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Ideal body condition improves reproductive performance and influences genetic health in female mink

Laura Boudreau[a], Bernhard Benkel[a], Tessema Astatkie[b], Kirsti Rouvinen-Watt[a,*]

[a] Department of Plant and Animal Sciences, Faculty of Agriculture, Dalhousie University, P.O. Box 550, Truro, NS B2N 5E3, Canada
[b] Department of Engineering, Faculty of Agriculture, Dalhousie University, P.O. Box 550, Truro, NS B2N 5E3, Canada

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ABSTRACT

Selection for large body size in mink (*Neovison vison*) can result in obesity, which is associated with poor reproduction and metabolic disorders. Caloric restriction is effective in diminishing oxidative stress and delaying aging-related diseases. This study investigated the effects of moderate diet restriction on body condition, health, and reproductive success of mink breeder females. One-hundred control females were fed according to conventional feeding practice, while the feed allowance of their 100 sister-pair females was restricted in order to maintain an ideal body condition during the fall and eliminate the need for drastic slimming prior to breeding. Repeated measures analyses revealed that body weight gain during the fall and weight loss prior to breeding was significantly less for the restricted females. The restricted females had significantly larger live litters (5.88 kits) than the control dams (4.62 kits; $P < 0.05$). They were also able to maintain their body weight and condition during early lactation and were able to regain weight and condition post-lactation, unlike their control sisters. Based on their comet scores (restricted: 88; control: 116), the restricted primiparous females experienced less DNA damage ($P < 0.05$), while no significant differences were apparent for the multiparous females (restricted: 170; control: 153). No changes in telomere length were observed among the dams. Moderate diet restriction of mink breeder females during the fall eliminated extreme fluctuations in body weight and condition throughout the seasonal production cycle and improved their litter size, and in primiparous females, lessened DNA damage.

1. Introduction

The mink industry promotes intense selection for large litter size and big body size as these determine profitability (Lagerkvist, 1997). Feeding practices that encourage maximum body weight gain in the fall result in increased fattening (Korhonen and Niemelä, 1998), and an appropriate body condition for breeding is not always achieved. This can have deleterious impacts on reproductive success. Higher percentages of barren females, a decrease in the number of live born kits, and higher kit losses have been reported for females fed at high feeding intensity in the fall (Tauson and Aldén, 1984), whereas intense selection for a large body size in female mink has been shown to result in smaller litter size, increased kit mortality, and a decrease in pelt quality (Lagerkvist et al., 1994). In addition, females that exhibit stereotypic behavior have been shown

Abbreviations: BCS, body condition scores; DNA, deoxyribonucleic acid; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; GnRH, gonadotropin-releasing hormone; LH, luteinizing hormone; mtDNA, mitochondrial DNA; PCR, polymerase chain reaction; qPCR, quantitative real-time polymerase chain reaction; RT-PCR, real-time polymerase chain reaction.

* Corresponding author. Tel.: +1 902 8936646; fax: +1 902 8956734.
E-mail address: kirsti.rouvinen-watt@dal.ca (K. Rouvinen-Watt).

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to have lower body weights, improved conception rates, larger litters, and reduced kit mortality in comparison to non-stereotyping females (Jeppesen et al., 2004). To avoid the ill effects of obesity and increase breeding success, it is customary to rapidly slim breeder females prior to mating. Slimming may have some undesired consequences such as increased stereotypic behavior (Damgaard et al., 2004) and an increased risk of metabolic diseases such as fatty liver, and nursing sickness (Clausen et al., 1992; Rouvinen-Watt, 2003; Rouvinen-Watt et al., 2010). Body condition also influences glucose homeostasis in mink, with disruptions leading to illness, death, and higher number of barren females (Hynes and Rouvinen-Watt, 2007) where both abnormally thin and obese dams showed higher glucose levels during gestation and greater variations in glucose levels throughout the reproductive cycle than dams in an ideal body condition.

Obesity is also associated with oxidative stress as it increases concentrations of free fatty acids and gives rise to reactive oxygen species (Furukawa et al., 2004). In DNA, reactive oxygen species can cause strand breaks in the double helix (Beckman and Ames, 1998) and when nucleotides become altered, genomic stability is compromised leading to premature replicative senescence, cellular dysfunction, or cell death (Lombard et al., 2005; Dalle-Donne et al., 2006). Telomeres are hexamer DNA repeat sequences of TTAGGG, which cap the ends of most eukaryotic chromosomes. They prevent the chromosome ends from being recognized as double strand breaks, protect chromosomes from degradation, and maintain genomic stability (Lydall, 2009). Since telomere length generally decreases with age, it is a useful marker of the replicative history and potential of cells (Gil and Coetzer, 2004). Both psychological and metabolic stress can lead to a state of systemic inflammation and oxidative stress, which can be detrimental to telomeres (Epel, 2009). For example, shorter telomere lengths have been reported in the white blood cells of obese women as compared to lean women, and the same was found for old versus young women (Valdes et al., 2005). A negative association has also been found between body mass index and telomere length in subcutaneous adipose tissue, and obese and previously obese women were reported to have shorter telomeres than individuals who had never been obese (Moreno-Navarrete et al., 2010). Telomere length has not previously been studied in the mink and it is anticipated that increasing body condition, a state of increased oxidative stress and premature aging, would cause reductions in their leukocyte telomere length as shown in other mammals.

Weight loss is one of the best known tools for the alleviation of obesity and its harmful comorbidities. Adjusting feed availability throughout the production cycle to maintain a more ideal body condition and improve the health and reproductive success of mink breeder females has been suggested (Rouvinen-Watt, 2003; Hynes and Rouvinen-Watt, 2007). Body condition scoring of mink (Rouvinen-Watt et al., 2005) has been shown to be a reliable measure of the level of fatness (Hansen et al., 2009), and has recently been incorporated as an animal-based measure in the on-farm welfare assessment protocols for farmed mink (Mononen et al., 2012). The specific objectives of this research were to study the effects of moderate diet restriction on body condition, health, and reproductive success of mink breeder females and to examine the effects of moderate diet restriction on genomic health as measured by molecular genetic markers of oxidative stress and aging. It is hypothesized that the traditional treatment for diabetes, caloric restriction, will aid in the prevention of nursing sickness and fatty liver in mink (Rouvinen-Watt, 2003; Rouvinen-Watt et al., 2010), improve litter size, and, as shown in a previous study of rats (Crisóstomo et al., 2010), diminish oxidative stress and damage, leading to improved DNA integrity.

2. Materials and methods

2.1. Animals and treatments

This experiment was conducted between September 2009 and June 2011. A total of 400 standard black female mink (*Neovison vison*), selected based on standard ranch criteria for breeder females and housed individually in standard sized cages in a multi-row barn at the Canadian Centre for Fur Animal Research (Truro, Nova Scotia), were included in the trial; 200 females each year. The diet consisted of daily commercially produced standard wet mink feed, with the typical nutrient composition shown in Table 1. Water was available *ad libitum* from a nipple drinker. Animal husbandry conditions and experimental procedures were all in accordance with the guidelines of the Canadian Council on Animal Care (CCAC, 1993) and approved by the Animal Care and Use Committee of Dalhousie University's Faculty of Agriculture (formerly Nova Scotia Agricultural College).

In the first year, beginning in September, one-hundred females were placed in the control group and fed *ad libitum* from September to December, as is a typical farm feeding practice (Rouvinen-Watt et al., 2005). The other 100 full-sister females were placed in the moderate diet restriction group and fed about 20% less than the control group during September to December in order limit excessive body fat accumulation during the fall and the need for drastic slimming in the winter prior to breeding (Rouvinen-Watt et al., 2005; Hynes et al., 2004). The feed allowance of the restricted females was regulated daily on an individual basis. Activity level and weather conditions were taken into account and so the amount of restriction varied. During periods of cold weather, more feed was provided to maintain the restricted females in an ideal body condition, while the *ad libitum* feeding of the control females was also increased. For the remainder of the production year, both groups were treated the same. During January and February, in order to prepare for breeding, the goal was to slim both groups of females to a body condition score of 2.5. During gestation and lactation, the goal was to maintain an ideal body condition of 3 in both groups. This was achieved by feeding high-energy diets multiple times a day during lactation. Feed was delivered using an automated feeding machine and the feed allotment was adjusted based on the amount consumed on the previous day. Daily feed consumption was not measured. The sister pairs were followed up for two reproduction cycles.