WEIGHT LOSS AND CATABOLIC ADAPTATIONS TO STARVATION IN GREY SEAL PUPS

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Abstract—1. Five grey seal pups lost from 18 to 32% of their initial body weight during a 21 day starvation period. Blubber fat mass density was 0.93 ± 0.03 g/cm³.
2. A considerable loss of blubber fat was recorded, but analysis of the weight loss and body size data indicated that blubber fat was retained for thermoregulatory reasons, particularly in the lean, smaller seals.
3. It is possible that phocid seals during periods of negative energy balance have a higher rate of protein catabolism than normal for terrestrial mammals.

INTRODUCTION

The energy balance of mammals as reflected in their body composition and maintenance requirements is, in a technical sense, well understood and applied in animal husbandry. A review of seal energetics (Lavigne et al., 1982) has identified several areas where data are lacking for this group of mammals. For example, phocid seal pups suffer a considerable periods of starvation after weaning, but the corresponding weight loss and changes in body composition are poorly known. This starvation take place in the period when the pups are changing from the terrestrial to the aquatic thermal environment and are facing increased energy requirements for swimming to obtain food.

The present work describes weight loss in five starving grey seal (Halichoerus grypus) pups and consider the possibility that the need for maintaining blubber for thermal insulation is in conflict with the normal utilization of fat during starvation.

MATERIALS AND METHODS

Five grey seal pups were kept in an outdoor freshwater pool with adjacent haul-out platform for a three-week starvation period. The animals were not restrained, water temperature was 6°C and air temperature ranged from -3°C to 8°C. Body circumference (chest girth) of the seals was measured with a tape, while the seals' behavior allowed that blubber thickness could be determined for only three animals using an ultrasonic tissue depth meter (Kretz Technik) with accuracy around 0.1 cm. Body weights were recorded at two to four days intervals. Resting metabolism was determined at intervals through the experimental period and is reported elsewhere (Brodie and Päschke, 1982). Blubber samples were collected from three killed grey seals and stored by freezing. Mass density was subsequently calculated from weighing and volume measurements. During these measurements some liquid blubber oil escaped into the water used for the volume determination. Thus a 10.95 g piece of blubber would typically lose 0.4 g to the water.

The energy equivalent of the recorded weight loss of the grey seal pups was estimated by employing a growth/starvation model employing separate compartments for lean and fat body mass (Ørilstland, 1977). Normally, when simulating starvation, the calculations will first draw the metabolic energy requirements from the fat body mass compartment. When all mobilizable fat is depleted, further energy is taken from the lean body mass. For the present analysis, however, the fat body compartment was increased sufficiently to cover the energy demands for the whole starvation period. The caloric density was adjusted to provide the best possible simulation of the experimental weight loss as judged by the minimum squares method. In other words, the body mass was considered as only one compartment, and the rate of weight loss controlled by adjusting the fat content of this compartment. At the same time the metabolic values employed in the simulations were kept above the minimum levels required for maintaining heat balance in each animal according to empirical values for heat balance integrated in a model for harp seal (Phoca groenlandicus) pups (Ørilstland and Ronald, 1978).

RESULTS

Both body weight and chest girth of the experimental animals decreased during the starvation period (Table 1). The initial average body weight of all five animals was 39.2 ± 8.6 (SD) kg decreasing to 26.6 ± 8.1 (SD) kg after 19-21 days of starvation. The corresponding decrements in chest girth was 95.3 ± 9.3 (SD) cm and 81.6 ± 12.0 (SD) cm. A blubber mass density of 0.93 ± 0.03 (SD) g/cm³ was found.

Blubber thickness was initially 3.5 cm for the largest animal (seal 4), and 1.9 cm for the smallest animal (seal 1), examined (Fig. 2). By the end of the 21 day starvation period the blubber thickness was 2.1 cm and 1.2 cm for the largest and the smallest seal respectively. Satisfactory simulations (Fig. 1) were obtained under two quite different assumptions. First, assuming that all weight loss was due to depletion of fat only, the daily total metabolism of the seal pups had to be set from 4 to 10.6 times the standard resting metabolism according to Kleiber (1975) (Fig. 2a). Secondly, it was assumed that the total metabolism will range between two and three times the standard resting values. Under this assumption the simulations indicated a positive correlation between the caloric equivalent of weight loss and
Table 1. Body weight and circumference changes in five starving grey seal pups

<table>
<thead>
<tr>
<th>Seal 1</th>
<th>Seal 2</th>
<th>Seal 3</th>
<th>Seal 4</th>
<th>Seal 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>W</td>
<td>G</td>
<td>D1</td>
<td>W</td>
</tr>
<tr>
<td>1</td>
<td>29.0</td>
<td>82</td>
<td>1</td>
<td>41.4</td>
</tr>
<tr>
<td>2</td>
<td>25.8</td>
<td>77</td>
<td>2</td>
<td>39.0</td>
</tr>
<tr>
<td>7</td>
<td>22.6</td>
<td>74</td>
<td>7</td>
<td>37.9</td>
</tr>
<tr>
<td>12</td>
<td>21.0</td>
<td>71</td>
<td>9</td>
<td>36.8</td>
</tr>
<tr>
<td>14</td>
<td>20.0</td>
<td>70</td>
<td>12</td>
<td>35.6</td>
</tr>
<tr>
<td>16</td>
<td>19.5</td>
<td>67</td>
<td>14</td>
<td>34.7</td>
</tr>
<tr>
<td>19</td>
<td>18.1</td>
<td>66</td>
<td>16</td>
<td>33.8</td>
</tr>
<tr>
<td>21</td>
<td>18.1</td>
<td>21</td>
<td>20</td>
<td>31.8</td>
</tr>
</tbody>
</table>

DW: 10.9  13.3  10.8  8.4  9.7  
% loss: 38   32   25   18   31

W: body weight (kg); DW: weight loss; G: chest girth (cm); D1: day of starvation.

blubber thickness (Fig. 2b). The expression:

\[ Q = 2000 \exp 0.34Y \text{ (kcal/kg)} \]

where \( Y \) is the blubber thickness in cm, may be considered a first rough approximation of this relationship.

For each seal the mean difference between the experimental and simulated weight loss was less than 0.2 kg with a standard deviation less than 0.7 kg. The maximum difference between the experimental and simulated weight loss for all five seals was 1.4 kg.

DISCUSSION

Surprisingly the present simulations of the weight loss data indicate that lean small grey seal pups may maintain a higher rate of lean body, i.e. protein utilization, than larger and fatter pups (Fig. 2b). When energy requirements are covered mainly by utilization of the lean body tissues the rate of weight loss will be relatively quick, as demonstrated by seal 1 losing 38% of its initial body weight, while the larger seal 4 lost 18% during the same 21 day period (Table 1). This difference in weight loss is not due solely to metabolic differences. For example, if the same near-fat equivalent of 9000 kcal/kg weight loss is assumed for both animals, unrealistic metabolic values from 4 to 10.6 times standard would be required to cause the recorded weight loss (Fig. 2a). There was neither experimental (Brodie and Päschke, 1982) nor behavioural indications of such metabolic differences.

There is a paucity of data on both activity patterns and resting metabolism in starving seals. The metabolic measurements on the present five grey seal pups (Brodie and Päschke, 1982) seems not to be conclusive: During the first part of the starvation period the resting metabolism of the pups surprisingly was close to standard values for adult mammals (Kleiber, 1975). When the pups were thinnest, after about 25

Fig. 1. Comparison of simulated (solid lines) and recorded (symbols) body weights during starvation of five grey seal pups. The numbers at the lines refer to the individual seals (Table 1).

Fig. 2. (A) The relationship between metabolism and chest girths that provided satisfactory simulations (Fig. 1) of weight loss in five starving grey seal pups. The numbers refer to the individual seals (Table 1). Metabolism is expressed as factors that, multiplied with Kleiber's formula, will provide the actual values. (B) The relationship between the caloric equivalent of weight loss and chest girth providing equally good simulations of weight loss. Vertical lines indicate the range of caloric equivalents corresponding to metabolism values ranging between two and three times standard.
days, higher metabolic values were recorded (Brodie and Päsche, 1982). It is reasonable to assume, however, that this increment of the metabolism was at least partly due to the refeeding that started after 21 days. The depression of resting metabolism that develops during a starvation period is known to disappear quickly upon refeeding (Grande et al., 1958; Cumming and Morrison, 1960). Thus, the present assumption of a total daily metabolism of two to three times the standard resting levels seems appropriate. When used in simulations such metabolic levels in agreement with the rates of weight loss (Table 1) alone suggest that the leanest pup had the highest protein to fat catabolism (Fig. 2b). The present simulations included a linear metabolic depression mechanism (Örtiland, 1977; Markussen and Örtiland, 1984), but a constant protein to fat catabolism ratio, i.e. caloric equivalent of weight loss. Both the metabolic depression and a normally variable caloric equivalent of weight loss during starvation will affect the weight loss. Thus better data on both resting and total daily metabolism is needed before the above two functions can be determined for seals.

Because the total blubber mass is distributed over approximately 80% of the total body area (Örtiland and Ronald, 1978), thickness measurements on a few body locations can hardly be carried out with sufficient accuracy to determine the blubber loss of individual seals. The present measurements of reductions of blubber thickness suggested, as could be expected, that blubber was catabolized. The blubber mass density of 0.93 ± 0.03 g/cm³ agrees well with the value 0.9262 quoted for harp seals (Shepeleva, 1973). This mass density value allow calculations of blubber weight loss from circumference and thickness decrements.

For seal 1 the decrease in chest girth equals a radius decrement of 3 cm while the 10.9 kg total weight loss correspond to a blubber thickness decrement of 1.9 cm using the mass density value 0.93 g/cm³. Also the ultrasonic indication of a blubber thickness decrement of 1.4 cm suggest considerable loss of fat free body mass. The 1.4 cm indicate a blubber weight loss of 7.9 kg, i.e. about 70% of the actual body weight loss.

Similarly for seal 4 the chest girth decrement equals radius decrement 1.8 cm, while the body weight loss indicate a blubber thickness decrement of 1.1 cm. The ultrasonic measurements indicate that 64% of the body weight loss was due to blubber mass loss.

In agreement with the present work, body weight changes of harp seal (Pagophilus groenlandicus) pups (Stewart and Lavigne, 1980) also suggest a significant catabolism of lean body mass, while considerable blubber deposits are maintained during the normal post-weaning starvation period.

Although the evidence is circumstantial, the intriguing possibility emerges that phocid seals suffering negative energy balance have a higher rate of lean body catabolism than normal for terrestrial mammals. Due to the low energy density of the lean body mass this metabolic peculiarity cause a rapid weight loss and thus poor starvation survival capability. The alternative, however, is loss of blubber insulation with a corresponding risk of fatal depression of deep body temperature.

REFERENCES


