

Body Condition and Fertility in Dogs



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KEYWORDS

• Obesity • Leptin • Reproduction • Pregnancy • Parturition • Semen

KEY POINTS

- Body condition and fat mass influences the onset of puberty in dogs.
- Gonadectomy and its timing in dogs has effects on body condition in adulthood.
- Male and female dog fertility is influenced by body condition.
- Obesity increases the risk of negative pregnancy and parturition outcomes.
- Balanced diet and regular exercise are recommended in male and female dogs.

INTRODUCTION OF BODY CONDITION SCORING IN DOGS

To obtain a numerical assessment of nutritional status in veterinary patients, a subjective scoring system is used (World Small Animal Veterinary Association). Based on visual inspection and palpation of subcutaneous fat, a dog can be assigned a body condition score (BCS) between 1 and 9 and categorized as very thin (1), thin (3), ideal (5), overweight (7), and obese (9) (**Fig. 1**).¹ Although this is helpful to both owners and veterinarians in managing the overall health of canines, it is only semiquantitative and does not reflect other aspects of nutritional and metabolic health, such as visceral fat accumulation and muscle atrophy. Whole body imaging would be more advantageous to determine lean versus fat mass. Studies using dual-energy-X-ray absorptiometry support the BCS scale as predictive for estimating body composition.² However, this is more challenging when a dog is overweight or obese.³ According to the American Veterinary Medical Association, an adult dog is considered obese when it is 30% more than its ideal weight. However, this can be challenging to assign when breed differences exist in form and stature. Therefore, we group dogs based on body weight into size classes, toy (<5 kg), small (5 to <10 kg), medium (10 to <25 kg), large (25–40 kg), and giant (40+ kg), with breeds falling into one of these classes.⁴ This has

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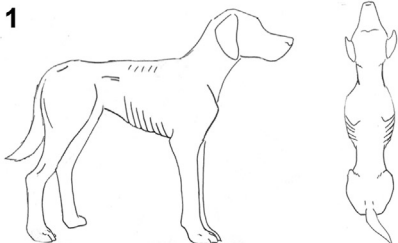
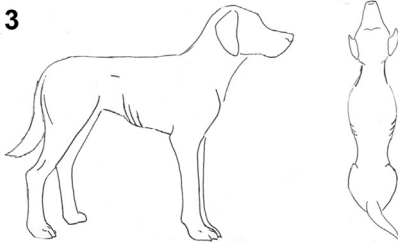
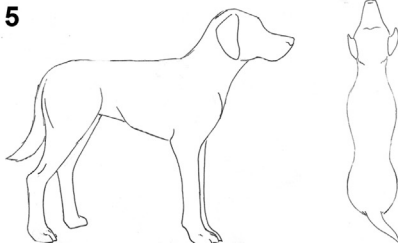
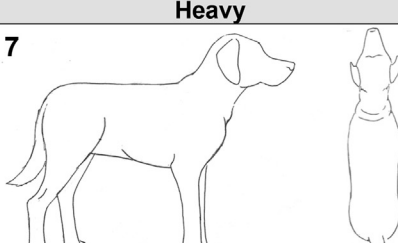
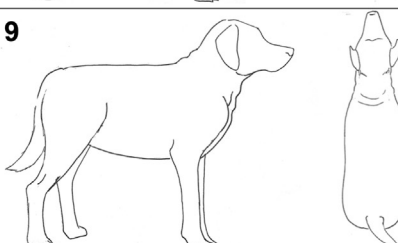
Thin		
1		1 – No visible fat and minimal muscle mass; Ribs, vertebrae, bony pelvis and prominences obvious
		2 – No palpable fat, muscle mass present; Ribs, vertebrae, and bony pelvis visible
3		3 – No palpable fat, waist and abdominal tuck present; Ribs palpable, vertebrae and bony pelvis visible
Ideal		
5		4 – Minimal fat, waist and abdominal tuck present; Ribs, vertebrae and bony pelvis palpable
		5 – Adequate fat, waist and abdominal tuck present; Ribs palpable, other bony processes not apparent
Heavy		
7		6 – Excess fat, waist present but not readily apparent, abdominal tuck present; Ribs palpable, other bony processes not apparent
9		7 – Heavy amount of fat, no or hardly discernible waist, abdominal tuck inconsistent; Ribs not readily apparent on palpation, excess fat deposits covering vertebrae and tail base
		8 – Very heavy amount of fat, no waist and abdominal tuck; Ribs not apparent on palpation and heavy fat deposits covering vertebrae and tail base with abdominal distention
		9 – Massive amount of fat over chest, entire spine and tail base, no waist and abdominal tuck; Fat covering neck and limbs, abdominal distention

Fig. 1. Canine Body Condition Score chart, adapted from the Purina 9-point body condition scale. Illustrations by © Samantha J. McCarter.

recently been expanded to include 6 size categories (I–VI) that different breeds can be classified into based on body weight.⁵ Modeling decades worth of body weight data from client owned dogs has allowed scientists to generate predictive models of ideal growth in dogs by breed and sex beginning as early as 12 weeks of age.

OBESITY IN ADULT DOGS

Obesity is a global health problem not only in humans but also in our dog population. One-third of Americans are overweight or obese and there is a correlation with increasing obesity in dogs. The canine incidence was 55.8% as reported by the Association for Pet Obesity Prevention in 2018 with 36.9% overweight and 18.9% obese (<https://petobesityprevention.org>). The close human–animal bond between dogs and their owners, and several of the environmental aspects they share explains why age, weight status, and physical activity of dog owners are associated with obesity risk of their pets.⁶ Furthermore, body condition is also associated with the “job” of the animal such as actively performing dogs need muscle and lean body mass to perform their tasks. However, 26% of show dogs placed first to fifth in their class were overweight while none was underweight, and overweight status was more prevalent in certain breeds such as the Basset hound, Labrador retriever, or Pug.⁷ Another study found 18.6% of dogs at a dog show being overweight and 1.1% obese with certain breeds and breed groups having generally higher BCS (eg, Molossoïd breeds, Swiss Mountain and Cattle dogs, Retrievers, Water dogs, and so forth).⁸ Many of the show dogs are considered to be exemplary of their breeds and are used for breeding, so discussing the reproductive consequences of overweight and obese status in affected individuals is important.

It is generally recognized that intact female dogs are more likely to be obese than intact male dogs. In Golden Retrievers, intact female dogs have a 43% increased risk of overweight/obesity compared with intact male dogs.⁹ Among all gonadectomized dogs (males and females) in their study, spayed females had a 24% lower risk of becoming overweight/obese compared with neutered males. Furthermore, it was also observed in a large cohort of client-owned dogs in Denmark that adult male dogs have a propensity for increased body weight gain with castration.¹⁰ In a study that analyzed the timing of gonadectomy and onset of an overweight/obesity BCS, nearly 3000 Golden Retrievers were assessed. They adjusted for age at study enrollment, owner-reported activity level, and sex of the dog, and separated into age cohorts (≤ 6 months, >6 months to ≤ 12 months, and >12 months). Gonadectomy was always associated with an increased risk of being overweight/obese.⁹ Therefore, one might conclude that if gonadectomy is performed at any time, then being overweight/obese is inevitable in this breed. However, other data specific to Golden Retrievers suggest that delaying to postpubertal age would be advantageous for preventing certain neoplastic and musculoskeletal disorders.¹¹ Performing gonadectomy at 6 to 12 months of age increased the risk of becoming overweight/obese by 42% compared with delaying until after 12 months of age in Golden Retrievers.⁹ Considered together, in this breed, delaying gonadectomy has beneficial effects on body condition and overall health. However, it is also noteworthy that increased energy expenditure, timing of feeding, and providing adequate rather than excessive macronutrients would also aid in preventing obesity after gonadectomy in dogs as well as in intact animals, and warrants consideration.

Obesity has negative impacts on various body systems and physiologic processes as well as shortening the dog’s life span (see complete 2016 issue on Small Animal Obesity in this journal). With regards to the reproductive system, the consequences

of obesity are not well documented in dogs. In humans, obesity negatively affects reproductive health both in women (eg, ovulatory dysfunction, infertility, miscarriage, pregnancy and parturition complications), and in men (eg, decreased semen quality).^{12–17} On the other end, low body condition or undernutrition resulting in negative energy balance (NEB) also has severe consequences on fertility and reproductive performance. An example is the high-producing lactating dairy cow, where severe NEB postcalving is linked to impaired fertility through various mechanisms, for example, irregular cycles, delayed first ovulation, decreased oocyte quality, uterine inflammation/disease, impaired embryo development, and metabolic disorders, thus reduced conception and pregnancy rates.^{18,19} In the dog, knowledge about the adverse outcomes of undernourishment is generally limited to the peripartum and postpartum periods.

THE INFLUENCE OF NUTRITION AND BODY CONDITION ON THE HYPOTHALAMO-PITUITARY-GONADAL AXIS

In mammalian species, including dogs, there is an inextricable link between body condition and the onset of puberty. Although BCS is determined subjectively with visual inspection of subcutaneous fat for the most part, internal obesity (visceral) also contributes to BCS. Leptin is an established biomarker of adiposity because its peripheral concentrations showed a significant, positive correlation with BCS and both subcutaneous and visceral fat areas in dogs.^{20,21} The relationship between leptin and puberty will be discussed.

Similar to other mammals, the domestic dog relies on gonadotropin releasing hormone (GnRH) originating from the hypothalamus to stimulate pulsatility of gonadotropins, luteinizing hormone (LH), and follicle-stimulating hormone (FSH), which promote cyclicity in the bitch. GnRH regulates the onset of puberty and cyclicity with contributions from genetics (breed), nutrition, and perhaps even the circadian rhythm. The “critical-weight hypothesis” suggests body weight is a key indicator of pubertal onset. Using the Labrador and the Beagle dog, onset of puberty was achieved when they attained 71% and 81% of their adult body weight, respectively.^{22,23} This is similar to what has been reported in cats where puberty has been reported at 80% adult body weight.²⁴ With adequate prepubertal energy intake, an appropriate body weight is achieved with the accumulation of fat mass. Leptin from adipose tissue will influence GnRH pulsatility and puberty onset. This is supported by the expression of leptin receptors on hypothalamic neurons, such as kisspeptin neurons, that synapse with GnRH neurons. Gonadectomy, including early (<6 months) and late (>12 months), likely influences the onset of becoming overweight/obese by several different mechanisms but potentially through the hypothalamic-pituitary-gonadal (HPG) axis via removing hypothalamic negative feedback and resulting in chronically increased LH²⁵, and perhaps the removal of estrogen, a known regulator of food intake in cats.²⁶ However, the precise mechanism is not fully understood.

The timing of puberty in female and male dogs varies by breed (earlier in small breeds than in large breeds) and individual animal, and occurs on average at 7 to 12 months of age (range 5 to >12 months).^{27,28} In the female dog, the onset of puberty is defined as the first sign of proestrus bleeding. This would be associated with an increase in circulating estrogen and progesterone. Although fertile, puberty is different than sexual maturity (full reproductive potential), which is postulated to be after the second estrus.²⁸ This will depend on a number of factors including body condition, genetics, and breed. Puberty in the male dog is defined as the first appearance of spermatozoa in the ejaculate together with the attainment of libido and the ability to

copulate, and it occurs slightly later than in the bitch.^{27,28} Full reproductive potential and fertility is not reached until months later, closer to 2 years of age, with maximum ejaculate volume and total number of spermatozoa in the ejaculate.²⁷ The effect of body condition on the timing of female and male puberty in the dog is not fully known. In humans, being overweight or obese in childhood is associated with reaching pubertal milestones earlier in both boys and girls, whereas being underweight is related to delayed puberty onset.^{29,30}

The canine estrous cycle is composed of 4 stages: proestrus, estrus, diestrus, and anestrus. The bitch cycles approximately twice a year; however, this is highly variable from animal to animal and cycle to cycle within the same animal. Some bitches, especially in certain breeds, may only cycle once per year. During proestrus, circulating levels of estradiol and testosterone increase before the LH surge that initiates ovulation. The LH surge demarcates the transition from proestrus to estrus. It is during estrus that the vaginal epithelium appears fully cornified due to estrogen exposure. Progesterone dominates during estrus increasing from basal levels even before ovulation is complete 2 to 3 days after the LH surge. Cytologic diestrus begins when the vaginal epithelium of the bitch is no longer 100% cornified. During this stage of the estrous cycle, progesterone reaches maximal concentrations because the corpora lutea are nourished by luteotropins, LH, and prolactin. Circulating levels of progesterone peak and then decline over several weeks. This occurs whether the bitch is experiencing a nonpregnant or pregnant diestrus with mammary development often occurring in either scenario. Anestrus is a variable length of time when the uterus undergoes involution and repair before entering into proestrus again. Circulating levels of FSH are high along with increasing LH pulsatility during late anestrus.^{28,31}

BODY CONDITION AND FERTILITY IN THE BITCH

Ovarian Function and Cyclicity

In women, obesity, being underweight, or excessive exercise may have negative consequences on ovarian function and cyclicity.^{17,32} Approximately 22% of body fat content is required to maintain ovulatory cyclicity in women.³³ Being over conditioned or under conditioned can influence reproductive performance in bitches, as well. Today, athletic lean hunting dogs as well as sedentary, overweight/obese dogs are being used in breeding programs. Bitches outside an ideal body condition may experience decreased fertility with irregular estrous cycles³⁴ in the form of split heats or anovulatory cycles, although the precise cause of inadequate HPG signaling in the bitch is unknown. Prolactin secretion is altered in obese dogs (hyperprolactinemia).³⁵ One might speculate this may contribute to irregular estrous cycle activity in bitches as dopamine agonism can increase plasma LH and promote folliculogenesis in the bitch.³⁶ In intact female Beagles, ad libitum feeding of a balanced commercial diet significantly increased plasma leptin levels and body condition from lean to obese over the 24 weeks transition period³⁷ but reproductive parameters such as cyclicity were not evaluated. Leptin excess as with obesity can be inhibitory to LH signaling to the female gonad. Furthermore, in addition to altering sex steroid hormone levels, chronic leptin production will also promote leptin resistance, hyperphagia, and weight gain in dogs. Obesity is associated not only with increased leptin but insulin-like growth factor 1 (IGF-1) levels.³⁸ Receptors for both hormones were found on canine ovarian follicular cells and in the corpus luteum.^{39–41} and leptin receptors were also present in canine oocytes and cumulus cells.⁴² As such, high circulating leptin and IGF-1 concentrations can exert direct effects on the ovary. A recent study in intact overweight and

ideal-conditioned bitches did not find an association between serum leptin and progesterone levels, and no significant changes in peripheral leptin were noted by estrous cycle stage in either groups.⁴³ Until the metabolic regulation of fertility in the bitch is fully elucidated, increased body condition or being underweight cannot be excluded as potential causes for abnormal cyclicity and need to be considered during clinical diagnostic workup of anovulation and infertility. However, a healthy weight in dogs can be achieved through diet and exercise, as in people and other animals.

Pregnancy and Parturition

Current recommendations in breeding bitches include beginning pregnancy at an ideal BCS and only increasing body weight by 15% to 25% during pregnancy. This is for average-sized litters and therefore depends on litter size. After delivery, bitches would ideally weigh only 5% to 10% more than their preconception body weight.⁴⁴ Pregnant female dogs rely on ovarian progesterone for pregnancy maintenance the entire length of gestation. Pulsatility of LH along with prolactin is crucial during pregnancy for proper corpus luteum function in the bitch.⁴⁵ Circulating progesterone values alone are not good indicators of pregnancy status because they are not significantly different between pregnant and nonpregnant dogs, and only relaxin of placental origin is considered pregnancy-specific. Pregnancy termination can occur with either ovariectomy or hypophysectomy. Luteolysis, triggered by placental prostaglandin secretion from fetal trophoblasts at the end of gestation is necessary for the initiation of parturition.^{28,31,46}

Low body condition and being underweight

Poorer fertility, reduced conception, and difficulties in maintaining pregnancy are concerns in underweight, underconditioned bitches.^{34,47} In extreme cases, reducing the demand of pregnancy by decreasing litter size or abortion of the whole litter can occur.⁴⁸ Puppies born from underweight dams may have lower than normal birth weight and increased neonatal morbidity and mortality.⁴⁴ Maternal nutrition before and during conception and throughout pregnancy is therefore crucial, not only for energy but also for macronutrient and micronutrient requirements.

The counterregulatory responses of glucagon and norepinephrine are suppressed in pregnant bitches,⁴⁹ making hypoglycemia more difficult to cope with. If fetal nutrient demands are too high, or the nutrient supply of the dam is insufficient such as with underweight and undernourished dams, pregnancy toxemia (ketosis) can develop during late gestation, which is characterized by persistent hypoglycemia, ketonemia and ketonuria, with associated clinical signs, for example, weakness, ataxia, collapse, seizures, and coma.^{28,50} Ketosis is a life-threatening condition both for the dam and the puppies. In a recent study in dogs undergoing Cesarean section electively at term or due to dystocia, higher maternal serum nonesterified fatty acids and β -hydroxybutyrate concentrations were found in small size bitches and in bitches where the proportion of the total litter weight (combined weight of all puppies) by maternal pregnant body weight was larger than 10%.⁵¹ Although none of these bitches showed clinical signs of pregnancy toxemia, this finding underlines the high metabolic demand of pregnancy, especially if bitches are carrying a large litter compared with their body size.

Finally, although hypoglycemia and hypocalcemia have not been consistently found in parturient eutocic or dystocic bitches,^{52,53} low glucose and ionized calcium levels may occur more frequently in undernourished bitches, and this, along with decreased muscle mass, can predispose them to dystocia.

Being overweight and obesity

Being overweight and obese were noted to result in poorer conception and smaller litter size in the bitch.^{34,47} Besides the metabolic and endocrine alterations, obesity is associated with chronic, low-grade systemic inflammation where concentrations of proinflammatory cytokines are increased.⁵⁴ This inflammatory milieu may interfere with implantation and establishment of pregnancy, which is characterized by delicately balanced immune events at the embryo–maternal interface.^{55,56} The canine uterus expresses IGF1 and its receptor,⁵⁷ and leptin and leptin receptor were also found in the uterus and placenta of the bitch with potential role in implantation and parturition,⁵⁸ providing another link where nutrition can interact with reproduction. Of note is that peripheral leptin increases during canine pregnancy with a tendency for higher concentrations with larger litter size,^{59,60} and this gestational increase is likely physiologic due to placental contribution⁵⁸ and perhaps also by greater adipose tissue secretion.

During canine pregnancy, fetal nutrient demands are met by maternal endocrine and metabolic adaptation. One of the mechanisms of nutrition partitioning is the development of maternal insulin resistance to provide glucose to the developing fetus. In dogs, signs of diabetes mellitus can be observed during diestrus because altered carbohydrate metabolism occurs in dogs under the influence of progesterone; growth hormone is stimulated by progesterone, and insulin antagonism can result in hyperglycemia. Although canine pregnancy is normally associated with decreased insulin sensitivity from midgestation onward and it is usually more profound than during the nonpregnant diestrus,^{31,50,61} it rarely progresses to gestational diabetes mellitus (GDM). Obesity in dogs has been associated with insulin resistance,³⁸ and obese women are at an increased risk of metabolic disorders and other complications during pregnancy, which also affect neonatal outcomes, for example, GDM, preeclampsia, preterm birth, macrosomia, stillbirth, and increased risk of infant mortality.^{14–16,62} Macrosomia is observed in diabetic bitches,²⁸ similar to babies born to women with GDM. It is plausible therefore to assume that overweight and obese bitches could be at a higher risk to develop GDM, but the extent to which obesity may exacerbate insulin resistance during pregnancy resulting in GDM in the dog is so far unknown.

Bitches that are obese or overweight have a higher risk of dystocia,^{47,63,64} including uterine inertia.^{28,65} Dystocia may result from increased adipose tissue within and around the birth canal⁶³ or from postulated fat infiltration of the uterine musculature predisposing to diminished contractions³⁴; however, the exact mechanisms are still unknown and are probably more complex than we know. Obese women are prone to having postdated pregnancies, prolonged labor, oxytocin augmentation for labor, and are at a higher risk for labor induction and Cesarean section delivery.^{12,14–16} Leptin, the main adipokine, may be one of the contributing factors, because it negatively affects human myometrial contractility in vitro.⁶⁶ A recent study in nonobese dogs showed that the presence of leptin receptors in interplacental uterine sites and thus leptin signaling was linked to primary uterine inertia in more than half of the bitches diagnosed with this condition.⁶⁷ Therefore, high circulating leptin levels and other physiologic, metabolic, or endocrine alterations of obesity could predispose to dystocia and decreased uterine contractions. As obese bitches are generally less active, the impact of exercise, physical fitness and general muscle strength on the course of parturition and dystocia risk needs to be weighed in as well. Some of the basic management principles laid out to reduce the incidence of dystocia/uterine inertia in the bitch were described several decades ago⁶⁵ and are still valid, for example, a well-balanced diet, not allowing the bitch to become overweight and providing exercise, maintaining general good health, providing a familiar and comfortable environment for the whelping

with supervision that is not distracting and efficient, and avoiding breeding bitches with highly excitable and neurotic temperament.

Obese dogs have compromised cardiopulmonary function due to the physical effects of increased fat mass, inflammatory mediators, and neurohormonal influence,⁶⁸ such as moderate increases in blood pressure, increased heart rate, cardiac remodeling, increased respiratory rate, reduced tidal volume, and lower blood oxygen saturation. Because pregnancy itself alters respiratory, cardiovascular, neurologic, hepatic, renal, and gastrointestinal physiology, and there is also the mechanical effect of a distended uterus,⁶⁹ obese bitches have an increased risk for cardiopulmonary complications during pregnancy or anesthesia for Cesarean section. These effects may be more pronounced in brachycephalic breeds due to their airway conformation. Adiposity may predispose to osteoarthritis,⁷⁰ and even 15% to 25% body weight gain during normal pregnancy could have added negative impacts, although short term, by increasing the mechanical stress on the joints and the skeletal system.

Postpartum and Neonatal Health

As the nutritional and energy requirements of lactation are much higher than those of pregnancy,^{44,71} underweight bitches in low body condition are at risk of further weight loss after parturition and inadequate milk production (hypogalactia),^{47,64} which can negatively impact the health of their puppies. In these bitches, provision of adequate calories from a complete and balanced, high-quality, highly digestible commercial diet with 28% to 32% animal-based protein, minimum 18% to 20% fat, and 20% to 30% carbohydrate content (eg, all life stages or puppy food) that is supported by research and feeding studies^{44,48} is especially important, together with monitoring the bitch's weight and body condition (See article "Nutrition for the Pregnant Bitch and Puppies" by Kim and Wakshlag of this issue). The puppies' daily weight gain should be closely monitored because this is the most important indicator of adequate milk production in a healthy dam that nurses her pups. If hypogalactia is expected or confirmed, galactagogues (metoclopramide at 0.1–0.2 mg/kg subcutaneously or orally q 6–12 hours or domperidone at 2.2 mg/kg orally q 8–12 hours) alone or in combination with oxytocin (0.25–1 IU/animal subcutaneously q 2–4 hours for 1–2 days) can be given to increase milk production through increasing prolactin secretion and stimulation of milk let-down.^{72,73} Proactively addressing the risk of failure of passive immune transfer in the puppies may be necessary by providing previously banked canine colostrum or serum/plasma, or fostering neonates on a surrogate dam that is producing colostrum. Supplemental feeding of puppies with a canine milk replacer may also be indicated.

The metabolite profile of human milk is influenced by maternal obesity, alters offspring gastrointestinal microbiome and increases the risk of offspring obesity.^{74–76} The composition of milk from obese versus lean bitches is unknown. Maternal obesity was implicated in contributing to dystocia and increased neonatal mortality in dogs,⁴⁷ perhaps also through inadequate milk production.⁶⁴ Recommendations on managing hypogalactia in obese bitches are similar to those outlined above. The extent of which maternal obesity during pregnancy and lactation affects puppies both short-term and long-term is not known.

BODY CONDITION AND FERTILITY IN THE STUD DOG

Low Body Condition and Being Underweight

Although a previous study found no alterations in the spermogram of thin compared with normal weight men,⁷⁷ a meta-analysis concluded that low body mass index (BMI)

is associated with decreased semen volume and total sperm count, whereas no significant difference in sperm concentration or motility was found.⁷⁸ More recently, a systematic review and meta-analysis of human studies showed that being underweight was linked to decreased sperm normal morphology with no other parameters of the spermiogram being affected.⁷⁹ We do not know how low body condition affects reproductive function in male dogs, but it is reasonable to assume that similar to men, semen quality may be negatively affected.

Obesity and Being Overweight

In men, with regards to obesity, a 12% increased risk of infertility was found for every 3 units of BMI beyond 25 (BMI category 18.5–24.9 considered normal weight). Obesity is associated with dysregulation of the HPG axis, changes in adipokines, reproductive and metabolic hormones, increased production of reactive oxygen species and inflammatory mediators that affect spermatogenesis, and with epigenetic changes. Inhibin B, total testosterone, and sex hormone-binding globulin are reduced, whereas increased adipose tissue aromatization leads to high estradiol concentrations exerting a negative feedback on the HPG axis and consequently on Leydig cell testosterone secretion and spermatogenesis.^{17,79} Being overweight or obese was found to be associated with lower semen volume, sperm concentration and total sperm count, % sperm vitality, total motility, and normal morphology compared with normal weight in men according to a recent large review and meta-analysis.⁷⁹

Thermoregulation of the testes might be defective in obese males due to periscrotal fat deposition, which can lead to increased intrascrotal temperatures and spermiogram abnormalities (oligospermia, teratospermia, and asthenozoospermia) in dogs^{28,80} and men.¹⁷ Leptin, IGF-1 and their receptors were found on germ and Leydig cells of the canine testis,⁸¹ so these hormones may directly modulate spermatogenesis and Leydig cell function during obesity. There are only a few studies that investigated the relationship between semen quality and body condition in dogs. A recent small study found that obese dogs had lower ejaculate volumes and reduction in some of the sperm kinematic parameters but no difference in DNA fragmentation compared with controls. Additionally, lectin histochemistry revealed changes in the glycosylation status of ejaculated spermatozoa surface in the obese group.⁸² Another study in 28 healthy show-type male Labrador retrievers found no difference in serum levels of testosterone and Anti-Müllerian hormone (AMH), a biomarker of Sertoli cell function,⁸³ between lean (BCS 4–5/9) and overweight (BCS 6–8/9) dogs.⁸⁴ Semen collection and evaluation were not performed in that study. Based on information from the human literature and the very limited canine studies, it is prudent to assume that being overweight or obese could also result in reduced semen quality in the dog.

ENDOCRINE DISORDERS AND CANINE OBESITY

One of the clinical signs of canine hyperadrenocorticism and hypothyroidism is weight gain and obesity or fat redistribution, and both conditions have been reported in association with female and male reproductive dysfunction.^{28,85} Hyperadrenocorticism is usually diagnosed in middle-age to older dogs that are likely not in breeding programs. Anestrus and testicular atrophy are the main clinical symptoms in affected dogs, which is the result of negative feedback from hypercortisolism on the pituitary gonadotrophins and perhaps also from hyperprolactinemia in females.⁸⁵ The reproductive consequences of hypothyroidism have been evaluated in a few prospective studies. In experimentally induced hypothyroid female Beagles, clinical hypothyroidism was associated with weaker and longer uterine contractions during parturition, increased

neonatal mortality, decreased birth weight, and on the long-term also with decreased pregnancy rates, whereas other reproductive parameters (eg, interestrus interval, serum progesterone levels, and so forth) were unaffected. These reproductive abnormalities could be reversed by levothyroxine supplementation along with other clinical symptoms including returning to normal weight.^{86,87} In male Beagles, where hypothyroidism was induced by oral administration of ¹³¹I, obesity developed in all animals with typical clinical and laboratory signs associated with this condition; however, reproductive function, that is, libido, total scrotal width, semen quality (daily sperm output, motility, morphology), and testicular biopsy did not differ between hypothyroid obese and normal control dogs. Interestingly, hypothyroid dogs had a prolonged testosterone response to GnRH stimulation test.⁸⁸ Weight gain was reported in these studies, and although thyroid dysfunction is the most likely cause of the reproductive abnormalities observed, a role for obesity cannot be completely ruled out. Because normal thyroid function is crucial for general health and normal reproductive processes, screening for lymphocytic (autoimmune) thyroiditis is recommended by the Orthopedic Foundation for Animals and parent clubs of several breeds where the prevalence of this condition is high and thought to be hereditary.

RECOMMENDATIONS FOR THE BROOD BITCH AND STUD

It is beyond the scope of this article to discuss all aspects of nutritional management including questions on dietary supplements. We refer to relevant journal articles (See article “Nutrition for the Pregnant Bitch and Puppies” by Kim and Wakshlag of this issue) and books focusing on small animal nutrition aspects.

Proper nutrition for dogs starts during their growth and development, and continues through all their reproductive stages.⁴⁴ Weight and body condition should be regularly monitored and nutrition adjusted to keep them in ideal condition. Bitches that are intended to be bred should be at peak health to have the best chance of a successful pregnancy and parturition, and to raise healthy puppies. A complete and balanced diet approved by the Association of American Feed Control Officials and supported by feeding trials is recommended at all times, with specific recommendations during pregnancy and lactation to incorporate the needs of the developing fetus(es) and lactation. Moderate, regular exercise is important to keep bitches in optimal shape and prepare them for an easier, smooth whelping. Ideally, obesity should be addressed and managed before breeding plans are made; however, this is not always the real-life situation. There are no standardized weight-management programs in place for overweight and obese dogs while they actively reproduce. The provision of adequate amounts of nutrients to the developing conceptuses and later through milk to the neonates is of high importance. Weight loss during these times can disrupt this balance and is therefore not recommended. The same basic principles apply for the stud dog for maximizing health and semen quality. Although a healthy weight and ideal body condition should be promoted in our breeding bitches and stud dogs, there is need for more research to fully understand the consequences of obesity on canine fertility and reproductive performance, including epigenetic effects of maternal weight during pregnancy and lactation on the future reproduction of female and male offspring.

CLINICS CARE POINTS

- Consideration should be given for time of gonadectomy in dogs and plan for ensuring ideal body condition long term.

- Body condition should be well monitored post-pubertal to ensure ideal prior to breeding.
- Body condition outside of ideal should be a differential in case of adverse reproductive outcome.
- Not all under- or overconditioned dogs will present with fertility/reproductive problems despite having an increased risk.
- Reversal of obesity in breeding bitches is best before conception.
- Besides monitored caloric intake, an exercise plan can also help maintain an ideal body condition in dogs.

DISCLOSURE

The authors have nothing to disclose.

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