contribution made by motor activity to 24 h energy expenditure in the two groups in order to assess whether spontaneous activity contributes to the development and maintenance of obesity in the *ob/ob* mouse. Additional studies could also help to resolve the current discussion and controversy on 'cafeteria-feeding' and 'diet-induced thermogenesis'[25,26].

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Molt-induced muscle atrophy decreases the zinc content of the pectoralis of the Giant Canada Goose *(Branta canadensis maxima)*

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Summary. During molt-induced atrophy of the pectoralis muscle of the Giant Canada Goose *(Branta canadensis maxima)*, the zinc content of the muscle was significantly reduced ($p \leq 0.0139$), though the concentration of zinc per unit weight of muscle appeared higher ($p \leq 0.0232$). Zinc lost from the muscle during molt could be utilized for growth of the new flight feathers.
Key words. Zinc; muscle; molt; geese.

Zinc is a ubiquitous element in the tissues of both plants and animals[2,3]. More than 200 different enzymes require zinc for maximum catalytic activity[4]. Zinc is important in a wide variety of functions, and is especially essential for tissue growth[4–6]. Most (90%) of the zinc in the human body is located in the musculoskeletal system, most of which is in the muscles[2,3]. While the function of zinc in muscle is largely unknown[2,7], other than being a component of certain enzymes, it is known to prolong contraction[8], increase oxygen affinity of myoglobin[3], assist in glycolysis[9], and is necessary for the growth of muscle and the differentiation of muscle fiber types[10]. Red muscle and slow muscle contain proportionately more zinc than do white muscle and fast muscle[7,10], respectively.

Disuse of a muscle can result in a reduction in muscle mass and the concentration of many enzymes[11,12]. Little is known about zinc in muscle under these conditions. While the concentration of zinc in muscle does not change in response to a deficiency of zinc in the diet[7], it is believed that zinc is lost from muscle during injury induced atrophy[13].

A natural model of disuse atrophy occurs in the pectoralis muscle of ducks and geese during their annual feather molt. These birds are flightless during this period[14], and they exhibit a concomitant decrease in the mass of their major flight muscles while they are growing new flight feathers[15–17]. We have recently examined both the concentration (amount/unit of muscle) and content (total amount in entire muscle) of iron in the pectoralis muscle of a wild population of molting geese[18]. The purpose of the present study was to examine the effect of this molt-induced disuse atrophy on the concentration and content of zinc in the pectoralis of the same population.

Materials and methods. Adult male Giant Canada Geese *(Branta canadensis maxima)* were collected from a nonmigratory feral population on the Toronto Islands (43°37′N, 79°20′W) during molt (June 1982), postmolt (October 1982) and premolt (March 1983) periods. Molting birds were obtained during the annual goose 'round up' conducted on the Toronto Islands by the Canadian Wildlife Service, Ontario Ministry of Natural Resources and Toronto Parks Department. Postmolt and premolt birds were captured through the use of a cannon net. Birds were euthanized by an i.p. injection of a euthanasia solution (T-61, Hoechst Inc.).

Ingesta-free body weights were determined, and the right pectoralis muscle *(M. pectoralis)* was excised from each bird. Each muscle was then oven-dried, ground and lipid extracted in order to obtain the corresponding lean dry weight[18]. Tissue samples were prepared for analysis by flame atomic absorption spectroscopy[19]. Zinc concentration was analyzed in a Varian 1275 AA spectrophotometer at a wavelength of 213.9 nm, with a slit of 1 cm at 5 amperes. The standards used were 0, 12.5, 50 and 100 ppm zinc. A statistical analysis was conducted using the software of Statistical Analysis System[20]. The variation between periods for each factor was tested with a one-way analysis of variance (ANOVA), and the differences between cell means were assessed by the method of least squares means[21].

Results. The results (table) indicate that while there is no significant difference in body weights between premolt, molt and postmolt periods, molting birds have significantly lighter pectoralis muscles. Zinc concentration and zinc content are, respectively, significantly higher and significantly lower in the pectoralis of molting birds as compared to premolt and postmolt

Zinc content and concentration in the pectoralis muscle of adult, male, Giant Canada Geese (mean ± SE)

Period	n	Ingesta-free b. wt (g)	Right pectoralis lean dry wt (g)	Zinc concentration in lean dry pectoralis (μg/g)	Zinc content in whole muscle (mg)
Premolt (March)	8	4228.0 ± 136.8 (NS)[a]	94.1 ± 5.1 ($p \leq 0.0001$)[b]	44.5 ± 2.9 ($p = 0.0069$)[b]	4.18 ± 0.34 ($p = 0.0030$)[b]
Molt (June)	8	4210.4 ± 134.5 (NS)[a]	55.1 ± 2.1 ($p \leq 0.0001$)[b]	55.8 ± 3.7 ($p = 0.0232$)[b]	3.07 ± 0.21 ($p = 0.0139$)[b]
Postmolt (October)	9	4200.9 ± 83.9	84.1 ± 2.1	46.8 ± 0.9	3.93 ± 0.11

[a]No significant difference between the two adjacent means in the column; $p > 0.8500$; [b]Significant difference between the two adjacent means in the column; where $p \leq 0.0232$.

birds. Three of the four comparisons between premolt and postmolt periods indicate that the differences observed are not significant ($p > 0.4500$); the comparison for lean dry pectoralis weight is, however, less conclusive ($p = 0.0493$).

Discussion. Zinc became more concentrated as the protein mass of the pectoralis muscle decreased during molt. However, the total amount of zinc in the muscle was significantly reduced during this period. This contrasts with our earlier findings for iron[18]. While iron concentration also increased during molt, the total iron content of the muscle showed no significant change. There are numerous examples of the competitive inhibition of iron metabolism by zinc[22]. Zinc and iron are both carried in the blood by transferrin, and it is thought that this might account in part for the competitive interaction of the two metals[22]. The contrasting results for zinc and iron in the present study could be due to such a competitive inhibition.

The mechanisms controlling the distribution of zinc in the body have not been fully elucidated[23,24]. It is widely held that most body deposits of zinc are usually stable, and that a constant dietary supply of zinc must be maintained[2] due to the lack of a special storage form of zinc[25]. Fluctuations in the intake of zinc are counteracted by the homeostatic regulation of absorption in the small intestine [3,26]. Tissue breakdown, however, is associated with an increase in plasma zinc concentration, and zinc absorbed into the blood is thought to represent a circulating pool available for exchange[24,26]. Consequently, the zinc released into the blood from the pectoralis during molt-induced atrophy might be made available to the body for other purposes.

In birds, large amounts of zinc are crucial for new feather growth[27]. Zinc deficiency during this period results in stunted, frayed, easily broken feathers. Furthermore, it is believed that the period of growth of the primary and secondary feathers might be particularly sensitive to zinc deficiencies[28]. It is during this period that the major flight muscles atrophy[16,17,29]. It seems reasonable to postulate, therefore, that the zinc release from the pectoralis muscle during molt-induced atrophy might be used for feather growth. In addition, it might also be utilized by the leg muscles which show marked hypertrophy during this period[16,17,29].

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