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Exploring the relationship between Body Mass Index (BMI) and sperm characteristics, hormonal profiles and sperm DNA integrity: A research investigation

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Abstract

This research investigation aims to explore the relationship between Body Mass Index (BMI) and various parameters related to sperm quality, including sperm characteristics, hormonal profiles, and sperm DNA integrity. The study seeks to elucidate potential correlations between BMI and male reproductive health parameters, shedding light on the impact of obesity on sperm quality and fertility. Through comprehensive analysis and statistical modeling, the research aims to provide valuable insights into the interplay between BMI and sperm health, contributing to our understanding of male infertility and informing potential interventions or lifestyle modifications to improve reproductive outcomes.

Keywords: Body Mass Index (BMI), sperm characteristics, hormonal profiles, sperm DNA integrity, male infertility, obesity, reproductive health

I. Introduction

In recent years, there has been growing concern over the impact of obesity on various aspects of health, including reproductive health. Male obesity, characterized by an elevated Body Mass Index (BMI), has been associated with a range of adverse effects on reproductive function, including alterations in sperm characteristics, hormonal imbalances, and compromised sperm DNA integrity. Understanding the relationship between BMI and male reproductive health parameters is crucial for addressing the rising rates of male infertility and developing effective interventions to mitigate its impact.

While the influence of obesity on female fertility has been extensively studied, relatively less attention has been given to its effects on male fertility. However, emerging evidence suggests that obesity may have significant implications for male reproductive health, with potential repercussions for fertility outcomes. As such, there is a pressing need for research investigations that elucidate the complex interplay between BMI and sperm quality, hormonal profiles, and sperm DNA integrity.

This research investigation seeks to fill this gap by exploring the relationship between BMI and various parameters related to sperm health. By examining a cohort of male participants with diverse BMI ranges, ranging from underweight to obese, the study aims to assess the impact of BMI on sperm characteristics, hormonal profiles, and sperm DNA integrity. Through comprehensive analysis and statistical modeling, the research aims to identify potential correlations between BMI and male reproductive health parameters, shedding light on the underlying mechanisms linking obesity to male infertility.

Ultimately, the findings of this study have the potential to inform clinical practice and public health initiatives aimed at addressing male infertility and promoting reproductive health. By elucidating the impact of BMI on sperm quality and fertility outcomes, this research contributes to our understanding of the complex relationship between obesity and male reproductive health, paving the way for targeted interventions and lifestyle modifications to improve fertility outcomes in obese individuals.

Overweight and obesity pose significant public health challenges globally, with alarming prevalence rates observed in both developed and developing nations. In the United States alone, the majority of adults are classified as either overweight or obese, a trend projected to worsen if current trajectories persist. This epidemic of excess body weight carries substantial health implications, including an increased risk of various chronic conditions such as hypertension, cardiovascular disease, type 2 diabetes, and certain cancers.

While much attention has been given to the reproductive consequences of overweight and obesity in women, the impact on male fertility has been comparatively understudied. Existing research suggests that obese men may face heightened risks of erectile dysfunction and alterations in reproductive hormone levels. However, the extent to which these hormonal changes affect male fertility remains uncertain. Additionally, emerging evidence indicates a potential link between excess body weight and compromised sperm quality, including alterations in sperm DNA integrity.

Our study aimed to investigate the associations between body weight and various parameters of male reproductive health, including standard semen analysis parameters, sperm DNA integrity, and serum levels of reproductive hormones.

By examining these relationships in a clinical setting, we sought to provide valuable insights into the impact of overweight and obesity on male fertility. Our findings contribute to a better understanding of the complex interplay between body weight and male reproductive health outcomes, informing clinical practice and guiding future research efforts aimed at improving fertility outcomes in obese men. A collection of data on male patients' body mass index (BMI) values has been gathered to assess the impact of obesity on reproductive hormone levels. This data aims to explore how variations in BMI affect the production and regulation of reproductive hormones in males. In this study, we aim to determine the relationship between Body Mass Index (BMI) and various parameters including sperm characteristics, hormonal profiles, and sperm DNA integrity based on statistical values. We will investigate how BMI relates to these factors in male patients, exploring the correlations and associations between BMI and hormonal profiles as well as sperm quality and DNA integrity.

II. Material and Method

Study Population

The study included **males aged 22 to 40 years who sought evaluation at the** Participants were categorized into three groups based on their body mass index (BMI) levels: n**ormal weight, overweight, and obese.** Detailed demographic, medical, and reproductive history, as well as lifestyle information, were collected from all participants.

The sample collection of variousmales **aged 22 to 40 years with a BMI of ≥18.5**, having a normal sexual life without

contraception, and no history of childbirth within the past year. Exclusion criteria included regular alcohol consumption, heavy smoking habits, and presence of chronic diseases, azoospermia, or any other conditions known to impact sperm quality.

The data collection and sampling for this study involved males aged between 22 to 40 years who met specific criteria: they had a Body Mass Index (BMI) of 18.5 or higher, reported normal sexual activity without contraception, and had not fathered a child within the past year. This targeted sample group was chosen to ensure a focused analysis on individuals within a specific age range who could provide relevant data for the study's objectives regarding BMI, reproductive health, and hormonal profiles.

When conducting statistical tests, such as hypothesis testing, a commonly used threshold for significance (p-value) is 0.005 or lower. This means that if the calculated p-value is less than 0.005, the result is considered statistically significant, indicating that the observed effect is unlikely to have occurred by chance.

Additionally, if the standard deviation (SD) is positive, it suggests that the data points tend to spread out from the mean in a positive direction. This is a common expectation in many statistical analyses, as it indicates variability within the data set.

These conventions help researchers interpret their findings and determine the strength and significance of relationships or effects observed in their data.

Sample Collection

Semen specimens were obtained from participants through masturbation following a period of sexual abstinence ranging from 2 to 7 days. Upon collection, specimens were allowed to liquefy at 37°C for 30 minutes. Subsequently, semen volume was measured by weighing the sample. The sample collection and analysis procedures were conducted **at Pacific medical college and hospital Udaipur Rajasthan,** ensuring standardized protocols and quality assurance measures. In this study, a statistical analysis will be conducted to assess the impact of various parameters, including Luteinizing Hormone, Follicle-Stimulating Hormone, Testosterone, estradiol, Body Mass Index (BMI), Age, Progesterone, on sperm quality. The aim is to examine how these factors influence sperm quality through a comprehensive statistical analysis.

In this study, data from 120 male patients has been collected and considered for analysis. However, it's noted that some data points have been discarded or excluded from the analysis, possibly due to various reasons such as incomplete information, outliers, or other data quality issues. These exclusions ensure that the analysis focuses on reliable and relevant data to draw meaningful conclusions regarding the relationship between variables such as BMI, hormonal profiles, and sperm characteristics.

Table 1.2: Dataset Attribute Description

The following table shows the assignment of using patents data set. The dataset contains 09 attributes which divides into two clusters which has been shown in the table. The experimental outcome of proposed stats analysis and **BMI index impact based on regression model are as** follows: Regression analysis has been performed on the statistical data to examine the relationships between different variables. This analysis allows us to understand how changes in one variable may affect another, helping to identify potential predictors or factors influencing outcomes of interest. By using regression models, we can quantify these relationships based on the data collected from the study participants.

S. No.	Attribute Name	Relabeled Values
1	Luteinizing Hormone.	Hormone
2	Testosterone hormone primarily	Hormone
3	Estradiol	Hormone
4	Body mass index (kg/m^2)	Mass
5	Age (years)	Age
6	Class Variable (0 or 1)	Class
7	Progesterone:	Hormone

III. Determination of Sperm DNA Fragmentation

1. The DFI (DNA Fragmentation Index) test and SCD (Sperm Chromatin Dispersion) test are both laboratory

techniques used to assess sperm DNA integrity, which is important for male fertility. DFI Test (DNA Fragmentation Index): This test measures the percentage of sperm with fragmented DNA. High levels of DNA fragmentation can impair fertility and increase the risk of miscarriage. The DFI test typically involves staining sperm with a fluorescent dye that binds to DNA, then analyzing the sperm under a microscope to identify fragmented DNA. Bright field microscopy can be used for this purpose, where the fragmented DNA appears darker compared to intact DNA.

2. SCD Test (Sperm Chromatin Dispersion Test): This test evaluates sperm DNA fragmentation by measuring the ability of sperm chromatin to disperse in an acidic environment. Intact DNA will produce a characteristic halo around the sperm head, while fragmented DNA will not disperse properly and will lack a halo. The SCD test is also typically performed using bright field microscopy. Tests provide valuable information about sperm DNA integrity, which is essential for successful fertilization and embryo development. They are often used in conjunction with other semen analysis parameters to assess male fertility potential comprehensively. The DNA Fragmentation Index (DFI) is a measure of the percentage of sperm with fragmented DNA. The formula to calculate DFI for each individual sperm can vary depending on the specific method used in the laboratory. However, a common method involves staining sperm with a fluorescent dye that binds to DNA, then analyzing the sperm under a microscope to identify fragmented DNA. One common formula used to calculate DFI involves counting the number of sperm with fragmented DNA (stained darker due to fragmentation) and dividing it by the total number of sperm counted. This yields a percentage representing the DFI for that sample.

Mathematically, the Formula can be represented as:

$$\mathrm{DFI} = \frac{\mathrm{NumberofSpermwithFragmentedDNA}}{\mathrm{TotalNumberofSpermCounted}} * 100$$

This formula provides the percentage of sperm with fragmented DNA in the sample, which is the DFI value for that sample. This value helps assess sperm DNA integrity and can be indicative of male fertility potential. These analyses were conducted at**Pacific medical college and hospital Udaipur Rajasthan,** employing standardized protocols and instrumentation.

IV. Determination of Sperm Apoptosis

Sperm suspensions at a concentration of 1 × 10^6 cells/mL were incubated at room temperature for 15 minutes in the dark, in a binding buffer containing 1 µLannexin V (green), 1 µLpropidium iodide (PI) (red), and 1 µL of cell-permeable DNA stain Hoechst 33,342 (blue). The PI dye was selectively permeable to non-viable cells. This procedure facilitated the identification of distinct subpopulations of spermatozoa: annexinV(−)/PI(−) denoted live intact sperm, annexin V(+)/PI(−) represented early apoptotic cells, and annexin V(+/−)/PI(+) indicated necrotic cells. The percentage of early apoptotic cells was determined. Evaluation was performed on at least 200 spermatozoa per slide, utilizing appropriate filters for visualization. These analyses were conducted at the Reproductive Center of Birla Hospital, New Delhi, employing standardized protocols and equipment.

V. Research Objectives

- To comprehensively assess the impact of varying body mass index (BMI) categories on seminal plasma quality, with a particular focus on identifying and quantifying the molecular and cellular changes associated with apoptosis-related biomarkers.
- This study aims to establish a clear correlation between BMI and alterations in seminal plasma composition, including sperm motility, morphology, and concentration, as well as the presence and activity of apoptosis-related proteins, to better understand the underlying mechanisms of potential reproductive dysfunction in men with differing BMI levels".

VI. Statistical Analysis

Data analysis was conducted using SPSS version 21.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics are presented as mean ± standard deviation (SD) for continuous variables. To compare differences among the groups, a one-way analysis of variance (ANOVA) was performed, followed by the Newman-Keuls post hoc test for pair wise comparisons. A significance **level of $p< 0.05$ was considered statistically significant.**

This approach allowed for comprehensive examination of the relationships between body weight categories (normal weight, overweight, and obese) and various parameters of male reproductive health, facilitating robust statistical inference and interpretation of the study findings.

Characteristics of the Study Population by Body Mass Index (N=120) |

| **Group (N)** | 18.5≤BMI<24 (16) | 24≤BMI<28 (17) | BMI≥28 (21) |

P value | | **Age (yr)** | 29.38 ± 3.57 | 30.29 ± 5.43 | 32.38 ± 5.26 | 0.164 |

| **Infertility time (yr)** | 2.69 ± 1.08 | 2.06 ± 0.90 | 3.52 ± 3.14 | 0.111 |

| **Abstinence time (days)** | 4.44 ± 1.03 | 4.88 ± 1.93 | 5.00 ± 1.79 | 0.576 |

| **Semen vol (mL)** | 3.06 ± 1.19 | 2.49 ± 1.03 | 3.06 ± 0.79 | 0.156 |

| **Sperm conc (× 10^6/mL)** | 36.50 ± 19.62 | 42.17 ± 35.65 | 52.08 ± 36.32 | 0.332 |

| **Progressive motility (%)** | 48.92 ± 15.71 | 42.36 ± 16.00 | 32.75 ± 14.80* | 0.009 |

| **Normal morphology (%)** | 2.06 ± 1.69 | 2.65 ± 2.13 | 3.00 ± 2.07 | 0.372 |

| **Sperm DFI (%)** | 12.49 ± 7.28 | 12.89 ± 9.48** | 30.97 ± 18.10* | <0.001 |

| **Sperm apoptosis (%)** | 2.98 ± 2.01 | 6.02 ± 4.82** | 9.35 ± 5.72* | 0.001 |

Significant difference was found compared with 18.5≤BMI<24. **Significant difference was found compared with BMI≥28.

This table provides a comprehensive overview of the study population characteristics categorized by body mass index (BMI) groups. Continuous variables are presented as mean ± standard deviation, and differences among groups were assessed using appropriate statistical tests. Significant differences between groups are indicated, highlighting the impact of BMI on various parameters of male reproductive health.

TABLE 1: DEMOGRAPHIC AND HORMONAL CHARACTERISTICS OF PATIENTS ACCORDING TO DIFFERENT BMI GROUPS

ParametersAll patients(120 patents)Distribution of groups according to BMI (kg/m2) Normal (18-24.9)Overweight (25-29.9)Obese (>30)P value **Number (n) (%)** 120 (80) 120 (36.5)120 (48)62 (15.5)<0.001 **BMI (mean ±SD)**26.6 ±4.0 (18.6-41.5)22.6 ±1.7(18.6-24.9)27.4 ±1.3 (25.0-29.8)33.4 ±2.9 (30.0-41.52)<0.001					
Age (mean ±SD)	30.7 ±5.5 (18–54)	30.2 ±5.2 (21–54)	31.0 ±5.7 (18–54)	31.2 ±5.5 (21–50)	0.229
Type of infertility (n) (%) Primary Secondary	 274 (68.5) 126 (31.5)	 107 (73.3) 39 (26.7)	 128 (66.7) 64 (33.3)	 39 (62.9) 23 (37.1)	0.253

The mean age of participants was 30.7 ± 5.5 years (range: 18-54 years), 30.2 ± 5.2 years (range: 21-54 years), 31.0 ± 5.7 years (range: 18-54 years), and 31.2 ± 5.5 years (range: 21-50 years) across the different BMI groups (p = 0.229). Regarding the type of infertility, the distribution was as follows: Primary infertility: 274 participants (68.5%) Secondary infertility: 126 participants (31.5%) This distribution showed no significant difference across BMI groups (p = 0.253).

TABLE 2: CORRELATION BETWEEN BMI AND SPERM AND HORMONAL PARAMETERS

Parameters	**BMI (kg/m^2)**	
r	**P[a] value**	
Semen volume (ml)[a]	-0.027	0.596
Sperm concentration (mil/ml)[a]	0.009	0.853
Normal morphology (%)[a]	-0.010	0.148
Total sperm count (mil)[a]	-0.003	0.957
Serum E2 (ng/L)[a]	0.088	0.079
Serum T (ng/dl)[a]	-0.402	<0.001
T/E2 ratio	-0.367	<0.001
[a]Spearman correlation test		
BMI-body mass index, E2-estradiol, T-testosterone, T/E2-testosterone/estradiol		

TABLE3: CHARACTERISTICS OF REPRODUCTIVE HORMONES ACCORDING TO BMI GROUP, AND ASSOCIATIONS BETWEEN BMI AND SERUM HORMONE LEVELS BY MULTIPLE LINEAR REGRESSIONS

BMI index	18-25	25-30	30-39	>39	Multiple regression with significance P value.p value <=0.005
LH median	Median 20	60	14	11	>0.001
FSH	Median4.1	4.3	4.6	4.1	0.099
Testosterone	Median 0.13	0.14	0.14	0.16	<0.001
sr E2,	Median 38	29	23	26	<0.001
inhibin B	Median 202	90	89	23	<0.001
Estradiol	Median 2.8	75	23	10	<0.002
Progesterone:	Median 2.0	89	18	10	<0.001

The median levels of reproductive hormones were as follows: LH (median: 20, $p < 0.001$), FSH (median: 4.1, $p = 0.099$), Testosterone (median: 0.13, $p < 0.001$), serum estradiol (median: 38, $p < 0.001$), inhibin B (median: 202, $p < 0.001$), FAI (median: 54, $p < 0.001$), and AMH (median: 54, $p < 0.001$). These results indicate significant differences in hormone levels across BMI groups, particularly for LH, Testosterone, serum estradiol, inhibin B, **estradiol, Progesterone.**

TABLE4: ASSOCIATION BETWEEN DNA FRAGMENTATION, AND BODY MASS INDEX

Factors	Total (n = 115)	DFI ≥ 30	DFI < 30	P value*
BMI (kg/m^2)	134 (46.2)	25 (18.7)	109 (81.3)	0.024
<23	134 (46.2)	25 (18.7)	109 (81.3)	0.024
≥23	156 (53.8)	47 (30.1)	109 (69.9)	156 3.8)

The analysis revealed that BMI (Body Mass Index) was significantly associated with DNA Fragmentation Index (DFI) status among the participants ($p = 0.024$). Specifically, among individuals with a BMI < 23 kg/m², 25 (18.7%) had a DFI ≥ 30, while 109 (81.3%) had a DFI < 30. In contrast, among those with a BMI ≥ 23 kg/m², 47 (30.1%) had a DFI ≥ 30, while 109 (69.9%) had a DFI < 30. These findings suggest that BMI may play a role in DNA fragmentation status among the participants, with a higher proportion of individuals with a BMI ≥ 23 kg/m² having a DFI ≥ 30 compared to those with a BMI < 23 kg/m².

VII. Discussion

This study examined the relationship between BMI and various aspects of semen quality in male patients at **Pacific medical college and hospital Udaipur Rajasthan.**Findings indicated that progressive sperm motility was lower in obese men compared to men with a normal BMI, while there was no notable distinction in progressive sperm motility between overweight and obese men.

This study assessed the impact of BMI on several semen quality parameters in male patients, with the exception of DFI. The analysis revealed that higher BMI was inversely correlated with sperm concentration, total sperm count, progressive sperm motility, sperm vitality, and normal sperm morphology. Severely obese men were more likely to have below-normal sperm morphology and progressive sperm motility compared to men with a healthy BMI. Additionally, the study found a significant negative correlation between BMI and serum levels of total testosterone, SHBG, inhibin B, and AMH, while serum estradiol levels showed a positive correlation with BMI.

While each BMI category displayed individual variations in semen quality, a clear decline in all standard semen quality markers was observed as BMI increased. Other studies have also indicated a negative impact of BMI on semen quality, with findings often pointing to one or two semen parameters being adversely affected by higher BMI. For instance, a study of Danish military conscripts found lower sperm concentration and count at higher or lower BMI, but no significant association between BMI and other semen parameters. However, that study included a large sample size with limited representation of obese individuals (BMI ≥ 30 kg/m2).

Another study involving American couples trying to conceive found that increasing BMI was associated with lower ejaculate volume and reduced sperm concentration, particularly as waist circumference increased. Although a substantial number of obese men were included in the study, differences in semen analysis methods from the WHO standard could affect the comparability of the results to our findings. Additionally, both these studies were conducted on men from the general population, unlike the majority of research on BMI and semen quality, which often focuses on men with impaired

spermatogenesis or couples experiencing infertility.

Our findings regarding total testosterone and SHBG align with most research on the relationship between BMI and reproductive hormones. Obese men often experience elevated serum insulin levels, which can decrease SHBG synthesis in the liver, resulting in more unbound testosterone being converted to estradiol through aromatase activity in adipose tissue. This process may account for the observed lack of a link between BMI and the free androgen index, although the index may not accurately represent free testosterone levels within the testes.

Additionally, our results showing no correlation between BMI and serum levels of LH and FSH are consistent with most studies on overweight and obese men. Since FSH levels appear to remain steady in these men, the decline in semen quality may be due to other contributing factors.

157 Result Analysis

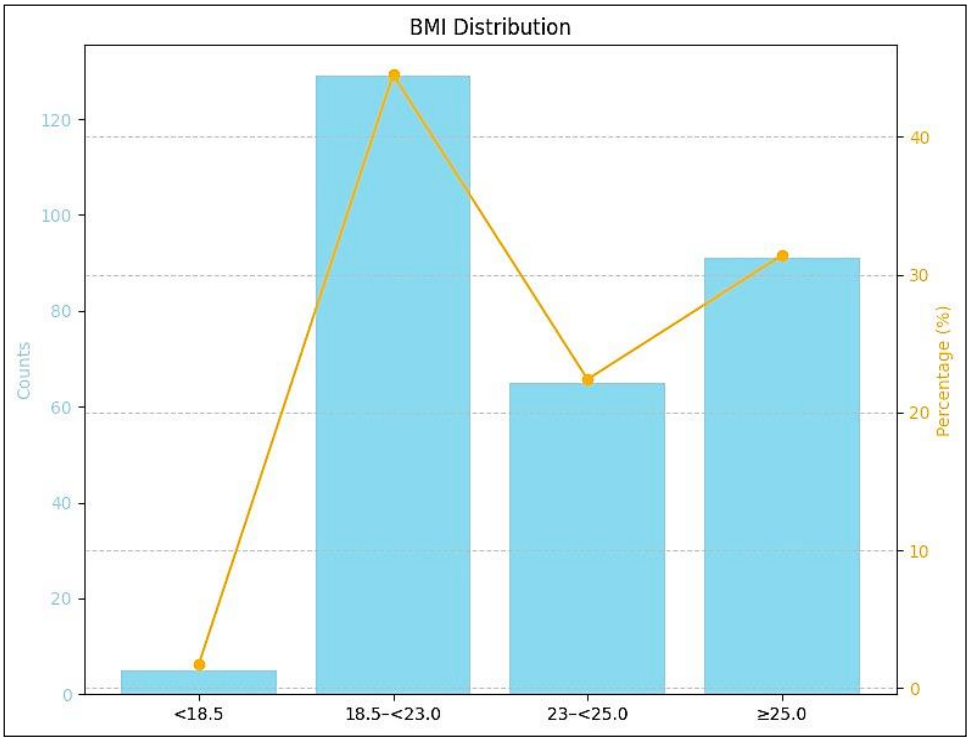

FIG 1: BAR GRAPH WITH COUNTS REPRESENTED BY BARS (IN BLUE) AND PERCENTAGES REPRESENTED BY A LINE PLOT (IN ORANGE) FOR THE DIFFERENT BMI CATEGORIES. THE X-AXIS REPRESENTS THE BMI CATEGORIES, WHILE THE LEFT Y-AXIS REPRESENTS THE COUNTS, AND THE RIGHT Y-AXIS REPRESENTS THE PERCENTAGES

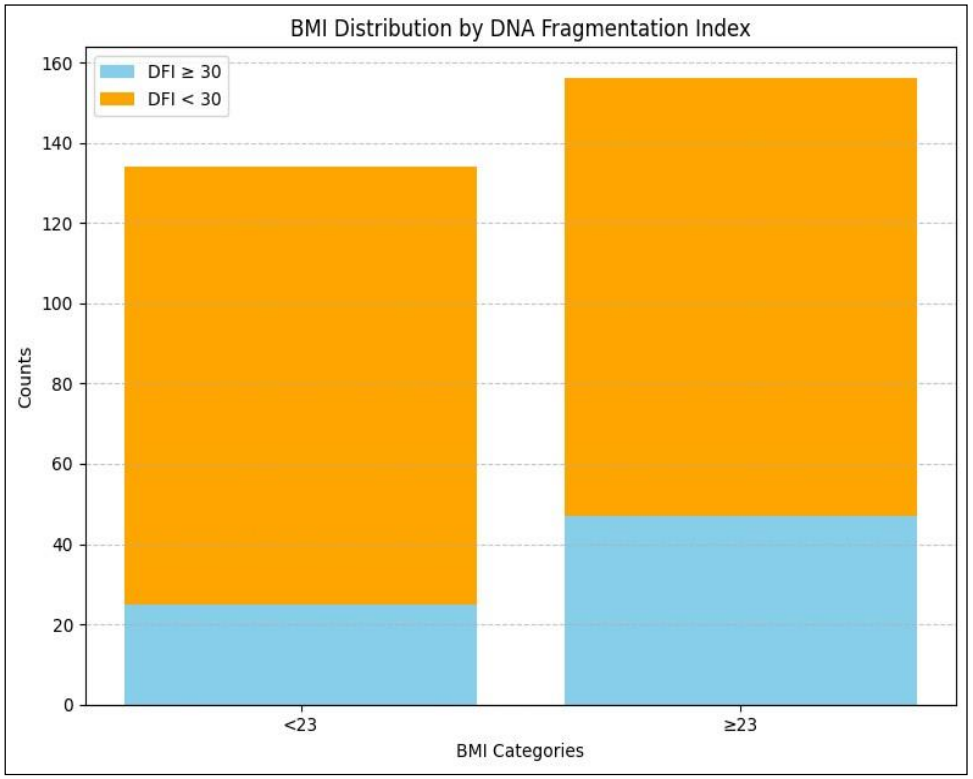

FIG 2:STACKED BAR GRAPH WHERE EACH BAR REPRESENTS THE BMI CATEGORIES '<23' AND '≥23'. THE HEIGHT OF EACH SEGMENT WITHIN THE BAR REPRESENTS THE COUNTS OF PARTICIPANTS WITH DFI ≥ 30 AND DFI < 30 FOR THAT BMI CATEGORY. THE BLUE SEGMENTS REPRESENT DFI ≥ 30, WHILE THE ORANGE SEGMENTS REPRESENT DFI < 30

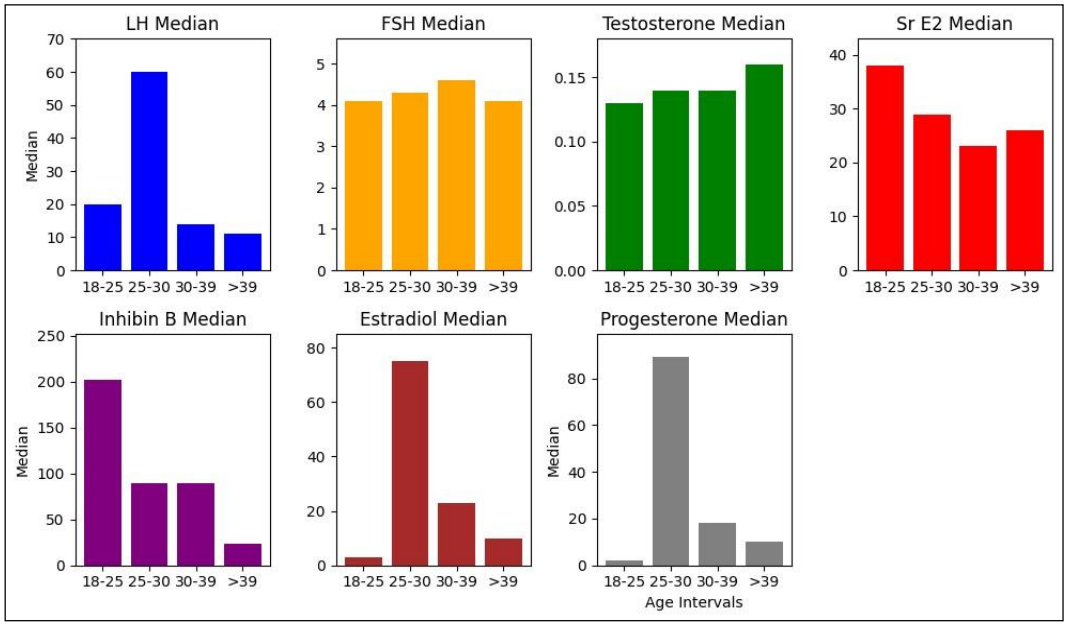

FIG 2: GROUPED BAR GRAPH WHERE EACH BAR REPRESENTS A BMI CATEGORY, AND EACH HORMONE IS REPRESENTED BY A DIFFERENT COLOR. THE HEIGHT OF EACH BAR REPRESENTS THE MEDIAN VALUE OF THE CORRESPONDING HORMONE FOR THAT BMI CATEGORY

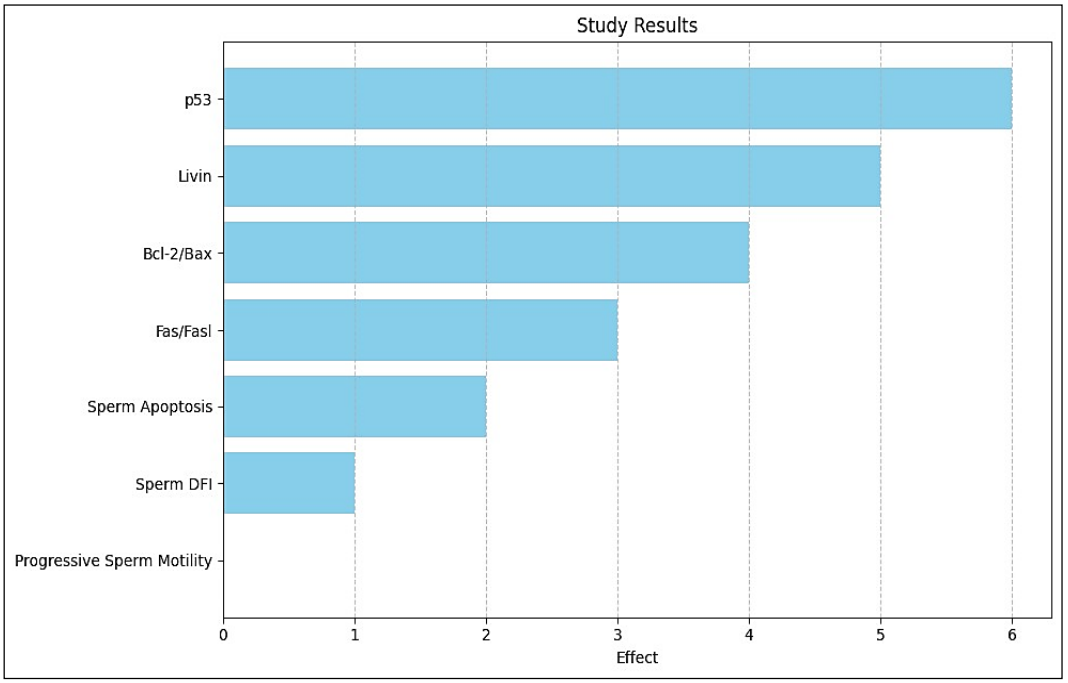

FIG 3: HORIZONTAL BAR GRAPH REPRESENTING THE ROLE OF DIFFERENT INDICATORS BASED ON THE STUDY FINDINGS. ADDITIONALLY, IT WILL DISPLAY A DATA FRAME SHOWING THE INDICATORS AND THEIR CORRESPONDING ROLES AS MENTIONED IN THE STUDY. VISUALIZE THE STUDY FINDINGS

TABLE 1: DATA FRAME SHOWING THE PARAMETERS AND THEIR CORRESPONDING EFFECTS AS MENTIONED IN THE STUDY

Index	parameter	Effect
4	Bcl-2/Bax	Significant biomarker in response to sperm apoptosis and damage
3	Fas/Fasl	Significant biomarker in response to sperm apoptosis and damage
5	Livin	Significant biomarker in response to sperm apoptosis and damage
0	Progressive Sperm Motility	Decreased in obese men
2	Sperm Apoptosis	Increased in overweight and obese men
1	Sperm DFI	Increased in overweight and obese men
6	p53	Role in sperm apoptosis and damage within obese men

The study comprised primarily Caucasian men (85%) with a mean (SD) age of 36.3 (5.4) years. The majority of participants were overweight or obese (BMI ≥25) (75%) and nonsmokers (71%). A notable proportion of men (37%) had previously undergone infertility evaluation, and 41% had successfully impregnated their partner in the past. Overall, 47% of men exhibited normal semen analysis results, while 14% had a sperm concentration below 20 million/mL, 46% had less than 50% motile sperm, and 21% had less than 4% normal morphology sperm.

Across different BMI categories, no significant differences were observed in lifestyle factors, reproductive history, or semen analysis characteristics. However, there was a trend suggesting a higher prevalence of below-reference sperm morphology and a history of undescended testes and groin injury with increasing BMI. These findings underscore the importance of exploring the potential impact of overweight or obesity on male reproductive health outcomes, particularly concerning sperm quality and fertility.

The impact of weight loss on semen quality remains under-investigated. Only one study has examined the potential benefits of weight loss on semen quality, where obese men followed a weight loss program emphasizing a healthy diet and regular exercise. This study reported improvements in total sperm count and morphology with weight loss. It remains unclear whether these benefits were a direct result of a reduction in BMI or the healthier lifestyle changes.

Future research on the effects of lifestyle modifications and weight reduction on semen quality in obese men could provide valuable insights for the clinical management of infertile men with elevated BMI.

In summary, we found that BMI was inversely related to sperm concentration, total sperm count, progressive sperm motility, and sperm morphology. The decline in semen quality was most pronounced in men with a BMI above 35 kg/m2. We also observed significant negative correlations between BMI and FSH as well as inhibin B levels, suggesting that both sperm production and maturation may be compromised by high BMI.

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