.M., Tiodjio, K.S., Alapha, Z.F. and Gonsu, F.J. (2028) Profil épidémiologique, échographique et hystérosalpingographique de l'infertilité féminine à l'Hôpital Régional de Ngaoundéré. *Journal Africain d'Imagerie Médicale*, **10**, 185-192. <http://www.jaim-online.net>
- [27] Obinchemti Egbe, T., Ngo Mbaki, C., Tendongfor, N., Temfack, E. and Belley-Priso, E. (2020) Infertility and Associated Factors in Three Hospitals in Douala, Cameroon: A Cross-Sectional Study. *African Health Sciences*, **20**, 1985-95. <https://doi.org/10.4314/ahs.v20i4.57>
- [28] Egbe, T.O., Nana-Njamen, T., Elong, F., Tchounzou, R., Simo, A.G., Nzeuga, G.P., *et al.* (2020) Risk Factors of Tubal Infertility in a Tertiary Hospital in a Low-Resource Setting: A Case-Control Study. *Fertility Research and Practice*, **6**, Article No. 3.

- <https://doi.org/10.1186/s40738-020-00073-4>
- [29] Voundi-Voundi, E., Toukam, M., Noa Ndoua, C., Nguefack-Tsague, G., Belinga, E., Ngono, V., Nyada, S., Kasia, B., Mbacham, S., Nyimbe Mviena, L., Sahmo, S.S. and Kasia, J.M. (2024) Prevalence and Associated Factors of Female Infertility at the Hospital Centre for Endoscopic Surgery and Human Reproductive Research and Application, Yaounde, Cameroon. *Health Sciences and Disease*, **25**, 6-11.
- [30] Population Stat (2025) Population of Douala, Cameroon (Live). <https://populationstat.com/search/>
- [31] Roger, F., Benjamin, N.N., Ghislain, T.Y.J. and Emmanuel, E.G. (2011) Relationship between Climate and Groundwater Recharge in the Besseke Watershed (Douala—Cameroon). *Journal of Water Resource and Protection*, **3**, 607-619. <https://doi.org/10.4236/jwarp.2011.38070>
- [32] Tchakonté, S., Ajeegah, G.A., Camara, A.I., Diomandé, D., Nyamsi Tchatcho, N.L. and Ngassam, P. (2015) Impact of Urbanization on Aquatic Insect Assemblages in the Coastal Zone of Cameroon: The Use of Biotraits and Indicator Taxa to Assess Environmental Pollution. *Hydrobiologia*, **755**, 123-144. <https://doi.org/10.1007/s10750-015-2221-5>
- [33] Tchakonte, S., Nana, P., Tamsa, A.A., Tchatcho, N.L.N., Koji, E., Onana, F.M., *et al.* (2023) Using Machine Learning Models to Assess the Population Dynamic of the Freshwater Invasive Snail *Physa Acuta* Draparnaud, 1805 (Gastropoda: Physidae) in a Tropical Urban Polluted Streams-system. *Limnologia*, **99**, Article ID: 126049. <https://doi.org/10.1016/j.limno.2022.126049>
- [34] World Health Organization (2010) WHO Laboratory Manual for the Examination and Processing of Human Semen. 5th Edition, WHO.
- [35] International Organization for Standardization (2021) ISO 23162:2021 Basic Semen Examination—Specification and Test Methods. ISO.
- [36] Björndahl, L., Barratt, C.L.R., Mortimer, D., Agarwal, A., Aitken, R.J., Alvarez, J.G., *et al.* (2022) Standards in Semen Examination: Publishing Reproducible and Reliable Data Based on High-Quality Methodology. *Human Reproduction*, **37**, 2497-2502. <https://doi.org/10.1093/humrep/deac189>
- [37] Archary, P., Potgieter, L., Elgindy, E., Adageba, R.K., Mboloko, J., Iketubosin, F., *et al.* (2023) Assisted Reproductive Technologies in Africa: The African Network and Registry for ART, 2018 and 2019. *Reproductive BioMedicine Online*, **46**, 835-845. <https://doi.org/10.1016/j.rbmo.2023.01.014>
- [38] Sengupta, P., Borges, E., Dutta, S. and Krajewska-Kulak, E. (2017) Decline in Sperm Count in European Men during the Past 50 Years. *Human & Experimental Toxicology*, **37**, 247-255. <https://doi.org/10.1177/0960327117703690>
- [39] Centola, G.M., Blanchard, A., Demick, J., Li, S. and Eisenberg, M.L. (2016) Decline in Sperm Count and Motility in Young Adult Men from 2003 to 2013: Observations from a U.S. Sperm Bank. *Andrology*, **4**, 270-276. <https://doi.org/10.1111/andr.12149>
- [40] Elbardisi, H., Majzoub, A., Al Said, S., Al Rumaihi, K., El Ansari, W., Alattar, A., *et al.* (2018) Geographical Differences in Semen Characteristics of 13 892 Infertile Men. *Arab Journal of Urology*, **16**, 3-9. <https://doi.org/10.1016/j.aju.2017.11.018>
- [41] Palani, A., Sengupta, P., Agarwal, A. and Henkel, R. (2020) Geographical Differences in Semen Characteristics: Comparing Semen Parameters of Infertile Men of the United States and Iraq. *Andrologia*, **52**, e13519. <https://doi.org/10.1111/and.13519>
- [42] Qiao, J., Wang, Y., Li, X., Jiang, F., Zhang, Y., Ma, J., *et al.* (2021) A Lancet Commission on 70 Years of Women's Reproductive, Maternal, Newborn, Child, and Adoles-

- cent Health in China. *The Lancet*, **397**, 2497-2536.
[https://doi.org/10.1016/s0140-6736\(20\)32708-2](https://doi.org/10.1016/s0140-6736(20)32708-2)
- [43] Aantjes, C.J. and Govender, K. (2024) Are We Getting Any Closer to Including Men and Boys in Sexual and Reproductive Health? A Multi-Country Policy Analysis on Guidance to Action in East and Southern Africa. *International Journal of Sexual Health*, **36**, 464-483. <https://doi.org/10.1080/19317611.2024.2353624>
- [44] Guzick, D.S., Overstreet, J.W., Factor-Litvak, P., Brazil, C.K., Nakajima, S.T., Coutifaris, C., *et al.* (2001) Sperm Morphology, Motility, and Concentration in Fertile and Infertile Men. *New England Journal of Medicine*, **345**, 1388-1393.
<https://doi.org/10.1056/nejmoa003005>
- [45] Keihani, S., Verrilli, L.E., Zhang, C., Presson, A.P., Hanson, H.A., Pastuszak, A.W., *et al.* (2021) Semen Parameter Thresholds and Time-To-Conception in Subfertile Couples: How High Is High Enough? *Human Reproduction*, **36**, 2121-2133.
<https://doi.org/10.1093/humrep/deab133>
- [46] Wdowiak, N., Wójtowicz, K., Wdowiak-Filip, A., Pucek, W., Wróbel, A., Wróbel, J., *et al.* (2024) Environmental Factors as the Main Hormonal Disruptors of Male Fertility. *Journal of Clinical Medicine*, **13**, Article 1986.
<https://doi.org/10.3390/jcm13071986>
- [47] Van Waeleghem, K., De Clercq, N., Vermeulen, L., Schoonjans, F. and Comhaire, F. (1996) Deterioration of Sperm Quality in Young Healthy Belgian Men. *Human Reproduction*, **11**, 325-329. <https://doi.org/10.1093/humrep/11.2.325>
- [48] Rahban, R., Priskorn, L., Senn, A., Stettler, E., Galli, F., Vargas, J., *et al.* (2019) Semen Quality of Young Men in Switzerland: A Nationwide Cross-Sectional Population-based Study. *Andrology*, **7**, 818-826. <https://doi.org/10.1111/andr.12645>
- [49] Rovito, M.J., Leonard, B., Llamas, R., Leone, J.E., Talton, W., Fadich, A., *et al.* (2017) A Call for Gender-Inclusive Global Health Strategies. *American Journal of Men's Health*, **11**, 1804-1808. <https://doi.org/10.1177/1557988317723424>
- [50] Heise, L., Greene, M.E., Opper, N., Stavropoulou, M., Harper, C., Nascimento, M., *et al.* (2019) Gender Inequality and Restrictive Gender Norms: Framing the Challenges to Health. *The Lancet*, **393**, 2440-2454.
[https://doi.org/10.1016/s0140-6736\(19\)30652-x](https://doi.org/10.1016/s0140-6736(19)30652-x)
- [51] Ricci, E., Noli, S., Ferrari, S., La Vecchia, I., Cipriani, S., De Cosmi, V., *et al.* (2018) Alcohol Intake and Semen Variables: Cross-Sectional Analysis of a Prospective Cohort Study of Men Referring to an Italian Fertility Clinic. *Andrology*, **6**, 690-696.
<https://doi.org/10.1111/andr.12521>
- [52] Mostafa, R.M., Nasrallah, Y.S., Hassan, M.M., Farrag, A.F., Majzoub, A. and Agarwal, A. (2017) The Effect of Cigarette Smoking on Human Seminal Parameters, Sperm Chromatin Structure and Condensation. *Andrologia*, **50**, e12910.
<https://doi.org/10.1111/and.12910>
- [53] du Plessis, S.S., Agarwal, A. and Syriac, A. (2015) Marijuana, Phytocannabinoids, the Endocannabinoid System, and Male Fertility. *Journal of Assisted Reproduction and Genetics*, **32**, 1575-1588. <https://doi.org/10.1007/s10815-015-0553-8>
- [54] Belloc, S., Cohen-Bacrie, M., Amar, E., Izard, V., Benkhalifa, M., Dalléac, A., *et al.* (2014) High Body Mass Index Has a Deleterious Effect on Semen Parameters Except Morphology: Results from a Large Cohort Study. *Fertility and Sterility*, **102**, 1268-1273. <https://doi.org/10.1016/j.fertnstert.2014.07.1212>
- [55] Maldonado-Cárceles, A.B., Mínguez-Alarcón, L., Mendiola, J., Vioque, J., Jørgensen, N., Árense-Gonzalo, J.J., *et al.* (2018) Meat Intake in Relation to Semen Quality and

- Reproductive Hormone Levels among Young Men in Spain. *British Journal of Nutrition*, **121**, 451-460. <https://doi.org/10.1017/s0007114518003458>
- [56] Liu, M., Liu, L., Chen, L., Yin, X., Liu, H., Zhang, Y., *et al.* (2017) Sleep Deprivation and Late Bedtime Impair Sperm Health through Increasing Antisperm Antibody Production: A Prospective Study of 981 Healthy Men. *Medical Science Monitor*, **23**, 1842-1848. <https://doi.org/10.12659/msm.900101>
- [57] Józków, P. and Rossato, M. (2016) The Impact of Intense Exercise on Semen Quality. *American Journal of Men's Health*, **11**, 654-662. <https://doi.org/10.1177/1557988316669045>
- [58] Avendaño, C., Mata, A., Sanchez Sarmiento, C.A. and Doncel, G.F. (2012) Use of Laptop Computers Connected to Internet through Wi-Fi Decreases Human Sperm Motility and Increases Sperm DNA Fragmentation. *Fertility and Sterility*, **97**, 39-45. <https://doi.org/10.1016/j.fertnstert.2011.10.012>
- [59] Gorpichenko, I., Nikitin, O., Banyra, O. and Shulyak, A. (2014) The Influence of Direct Mobile Phone Radiation on Sperm Quality. *Central European Journal of Urology*, **67**, 65-71. <https://doi.org/10.5173/cej.2014.01.art14>
- [60] Mann, U., Shiff, B. and Patel, P. (2020) Reasons for Worldwide Decline in Male Fertility. *Current Opinion in Urology*, **30**, 296-301. <https://doi.org/10.1097/mou.0000000000000745>
- [61] Wdowiak, A., Wdowiak, E., Bień, A., Bojar, I., Iwanowicz-Palus, G. and Raczkiwicz, D. (2019) Air Pollution and Semen Parameters in Men Seeking Fertility Treatment for the First Time. *International Journal of Occupational Medicine and Environmental Health*, **32**, 387-399. <https://doi.org/10.13075/ijomeh.1896.01355>
- [62] Liu, J., Dai, Y., Li, R., Yuan, J., Wang, Q. and Wang, L. (2023) Does Air Pollution Exposure Affect Semen Quality? Evidence from a Systematic Review and Meta-Analysis of 93,996 Chinese Men. *Frontiers in Public Health*, **11**, Article 1219340. <https://doi.org/10.3389/fpubh.2023.1219340>