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Prevalence of Male Infertility with Poor Semen Quality and Correlation with Trace Metal Concentration in and around Chennai, India

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Abstract: ***Present work carried out to determine the relationship of the concentration of trace metal ions present in seminal plasma with semen parameters and reproductive endocrine function in men in and around Chennai. The semen analysis results revealed that the most affected age group was 31-40 years. The abnormalities of semen were observed high in smokers, alcoholics and non-vegetarians, respectively. Mean value of trace metal ions levels present in seminal plasma were significantly higher in Azoospermia, Asthenozoospermia, Asthenoteratozoospermia, Oligoasthenozoospermia andOligoasthenoteratozoospermia participants, when compare to Normozoospermia participants and shows adverse effect on male infertility. This study concludes that life style changes and its associated factors have high impact on incidence of male infertility among in and around Chennai population.***

Keywords: Sperm, Seminal fluid, Trace metals, Normozoospermia, Azoospermia, Asthenozoospermia, Asthenoteratozoospermia, Oligoasthenozoospermia, Oligoasthenoteratozoospermia

1. Introduction

Infertility is a reproductive disease, is one of the most tragic of all marital problems and it is a social stigma in our society. Infertility is a major problem in a developed and developing countries due to modern life style. According to WHO estimation, there is 60–80 million infertile couple worldwide (8–12%). About 40–50% of infertility is totally or in part due to male factor in worldwide and, the unexplained infertility varies from 10–20%,which is affecting 10–15% of reproductive age of couples [1].Recent report reveals that the male infertility rate younger than age 30 years has also increased worldwide by 15% [2], and the it shows the male infertility in worldwide, 59% in France, 36% in South Africa, Indonesia and Finland, 35% in Nigeria and some parts of sub-Saharan Africa including the Republic of Sudan and Cameroon, 26–32% in Kashmir Valley (India) and UK, 15.7% in Denmark and 10% in USA [3–10].

The Multi centeric study conducted by WHOfrom1982–1985 indicates 20% of infertility cases were due to male factors, 38% of female factors, 27% of both, and 15% could not be satisfactorily attributed to either partner [11]. A recent report in India states that nearly 50% of infertility is related to reproductive anomalies or disorders in the male.

Male infertility is the inability to fertilize by a male after one year of unprotected sexual intercourse with a healthy fertile female and it is most important health crisis today all over the world including India which is evaluated by semen analysis (SA).The known causes of male infertility are relatively abundant. It has been coupled with numerous genetic and non-genetic conditions, such as hypogonadotrophic hypogonadism, testicular maldescence, and structural abnormalities of the male genital tract, Anti-sperm anti-bodies, chronic illness, endocrine disturbance, genital infections, impotency, previous scrotal or inguinal surgery, retrograde ejaculation, systemic diseases, testicular cancer, testicular trauma, varicoceles, medications and exposure to chemicals and various environmental factors [12,13].

Male infertility caused by a variety of other factors which includes environmental (pollution, chemicals, etc.), lifestyle (smoking and chewing, alcohol, caffeine, some dietary components and some modern electronic gadgets etc.) and occupational (exposing of heavy metals, stress, high temperature etc.) factors. All the above said factors are affecting the male fertility by interfering with spermatogenesis, spermiogenesis, sperm motility, sperm morphology, sperm DNA, sperm chromatin integrity and hormonal regulations or by reducing the fertilizing capacity of spermatozoa [14, 15].

In recent times there has been a decline in the semen quality of young healthy men worldwide, which is significant associations have been reported between impaired semen quality and exposures to heavy metals, mycotoxins, pesticides, industrial chemicals and endocrine disturbing factors, testicular maldescence, impotency, varicoceles, scrotal surgery, chronic illness and structural abnormalities of the male genital tract [16, 17].

Some of the trace elements have been essential for testicular development and spermatogenesis. Zinc, magnesium, calcium, sodium, potassium etc. are some of the important metal ions to play in the physiology of spermatozoa [18–20]. But some of the heavy metals such as lead, mercury, chromium, copper, manganese, arsenic, iron and etc. directly linked with male fertility by decreasing semen quality, sub-

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fertility, and change in birth sex ratio, sexually transmitted infections, genito-urinary tract infections/inflammations, deficiencies of dietary antioxidant nutrients and an increase in the prevalence of developmental abnormalities of the male reproductive tract [21, 22].

Present work carried out to determine the relationship of the concentration of trace metal ions present in seminal plasma with semen parameters and reproductive endocrine function in men.

2. Experimental Methods

2.1 Study Area

This analytical study was conducted at the Department of Andrology, Kanmani Fertility Centre Pvt. Ltd, Thyagaraya Nagar, Chennai, India. The study was approved by the Research Ethics committee of The New College Institutional Ethical Committee and informed consent was given by the individual participant.

2.2. Study sample size

A total number of 70 infertile men from in and around Chennai, were participated in this study. Sample size was calculated using sample size determination in health studies formula and a prevalence of 10% [23].

2.3. Inclusion criteria

Male subjects aged 20-40 years who had history of infertility for more than year and who sought help for infertility from the Kanmani Fertility Centre Pvt. Ltd. Chennai, Tamil Nadu was recruited.

A collected data from the questionnaire survey regarding age, marital status, duration of infertility, history of infertility in the family, occupation, lifestyle, environmental factors, medical histories, health problems and parity. Mainly a history of trace metals exposure or resided in areas known to have a trace metal contaminations, alcoholic consumers, tobacco user.

2.4. Semen collection and analysis

Human ejaculate was obtained 2-7 days after period of sexual abstinence. Samples were incubated for 15-30 minutes at 37°C for liquefaction. A routine semen analysis was performed upon liquefaction according to WHO 2010criteria to measure volume, pH, sperm concentration, motility, viscosity, viability and morphology. The remaining semen sample was centrifuged at 1000 rpm for 10 min; the seminal plasma was separated and stored at –70°C until further analysis. Morphology was determined according to WHO criteria using the papanicolaou's staining procedure. At least 300 cells were examined at a final magnification of ×1000. Viscosity of the liquefied sample was estimated by introducing a glass rod into the sample and observing the thread that forms on withdrawal of the rod. Threads obtained from normal samples should not exceed 2 cm in length. Motility was expressed as a percentage of motile spermatozoa and their mean velocity. The conventional analysis is recommended in which a fixed volume of semen is delivered into a clean glass slide and covered with cover slip [24]. The preparation is then examined at a magnification of 400xs. The microscopic field is scanned systematically, and the motility of each spermatozoon encountered is graded A, B and C. At least 100 spermatozoa are classified in this way. The presence of 32% or more with forward progression (categories A and B) were considered as normal results. Sperm motility was calculated by multiplying sperm concentration and semen volume (ml).

2.5. Estimation of trace metals

The following protocols were used to determine the metal ions in the seminal plasma. The reagents for copper, zinc, calcium, sodium, potassium and magnesium analysis were purchased from Coral Clinical Systems, Tulip Group, Chennai, Tamil Nadu, India.

2.5.1. Determination of seminal plasma zinc [25]

The semen zinc was estimated by color nitro-PAPS method. 1 ml of zinc working reagent and 0.05 ml of standard, or distilled water (blank), 0.05 ml of seminal plasma were mixed well, and incubated at room temperature (25 ºC) for 5 min. The absorbance of standard (Abs.S) and test sample (Abs.T) were measured against the blank within 20 min by using spectrophotometer at 570 nm (yellow filter). Zinc concentrations calculated from the calibration curve.

2.5.2. Determination of seminal plasma copper, magnesium and calcium [26]

The seminal plasma copper, magnesium and calcium were estimated by Di-Br-PAESA(Copper), Calmagite (Magnesium) and OCPC (Calcium)spectrophotometer methods, respectively. To working buffer reagent, R1 (Cu, 0.5 ml; Mg,0.5 ml;Ca, 0.5 ml) and color reagent, R2 (Cu, 0.5 ml; Mg, 0.5 ml; Ca, 0.5 ml), added seminal plasma (Cu, 0.05 ml; Mg,0.01 ml; Ca, 0.02 ml), standard, or distilled water for reagent blank, and mixed well, incubated at room temperature (Cu,25 ºC for 10 min; Mg,25 ºC for 5 min; Ca,25 ºC for 5 min). The absorbance of standard (Abs.S) and test sample (Abs.T) were measured against the blank within 30 min for copper and magnesium, 60 min for calcium by using spectrophotometer (Cu, 580 nm; Mg, 510 nm; Ca, 570 nm). All the metal ions concentrations calculated from the calibration curve.

2.5.3. Determination of seminal plasma sodium and potassium [26]

Sodium and potassium ions were determined on the basis of ion selective electrode method (ISE).Seminalplasmasamples were collected and analyzed using direct ISE analyzer (Elite-3i, Tulip Diagnostics, India). Standard operating procedure was prepared and strictly adhered to during sample collection to avoid pre-analytical errors. The auto-analyzer was routinely calibrated every 24hours by linear calibration.

2.5.4. Determination of lead, chromium and selenium [26]

Amount of lead, chromium and selenium in seminal plasma was estimated with electrothermal atomic absorption spectrophotometer. Approximately 100µl of seminal plasma sample was hydrolysis with 500µl of super-grade 0.8 M HNO_3 in a reaction tube. The mixture was dissolved in 1 ml

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of 1% HNO_3 which was applied to a graphite tube for estimation of lead. The recovery of lead, chromium and selenium in spiked semen samples was 97%. The instrument was calibrated using 0, 50, 100and 200µg/L standards for lead, chromium and selenium, respectively. A sample blank was prepared each time a set of samples to control is the assayed in order to avoid possible metal contamination from external sources. The instrument was allowed to process the sample and display the concentration in µg/L.

2.5.5. Statistical analysis

The experiments conducted in triplicates in this study were subjected to various statistical analysis using ANOVA software that the standard error mean (SEM) and *p* value significance were estimated and the results were inferred for logical interpretations.

3. Results and Discussion

The enrolled study participants were categorized into the following six groups on the basis of sperm count, motility and morphology (**Table 1** and **Figure 1**). Normozoospermia (12.8%, n=9), azoospermia (15.7%, n=11), asthenozoospermia (21.4%, n=15), asthenoteratozoospermia(18.5%, n=13), oligoasthenozoospermia (14.2%, n=10) and oligoasthenoteratozoospermia(17.1%, n=12).

Table 1: Subjects were categorized into six groups on the basis of sperm count, motility and morphology

S. No.	*Diagnosis*	*Results in % (n = No. of Pts)*
1	Normozoospermia	12.8 (9)
2	Azoospermia	15.7 (11)
3	Asthenozoospermia	21.4 (15)
4	Asthenoteratozoospermia	18.5 (13)
5	Oligoasthenozoospermia	14.2 (10)
6	Oligoasthenoteratozoospermia	17.1 (12)

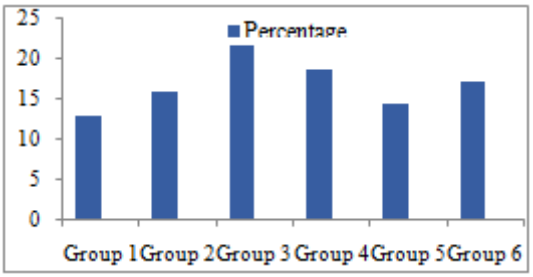

Figure 1: Study participants were categorized into six groups on the basis of sperm count, motility and morphology

3.1. Age and Male Infertility

Among the study participants, 38.5% (n=27) of them in age group 20-30years and 61.5% (n=43) of them in age group 31-40 years. The collected data shows that normozoospermia, azoospermia, asthenozoospermia, asthenoteratozoospermia, and oligoasthenozoospermia was found maximum in age group 31-40years and oligoasthenoteratozoospermia was found high in age group in 20-30 years (**Table 2** and **Figure 2**). A study conducted by Jung et al, [27] shows similar results that that the overall semen quality will be decreased in higher age group. Hellstorm et al, [28] also states that the overall semen quality will be gradually decreased in age group of 30-40 years. Levitas et al, [29] also concluded in his study that maximum infertility seen in the age group 30-40 years. A meta analysis study conducted by Kidd et al, [30] and Levitas et al, [29] also suggest that azoospermia and asthenoteratozoospermia were observed maximum in the age group 30-40 years. Elzanaty, [31] and Henkel et al, [32] also states that age related modification in accessory sex organ may decline sperm motility.

Table 2: Relationship between study participants age and semen quality

S. No.	*Diagnosis*	*20–30 Age group Results in % Avg. 38.5% (n = No. of Pts)*	*31–40 Age group Results in % Avg. 61.5% (n = No. of Pts)*
1	Normozoospermia	22.2 (2)	77.8 (7)
2	Azoospermia	36.4 (4)	63.6 (7)
3	Asthenozoospermia	33.4 (5)	66.6 (10)
4	Asthenoteratozoospermia	30.7 (4)	69.3 (9)
5	Oligoasthenozoospermia	50.0 (5)	50.0 (5)
6	Oligoasthenoteratozoospermia	58.4 (7)	41.6 (5)

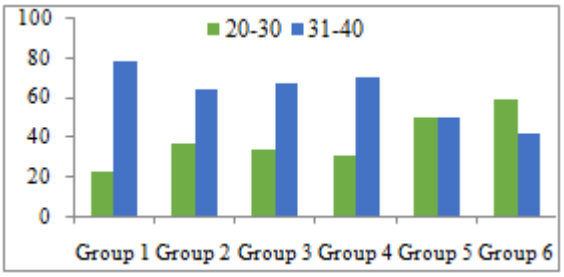

Figure 2: Positive correlation between age of study participants and semen quality.

3.2. Smoking and Male Infertility

Correlation of smoking habit of study participants and semen analysis reports clearly shows that 70.0% (n=49) were smoker and 30.0% (n=21) were nonsmoker. The study results shows that azoospermia, asthenozoospermia, asthenoteratozoospermia, Oligoasthenozoospermia and oligoasthenoteratozoospermia were seen maximum in participants having smoking habit when compared to participants not having smoking habit and 10.2% (n=5) of smoker were normozoospermia (**Table 3** and **Figure 3**).These findings also similar to Gaur et al, [33] indicate a strong dose-dependent relationship between smoking and a decrease in semen quality. Various toxic substances in cigarette and tobacco products have shows high impact on seminal volume, liquefaction time, viscosity and leads to various male infertility [34]. Bhasin et al, [35] also have similar results and states that testosterone production was reduced by chronic smoking. Active and passive smoking have strong impact on sperm and egg production in both male and female infertility [36]. A study conducted by Durphy et al, [37] shows that smoking can decreased the chances of conception in couples. A research study conducted by Zhang et al, [38] shows that there is a strong relationship between the number of the cigarettes smoked per day and decline in sperm motility. Our obtained results were similar with the study conducted by Sharma et al, [39] shows that smoker are high risk of asthenozoospermia, when

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compared to non smoker. Briggs [40], reported that the person who smoked 30 cigarettes per day shows the reduction of blood serum testosterone when compared to non smokers.

Table 3: Relationship between study participants smoking and semen quality

S. No.	*Diagnosis*	*Smoker 70.0% (n = No. of Pts)*	*Non-Smoker 30.0% (n = No. of Pts)*
1	Normozoospermia	10.2 (5)	19.0 (4)
2	Azoospermia	18.3 (9)	9.5 (2)
3	Asthenozoospermia	24.4 (12)	14.2 (3)
4	Asthenoteratozoospermia	22.4 (11)	9.5 (2)
5	Oligoasthenozoospermia	16.3 (8)	9.5 (2)
6	Oligoasthenoteratozoospermia	18.3 (9)	14.2 (3)

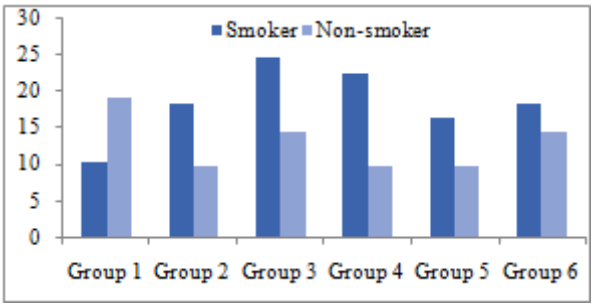

Figure 3: Correlation between smoking habit of study participants and semen quality.

3.3. Alcohol consumption and Male Infertility

Association of alcoholic habit of study population and semen test report shows that 57.1% (n=40) of participants were alcoholic and 42.8% (n=30) of population were non alcoholic. From the **Table 4** and **Figure 4**, it is clear that azoospermia, asthenozoospermia, asthenoteratozoospermia, oligoasthenozoospermia and oligoasthenoteratozoospermia were seen high in participants having alcoholic habit when compared to participants not having alcoholic habit. 17.5% (n=7) of normozoospermia population were also having alcoholic habit. Many of the participants of this experiment had abnormal sperm morphology who was chronic alcoholic, Similarly, results was obtained by Soares et al, [41] and Colagar et al, [42] reveled that alcohol had detrimental effects on sperm count, motility and morphology. These results were in similar with previous studies by Joo et al, [43] states that alcoholic consumption has significant correlation with male infertility. Chronic alcoholism can leads to ejaculatory dysfunction and has been associated with poor reproductive function [44]. In this present study the correlation between alcohol consumption and poor semen quality was supports to the research findings by Jensen et al, [45]; Kalyani et al, [46] and Dhaliwal et al, [47]. Moderate or heavy alcoholic are more affected with male infertility. Many earlier research studies supports our results that continues alcohol intake cause male infertility [48-49]. In addition, semen volume can be drastically decreased when the persons drinks more than 30 times in a month [50]. A research conducted by Kucheria et al, [51] shows that alcohol dependence syndrome male have positive correlation with low seminal fluid volume and low sperm concentration.

Table 4: Relationship between study participants alcoholic habit and semen quality

S No.	*Diagnosis*	*Alcoholic Results in % 57.1% (n = No. of Pts)*	*Non-Alcoholic Results in % 42.8% (n = No. of Pts)*
1	Normozoospermia	17.5 (7)	6.6 (2)
2	Azoospermia	25.0 (10)	3.3 (1)
3	Asthenozoospermia	22.5 (9)	20.0 (6)
4	Asthenoteratozoospermia	17.5 (7)	20.0 (6)
5	Oligoasthenozoospermia	20.0 (8)	6.6 (2)
6	Oligoasthenoteratozoospermia	22.5 (9)	14.2 (3)

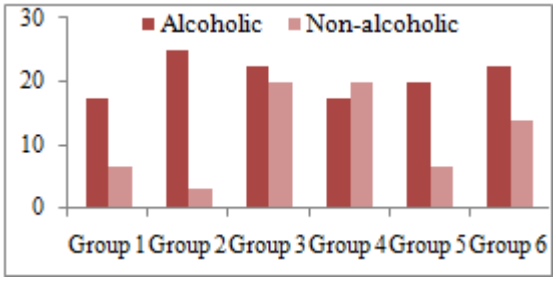

Figure 4: Correlation between alcoholic habit of study participants and semen quality.

3.4. Food Habit and Male Infertility

Combination of food habits and semen analysis of the participants shows that 62.8% (n=44) of participants are mainly consume non vegetarian regularly and 37.1% (n=26) of participants having vegetarian food habit. The data on the study population with different food habits namely vegetarian and non vegetarian shows that high incidence of normozoospermia, azoospermia, asthenozoospermia, asthenoteratozoospermia, oligoasthenozoospermia and oligoasthenoteratozoospermia was found with persons who had the non vegetarian food habit (**Table 5** and **Figure 5**). Evidence suggests that high intake of dietary fatty acids (FAs) may have reasonable effects on male fertility. Our study results also support to Abhishek et al, [52] that consuming the animal meat will results in decreasing the concentration of estrogen hormone and may alter the production of sperm. Diet with trans fats and saturated fats have negative impact on sperm production and the testicular lipid metabolism [53]. Bakos et al, [54] reported that high fat content diet which induces obesity results in decreasing the sperm motility and fertilizing capacity. Morgan et al, [55] also reported that elevated blood cholesterol level is directly affected the elevated levels of plasma cholesterol induced by a cholesterol-rich diet negatively affected spermatogenesis, which support our results.

Table 5: Relationship between study participant's food habit and semen quality

S. No.	*Diagnosis*	*Vegetarian Results in % 37.1% (n = No. of Pts)*	*Non- Vegetarian Results in % 62.8% (n = No. of Pts)*
1	Normozoospermia	11.5 (3)	13.6 (6)
2	Azoospermia	15.3 (4)	15.9 (7)
3	Asthenozoospermia	19.2 (5)	22.7 (10)
4	Asthenoteratozoospermia	3.8 (1)	27.2 (12)
5	Oligoasthenozoospermia	7.69 (2)	18.1 (8)
6	Oligoasthenoteratozoospermia	11.5 (3)	20.4 (9)

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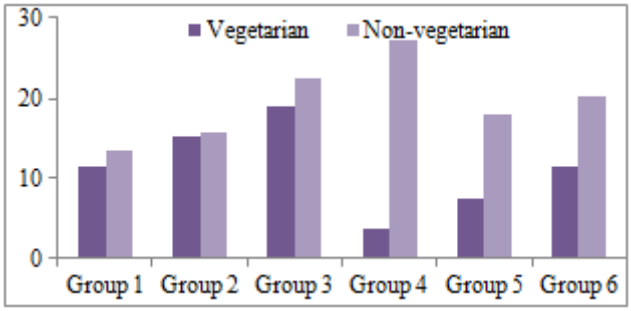

Figure 5: Correlation between food habit of study participants and semen quality.

3.5. Trace metals concentration in seminal plasma and Male Infertility

Concentration of trace metal ions in seminal plasma and semen quality in infertile males were analysed and represented in **Table 6**. Correlation of trace metal concentration and poor semen quality were expressed in **Figures 6** & **7**. The Mean and SEM of all trace metal ions have shows significance in their concentration within the study group. Since *p* value for all trace metal elements is less than 0.05 the trace elements in seminal plasma have shows positive correlation with poor semen quality in selected study participants.

3.5.1. Zinc concentration and Male Infertility

Among the study participants high concentration of zinc was observed in normozoospermia, and low concentration was observed in azoospermia. Prasad, [56] study also support our results that low zinc level is positively correlation with poor semen quality. Batra et al, [57] concludes that high deposition of heavy metals in testicular tissues may reduce the seminal plasma zinc levels. Many research studies shows that correlation of zinc concentration and semen quality is not conclusive but Fuse et al, [58]; Chia et al, [59]; Wong et al, [60]; Liu et al, [61]; Madding et al, [62] reported positive correlation between zinc and poor semen quality. Nine studies conducted by Colagar et al, [63]; Li et al, [64]; Liao et al, [65]; shi et al, [66]; Xu, et al, [67]; Zhang et al, [68]; Zheng et al, [69] reported that the zinc concentrations in seminal plasma from infertile men were significantly lower than those from normal men.

Table 6: Concentration of trace metal ions in seminal plasma and semen quality in infertile Males

Elements	*Normoz. Mean ± SEM*	*Azoos. Mean ± SEM*	*Astheno. Mean ± SEM*	*Astheno terato Mean ± SEM*	*Oligo astheno Mean ± SEM*	*Oligo astheno terato Mean ± SEM*
Zn (mg/dl)	6.3±0.03	1.3±0.09	5.0±0.06	4.6±0.10	5.4±0.01	2.6±.0.03
Mg (mg/dl)	2.6± 0.01	2.0±0.02	2.3±0.07	2.1±0.06	2.3±0.09	2.2±0.10
Pb (µg/l)	19.3± 0.1	40.2±0.19	46.3±0.17	153.2±0.17	155.4±0.2	167.4±0.2
Cu (µg/dl)	81.0± 0.16	73.0±0.16	89.0±0.10	149.0±0.13	138.0±0.19	153.0±0.2
Na (mEq/l)	138.3±0.23	139.0±0.20	139.4±0.23	139.0±0.20	139.8±0.15	140.2±0.2
K (mEq/l)	11.9±0.05	18.8±0.09	23.2±0.03	22.8±0.04	22.4±0.10	22.6±0.07
Ca (mg/dl)	13.2± 0.01	9.6±0.05	13.5±0.08	13.6±0.05	22.6±0.06	24.2±0.06
Se (µg/l)	178.2± 0.31	77.6±0.10	124.2±0.25	60.4±0.10	47.3±0.20	42.0 ±0.16
Cr (µg/l)	2.2± 0.01	4.8±0.05	2.6±0.09	4.2±0.07	3.86±0.04	4.9±0.08

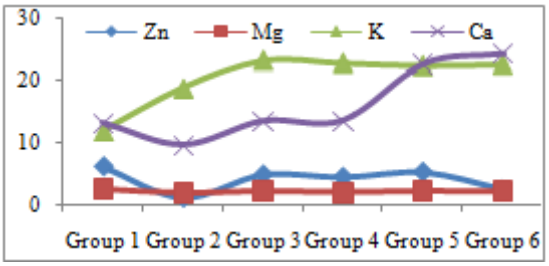

Figure 6: Correlations of trace metal ions in seminal plasma and semen quality in infertile men.

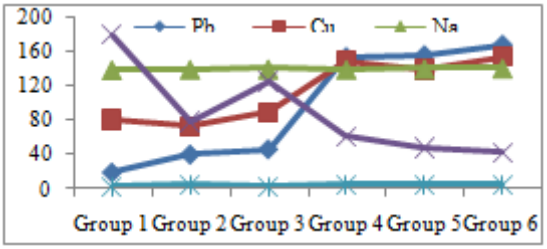

Figure 7: Correlations of trace metal ions in seminal plasma and semen quality in infertile men

3.5.2. Magnesium concentration and Male Infertility

The magnesium concentration obtained maximum in normozoospermia participants and minimum in azoospermia participantsin this study showing similar results of Deger and Akkus [70] reported 6.9±2.1 mg/dl in azoospermia participants and 11.9±3.0 mg/dl in normozoospermia participants. But zarghami et al [71] and Hsieh et al [72] mentioned that high level of seminal magnesium was recorded in asthenozoospermic subjects rather than the normozoospermia subjects. Our study shows a strong correlation between Mg in seminal plasma and semen quality, while other studies conducted by Sorensen et al, [73] and Fakih et al, [74] did not show any correlation between Mg and semen quality. Viski et al, [75] mentioned that magnesium therapy shows positive significant in semen quality in infertile males.

3.5.3. Lead concentration and Male Infertility

Among the study subjects high concentration of lead was found in oligoasthenoteratozoospermia (167.4±0.200 µ/l) and low concentration was seen in normozoospermia (19.3± 0.100 µ/l). Morita et al, [76] and Meirow et al, [77] states that environmental toxicants exposure results in poor gamete formation in male. A study conducted by Wu et al, [78] mention that low level of lead accumulation was observed in infertile men who were not occupational exposure to lead. Seminal plasma lead concentration may increase due to smoking habit and leads to male infertility [79]. The mean lead value was significantly higher than normal range for

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normozoospermia, and similar ranges reported by Xuezhi et al, [80] and Robins et al, [81] in men occupationally exposed to lead. The median values of semen lead concentrations were slightly higher in oligozoospermia than in the normozoospermia and this obtained data was similar to El-Zohairy et al, [82]. Semen lead concentrations in study population showed significant correlation with semen quality and this is in contrast to Fatima et al, [83] who found blood and semen lead concentrations not significant correlation with semen parameters.

3.5.4. Copper concentration and Male Infertility

The obtained data shows that high copper concentration was observed in oligoasthenoteratozoospermia and low concentration was seen in normozoospermia. Similar results by Maryam et al, [84], Jockenhovel et al, [85] shows significant correlations between seminal plasma copper concentration and sperm concentration, pH, vitality, motility and normal morphology. Aydemir et al, [86] showed that copper levels in seminal plasma in azoospermia participants were significantly higher than those in normozoospermia participants. Shinohara et al, [87] found significant correlations between poor semen quality and copper concentration. Katayose et al, [88] demonstrated that higher concentrations of copper had significant adverse effects on sperm motility which is supportive to our results.

3.5.5. Sodium, potassium and calcium concentration and Male Infertility

The mean value of sodium and potassium level in seminal plasma not significant with semen quality which in contrast to results obtained by Abdel-Rahman et al, [89] shows sodium level have strong impact on semen quality. Vickram et al, [90] mentioned higher concentrations of potassium and sodium in seminal plasma have important role in acrosomal reactions. Our study results is in contrary to the results by Kaya et al, [91]who mentioned negative correlation between Na and K concentrations and semen quality. Research studies conducted by Abdul – Wahab et al, [89] ; Battersby and Chandler, [92] ; Bondani et al, [93]; Gaffuri et al, [94]; Girgis et al, [95]; Gusani et al, [96] shows the positive correlation of sodium and potassium concentration and semen quality and Skandhan et al, [97]; Kaya et al,[98] ; Kanwal et al, [99]; Wong et al, [100] shows negative correlations of trace elements and semen quality. This study showed that the seminal plasma calcium level was significantly higher in the oligoasthenoteratozoospermia and oligoasthenozoospermia participants compared to the normozoospermia participants but in contrast Wong et al, [100] in his study in Netherland reported low Ca in the seminal plasma of infertile men which accounts for hypomotility. Finding by logoglu et al, [101] suggest that infertility seen in normozoospermic subjects may be due to significantly decreased seminal calcium. Higher concentration calcium in seminal plasma in infertile male was recorded and this may due to consume calcium pills during treatment. In a pilot study performed by Umeyama et al, [102] seminal calcium level were almost similar in both fertile and infertile men, and the highest level was determined in the normozoospermia subjects. However, another study conducted by Arver [103] indicating that a sperm motility was decreased due to high concentration of calcium confirms our results. Fraser [104] reported that, to successful fertilization an optimal calcium level is required. Abou-Shakra et al, [105] determined the lowest concentration in the normozoospermic infertile group, being non significant in relation to infertility classification, which support our results.

3.5.6. Selenium concentration and Male Infertility

The results of the present study were showed that there was significant low concentration of selenium in all groups when compared with that of normozoospermia. Study conducted by Xu et al, [106]; Xu et al, [107]; Shinohara et al, [108]; Behne et al, [109]; also agree with our findings that low level seminal plasma selenium concentration was observed in infertile groups. Saaranen et al, [110] and Akinloye et al, [111] observed significant increase of selenium concentration in azoospermic, when compared with oligozoospermic subjects and normozoospermia contrast to our findings. Our results demonstrated that there was positive significant correlation between selenium and semen quality. Our findings are not agreed with those of other studies conducted by Xu B et al, [112]; Oldereid et al, [113] but agreed with Behne et al [109].

3.5.7. Chromium concentration and Male Infertility

This study determined the chromium concentration in seminal plasma, and obtained results shows that maximum concentration was observed in azoospermia and oligozoospermic subjects, when compared to normozoospermia. Umeyama et al, [114]; Skandhan et al, [115], also observed similar results that the oligozoospermic subjects had the high mean value in seminal chromium of all the study groups. Occupational exposure of chromium and heavy metals associated with poor semen quality. The concentration of chromium in seminal fluids in welders was significantly high when compare to non welders [116]. Li et al, [117] shows that sperm counts and sperm motility was reduced half during occupational exposure. Previous studies by Rosen and Weintraub, [118] in virile oligozoospermics have shown a correlation between high serum FSH (but not LH) and low sperm counts by occupational exposure. High chromium concentration in seminal plasma has adverse effect on sperm production, motility and sperm count in oligozoospermic and azoospermic infertile men [119].

4. Conclusion

This study concludes that trace metal ions present in seminal plasma due to life style changes and its associated factors have high impact on incidence of male infertility among in and around Chennai population.

References

[1] O. Rutstein et al, Infecundity, Infertility, and Childlessness in Developing Countries, DHS Comparative Reports No 9, Calverton, Maryland, USA: ORC Macro and the World Health Organization, 2004.
[2] J.A. Martin et al, “Births: final data for 2006,” National Vital Statistics Reports, 57, pp. 1–101, 2009.
[3] P. Thonneau et al, “Incidence and main causes of infertility in a resident population (1,850,000) of three French regions (1988-1989),” Human Reproduction, 6, pp. 811–816, 1991.

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[4] R.H. Mehta, S. Makwana, G.R. Ranga, "Prevalences ofoligozoospermia and azoospermia in male partners of infertile couples from different parts of India," Asian Journal of Andrology, 8, pp. 89–93, 2006.
[5] H. Fisch et al, "Geographic variations in sperm counts: a potential cause of bias in studies of semen quality," Fertility and Sterility, 65, pp. 1009–1014, 1996.
[6] U. Larsen, "Primary and secondary infertility in sub-Saharan Africa," International Journal of Epidemiology, 29, pp. 285–291, 2000.
[7] E.F. Okonofua et al, "The social meaning of infertility in Southwest Nigeria," Health Transition Review, 7, pp. 205–220, 1997.
[8] O.O. Adetoro et al, "The prevalence of infertility in a rural Nigerian community," African Journal of Medicine and Medical Sciences, 20, pp. 23–27, 1991.
[9] L. Schmidt et al, "Infertility and the seeking of infertility treatment in a representative population," British Journal of Obstetrics and Gynaecology, 102, pp. 978–984, 1995.
[10] E. Ugwuja e al, "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, pp. 67–73, 2008.
[11] F.H. Comhaire, World Health Organization, "Towards more objectivity in diagnosis and management of male infertility," International Journal of Andrology, 7, pp. 1–53, 1987.
[12] A. Jungwirth et al, "Guidelines on Male Infertility," European Urology, 62, pp. 324–332, 2012.
[13] S. Kumar et al, "Lifestyle factors in deteriorating male reproductive health," Indian Journal of Experimental Biology, 47, pp. 615–624, 2009.
[14] R.M. Sharpe, "Lifestyle and environmental contribution to male infertility," British Medical Bulletin. 56, pp. 630–642, 2000.
[15] R. Ivell, "Lifestyle impact and the biology of the human scrotum," Reproductive Biology and Endocrinology, 5, pp. 15–20, 2007.
[16] O. Abarikwu, "Causes and Risk Factors for Male-Factor Infertility in Nigeria: A Review," African Journal of Reproductive Health, 17, pp. 150–166, 2013.
[17] J. Poongothai, "Etiology, investigation and treatment of Human men's infertility," Journal of Infertility and Reproductive Biology, 1, pp. 31–36, 2013.
[18] M. Hidiroglou, "Trace element deficiencies and fertility in ruminants: a review," Journal of Dairy Science, 8, pp. 1195–1206, 1979.
[19] S. Yamaguchi et al, "Zinc is an essential trace element for spermatogenesis," Proceedings of the National Academy of Sciences of the United States of America, 106, pp. 10859–10864, 2009.
[20] E. Tvrda et al, "Iron and copper in male reproduction: a double-edged sword," Journal of Assisted Reproduction and Genetics, 32, pp. 3–16, 2015.
[21] M. Marcus et al, "Changing sex ratio in the United States 1969–1995," Fertility and Sterility, 70, pp. 270–273, 1998.
[22] S.H. Swan et al, "The question of declining sperm density revisited: an analysis of 101 studies published 1934–1996," Environmental Health Perspectives, 108, pp. 961–966, 2000.
[23] S.K. Lwanga et al, "Sample Size Determination in Health Studies: A Practical Manual", Geneva, World Health Organization, 1991.
[24] World Health Organization, Department of Reproductive Health and Research, "WHO laboratory manual for the examination and processing of human semen," fifth edition, WHO 2010.
[25] M. Saito et al, "Estimation of zinc in serum by colorimetric assay," Clinica Chimica Acta, 120, pp. 127–135, 1998.
[26] M. Katayama et al, "Determination of Trace Metals in Human Seminal Plasma Using Inductively Coupled Plasma Mass Spectrometry and Multivariate Statistical Analyses for Sperm Parameters," Journal of Molecular Biomarkers and Diagnosis, 4, pp. 147–155, 2013.
[27] A. Jung et al, "Comparison of semen quality in older and younger men attending an andrology clinic," Andrologia, 34, pp. 116–122, 2002.
[28] W.J.C. Hellstorm et al, "Effects of acute treatment with tamsulosin versus alfuzosin on ejaculatory function in normal volunteers," Journal of Urology, 176, pp. 1529–1533, 2006.
[29] E. Levitas et al, "Relationship between age and semen parameters in men with normal sperm concentration: analysis of 6022 semen samples," Andrologia, 39, pp. 45–50, 2007.
[30] S.A. Kidd et al, "Effects of male age on semen quality and fertility: a review of the literature," Fertility and Sterility, 75, pp. 237–248, 2001.
[31] S. Elzanaty, "Association between age and epididymal and accessory sex gland function 124 and their relation to sperm motility," Arch Andrology, 53, pp. 149–156, 2007.
[32] R. Henkel et al, "Effect of reactive oxygen species produced by spermatozoa and leukocytes on sperm functions in nonleukocytospermic patients," Fertility and Sterility, 83, pp. 635–642, 2005.
[33] D.S. Gaur et al, "Effect of cigarette smoking on semen quality of infertile men," Singapore Medical Journal, 48, pp. 119–123, 2007.
[34] G. Holzki et al, "Cigarette smoking and sperm quality," Andrologia, 23, pp. 141–144, 1991.
[35] S. Bhasin et al, "Testosterone replacement increases fat-free mass and muscle size in hypogonadal men," Journal of Clinical Endocrinology and Metabolism, 82, pp. 407–413, 1997.
[36] A.R. Greenlee et al, "Risk factors for female infertility in an agricultural region," Epidemiology, 4, pp. 429–436, 2003.
[37] B.C. Durphy et al, "Male alcohol consumption and fecundity in couples attending an infertility clinic," Andrologia, 23, pp. 219–221, 1991.
[38] S.C. Zhang et al, "Analysis of change in sperm quality of Chinese fertile men during 1981–1996," Journal of Reproduction and Contraception, 10, pp. 33–39, 1999.
[39] R. Sharma, K.R. Biedenharn, J.M. Fedor, A. Agarwal, Lifestyle factors and reproductive health: taking control of your fertility, Reproductive Biology and Endocrinology, 11, pp. 66, 2013.
[40] M.H. Briggs, "Cigarette smoking and infertility in men," Medical Journal of Australia, 1, pp. 616–617, 1973.

Licensed Under Creative Commons Attribution CC BY

[41] S.R. Soares et al, "Clinical factors affecting endometrial receptiveness in oocyte donation cycles," Fertility and Sterility, 89, pp. 491–501, 2008.
[42] A.H. Colagar et al, "Zinc levels in seminal plasma are associated with sperm quality in fertile and infertile men," Nutrition Research, 29, pp. 82–88, 2009.
[43] K.J. Joo et al, "The effects of smoking and alcohol intake on sperm quality: light and transmission electron microscopy findings," Journal of International Medical Research, 40, pp. 2327–2335, 2012.
[44] A. Tsujimura et al, "Effects of life style factors on infertility in men," Arch Andrology, 50, pp. 15, 2004.
[45] T.K. Jensen et al, "Does moderate alcohol consumption affect fertility? Follow up study among couples planning first pregnancy," British Medical Journal, 317, pp. 505–510, 1998.
[46] R.Kalyani et al, "Factors influencing quality of semen: a two year prospective study," Indian Journal of Pathology and Microbiology, 4, pp. 890–895, 2007.
[47] L.K. Dhaliwal et al, "Psychological aspects of infertility due to various causes – a prospective study," International Journal of Fertility and Women's Medicine, 1, pp. 44–48, 2004.
[48] A.M.E. De Jong, R. Menkveld, J.W. Lens, S.E. Nienhuis, J.P.T. Rhemrev, Effect of alcohol intake and cigarette smoking on sperm parameters and pregnancy, Andrologia. 46(2014) 112–117.
[49] H. Guo et al, "Effects of cigarette, alcohol consumption and sauna on sperm morphology," National journal of Andrology, 12, pp. 215–217, 2006.
[50] K.R. Muthusami et al, "Effect of chronic alcoholism on male fertility hormones and semen quality," Fertility and Sterility, 4, pp. 919–924, 2005.
[51] K. Kucheria et al, "Semen analysis in alcohol dependence syndrome," Andrologica, 17, pp. 558–563, 1985.
[52] A. Kasana et al, "Homeopathy and its scope in Increasing sperm count and its action on male fertility," International Journal of Complementary and Alternative Medicine, 6, pp. 1–3, 2017.
[53] L. Rato et al, "High-energy diets: a threat for male fertility?", Obesity Reviews, 15, pp. 996–1007, 2014.
[54] H.W. Bakos et al, "Paternal body mass index is associated with decreased blastocyst development and reduced live birth rates following assisted reproductive technology," Fertility and Sterility, 95, pp. 1700–1704, 2011.
[55] D.H. Morgan et al, "Cholesterol-enriched diet disrupts the blood-testis barrier in rabbits," American Journal of Physiology-Endocrinology and Metabolism, 307, pp. 1125–1130, 2014.
[56] A.S. Prasad, "Zinc deficiency in humans: a neglected problem," The Journal of the American College of Nutrition, 17, pp. 542–543, 1998.
[57] N.B. Batra et al, "Reproductive potential of male Portan rats exposed to various levels of lead with regard to zinc status," British Journal of Nutrition, 91, pp. 387–391, 2004.
[58] H. Fuse et al, "Relationship between zinc concentrations in seminal plasma and various sperm parameters," International Urology and Nephrology, 31, pp. 401–408, 1999.
[59] S.E. Chia, "Comparison of zinc concentrations in blood and seminal plasma and the various sperm parameters between fertile and infertile men," Journal of Andrology, 21, pp. 53–57, 2000.
[60] W.Y. Wong et al, "Male factor sub fertility: possible causes and the impact of nutritional factors," Fertility and Sterility, 73, pp. 435–442, 2000.
[61] Z. Liu, "The micronutrient element zinc modulates sperm activation through the SPE-8 pathway in Caenorhabditis elegans," Development, 140, pp. 2103–2107, 2013.
[62] C.I. Madding et al, "Serum and semen zinc levels in normozoospermic and oligozoospermic men," Annals of Nutrition and Metabolism, 30, pp. 213–218, 1986.
[63] A.H. Colagar et al, "Zinc levels in seminal plasma are associated with sperm quality in fertile and infertile men," Nutrition Research, 29, pp. 82–88, 2009.
[64] Y. Li et al, "Seminal plasma zinc and sperm quality correlation analysis of male infertile patients," Inner Mongolia Journal of Traditional Chinese Medicine, 24, pp. 90–92, 2013.
[65] C.S. Liao, "Analysis of seminal plasma zinc measurement and malesterility," China Medical Herald, 8, pp. 86–89, 2008.
[66] K.H. Shi et al, "Correlation study of the microelement content in male infertility patient's blood and semen," The Chinese Journal of Human Sexuality, 23, pp. 28–30, 2014.
[67] X. Xu et al, "Relationship between the levels of Zn, Cu, Fe, Mu, Ni in seminal plasma and male infertility," Journal of Ningxia Medical College, 19, pp. 13–16, 1997.
[68] D. Zhang et al, "Clinical study of Zn complex glucose acid as an adjuvant drug for the treatment of the male infertility due to semen of poor quality", China Journal of Urology, 24, pp. 564–567, 2003.
[69] L.P. Zheng, "The comparative analysis of trace elements in blood and seminal plasma of infertile and healthy male," Progress in Modern Biomedicine, 12, pp. 681–683, 2012.
[70] O. Deger et al, "Semen magnesium levels in fertile and infertile subjects," Magnesium, 1, pp. 6–8, 1988.
[71] N. Zarghami et al, "Seminal plasma levels of 15-F 2α-isoprostane, malondialdehyde, and total homocysteine in normozoospermic and asthenozoospermic males," Indian Journal of Clinical Biochemistry, 20, pp. 86–91, 2005.
[72] Y.Y. Hsieh, C.C. Chang, C.S. Lin, "Seminal malondialdehyde concentration but not glutathione peroxidase activity is negatively correlated with seminal concentration and motility," International Journal of Biological Sciences, 1, pp. 23–29, 2006.
[73] M.B. Sorensen et al, "Zinc, magnesium and calcium in human seminal fluid: relations to other semen parameters and fertility," Molecular Human Reproduction. 5, pp. 331–337, 1999.
[74] H. Fakih et al, "Enhancement of human sperm motility and velocity in vitro: effects of calcium and creatine phosphate," Fertility and Sterility, 46, pp. 938–944, 1986.
[75] S. Viski et al, "Effects of magnesium on spermatogenesis. In: T. Theophanides, J. Anastassopoulou. (eds). Magnesium Current Status and

Licensed Under Creative Commons Attribution CC BY

New Developments," Kluwer Academic Publishers, 2, pp. 335–339, 1997.
[76] Y. Morita et al, "Oocyte apoptosis is suppressed by disruption of the acid sphingomyelinase gene or by sphingosine-1-phosphate therapy," Nature Medicine, 6, pp. 1109–1114, 2000.
[77] D. Meirow et al, "Administration of cyclophosphamide at different stages of follicular maturation in mice: effects on reproductive performance and fetal malformations," Human Reproduction, 16, pp. 632–637, 2001.
[78] H.M. Wu et al, "Lead level in seminal plasma may affect semen quality for men without occupational exposure to lead," Reproductive Biology and Endocrinology, 10, pp. 91–96, 2012.
[79] P.C. Hsu et al, "Effect of smoking on blood lead levels in workers and role of reactive oxygen species in lead-induced sperm chromatin DNA damage," Fertility and Sterility, 91, pp. 1096–1103, 2009.
[80] J. Xuezhi et al, "Studies on lead exposure on reproductive system: a review of work in China," Biomedical and Environmental Sciences, 5, pp. 266–275, 1992.
[81] T.G. Robins et al, "Semen quality and fertility of men employed in a South African lead acid battery plant," American Journal of Industrial Medicine, 32, pp. 369–376, 1997.
[82] E.A. El-Zohairy et al, "Reproductive hazards of lead exposure among urban Egyptian men," Reproductive Toxicology, 10, pp. 145–152, 1996.
[83] P. Fatima et al, "Relationship of blood and semen lead level with semen parameter," Mymensingh Medical Journal, 19, pp. 405–414, 2010.
[84] M. Eidi et al, "Seminal plasma levels of copper and its relationships with seminal parameters", Iranian Journal of Reproductive Medicine, 8, pp. 60–65, 2010.
[85] F. Jockenhovel et al, "Seminal lead and copper in fertile and infertile men," Andrologia, 22, pp. 503–511, 1990.
[86] B. Aydemir et al, "Impact of Cu and Fe concentration on oxidative damage in male infertility," Biological Trace Element Research, 112, pp. 193–203, 2006.
[87] A. Shinohara et al, "Trace elements and sperm parameters in semen of male partners of infertile couples," Japanese Journal of Hygiene, 60, pp. 418–425, 2005.
[88] H. Katayose et al, "Effects of various elements in seminal plasma on semen profiles," Journal of Mammalian Ova Research, 21, pp. 141–148, 2004.
[89] A.W.R. Hamad et al, "Sodium, Potassium, Calcium and Copper Levels in Seminal Plasma are Associated with Sperm Quality in Fertile and Infertile Men," Biochemical Pharmacology, 141, pp. 1–7, 2014.
[90] A.S. Vickram et al, "Effect of various biomolecules for normal functioning of human sperm for fertilization: A Review," International Journal of Pharmacy and Pharmaceutical Sciences, 4, pp. 18–24, 2012.
[91] A. Kaya et al, "Influence of ejaculation frequency on sperm characteristics, ionic composition and enzymatic activity of seminal plasma in rams," Small Ruminant Research, 44, pp. 153–158, 2002.
[92] S. Battersby et al, "Correlation between elemental composition and motility of human spermatozoa," Fertility and Sterility, 28, pp. 557–561, 1977.
[93] A. Bondani et al, "Co-relation between sperm motility and electrolyte composition of seminal fluid in normal and infertile men," Fertility and Sterility, 24, pp. 150–158, 1973.
[94] S. Gaffuri et al, "On medical therapy of conjugal sterility with a male component: HMG Clinical case studies," Minerva Ginecologica, 31, pp. 1911–1916, 1968.
[95] S.M. Girgis et al, "C-reactive protein in semen and serum of men with chronic prostatitis," Andrologia, 15, pp. 151–154, 1983.
[96] P.H. "Sodium and potassium in normal and pathological seminal plasma," Acta Europaea Fertilitaties, 19, pp. 333–336, 1988.
[97] K.P. Skandhan et al, "Correlation of sodium and potassium in human seminal plasma with fertilizing capacity of normal, and infertile subjects," Andrologia, 13, pp. 147–154, 1981.
[98] A. Kaya et al, "Influence of ejaculation frequency on sperm characteristics, ionic composition and enzymatic activity of seminal plasma in rams," Small Ruminant Research, 44, pp. 153–158, 2002.
[99] M.R. Kanwal et al, "Bulk cations and trace elements in the Nili-Ravi buffalo and crossbred cow bull semen," International Journal of Agriculture and Biology, 2, pp. 302–305, 2000.
[100] W.Y. Wong et al, "The impact of calcium, magnesium, zinc, and copper in blood and seminal plasma on semen parameters in men," Reproductive Toxicology, 15, pp. 131–136, 2001.
[101] G. Logoglu et al, "The role of seminal calcium in male infertility", Journal of Islamic Academic of Sciences, 10, pp. 25–27, 1997.
[102] T. Umeyama et al, "A comparative study of seminal trace elements in fertile and infertile men," Fertility and Sterility, 46, pp. 494–499, 1986.
[103] S. Arver, "Studies on zinc and calcium in human seminal plasma," Acta Physiologica Scandinavica, 507, pp. 1–21, 1982.
[104] L.R. Fraser, "Minimum and maximum extracellular Ca2+ requirements during mouse sperm capacitation and fertilization in vitro," Journal of Reproduction and Fertility, 81, pp. 77–89, 1987.
[105] F.R. Abou-Shakra et al, "The role of trace elements in male infertility", Fertility and Sterility, 52, pp. 307–310, 1989.
[106] D. Xu et al, "The associations between concentration of selenium in semen and sperm parameters as well as oxidative DNA damage in human sperm," Chinese journal of preventive medicine, 35, pp. 394–396, 2001.
[107] D.X. Xu et al, "The associations among semen quality, oxidative DNA damage in human spermatozoa and concentrations of cadmium, lead and selenium in seminal plasma," Mutation Research, 10, pp. 155–163, 2003.
[108] A. Shinohara et al, "Trace elements and sperm parameters in semen of male partners of infertile couples," Academic Journal for Endocrinology, 60, pp. 418–425, 2005.

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[109] D. Behne et al, "Selenium, rubidium and zinc in human semen and semen fractions," International Journal of Andrology, 11, pp. 415–423, 1998.
[110] M. Saaranen et al, "Lead, magnesium, selenium and zinc in human seminal fluid:compareswith semen parameters and fertility," Human Reproduction, 6, pp. 475–479, 1987.
[111] O. Akinloye et al, "Selenium Status of Idiopathic Infertile Nigerian Males," Biological Trace Element Research, 10, pp. 9–18, 2005.
[112] B. Xu et al, "Trace elements in blood and seminal plasma and their relationship to sperm quality," Reproductive Toxicology, 6, pp. 613–618, 1993.
[113] Y. Olderide et al, "Selenium in human male reproductive organs," Human Reproduction, 8, pp. 2172–2176, 1998.
[114] T.H. Umeyama et al, "A comparative study of trace elements in seminal fluid in fertile and infertile men," Journal of Andrology, 6, S129–S129, 1985.
[115] K.P. Skandhan et al, "Levels of cadmium, chromium, nickel, manganese and lead in normal and pathological human seminal plasma," Urologia, 72, pp. 461–464, 2005.
[116] J.T. Mortensen, "Risk for reduced sperm quality among metal workers with special reference to welders" British Journal of Industrial Medicine, 14, pp. 27–30, 1988.
[117] H. Li et al, "Effect of Cr (VI) exposure on sperm quality: human and animal studies," Annals of Occupational Hygiene, 7, pp. 505–511, 2001.
[118] S.W. Rosen et al, "Monotropic increase of serum FSH correlated with low sperm count in young men with idiopathic oligozoospermia and aspermia," Journal of Clinical Endocrinology and Metabolism, 32, pp. 410–416, 1971.
[119] I.E. Bassey et al, "Seminal Plasma Chromium, Cadmium and Lead Levels in Infertile Men," Journal of Medical Sciences, 13, pp. 497–500, 2013.

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