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Impact of male obesity on infertility: a critical review of the current literature

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Objective: To evaluate the current understanding of the effects and potential mechanisms of obesity on male fertility.
Design: Literature review of articles pertaining to obesity and male infertility.
Result(s): Recent population-based studies suggest an elevated risk for subfertility among couples in which the male partner is obese and an increased likelihood of abnormal semen parameters among heavier men. Male factor infertility is associated with a higher incidence of obesity in the male partner. Obese men exhibit reduced androgen and SHBG levels accompanied by elevated estrogen levels. Reduced inhibin B levels correlate with degree of obesity and are not accompanied by compensatory increases in FSH. This complexly altered reproductive hormonal profile suggests that endocrine dysregulation in obese men may explain the increased risk of altered semen parameters and infertility. Additional features of male obesity that may contribute to an increased risk for infertility are altered retention and metabolism of environmental toxins, altered lifestyle factors, and increased risks for sexual dysfunction. Neither reversibility of obesity-associated male infertility with weight loss nor effective therapeutic interventions have been studied yet.
Conclusion(s): The increasing prevalence of obesity calls for greater clinician awareness of its effects on fertility, better understanding of underlying mechanisms, and eventually avenues for mitigation or treatment. (Fertil Steril® 2008;90:897–904. ©2008 by American Society for Reproductive Medicine.)

Key Words: Obesity, male infertility, sperm parameters, oligozoospermia, reproductive hormones, estrogen, testosterone

The word obesity is derived from the Latin *obesus*, which means "one who has become plump through eating." It may have first appeared in the writings of Thomas Venner in 1620 (1). However, the negative effect of obesity on an individual's health has been known for a longer time and can be found in the writings of Hippocrates, Galen, and Avicenna (2). Avicenna was probably among the first who described the relationship between obesity and male infertility in his encyclopedic medical book *The Canon of Medicine*. In a chapter entitled "The health disadvantages of excessive weight," Avicenna wrote, "this human (man) has a cold temperament; this is why he is infertile, unable to impregnate (women) and has low semen" (3). In modern times, the relationship between obesity and male infertility has been largely ignored until recently (4, 5). Interest in the rapid increase in obesity has brought to light the detrimental effects of obesity on health in general and on the reproductive function in particular.

In women, the effects of extremes of body composition on reproductive function are readily evident by altered menstrual function and are well known and extensively studied (6). In men, the negative effects of obesity on reproductive function are less evident and have been less often studied. Numerous recent reports have now been published describing the relationship between obesity and semen characteristics, reproductive endocrine function, sexual function, and male infertility. In the present review, we present a critical analysis of the available literature linking obesity to male infertility. We also discuss the hormonal, toxicologic, and mechanical mechanisms that can explain this relationship.

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OBESITY AND MALE INFERTILITY

Evidence From Epidemiologic Studies

Evidence is accumulating that the observed alterations in semen and sexual function attributable to obesity are manifested as diminished fertility that can be ascertained at the population level. The first report, published in 2006 by Sallmen at al. (7), was a secondary analysis of data extracted from the Agricultural Health Study, which studied 52,395 certified pesticide applicators and 32,347 of their spouses (8). There were 1,329 couples that met the inclusion criteria, including data available regarding body mass index (BMI) for both partners. Infertility was defined as an attempt at conception by the couple that lasted more than 12 months in the last 4 years regardless of whether the couple achieved pregnancy or not. Male BMI was shown to be associated with infertility with an odds ratio (OR) of 1.12 (95% confidence interval [CI] 1.01–1.25) after correction for female BMI, male and female age, smoking status, alcohol use, and exposure to solvents and pesticides. The categorization of BMI into groups showed a dose-effect relationship, with a maximal effect in the BMI 32–43 kg/m^2 group and a plateau of effect beyond this (8). A critical review of this study finds several concerns that limit confidence in its conclusions. The small fraction 2.5% (1329 out of 52,395) of patients included from the population at risk may have distorted or magnified any systematic errors, and there is lack of detail regarding potentially confounding female infertility factors. Moreover, the incidence of infertility in the studied population was very high: 28% (9). This finding was attributed to the elevated age of the population (>30 years old), however, another possible reason might be the exposure to pesticide, a factor that may have affected obese subjects preferentially. Pesticide exposure was shown to be associated with infertility in this population, and modulation of pesticide effects in obese men through altered metabolism or accumulation would have escaped the adjustment for degree of exposure (10, 11). Finally, this analysis assumed that the BMI remained stable over a period of 4 years, an assumption that is not accurate in a young population (majority were <50 years old) (12). Despite these concerns, this study brought to attention the potential relationship between increasing BMI and infertility, perhaps particularly regarding the interaction of environmental toxins, obesity, and male fertility.

In another report, Ramlau-Hansen et al. (13) analyzed data extracted form the Danish National Birth Cohort (14). The original study included 100,000 pregnant women that were interviewed about several topics, including time to achieve pregnancy and male partner BMI. Time to pregnancy and BMI data were available for 53,910 women. Of those, 47,835 were used for final analysis after exclusion of women with possible female factor infertility. Subfecundity was defined as waiting time of more than 12 months to achieve a pregnancy that resulted in a live birth, and the analysis corrected for female BMI and the age of both partners. Couples with overweight (BMI 25–29 .99 kg/m^2) and obese (BMI $\geq$30 kg/m^2) male partners were more likely to have subfecundity, with ORs of 1.15 (95% CI 1.09–1.22) and 1.49 (95% CI 1.34–1.64), respectively, after correction for female BMI and male and female age (14). Some limitations in this study include the fact that BMI data were obtained more than 2 years after the attempt at pregnancy and that subfecundity was defined in relation to live birth. Patients who had miscarriages might have been misclassified as subfertile. Finally, this study included only couples with eventual success at conception, so that an effect of male obesity on failure to conceive altogether would not have have been ascertained. The major advantage of this study is the large number of subjects available for final analysis, which showed a clear relationship between increasing male BMI and subfecundity with a dose-response effect.

The most recent report came from a secondary analysis of a Norwegian database, the Norwegian Mother and Child cohort study, which considered women in their second trimester of pregnancy. Infertility was defined as time to pregnancy of more than 12 months. The weight and height of the male partner were reported by the female participant. The final analysis was performed on 26,303 women out of 45,132 at risk and was corrected for coital frequency, female BMI, male and female age, smoking status, and various risk factors for female infertility. In this study, couples with overweight men (BMI 25–29.9 kg/m^2) had an OR for infertility of 1.19 (95% CI 1.03–1.62), and those with obese men had an OR for infertility of 1.36 (95% CI 1.12–1.62). When BMI was divided into categories, the effect of BMI on infertility showed a dose-response relation with a plateau of the effect at the high BMI levels ($\geq$35 kg/m^2) (15). This plateau at high BMI levels was also seen in the study by Sallmen et al. (7). The use of BMI derived from partner reports is a concern addressed by the authors, who showed a good correlation of this data with self-reported height and weight for the men in this cohort. Another, more important, concern is limitation of the study population to couples who had successfully conceived, so that couples with more severe degrees of infertility could not be considered in the analysis. Such a selection bias can potentially dilute the effect of male obesity on infertility. The advantages of the study are the large number of patients analyzed and the accounting for coital frequency in the analysis. By accounting for coital frequency, it demonstrated that the relationship between male obesity and infertility can be mediated by factors other than sexual dysfunction.

Evidence From Studies of Couples Seeking Fertility Treatment

Evidence of the relationship between obesity and male factor infertility among infertile couples generally supports the thesis that obesity is associated with compromised male fertility. In this context, Magnusdottir et al. (16) studied male partners among 72 couples with infertility classified into three groups: male factor subfertility (abnormal sperm concentration and motility), idiopathic subfertility, and female factor subfertility. The incidence of obesity (BMI $\geq$30 kg/m^2) was three

times higher in men with male factor subfertility compared with the other groups (16).

In another study, Hanafy et al. (17) divided 80 men presenting at an andrology clinic for evaluation of infertility in their marriage into two groups (fertile normozoospermic and infertile oligospermic) based on their reproductive history and semen analysis. Body weight was higher (84.6 ± 16.3 kg) in the infertile group than in the fertile group (76.6 ± 12.5 kg) ($P<.05$), but BMI in the infertile group was only slightly higher and not statistically significantly different from that of the fertile group. This study excluded very heavy men (body weight >120 kg) for reasons that are not clear.

Finally, Zorn et al. (18) reported on BMIs in three groups of men in an infertility clinic population divided based on their sperm quality. The BMI levels were 27.15 ± 0.75 kg/m^2 in the nonobstructive azoospermic group (42 men), 26.22 ± 0.47 kg/m^2 in the oligoasthenospermic group (68 men), and 25.54 ± 0.31 kg/m^2 in the normozoospermic group (85 men). Unfortunately, the authors did not perform a statistical comparison between groups. If analyzed by *t* test, the relatively small increase in BMI among men with nonobstructive azoospermia is statistically significant relative to normozoospermic men ($P=.02$), whereas the difference in BMIs of oligoasthenospermic and normozoospermic men is not. Taken together, studies of male partners in infertile populations often, but do not always show a relationship between male infertility and elevated BMI.

MALE OBESITY AND ALTERATION IN SPERM PARAMETERS

The studies of the relationship between obesity and infertility, and between obesity and sperm density in infertile populations described in the preceding section are supported by studies directly examining the relation between obesity and various semen measures. A decrease in sperm concentration (density) and sperm motility is associated with decreased male fertility (19, 20). Sperm morphology as well is a determinant of male fertility regardless of sperm count and motility (21). There have been several studies examining semen quality in relation to obesity and these are summarized below.

Male obesity and sperm concentration and count

Jensen et al. (22) studied semen quality in 1,558 young Danish military recruits. The participants were recruited from two draft centers with a participation rate of 19%. The BMI was measured directly, a detailed questionnaire was administered, and physical examination and endocrine testing were performed to exclude individuals with known causes of infertility. Overweight and obese men (BMI ≥25 kg/m^2) had mean sperm concentrations (39 million sperm/mL) that were lower than those of normal-weight men (BMI 20–25 kg/m^2; 46 million sperm/mL). The prevalence of oligozoospermia (sperm concentration <20 million sperm/mL) was higher in overweight and obese men compared with normal-weight men (24.4% vs. 21.7%).

Moreover, overweight and obese men were found to have a 21.6% (95% CI 4%–39.4%) reduction in their sperm concentration compared with normal-weight men after correction for diseases in reproductive organs, in utero exposure to smoking, and period of abstinence A dose-response relationship between BMI and sperm concentration was not found, however (22). Despite many strengths, this study may have been limited by use of only a single sample for semen analysis. Intraindividual variability is large for all semen parameters, so that differences between populations will be less evident in single-sample studies (23–25).

Magnusdottir et al. (16) found that among men with normal semen (sperm concentration ≥20 × 10^6/mL and/or total sperm count ≥40 × 10^6 and progressive sperm motility ≥40%), there was statistically significant negative correlation between BMI and both sperm concentration ($r = -0.33$; $P=.02$) and total sperm count ($r = -0.30$; $P=.04$).

Fejes et al. (26) studied sperm parameters in relation to anthropometric measures of male partners in 81 Hungarian couples presenting for infertility treatment. The men were also well characterized using questionnaires, physical exam, and hormonal tests to diagnose secondary causes for male infertility. In this study, the authors elected to exclude males with secondary causes of infertility instead of correcting for it in the analysis. The participants gave two semen samples 3 weeks apart and the best values were used for analysis. In this study, hip circumference correlated negatively with sperm concentration ($r = -0.24$; $P=.033$), and weight and waist and hip circumferences correlated negatively to total sperm count ($r = -0.024$; $P=.031$; $r = -0.26$; $P=.007$; and $r = -0.22$; $P=.009$). However, there was no correlation between waist-hip ratio and total sperm count (26). The authors did not report the association between BMI or body weight and sperm concentration. The use of the best value of two semen analyses may have masked significant sperm quality differences among the weight groups.

In summary, there is good evidence that obesity can be associated with reduced sperm concentrations, but it has not been shown to have an effect that is either consistent (obese men may have normal sperm densities) or that exhibits a clear dose-response character.

Male Obesity and Sperm Motility

Studies of the relationship between male obesity and sperm motility have shown conflicting results. In the study by Jensen et al. (22), there was no relation between increasing male BMI and percent of motile sperm. Fejes et al. (26) found a negative correlation between body weight and total motile sperm count ($r = -0.22/0.048$) and between waist and hip circumferences and total motile sperm count. The waist/ hip ratio was not significantly correlated to sperm motility. The author did not report on the relation between BMI and sperm motility. Another study of couples presenting for infertility treatment was reported by Kort at al. (27). Male partners gave one sample for analysis and their BMI was recorded on

presentation. Males' BMI was shown to negatively correlate with motile sperm count. The motile sperm count in the different BMI groups was as follows: Normal weight men: 18.6 million motile sperm, overweight men 3.6 million motile sperm and obese men 0.7 million motile sperm (27).

Male Obesity and Sperm Morphology

The study of sperm morphology can be complicated by the differences in standards used and high interindividual variability in morphology. In their study of Danish men, Jensen et al. (22) used the strict morphology criteria in reporting sperm morphology. The interpretation of all slides was done by one investigator. In that study, there was no relationship between increasing male BMI and abnormal sperm morphology. In the paper by Kort et al. (27), sperm morphology was taken into account when they calculated a composite marker of male fertility, "the number of normal motile sperm," such that the interpretation of an effect of BMI on sperm morphology alone is impossible.

Male Obesity and Sperm Chromatin Integrity

Increased DNA fragmentation has been correlated with male infertility. Chromatin integrity in sperm was evaluated using the flow cytometry–based sperm degree of DNA fragmentation (SCSA) in different BMI groups. The SCSA was used to calculate the DNA fragmentation index (DFI). Increasing BMI was positively correlated with the DFI. Obese and overweight men had higher DFI (27% and 25.8%, resepectively) compared with normal-weight men (19.9%) (27).

BIOLOGIC BASIS FOR THE ASSOCIATION BETWEEN OBESITY AND ALTERATION IN SPERM PRODUCTION

The relationship between obesity, alteration in sperm production, and infertility is likely multifactorial. The hormonal changes associated with obesity likely play a major role. Other factors may include aspects of lifestyle and increased accumulation of reproductive toxins in fatty tissue.

Hypogonadotropic Hyperestrogenic Hypoandrogenemia

This hormonal profile is specific to the obese man. It is characterized by decreased total and, often, free T levels, decreased gonadotropin levels, and increased circulating estrogen levels. The decrease in androgen levels is proportional to the degree of obesity (28, 29). Both estrone and E_2 are increased in obese men compared with control subjects, a finding attributed to increased peripheral aromatization of androgens (30). Estrogen acts on the hypothalamus to affect GnRH pulses and at the pituitary level to regulate gonadotropin (FSH and LH) secretion (31). The increase in E_2 levels in obese men has the likely effect of reducing FSH and LH production, resulting in reduced testicular function and reduction in T production and intratesticular and circulating T levels. Such a role for E_2 is supported by studies of the effects on LH and T from administration of aromatase inhibitors to obese men (32).

In humans, a decrease in T/estrogen ratio has been shown to be associated with infertility. Pavlovich et al. (33) showed that men with severe male infertility had significantly lower T and higher E_2 than fertile control subjects, resulting in a decreased T/E_2 ratio. It also appears that excess estrogen has a direct deleterious effect on spermatogenesis. Daily sperm production per testis, absolute and relative weights of the testis, epididymis, and seminal vesicle and sperm numbers in both regions of the epididymis declined significantly in a dose-dependent manner in rats treated with high doses of estrogen (diethylstilbestrol 1 and 10 μg) (34). It is doubtful, however, whether modest increases in circulating E_2 levels of peripheral origin associated with obesity are sufficient to importantly alter intratesticular E_2 concentrations.

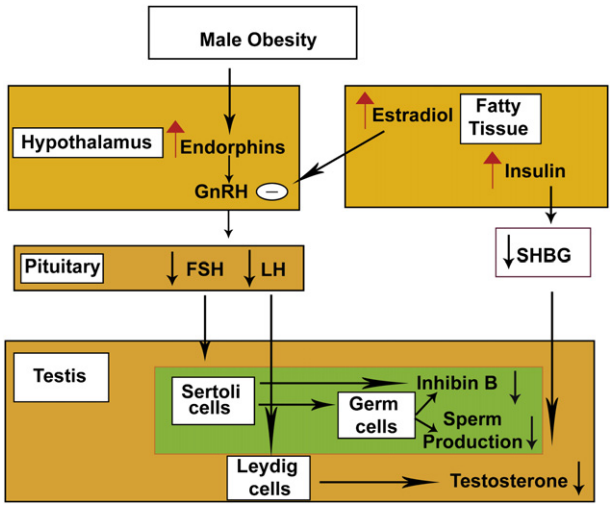
Sex hormone–binding globulin levels are reduced in obese men, an alteration principally mediated by the increased circulating insulin levels associated with the insulin resistance of obesity (35). This phenomenon attenuates the significance of low total T levels, because a lower SHBG concentration allows for a greater fraction of circulating T to circulate unbound, but it may magnify the negative feedback effect of elevated total E_2 levels. Reductions of free T are often seen among obese men, but they are proportionately less than the reductions seen for total T (36). Free hormone levels more accurately reflect rates of hormone production than total levels, and although no studies have directly assessed the effect of obesity on T production, such can be inferred from observations that free T levels are lower in obese men. This may be due to estrogen-mediated gonadotropin suppression as already described. However, after adjusting for SHBG levels, low T levels have been shown to be correlated with insulin resistance and obesity, denoting an independent effect of insulin resistance on T production (37). Sleep apnea, more common among the obese, has also been proposed to negatively affect morning serum T levels in obese men (38, 39).

Suppression of the Hypothalamic Pituitary Function

Other factors besides hyperestrogenemia have been invoked to explain the relative suppression of LH seen in obesity (28, 40). An increase in endorphins has a negative effect on the GnRH production by the hypothalamus, and endogenous opioids may be increased in obesity. Blank et al. (41) compared the effects of GnRH and naloxone infusion versus saline injection in five obese and five normal-weight men aged between 20 and 38 years. At baseline, obese men had significantly lower T levels than control subjects. After GnRH infusion, LH levels significantly increased in both obese and normal-weight men; however, FSH levels increased only in normal-weight men, denoting a certain level of pituitary suppression associated with obesity. After infusion of naloxone, LH levels increased only in obese males and not in normal-weight men. In obese men, LH pulse

FIGURE 1

Proposed pathways for hormonal alterations associated with male obesity.



Hammoud. Obesity and male infertility. Fertil Steril 2008.

frequency after naloxone increased by 51% from baseline. These results suggested a role for endogenous opioids in the pathophysiology of hypogonadotropic hypoandrogenism in extremely obese men (41). It has been suggested that patients with insulin-dependent diabetes have suppressed pituitary function after a GnRH stimulation test and have higher sperm ultrastructural defects and DNA fragmentation than control subjects (42–44). The effect of type 2 diabetes, which isfrequently associated with obesity, on the hypothalamic-pituitary-gonadal axis and sperm function is poorly understood.

Role of Inhibin B

Inhibin B is a marker of Sertoli cell function and associated spermatogenic activity (45). Several reports have shown that inhibin B levels are altered in obese men. Globerman et al. (36) showed that obese men are more likely to have low Inhibin B levels compared to controls. Winters et al. (46) compared the relationship between BMI and inhibin B levels in a group of 72 young adults aged 18–24 years and a group of 48 preadolescent boys aged 5–9 years. In the young adult group, mean inhibin B levels decreased with increasing BMI: The mean inhibin B was 248 pg/mL in those with BMI <25 kg/m^2, 231 pg/mL with BMI 25–30 kg/m^2, and 183 pg/mL with BMI >30 kg/m^2 ($P<.05$). This relationship was not evident in the preadolescent boys. The authors proposed a direct role for obesity in suppression of Sertoli cell function and spermatogenesis.

Despite low inhibin B levels among obese men, FSH levels can also be low and have been described as "inappropriately nonelevated" (36). Increased estrogen levels associated with obesity causing gonadotropin suppression might explain the low inhibin B reported by Winters et al. (46). Two observations, however, contradict this simple explanation and suggest a direct role for obesity in the alteration of Sertoli cell function and spermatogenesis. The first is that the increased estrogen associated with obesity are not as pronounced as the accompanying decreases in inhibin B (46), although this reservation lacks consideration of unbound estrogens. The second is that there is not a strong relationship between the relatively small decreases in FSH and the more dramatic decreases in inhibin B that accompany increasing degrees of obesity. (22, 26, 36, 46).

Interestingly, a similar negative relationship between inhibin B levels and BMI was also found in women with polycystic ovary syndrome (PCOS) and fertile control subjects (47, 48). In patients with PCOS, inhibin B levels were negatively correlated with insulin levels, suggesting a role for hyperinsulinemia in inhibin B alterations associated with obesity (47). In Figure 1, we show potential pathways for the alteration in reproduction hormones and spermatogenesis associated with obesity.

Accumulation of Toxic Substances and Endocrine Disruptors in the Fatty Tissue

Numerous studies have shown a potential negative effect of environmental toxins and endocrine disruptors on male fertility (49, 50). The majority of these toxins are fat soluble and tend to accumulate in the fatty tissue (10, 11). Because of their fat reserves, obese men tend to be at higher risk. This risk was demonstrated in a group of men presenting to a fertility clinic. Serum levels of multiple organochlorines were positively correlated with male BMI and infertility (16).

Life Style, Fat Deposition, and Increased Testicular Local Heat

It is known that increased testicular temperature to the level of body core temperature can severely alter spermatogenesis (51). Obesity is often associated with a lifestyle characterized by decreased physical activity with prolonged periods of sitting, which has been shown to affect sperm production by increasing local testicular temperature (52). This effect was demonstrated most in professions that require prolonged sitting, such as taxi drivers (53, 54), and in paraplegic men (55, 56). Furthermore, obesity is associated with increased fat deposition in the abdominal area and upper thighs with increased waist and hip circumferences. Obese infertile men can also have a characteristic scrotal fat deposition (57). It has been postulated that such fat distribution in the obese male can further increase the local testicular temperature to levels that affect sperm production (58).

Genetic Factors in the Relationship Between Obesity and Male Infertility

The genetics of obesity is complex. Obesity is probably due to the interaction between multiple genes and several environmental factors, including diet and activity level. There

are rare conditions in which a defined chromosomal or genetic defect can result in obesity and male infertility such as the Klinefelter (59), Prader Willi (60), and Laurence-Moon–Bardet-Biedel syndromes (61).

The lack of the obesity gene encoding for leptin caused obesity and infertility in both male and female mice (62). In humans, leptin deficiency due to mutation in the leptin gene and leptin resistance due to mutation in the leptin receptor gene were associated with severe early-onset obesity, delayed puberty, and hypogonadism (63).

OBESITY AND SEXUAL DYSFUNCTION

Another potential cause for infertility in obese men is the reduced coital frequency associated with obesity. In a survey of health professionals, obesity was associated with a 1.3-fold relative risk for erectile dysfunction (64). In men reporting symptoms of erectile dysfunction, overweight or obesity are found in 79% of subjects (65). Erectile dysfunction has been correlated with male infertility. In participants who answered the Sexual Health Inventory questionnaire, 27% of infertile men reported erectile dysfunction compared with 11% of the fertile control group (66).

The relationship between obesity and erectile dysfunction can be explained by the decreased T levels and elevated levels of several proinflammatory cytokines in obese individual (67). The markers of inflammation are positively associated with endothelial dysfunction that is linked directly to male erectile dysfunction through the nitric oxide pathway (68). Obesity is also associated with cardiovascular risk factors (69). These factors, such as smoking, diabetes, hypertension, and dyslipidemia, have a strong epidemiologic independent link to erectile dysfunction (65).

Limited data suggest that coital frequency may be reduced for obese men (70). This would contribute to findings of reduced fecundability among couples including obese men in studies not correcting for this factor. If an effect of obesity on coital frequency is confirmed, further study would be required to determine whether reduced coital frequency is an expression of erectile dysfunction, altered endocrine environment, or psychosocial aspects of the obese state.

EFFECT OF WEIGHT LOSS

There is a paucity of data describing the effect of weight loss in obese men on sperm production and fertility. Most reports studied the effect of weight loss on the reproductive hormonal profile. Obese men showed increases in SHBG and T (free and total) after a very-low-energy diet (71). This effect of weight loss was also found in obese men with metabolic syndrome who were in a program of a very-low-calorie diet (72) . Other studies showed that weight loss through gastroplasty was associated with correction of the abnormal hormonal profile in obese men, with increase in SHBG and total T levels and reduction in E_2 levels (36, 73). In this context, the effect of weight loss on inhibin B levels as a surrogate for spermatogenesis is of particular interest. Globerman et al. (36) studied inhibin B levels after silastic ring gastroplasty. Out of 13 obese men, the four men with the largest decrease in BMI showed an increase in inhibin B levels. However, mean inhibin B levels before and after gastroplasty were not statistically significant.

Studies suggest that physical activity and leanness is associated with reduced risk for sexual dysfunction (64). Esposito et al. (74) demonstrated, in a randomized study, that obese men who received detailed advice about how to achieve a weight loss of 10% or more had higher rate improvement in erectile dysfunction than control subjects. Also patients with obstructive sleep apnea that lose weight can increase their T levels (75).

CONCLUSIONS

Recent data show that at a population level and in infertile couples, obesity is associated with reduced male fertility. The effect of obesity on male infertility seems to be modest. However, with increasing incidence of obesity, it is expected that the number of obese men with reduced fertility will increase as well. Multiple hormonal changes associated with obesity are responsible for the alteration in sperm parameters and erectile dysfunction. In obese males, evidence suggests that increased estrogen as a result of aromatization in the fatty tissue may be an important mechanism for the hypoandrogenemia and altered sperm parameters. There is evidence that weight reduction can correct this hormonal imbalance. These data need to be complemented by studies showing the effect of weight loss on sperm parameters and fertility. Future research should focus on the relationship between percentage body fat, hormonal alteration, and semen quality. Also, it would be interesting to understand the effect of leptin-ghrelin on semen quality in obese men. Studies quantifying the effect of accumulated environmental toxins on male fertility are very challenging but would be very important in clarifying the relationship between obesity and male infertility.

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