

Effect of modifiable risk factors on semen parameters

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Abstract

Objective: This article examines the potential effects of lifestyle factors on male reproductive health. Evidence of a global decline in human sperm quality over recent decades has been accumulating. Environmental, occupational and modifiable lifestyle factors may contribute to this decline. This review focuses on key lifestyles factors such as diet, caffeine intake, tobacco chewing and alcohol intake. **Method:** A comprehensive literature search was performed to identify the major lifestyle factors associated with male infertility and semen quality. Database searches were limited to reports published in English only. **Results:** A prudent diet consists of high intake of fish, fruit, vegetables and legumes. Fat in diet is also as essential as other component of the diet. Although largely the evidence is observation based, evidence appears to support an approach of moderation carbohydrate and fats with better semen parameters. A good intake of antioxidants in diet and supplement correlates with higher sperm numbers and motility. The other very important modifiable factors are tobacco chewing, alcohol and caffeine intake. Nicotine in tobacco is found to suppress sperm progressive motility; it also reduces the percentage of viable spermatozoa and increases the altered chromatin compactness. Alcohol consumption leads to increased testosterone level due to change in oxidation metabolism of steroids in liver. Alcohol oxidation increases the Nicotinamide adenine dinucleotide (NAD) ratio which causes the re-dox state in favour of conversion of androstenedione into the reduced steroids testosterone and oestradiol. Caffeine intake has been associated with sperm DNA defects, aneuploidy and DNA breaks. **Conclusion:** The major lifestyle factors discussed in the present review are the potential issues that can possibly impair male infertility. However, their negative impact can be overcome by behavioural modification and better lifestyle changes.


Keywords: Alcohol and caffeine intake, male infertility, semen parameters, smoking

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INTRODUCTION

Infertility brings about psychological, economical and medical implications to the couple. WHO defines infertility as the failure to achieve clinical pregnancy after 12 months or more of regular unprotected sexual intercourse.^[1] It is estimated to affect 8% to 12% of

couples globally.^[2] In 1980, a major concern regarding the deteriorating trend of semen quality had emerged.^[3] To understand the problem, various studies were done, one of which was a meta-analysis reviewing 61 articles. They had concluded that there was a fall by 1% every year between 1928 and 1990. Many subsequent studies also followed concluding the same.^[4,5] As far as Indian

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men are concerned, we have very limited data. A study was conducted in South India over a period of 13 years, where they found decline in sperm count that was 30.31%, whereas sperm motility and morphology was reduced by 22.92% and 51.25%, respectively. Although the exact reason for the decline in semen quality was not stated, concurrent trends in worsening diet and quality of life could in some way explain these trends.^[6]

INFLUENCE OF DIET AND MODIFIABLE FACTORS ON SEMEN PARAMETERS

Numerous genetic and non-genetic ambient conditions contribute to male infertility. The common genetic factors include translocation of autosomal chromosomes, structural abnormalities of the sex chromosomes or mutations of cystic fibrosis genes. Dietary behaviour, professional circumstances and environmental toxins are some of the non-genetic factors. Unlike many of these risk factors causing decline in semen parameters, diet poses an opportunity for intervention. Hence, including it in the counselling of sub-fertile men has been found to be important. A balanced diet comprises of carbohydrate, fats, proteins, vitamins and minerals.^[7]

Carbohydrate

Carbohydrates are one of the three main classes of food and a source of energy. They come in simple forms such as sugar and in complex forms such as starch and fibre. It breaks down to glucose, which is utilised to give energy. High carbohydrate content is present in dairy products, grains, legumes, starchy vegetables and sugary food.^[8] Mostly milk is derived from pregnant cows and hence oestrogen content is in measurable concentration.^[9] Carbohydrate comprises of 47% of the western pattern diet and this kind of diet is associated with an increased risk of obesity.^[10] Obesity causes an alteration in semen parameters, especially total concentration,^[7] total progressive motile sperm count, sperm morphology, total motile sperm count and DNA fragmentation. In obese men, both oestrone and oestradiol are increased due to increased aromatisation of androgens which alters the hypothalamic–pituitary gonadal axis.^[8] Although there are not studies which imply that reduction in weight can improve fertility. Large, randomised control trials are needed to better characterise the therapeutic benefits of weight loss. A study conducted by Mendiola *et al.*^[11] compared the dietary habits of normospermic and oligoasthenotertatospermic patients. They found that the patients who were frequently consuming lipophilic

food like milk may have a negative effect on the semen quality. In 2012, another study compared dietary patterns and semen quality. In this cross-sectional study, diet of 188 young men was analysed. Two dietary patterns, western and prudent, were identified. ‘Western’ diet was characterised by high intake of refined grains, pizza and high energy drinks and sweets, whereas the ‘prudent’ diet was characterised by high intake of fish, fruit, vegetables and legumes. They concluded that higher consumption of a prudent dietary pattern was associated with higher sperm motility.^[12] Liu *et al.*^[13] studied the association between the dietary pattern and semen quality in a general Asian population of 7282 males. They concluded intake of a ‘western diet’ was linked to a poor sperm count and normal sperm morphology. Sugar-sweetened drinks intake is associated with a lower sperm count and high-carbohydrate food is related to elevated prevalence of abnormal total sperm motility and progressive motility.^[13]

Fats

Cholesterol is needed for membrane permeability and fluidity hence sperm membrane is extremely sensitive to any change in diet. The increase in the cholesterol level has shown to cause changes in the sperm bilayer membrane including the osmotic strength, acrosomal reaction, sperm count and motility. This causes a significant decrease in the sperm volume and increase in the number of abnormal sperms.^[14] A study done in Iran correlated the fat intake with semen parameters of 120 Iran men. Their study showed significant relationship between total fat intake and semen volume. They concluded that decrease in total fat and cholesterol can be effective in improving semen volume.^[15] A study done by Olsen and Ramlau-Hansen^[16] reported that a high intake of saturated fat intake was inversely associated with sperm concentration and total sperm count. Each 5% increment in total fat intake was associated with an 18% lower total sperm count.^[16] In a similar study, Attaman *et al.*^[17] also showed that a higher intake of total fat was negatively related to sperm count and concentration. Unlike saturated fats, these fatty acids can be further subdivided based upon double-bond locations within the hydrocarbon chain. Fatty acids are chains of carbons with a methyl group (CH₃) at one end and a carboxyl group (COOH) at the other. The carbon chain may be saturated or it may contain one or more double bonds as in mono and Polyunsaturated fatty acids (PUFA), respectively. Eicosanoids play a role in male fertility as they contribute to sperm structure. A dramatic effect on cell function as well as membrane fluidity depends up on the number, position and *cis/trans*

state of the double bond. The first carbon of the methyl group is called omega system and depending on the distance of the other carbons from omega is called omega-3, omega-6 and omega-9. Although dietary fatty acids are found in triglyceride form, fatty acids are phospholipids in the cell membrane. Safarinejad *et al.*^[18] did a randomised double-blind control trial of supplemental omega-3 against placebo. They found that the total sperm count increased from 38.7 to 61.7 suggesting the benefits of omega-3 against the effects of oxidative stress.^[18] There are some studies on dietary plant omega-3 sources and semen quality. Addition of oral antioxidants to men diagnosed with oligoasthenoteratozoospermia greatly increased motility and sperm quality.^[19]

Protein

Proteins are the building blocks of life which is made of a chain of amino acids. The essential amino acids are taken in diet. Contents of semen are derived from testis, epididymis and male accessory glands. Increasing seminal plasma proteins have been shown to be associated with increase in sperm motility.^[20] There is not much literature wherein effect of protein in diet have being studied on human semen. In an Indian study, Shanmugam *et al.*^[21] studied the same on male layer breeders because of restricted feeding practice. They concluded that the dietary crude protein and energy combination influences abnormal sperm in semen, fertility and hatchability.^[21]

Vitamins and minerals

An ideal diet generally provides all the vitamins, and minerals. However, most of the people follow a poor diet intake and hence require multivitamin supplements.

Vitamin C can be found in high concentrations in seminal plasma and prohibits DNA damage. Vitamin E which is a fat-soluble antioxidant neutralises free radicals and protects cellular membrane against O₂ free radicals.^[22] Moslemi and Tavanbakhsh^[23] studied 690 men with idiopathic asthenospermia who received daily supplement of selenium and vitamin E for 100 days. They found that 52.6% (362 men) had total improvement in sperm motility and morphology and 10.8% (75 men) had spontaneous conception with no treatment.^[23] Similar studies have shown associations between various vitamins and semen parameters.

Coenzyme Q10, an antioxidant, is a component of electron transport chain. In a study, CoQ10 therapy

was given to 60 men with idiopathic asthenoteratospermia. After 6 months, it was seen that CoQ10 increased in the semen, improving the sperm motility which resulted in 12 spontaneous pregnancy.^[22] A study done by Eskenazi *et al.*^[24] studied the association of antioxidants with semen quality in healthy men. They found that higher antioxidant intake correlated with higher sperm numbers and higher motility over normal dietary and supplement use.^[24]

TOBACCO SMOKING

Despite the well-known deleterious effect of cigarette smoking on general health, tobacco smoking is becoming worse day by day. Tobacco kills one of 10 adults worldwide especially in the developing countries according to WHO statistical data.^[25] Cigarette smoke contains several toxic compounds, including nicotine, carbon monoxide and cadmium which have detrimental effect on male germ cells.^[26] In 2013, Condorelli *et al.*^[27] did an experimental study on semen samples of 10 normozoospermic healthy men. They incubated the sperms with increasing concentrations of nicotine (0, 1, 10 and 100 ng/mL) and evaluated their effect on semen parameters. They found that nicotine suppressed, in a concentration- dependent manner, the sperm progressive motility starting from the lowest concentration used. It also reduced the percentage of viable spermatozoa and increased the number of spermatozoa in late apoptosis, with altered chromatin compactness even after just 3 hours of incubation. They concluded that nicotine may be considered a component of cigarette smoke deleterious for sperm parameters.^[27] Assisted reproduction has being known to overcome many barriers associated with male infertility. In a study by Zitzmann *et al.*^[28] assessed 300 couples for their smoking status, age, semen parameters and numbers of embryo transferred. They found that Intra-cytoplasmic sperm injection (ICSI) clinical pregnancy success rate was 22% in smoking male partners compared to 38% with non-smoker partners. Similar outcomes were observed in *in vitro* fertilisation pregnancy rates. They concluded that smoking by males decreases the success rate of assisted reproductive technology (ART).^[28] In 2016, Asare-Anane *et al.*^[29] recruited 140 individuals out of which 95 were smokers and 45 non-smokers. Smokers were classified into mild, moderate and heavy smokers based on the number of cigarette sticks used per day (<5, 5–10 and >10, respectively). They found that the mean semen volume, percentage motility, normal sperm morphology, total sperm count, follicle stimulating hormone (FSH) and free and total testosterone (TT) of non-smokers were

significantly higher ($P < 0.05$ in all). When they analysed the effect of number of sticks smoked per day with the semen parameters, they found that although the number per day did not have a significant effect on semen volume but it significantly reduced semen pH, sperm motility, viability, morphology and total sperm count ($P < 0.05$ in all).^[29] Not only exposure to tobacco after birth has an adverse effect of reproductive system of males but *in utero* exposure to tobacco has also been seen to have a poor effect on it. A follow-up study was done in 2007 by Ramlau-Hansen *et al.*^[30] to assess the semen parameters of men born to mother who were exposed to tobacco smoking during pregnancy. The characteristics of 347 participants according to maternal smoking during pregnancy were compared with the non-exposed men. After adjustment for potential confounders (including men smoking themselves), they found an inverse trend between prenatal exposure to tobacco smoke and crude median semen volume, sperm concentration and total sperm count. Men exposed to heavy smoking in foetal life had approximately 19% lower semen volume ($P=0.04$), 38% lower total sperm count (0.011) and 17% lower mean sperm concentration ($P=0.47$) compared with the non-exposed.^[30]

CAFFEINE INTAKE

In the industrialised world, consumption of caffeine (1,3,7-trimethylxanthine) found in coffee, tea, chocolate and soft drinks especially cola-containing beverage has increased among children and young adults. Colas are originally blends of coca leaf, and the cola nut, mixed with guar water. In a population-based study, semen qualities of 2554 young Danish men were assessed on the basis of their caffeine intake. The participants were categorised as daily intake of 100 to 200, 201 to 801 and >800 mg which corresponds to 1, 2 to 7 and >7 cups of daily coffee consumption. After control for confounders, they found that low and moderate daily caffeine intake was not associated with reduction in semen quality. But consumption of >800 mg of caffeine per day resulted in decline in the quality. They also reported that out of the total, 2114 men drank cola during the past week and 93 drank more than 14 bottles per week. They had poorer semen quality than men who did not. The semen volume, sperm concentration, total sperm count and percentage of spermatozoa with normal morphology decreased in those men.^[31] In a cross-sectional study done by Chiu *et al.*,^[32] consumption of sugar-sweetened beverages (SSBs) was analysed with semen quality in 305 men. Men in the top category of SSB intake had 6.3% lower sperm motility than men in the lowest three quartiles of intake. They also

found an inverse association between SSB and FSH levels with statistical significance ($P=0.07$).^[32] In a systemic review, Ricci *et al.*^[33] retrieved 28 literatures reporting observational information on coffee/caffeine intake and reproductive outcomes. They concluded that though semen parameters were not affected by caffeine (from coffee/tea) but suggested a negative effect of cola-containing beverages on semen volume, count and concentration. With regard to sperm DNA defects, they also found that caffeine intake was associated with aneuploidy and DNA breaks.^[34] In another study, Jurewicz *et al.*^[34] studied the aneuploidy and diploidy and compared it with everyday coffee drinking. They found a positive relationship between caffeine and the lack of chromosome X or Y ($P=0.13$).^[34]

ALCOHOL INTAKE

There are various literatures which have examined alcohol consumption as a risk factor for male infertility and effecting both testosterone metabolism and spermatogenesis. A systemic review and meta-analysis was done by Li *et al.*^[35] They studied 13 socio-psychological behavioural factors in 57 cross-sectional studies which included 29,194 participants from 26 countries. Their results showed that smoking deteriorates all of the sperm parameters in both fertile and infertile men. They also observed that higher age and alcohol consumption are major risk factors for lower semen volume.^[35] In a large cross-sectional study of 8344 healthy men from Europe and the USA, it was observed that alcohol consumption the week prior to the visit was consistently associated with higher testosterone levels and calculated free testosterone level (cFT) and lower sex hormone binding globulin (SHBG) but did not find it to be associated with serum inhibin B or FSH and Luteinizing hormone (LH). The raised testosterone level could be due to alcohol consumption causing detoxification which changes the metabolism of steroids in the liver. Alcohol oxidation increases the Nicotinamide adenine dinucleotide (NAD) ratio which causes the re-dox state in favour of conversion of androstenedione into the reduced steroids testosterone and oestradiol.^[36] Alcohol affects the semen parameters when consumed by mothers in the antenatal care. Alcohol readily crosses the placenta and enters the foetal bloodstream and may affect the foetus directly. In a cohort Danish study, 347 sons were selected and a follow-up study was done in 2005–2006. These participants were sons of mothers recruited in a cohort during their pregnancy from April 1984 to April 1987. The sperm concentration decreased with increasing

prenatal alcohol exposure ($P=0.05$), and the sons with the highest exposure (i.e. sons of mother drinking ≥ 4.5 drinks of alcohol per week during pregnancy) had 32 million/mL and lower adjusted sperm concentration in comparison with men exposed to <1 drink per week ($P=0.04$). Also, the semen volume and total sperm count was associated with prenatal alcohol exposure. They stratified on types of alcohol, that is beer, wine and spirits and found that both beer and spirits were statistically, significantly, inversely associated with sperm concentration ($P=0.005$ and 0.003 , respectively) and total sperm count ($P=0.02$ and 0.01 , respectively). The authors concluded a possible detrimental effect of maternal alcohol intake during pregnancy on sertoli cells.^[37] An Indian study analysed the impact of alcohol intake and cigarette smoking on male fertility over a period of 5 years. They included 100 alcoholics and 100 smokers and compared them with equal number of non-alcoholics and non-smokers. Semen value of these men were analysed for presence of asthenozoospermia. They found that only 12 cases of alcoholics showed normozoospermia, all of who were mild alcoholic. In the heavy alcoholic group, none of the men showed normal sperms. Teratozoospermia ($n=59$) and oligozoospermia ($n=51$) was seen in much higher number among these men compared to the control group. They observed that alcohol appeared to contribute towards developmental defects of sperm morphology and sperm production. This proportion increased with increase in the quantity of alcohol consumption. Among smokers, only six men had normal semen parameters.

CONCLUSION

Increasing trend in reproductive disorders in recent years has being associated with the new emergent lifestyles. Diet is one of the modifiable lifestyle factors which provide an opportunity for therapeutic intervention in the sub-fertile males. A balanced diet consists of carbohydrates, proteins, fats, vitamins and minerals. A prudent diet consists of high intake of fish, fruit, vegetables and legumes. Fat in diet is also as essential as other component of the diet. Cholesterol is required for membrane permeability and fluidity of sperm membrane. But an increase in the blood cholesterol leads adverse effect on the sperm bilayer. Hence, an equilibrium is required. Although largely, the evidence is observational based, evidence appears to support an approach of moderate amount of carbohydrate and fats with better semen parameters. A good intake of antioxidants in diet and supplements correlates with higher sperm numbers and motility. In the industrialised world, smoking, alcohol intake and

caffeine consumption has become very common. Various literatures have concluded that the toxins from cigarette smoke reach the male reproductive system and have adverse effect on the sperm quality. This may be attributed due to their direct interaction with the seminal fluid component and the accessory glands. This leads to reducing the forward line progression of spermatozoa, manifesting as asthenozoospermia. Even alcohol consumption causes progressive damage to sperm morphology and spermatogenesis. This damage from cigarette toxins and alcohol may be initiated in the male foetus also. Consumption of caffeine should be limited to moderate amount especially in men who are sub-fertile.

A good counselling regarding diet and lifestyle modifications can help in maintaining male fertility.

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Conflicts of interest

There are no conflicts of interest.

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