Ochyra, Łukasz, Łopuszyńska, Anna, Pawlicki, Mateusz, Piecewicz-Szczęsna, Halina. Diet and its association with reduced semen quality. Journal of Education, Health and Sport. 2022;12(11):278-283. eISSN 2391-8306. DOI http://dx.doi.org/10.12775/JEHS.2022.12.11.036
https://apcz.umk.pl/JEHS/article/view/40048
https://zenodo.org/record/7301540

The journal has had 40 points in Ministry of Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of December 21, 2021. No. 32343. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical Culture Sciences (Field of Medical sciences and health sciences); Health Sciences (Field of Medical Sciences and Health Sciences). Punkty Ministerialne z 2019 - aktualny rok 40 punktów. Załącznik do komunikatu Ministra Edukacji i Nauki z dnia 21 grudnia 2021 r. Lp. 32343. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).

Received: 15.09.2022. Revised: 20.10.2022. Accepted: 06.11.2022.

Diet and its association with reduced semen quality

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Abstract

Introduction: Infertility is defined as the inability to conceive a child for at least 12 months of regular unprotected intercourse and may affect up to 15% of couples in reproductive age. Decreased sperm quality may be caused by trauma, inflammation, or an inappropriate lifestyle. Studies suggest that diet may be a factor, which has influence on sperm parameters.

Material and methods: The literature of the PubMed scientific base was searched in 2015-2022 using the following keywords: semen, diet, infertility.

Results: Analyzes of eating patterns showed that eating meals rich in red meat, high-fat dairy, sweet energy drinks, and snacks could negatively affect semen. Whereas a pattern based on the consumption of fish, chicken, vegetables, fruits, legumes, and whole grains was associated with an increased concentration of sperm. A high-fat diet (HFD) leads to obesity, endocrine disorders, intestinal microflora dysbiosis and may be a factor that activates autophagy, which results in reduced sperm quality. A ketogenic diet can positively affect the semen of

obese, infertile men. Studies examining the Mediterranean diet suggest that higher compliance rates are associated with a higher percentage of mobility as well as a reduced risk of low sperm concentration. Conclusions: Diet can be an important factor influencing the quality of sperm in men, however there is a need for further extensive, multi-center research that will systematize this knowledge, which will enable the creation of specific nutritional recommendations for this group of people.

Keywords: semen, diet, infertility

Introduction

Infertility is a disorder affecting more and more people these days. According to WHO, this problem may affect up to 15% of couples in reproductive age. Infertility is defined as the inability to conceive a child for at least 12 months of regular unprotected intercourse. This disorder affects both women and men, however, according to studies, the male factor is the primary or a coexisting cause in approximately 50% of couples [1]. Moreover, it was found, that in 1973-2011 both sperm concentration, as well as their total number decreased significantly [2]. Decreased sperm quality may be caused by mechanical trauma to the testicle, complications of inflammation in the genital area, but also an inappropriate lifestyle and environmental factors. In addition to genetic and endocrine factors, it is suggested that smoking, alcohol consumption, low physical activity and diet may affect semen quality in men [3].

Material and methods

The literature of the PubMed scientific base was searched in 2015-2022 using the following keywords: semen, diet, infertility.

Results

Many studies focus on the analysis of individual nutrients and their effect on semen quality, while the diet is a collection of all consumed products, so it is necessary to evaluate it holistically. It is not easy, due to the fact, that many geographic areas use the method of nutrition that is specific to a given region. However, there are eating patterns that are widely known all over the world.
In the study by Jurewicz et al., the relationship between used nutritional pattern, the quality of sperm and the level of reproductive hormones was analyzed in 336 men. During the analysis of the diet, two patterns were distinguished: "Western", which was characterized by frequent consumption of red and processed meat, butter, high-fat dairy products, pizza, snacks, high-energy drinks and "cautious", which was dominated by the consumption of fish, chicken, fruit, vegetables, legumes and whole grains. It was found that the "cautious" pattern was associated with increased sperm concentration, testosterone levels and a reduced number of sperm with damaged DNA. There were no differences in sperm motility, number of sperm with abnormal morphology, and concentration of FSH and estradiol [4]. Another study by Nassan et al. found that the median total sperm count in men out of the highest quintile of observing the “cautious” pattern was about 43 million higher than in men from the lowest quintile. Moreover, the highest quintile of using the “western” pattern was characterized by a median of the total sperm count lower by 26 million compared to the lowest quintile [5].

A high fat diet (HFD) is a diet in which at least 35% of the calories are absorbed from fats, both saturated and unsaturated. Increased consumption of high-fat foods leads to the development of obesity. The increase in the amount of adipose tissue may cause endocrine disorders such as decreased testosterone, LH and SHBG levels (indicating central dysregulation of the hypothalamic-pituitary-gonadal axis), which adversely affect the quality of sperm [6]. In addition, increased BMI is proportional to decrease in parameters assessing semen quality and low total testosterone level [7]. In the study by Andersen et al., after an 8-week period in which there was a weight loss by 16.5 kg on average (average decrease in BMI from 37 ± 2.8 kg / m2 to 32 ± 2.9 kg / m2) caused by diet, an improvement in the concentration and number of sperm was found (1.49-fold increase in sperm concentration and 1.41-fold increase in their total number), which additionally confirms the negative impact of obesity on the quality of sperm in men [8].
Autophagy is a biological catabolic process that relies on the controlled breakdown of chemical molecules, organelles and cellular fragments. Under physiological conditions, it is used for the degradation of unnecessary or damaged intracellular proteins. It is also activated in response to harmful factors such as infections, oxidative stress or nutrient deficiency. Autophagy is also involved in the spermatogenesis process and the regulation of sperm survival and motility. The relationship with this process was analyzed in a study by Yang Mu et al. in

mice with a high-fat diet and a decrease in sperm production. It was found that HFD-fed mice had impaired spermatogenesis, what was manifested by abnormal levels of sex hormones in the serum (increased levels of estradiol and decreased testosterone levels), a decreased testicular weight to body weight ratio and an abnormal histological structure (atrophied seminal tubules and an increased number of vacuoles). It was also found that the increased level of the BECLIN1 protein mirrors the autophagy activity in these mice. This is important as it allowed the level of this protein to be tested in human sperm samples. Its elevated concentration in infertile, obese men indicated an excessive activation of autophagy, which could have an impact on reduced sperm parameters [9]. A study by Ning Ding et al. reports that dysbiosis of the intestinal microflora caused by the use of a high-fat diet may have a significant impact on spermatogenesis and sperm motility. Mice fed with normal diet and mice after fecal transplantation on HFD diets had significantly reduced sperm count and motility. Moreover, an increased population of two types of Gram-negative bacteria was found: Bacteroides and Prevotella. Endotoxin levels were positively correlated with the abundance of Bacteroides, while the high abundance of Prevotella was strongly associated with reduced sperm motility. Impairment of sperm production and motility was probably associated with high levels of endotoxins, epididymitis, and dysregulation of expression testicular genes [10]. The results of the research are promising and may contribute to discovering the potential cause of infertility, as well as enable the improvement of sperm quality in some men by restoring the normal composition of the intestinal flora.

Fatty acids (FA) have an important role in cellular mechanisms, as they are components of phospholipids that build cell membranes and participate in lipid-protein interactions [11]. In addition, they are used as an energy source and reserve material in the human body. Depending on the presence and amount of double bonds, there are saturated acids (not containing double bonds), monounsaturated acids (one double bond) and polyunsaturated acids (omega-3 and omega-6 fatty acids). The study by Minguez-Alarcon et al. analyzed the effect of fatty acids on the level of reproductive hormones and the volume of testicles in young men. It was found that the consumption of omega-3 fatty acids was positively correlated with the volume of testicles, while the consumption of omega-6 and trans fatty acids was correlated negatively. The median total testicular volume (ml) in males in increasing quartiles of fatty acid intake was 20.7; 21.0; 20.9; 22.9 for omega-3, 22.2; 21.9; 21.5; 20.0 for omega-6 and 21.3; 22.0; 21.9; 20.4 for trans acids. In addition, the consumption of monounsaturated fatty acids (MFA) and trans acids was negatively correlated with the level of testosterone (testosterone concentration 23.6 nmol/l in the first quartile of consumption and 19.4 nmol/l in the fourth quartile for MFA; concentration 22.8 nmol/l in the first quartile and 19.4 nmol/L in the fourth quartile for trans acids). Omega-3 acids may be positively related with testicular function, while omega-6 and trans acids show a negative correlation [12].

The ketogenic diet is characterized by a low intake of carbohydrates - less than 30 g per day (less than 10% of calories consumed), protein consumption depending on the needs and an increased consumption of fats. In this diet, it is important to eat foods such as fatty meats, fish, oils, butter, and nuts. Low consumption of carbohydrates leads to the minimization of insulin secretion and an increase in glucagon secretion, resulting in lipolysis and gluconeogenesis. Fats become the source of energy and the concentration of ketone bodies increases. In a study by Chin-Yu Liu et al., the effect of a ketogenic diet (KD) on metabolic dysfunction and spermatogenesis in mice induced by obesity on a high-fat diet was analyzed. After the 8-week experimental period, a clearly higher percentage of sperm with normal morphology and the percentage of motile sperm was found in mice treated with KD compared with HFD (approximately 2-fold increase in the percentage of normal sperm). In addition, the body weight of the mice on the ketogenic diet was 31.21 ± 1.73 g, and on the HFD 40.91 ± 4.21 g [13]. This type of nutrition can improve sperm quality in infertile, obese men.

The Mediterranean diet is based mainly on the consumption of plant-based products such as fruits, vegetables, bread and whole grains, beans and other legumes, nuts, seeds, olive oil (the main source of fat). Conversely, fish, white meat, dairy products, eggs, red wine are moderate, and red meat is low. This diet is rich in vitamins, unsaturated fatty acids and phenolic compounds of plant origin. The study by E. Ricci et al. examined the impact of following the Mediterranean diet on sperm quality in 309 men. Diet information was obtained using a validated eating frequency questionnaire (FFQ), while adherence to the Mediterranean diet was assessed using the Trichopoulou modified MDS index. It has been found that the use of this method of nutrition is associated with a reduced risk of low sperm concentration and total sperm count [14]. Another study by Salas-Huetos et al. found that the sperm of men with a higher rate of adherence to the Mediterranean diet (MD≥6) had a pH higher by 0,5, an 18.7% higher percentage of total mobility and 11.4% higher percentage of progressive mobility, as well as a 5.3% lower percentage of non-motile sperm compared to the semen of men with an MD≤3 [15].

The type of food consumed and its quantity are important factors determining the quality of the diet, however, the method of preparing meals should not be forgotten. AGEs are glycation end products, that were first identified in heat-treated food as the end products of a non-enzymatic reaction, called the Maillard reaction,

occurring between the aldehyde group of reducing sugars and the amino group of proteins [16]. The body produces AGEs naturally by processing sugars. This is part of normal metabolism, however, if their concentration in the tissues gets too high, they can increase oxidative stress and cause inflammation. Glycation end products can also be delivered to the body from outside, especially in food. Thermal treatment causes the formation of new AGEs, particullary in grilling, baking and frying, which may especially cause reduced sperm motility [17]. The study by Nevin et al. analyzed the effect of AGE on sperm damage. They were incubated with glucose and the AGE intermediates glyoxal (GO) and methylglyoxal (MG) to investigate the effects of glycation on sperm function and whether AGEs are formed. Carboxymethyl-lysine (CML), the dominant AGE, was measured and found to be increased in response to GO. Moreover, in sperm incubated with this substance, an approximately 3-fold increase in the level of 8-oxoguanine - the final product of oxidative DNA damage was observed in comparison with those incubated on a standard sperm preparation medium [18]. In a study by Tatsuya Nakano et al., it was tested whether methylglyoxal influences sperm motility and embryo development after fertilization in mice. A decrease in sperm motility was found both in the upper, less condensed part of the suspension (sperm concentration 80 million/ml) and in the lower, more condensed part (sperm concentration 228-268 million/ml). In the upper part of the suspension, the mobility index of 67.9% was reduced to 49.3%; 35.9%; 2.7% using MG concentrations of 500μM, 1mM and 5mM. In the lower part of the suspension, a significant decrease was noted when using MG at a concentration of 1mM and 5mM (a decrease from 37.2% to 19.8% and from 37.2% to 1.0%). In addition, it was found that the developmental capacity of oocytes fertilized with sperm treated with 500μM and 1 mM MG to the blastocyst stage significantly decreased in a concentration-dependent manner (51.4% and 35.0%, respectively), which confirms the effect of MG on embryonic development after fertilization [19].

The amount of sugar in the diet has increased significantly in recent years. One of the reasons may be the increasing consumption of sugar-sweetened beverages. A study by Hatch et al. found that increased dietary intake of such products was associated with a decreased fertility index (FR) (cycle-specific probability of fertilization). For men who consumed two to six servings of sugar-sweetened beverages per week, the FR was 0.85, while for more than seven servings it was 0.78. The greatest reduction in fertility was noted in men who drank at least seven servings of energy drinks (FR of 0.42). For diet drinks, the FR was 0.96 for the same amount [20]. What is more, another study found that higher consumption of sweet snacks and sugar-sweetened drinks was associated with lower sperm concentration (median concentration 55.741M/ml for the first quartile and 50.762M/ml for the fourth quartile) [21].

Conclusions

The review shows that diet can be an important factor in sperm quality in men. The use of a high-fat diet, foods rich in omega-6 and trans fatty acids leads to a number of disorders that have a negative impact on sperm quality. The ketogenic diet can positively affect the sperm of obese, infertile men, and following the Mediterranean diet is associated with a higher percentage of mobility, as well as a reduced risk of low sperm concentration. However, there is a need for further extensive, multi-center research that will systematize this knowledge, which will enable the creation of specific nutritional recommendations for this group of people.

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