ABSTRACT The loss of adipose tissue during energy restriction may be accompanied by a loss of lean body mass, including bone mass. Because most of the body lead burden is in the skeleton, we studied the effects of weight loss on the concentrations of lead in bone, blood and several organs in rats with prior but not current lead exposure. Concentrations of the essential divalent metals calcium, copper, iron, magnesium and zinc were also determined for comparison with lead. Lead-exposed rats (n = 25) were randomly assigned to one of three treatment groups: weight maintenance (WM), moderate weight loss (MWL) or substantial weight loss (SWL). For the two last-named groups, food intake was restricted for 4 wk to 70 and 40% of that of the WM group. Lead concentrations did not differ significantly (ANOVA, P > 0.05) among the three groups for blood, brain and bone. Significantly higher liver lead concentrations were observed in the SWL rats than in the WM and MWL groups. In general, organ concentrations of calcium, copper, magnesium and zinc were either lower or did not differ in the groups losing weight compared with the WM group. In contrast, organ iron concentrations of the SWL group were higher than those of the other groups except in brain where there were no significant differences. The total liver content of lead was highest in the SWL group, but the lead content of other organs did not differ among the treatment groups. The contents of calcium, copper, magnesium and zinc generally were lower in the MWL and SWL groups than in the WM group in the liver and some of the other organs. The results demonstrate that weight loss can increase the quantity and concentration of lead in the liver, even in the absence of continued lead exposure. The data also demonstrate considerable differences among organ divalent metals in response to weight loss. J. Nutr. 126: 317–323, 1996.

INDEXING KEY WORDS:
- lead
- weight loss
- essential metals
- liver
- rats

Excess body weight is one of the most widespread and serious nutrition problems in developed countries. It is a risk factor for a number of chronic diseases including hypertension, diabetes, cardiovascular heart disease and some cancers [Van Italie 1985]. Concern for their health and appearance has encouraged many overweight residents of developed countries to attempt to lose substantial amounts of weight (Pamuk et al. 1992), often under the direction of a physician. Such efforts may be successful, at least temporarily. Although adverse effects from weight loss that is too rapid have been reported (Callaway 1988), there have been few studies of the effects of loss of body mass on metabolism of essential and toxic trace elements.

Bone mass is highly associated with body weight (May et al. 1994), and the loss of adipose tissue during energy restriction may be accompanied by a loss of lean body mass, including bone mass [Avenell et al. 1994, Ramsdale and Bassey 1994]. In fact, diet-induced weight loss has been associated with rapid bone loss (Compston et al. 1992). Because most of the body lead burden is in the skeleton [Nordberg et al. 1991, O’Flaherty 1993, Silbergeld et al. 1993], it is possible that lead released from the skeleton during weight loss could result in increases in the lead concentrations of noncalcified tissues. In addition, lead released from adipose tissue or muscle during weight loss could serve as a source of lead.

Even in the absence of current lead exposure, there is a risk of lead toxicity due to the mobilization of bone lead that has accumulated from previous lead.

1 Supported in part by a grant from the American Heart Association—New Jersey Affiliate.
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3 To whom correspondence should be addressed.
exposures. This is due to the fact that approximately 70% of the body lead burden of younger children is sequestered in bone; in adults over 95% of lead is in the skeleton [Nordberg et al. 1991]. The half-life of bone lead is long, 5–20 y or more [Nordberg et al. 1991]. Due to widespread environmental exposure to lead in the United States and the long half-life of lead in bone, the concentrations of lead in the skeleton increase substantially with age [Barry 1975, Landrigan 1991, Nordberg et al. 1991]. The skeleton cannot be considered as merely an inert repository for lead [Lyles 1991]. It also cannot be assumed that this lead will remain indefinitely sequestered in bone because several factors may influence the release of lead from bone into the bloodstream. These factors include pathological conditions such as osteoporosis and kidney disease, and the skeletal demineralization that occurs with menopause, pregnancy, and lactation [Silbergeld 1991, Silbergeld et al. 1988]. However, the impact of weight loss on bone lead concentrations has not been previously investigated.

O'Flaherty [1991a, 1991b, 1991c and 1993] has published a series of elegant papers that describe physiologically based kinetic models for bone-seeking elements, particularly lead. These studies demonstrated that the whole-body kinetic behavior of lead is determined largely by the balance among excretion, bone uptake and release from bone. The studies further show that in the absence of current or recent lead exposure, blood and soft tissue lead will be almost entirely a reflection of transfer of lead to and from bone. These studies also suggest that the investigation of lead metabolism in rats is likely to be very useful for predicting effects in humans.

The objectives of this study were to determine the effects of energy restriction and the associated weight loss on organ concentrations and distribution of lead and to compare the impact of weight loss on lead with effects on the essential divalent metals calcium, copper, iron, magnesium and zinc.

MATERIALS AND METHODS

Animal care and treatment. Weanling female Sprague-Dawley rats (Taconic Farms, Germantown, NY) \(n = 25, 4\) wk old] were allowed to acclimate to the vivarium environment for a 1-wk period. They were housed individually in plastic cages. Twelve-hour light:dark cycles and constant temperature and humidity were maintained throughout the study. After 1 wk, rats were fed a modified AIN-76 diet containing 0.5% calcium and continued to be fed this diet for the remainder of the study. The composition of this diet has been previously described [Bogden et al. 1992]. Rats were also given drinking water containing 250 mg/L of lead as the acetate [Fisher Scientific, Fair Lawn, NJ], the same concentration used in a prior study [Bogden et al. 1995]. Glacial acetic acid was added to the drinking water solution at a concentration of 12.5 \(\mu L/L\) to prevent the precipitation of lead carbonate. Drinking water consumption was monitored daily.

Administration of lead-containing drinking water for 5 wk was followed by a 4-wk period without lead exposure to ensure that most of the body lead burden was in the skeleton [O'Flaherty 1991a and 1991b]. At this point, all rats had received the same treatment.

Rats \(n = 25\) were then assigned to one of three groups: weight maintenance [WM], moderate weight loss [MWL] and substantial weight loss [SWL]. To ensure comparable body weights in the three treatment groups, rats were weighed and grouped in sets of three in order of increasing body weight, except for the (13th ranked) rat with the median body weight. Each of the three treatments was then randomly assigned to one rat in each set. The remaining (13th) rat was assigned to the SWL treatment group. For the MWL and SWL groups, food intake was restricted to 70 and 40% of the intake of the WM group for 4 wk, the WM group continued to receive food without restriction. Food intake was measured daily to achieve this objective. Body weights of individual rats were monitored weekly prior to beginning food restriction and three times weekly once food restriction was initiated.

At the end of 4 wk of food restriction, blood was withdrawn by cardiac puncture from rats anesthetized with 25 mg/kg sodium pentobarbital [Steris Laboratories, Phoenix, AZ]. Rats were killed by decapitation while under anesthesia. The organs harvested from each rat were the liver, kidneys, left femur, brain, and bones of the lower vertebral column. Organs were briefly immersed in deionized/distilled water to remove surface blood contamination. Blood and organs were stored at –80°C in prerinsed weighed polyethylene or polypropylene containers.

A protocol describing the above procedures was approved by the Institutional Animal Care and Use Committee at the New Jersey Medical School. Laboratory analyses. Whole blood lead concentrations were determined by electrothermal atomic absorption spectrophotometry [Bogden et al. 1992]. A quality control sample, Bio Rad Whole Blood Control Level 3 (Bio-Rad, Anaheim, CA), was used for evaluation of the accuracy of these analyses. Concentrations determined for this sample were within 8% of the certified value.

Organ concentrations of calcium, copper, iron, magnesium and zinc were determined by previously described techniques [Naveh et al. 1987]. Briefly, organs were digested with a 3:1 mixture of double distilled nitric and perchloric acids (GFS Chemicals, Columbus, OH), and the residue was quantitatively

\(^4\) Abbreviations used: MWL, moderate weight loss; SWL, severe weight loss; WM, weight maintenance.
transferred to a 10 or 25 mL volumetric flask and diluted with distilled, deionized water. Further dilutions were necessary for some analyses, which were conducted by using flame atomic absorption spectrophotometry (Perkin-Elmer Model 603, Perkin-Elmer, Norwalk, CT). National Institutes of Standards and Technology bovine liver (SRM 1577b, Gaithersburg, MD) was used as a quality control sample for all analyses. Assays of this sample in our laboratory gave results within 5% of certified values. Lead concentrations of the same ashed samples were determined by electrothermal atomic absorption spectrophotometry (Perkin-Elmer Model 503 with HGA-2200 Heated Graphite Atomizer, Perkin-Elmer). The precision (CV) of the assays, based on analysis of standard reference materials and/or quality control samples, was 0.01 to 0.07. Calculations of concentrations were based on wet tissue weight.

Statistics. Dietary restriction will necessarily result in a decrease in the weight of some organs. Therefore, in addition to organ metal concentrations, the total organ contents of the metals studied were also calculated. Values in the text are means ± se.

Data reduction and analysis were performed using dBase III+ (Ashton-Tate, Torrance, CA) and the Statistical Analysis System (SAS Institute, Cary, NC). ANOVA was used to evaluate the effects of energy restriction on organ metal concentrations and contents. If ANOVA indicated that there were statistically significant ($P < 0.05$) differences among the three treatment groups for a specific measurement, then pair-wise comparisons were made by Duncan’s multiple range test at $\alpha = 0.05$ (Wallenstein et al. 1980). Kidney lead and calcium concentrations were log transformed before evaluation by ANOVA because of the expected considerable variability of these data (Bogden et al. 1992 and 1995).

RESULTS

Daily drinking water consumption during the 5-wk period of lead exposure was $14.7 \pm 1.5$, $12.9 \pm 1.1$, and $14.8 \pm 1.5$ mL/d for the WM, MWL and SWL groups, respectively. These values did not differ significantly (ANOVA, $P < 0.05$), indicating that lead exposure via the drinking water was comparable for the three treatment groups.

**Figure 1** provides rat body weights during the 98-d experimental period. Food restriction for 4 wk be-

---

**FIGURE 1** Body weights during 5 wk of lead exposure and 4 wk of food restriction for rats in weight maintenance, moderate weight loss and substantial weight loss treatment groups. There was a 4-wk interval between the end of lead exposure and start of food restriction. Rats were randomly assigned to treatment groups at the start of food restriction. Body weights of individual rats prior to food restriction were then used to complete the growth curve for each treatment group. Each point is the mean (± se) for 8–9 rats.
beginning on d 70 had the expected impact on body weight, with rats in the moderate weight loss group losing 13.7% of their d 70 body weight by the end of the study at 98 d. Rats in the substantial weight loss group lost 36.5% of their d 70 body weights. Those in the weight maintenance group experienced a modest (4.7%) weight gain.

Organ divalent metal concentrations were given in Table 1. Brain metal concentrations were not significantly affected by weight loss, except for small differences in copper among treatment groups.

There was a broad range of kidney calcium concentrations, but they did not differ significantly among treatment groups. Calcium concentrations of liver were significantly lower in the SWL group than in the other groups. Though femur and spinal column bone calcium concentrations were lowest in the SWL group, they did not differ significantly from the concentrations of the WM and MWL groups.

Kidney copper concentrations were lower in the MWL and SWL groups than in the WM group, whereas copper concentrations of calcified tissue did not differ among groups. Liver copper concentrations were highest in the MWL group.

Organ magnesium and zinc concentrations were not significantly affected by weight loss except for relatively low spinal column bone magnesium concentrations in the SWL group.

Liver lead concentrations were significantly higher in the SWL group than in the other two groups, with the mean concentration of the SWL group being 2.7 times the concentration of the WM group. Kidney lead concentrations were also highest in the SWL group, but showed considerable variability within treatment groups. Lead concentrations of femur and vertebral column bones were also highest in the SWL group, but did not differ significantly among the three treatment groups. Whole blood lead concentrations were 1.25 ± 0.10, 1.16 ± 0.10, and 1.32 ± 0.10 μmol/L for the WM, MWL, and SWL treatment groups, respectively; these concentrations did not differ significantly among groups. The ratios of the organ lead concentrations of the SWL group to the WM group were 1.41 for kidney, 2.69 for liver, 1.13 for femur, 1.13 for spinal column bone, and 1.06 for whole blood; thus, the ratio was greatest for the liver.

Iron concentrations in femur, kidney, liver, and spinal column bone were significantly higher in the SWL group than in the other two treatment groups, but brain iron concentrations were not influenced by weight loss. The ratios of iron concentrations in the SWL group to the WM group were 1.03 for brain, 2.20 for kidney, 1.83 for liver, 1.76 for femur, and 1.84 for spinal column bone.

The total organ contents of lead, calcium, copper, iron, magnesium and zinc are given in Table 2, which

### Table 1

<table>
<thead>
<tr>
<th>Organ</th>
<th>Treatment group</th>
<th>Lead</th>
<th>Calcium</th>
<th>Copper</th>
<th>Iron</th>
<th>Magnesium</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>nmol/g</td>
<td>μmol/g</td>
<td>nmol/g</td>
<td>μmol/g</td>
<td>nmol/g</td>
<td>nmol/g</td>
</tr>
<tr>
<td>Brain</td>
<td>WM</td>
<td>1.71 ± 0.19</td>
<td>0.94 ± 0.11</td>
<td>39.9 ± 0.7A</td>
<td>0.29 ± 0.01</td>
<td>6.13 ± 0.08</td>
<td>183 ± 3</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>1.34 ± 0.16</td>
<td>1.05 ± 0.15</td>
<td>43.1 ± 1.0A</td>
<td>0.29 ± 0.01</td>
<td>6.29 ± 0.08</td>
<td>188 ± 2</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>1.71 ± 0.17</td>
<td>0.86 ± 0.03</td>
<td>43.8 ± 1.3A</td>
<td>0.30 ± 0.01</td>
<td>6.11 ± 0.08</td>
<td>185 ± 3</td>
</tr>
<tr>
<td>Kidney</td>
<td>MW</td>
<td>1.39 ± 56B</td>
<td>51.0 ± 27.4</td>
<td>150 ± 7A</td>
<td>1.73 ± 0.05B</td>
<td>8.87 ± 0.47</td>
<td>395 ± 18</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>50 ± 3B</td>
<td>18.6 ± 4.6</td>
<td>110 ± 4B</td>
<td>2.42 ± 0.37AB</td>
<td>8.50 ± 0.26</td>
<td>386 ± 9</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>196 ± 66A</td>
<td>96.3 ± 52.9</td>
<td>116 ± 5B</td>
<td>3.80 ± 0.97A</td>
<td>10.28 ± 1.34</td>
<td>431 ± 32</td>
</tr>
<tr>
<td>Liver</td>
<td>WM</td>
<td>2.60 ± 0.40B</td>
<td>0.71 ± 0.02A</td>
<td>119 ± 12AB</td>
<td>7.00 ± 0.29C</td>
<td>10.05 ± 0.12</td>
<td>445 ± 7</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>3.15 ± 0.50B</td>
<td>0.70 ± 0.03A</td>
<td>144 ± 21A</td>
<td>10.51 ± 0.36B</td>
<td>10.48 ± 0.16</td>
<td>488 ± 10</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>7.00 ± 1.26A</td>
<td>0.61 ± 0.03B</td>
<td>90 ± 5B</td>
<td>12.81 ± 0.86A</td>
<td>10.37 ± 0.27</td>
<td>445 ± 23</td>
</tr>
<tr>
<td>Femur</td>
<td>WM</td>
<td>826 ± 70</td>
<td>4507 ± 63</td>
<td>65.0 ± 1.9</td>
<td>1.34 ± 0.07B</td>
<td>132 ± 2.4</td>
<td>2628 ± 38</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>735 ± 53</td>
<td>4406 ± 65</td>
<td>64.9 ± 2.0</td>
<td>1.60 ± 0.18B</td>
<td>128 ± 1.2</td>
<td>2595 ± 75</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>935 ± 84</td>
<td>4266 ± 102</td>
<td>64.2 ± 1.5</td>
<td>2.36 ± 0.14A</td>
<td>126 ± 3.0</td>
<td>2466 ± 59</td>
</tr>
<tr>
<td>Spinal column</td>
<td>WM</td>
<td>702 ± 67</td>
<td>3148 ± 77</td>
<td>49.4 ± 2.2</td>
<td>1.15 ± 0.03B</td>
<td>98.3 ± 3.1AB</td>
<td>2144 ± 60</td>
</tr>
<tr>
<td>bone</td>
<td>MWL</td>
<td>643 ± 59</td>
<td>3241 ± 110</td>
<td>48.6 ± 1.8</td>
<td>1.36 ± 0.11B</td>
<td>100.7 ± 3.2A</td>
<td>2182 ± 67</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>796 ± 59</td>
<td>2925 ± 133</td>
<td>47.9 ± 0.7</td>
<td>2.12 ± 0.13A</td>
<td>90.0 ± 3.7B</td>
<td>2107 ± 76</td>
</tr>
</tbody>
</table>

1 Data are means ± SE; n = 8 for WM and MWL and 9 for SWL. Means with different letter superscripts differ significantly (Duncan's test, P < 0.05).
2 Concentrations are based on wet tissue weights.
3 Kidney lead and calcium concentrations were log transformed before ANOVA.
also includes organ weights. Except for brain and spinal column bone, organ weights were significantly lower in the SWL group than in the other groups.

Brain metal content was not influenced by weight loss. The iron content of the liver was not significantly influenced by weight loss, while the hepatic calcium, copper, magnesium and zinc contents were lowest in the SWL group and highest in the WM group. In contrast, liver lead was highest in the SWL group. The total content of lead in other organs besides liver did not differ significantly among treatment groups.

The iron contents of the femur, kidney, and spinal column bone were highest in the SWL group and lowest in the WM group, but these differences were significant only for calcified tissues. Femur and spinal column bone calcium and magnesium were lowest in the SWL group.

Kidney calcium and magnesium contents did not differ significantly among groups, though kidney calcium content was highly variable. The zinc contents of the femur and liver were significantly lower in the SWL group than in the WM group, but the zinc contents of the kidney and spinal column bone did not differ among groups. The copper content of all organs except brain was lowest for the SWL group.

**DISCUSSION**

The results demonstrate that substantial weight loss does not have significant effects on blood, brain and bone lead concentrations, but can result in concentrations of lead in the liver more than 2.5 times those of rats not losing weight, even in the absence of recent lead exposure. In addition, lead was the only one of the six metals studied for which the liver content increased considerably with weight loss, despite the fact that lead ingestion had been discontinued 8 wk prior to blood and organ collection and ingestion of the five other essential metals continued up until this time. The source of this lead may have been the skeleton, but it may also have been derived from the muscle and adipose tissue catabolism that occurs in weight loss.

Degradation of cellular protein is a continuous process that provides tissues with a supply of amino acids during periods of reduced nutrient intake (Steele and Harper 1990). Lead is invariably bound to protein in vivo and may be released during its degradation. One possibility is that the increased liver lead observed in the SWL group is due to protein turnover in other organs during weight loss that contributes to an increase in available lead. However, increased liver concentrations of other divalent metals with high protein affinity such as zinc and copper were not found. Another possibility is that lead might be preferentially stored in some cells of the liver such as hepatocytes, Kupffer or endothelial cells. The effect of energy restriction on liver enzyme activity differs among these cell types (Ferland et al. 1990), and differing effects on cellular metal metabolism might also occur.

### TABLE 2

**Total organ metal contents for rats in the weight maintenance (WM), moderate weight loss (MWL) and substantial weight loss (SWL) treatment groups**

<table>
<thead>
<tr>
<th>Organ</th>
<th>Treatment Group</th>
<th>Organ weight</th>
<th>Lead</th>
<th>Calcium</th>
<th>Copper</th>
<th>Iron</th>
<th>Magnesium</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>g</td>
<td>µmol</td>
<td>µmol</td>
<td>µmol</td>
<td>µmol</td>
<td>µmol</td>
<td>µmol</td>
</tr>
<tr>
<td>Brain</td>
<td>WM</td>
<td>1.75 ± 0.04</td>
<td>3.00 ± 0.36</td>
<td>1.63 ± 0.18</td>
<td>69.6 ± 2.0</td>
<td>0.51 ± 0.02</td>
<td>10.7 ± 0.3</td>
<td>320 ± 8</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>1.73 ± 0.03</td>
<td>2.33 ± 0.28</td>
<td>1.81 ± 0.25</td>
<td>74.7 ± 2.2</td>
<td>0.51 ± 0.02</td>
<td>10.9 ± 0.2</td>
<td>326 ± 7</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>1.71 ± 0.03</td>
<td>2.94 ± 0.33</td>
<td>1.47 ± 0.05</td>
<td>74.5 ± 1.6</td>
<td>0.51 ± 0.01</td>
<td>10.4 ± 0.02</td>
<td>315 ± 6</td>
</tr>
<tr>
<td>Kidneys²</td>
<td>WM</td>
<td>1.83 ± 0.07A</td>
<td>274 ± 118</td>
<td>98 ± 53</td>
<td>275 ± 18A</td>
<td>3.17 ± 0.16</td>
<td>16.3 ± 1.3</td>
<td>728 ± 57</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>1.65 ± 0.10A</td>
<td>81 ± 5</td>
<td>30 ± 7</td>
<td>181 ± 11B</td>
<td>4.18 ± 0.86</td>
<td>13.9 ± 0.8</td>
<td>633 ± 36</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>1.34 ± 0.07B</td>
<td>288 ± 112</td>
<td>147 ± 88</td>
<td>155 ± 10B</td>
<td>4.70 ± 0.80</td>
<td>14.2 ± 2.6</td>
<td>587 ± 69</td>
</tr>
<tr>
<td>Liver</td>
<td>WM</td>
<td>7.74 ± 0.28A</td>
<td>20.1 ± 3.0A</td>
<td>5.48 ± 0.28A</td>
<td>927 ± 114A</td>
<td>54.2 ± 2.9</td>
<td>77.7 ± 2.9A</td>
<td>3441 ± 121A</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>5.52 ± 0.37B</td>
<td>18.0 ± 3.5B</td>
<td>3.85 ± 0.30B</td>
<td>766 ± 81A</td>
<td>57.6 ± 3.8</td>
<td>58.0 ± 4.3B</td>
<td>2689 ± 180B</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>4.58 ± 0.15C</td>
<td>31.4 ± 5.2A</td>
<td>2.82 ± 0.20C</td>
<td>411 ± 17B</td>
<td>58.4 ± 3.9</td>
<td>47.5 ± 1.9C</td>
<td>2027 ± 94C</td>
</tr>
<tr>
<td>Femur</td>
<td>WM</td>
<td>0.65 ± 0.03A</td>
<td>530 ± 35</td>
<td>2924 ± 109A</td>
<td>42.0 ± 1.5A</td>
<td>0.86 ± 0.04B</td>
<td>85.3 ± 2.9A</td>
<td>1707 ± 67A</td>
</tr>
<tr>
<td></td>
<td>MWL</td>
<td>0.65 ± 0.03A</td>
<td>481 ± 46</td>
<td>2857 ± 147A</td>
<td>41.8 ± 1.7A</td>
<td>1.06 ± 0.15AB</td>
<td>82.6 ± 4.0B</td>
<td>1689 ± 111B</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>0.55 ± 0.03B</td>
<td>504 ± 34</td>
<td>2349 ± 114B</td>
<td>35.4 ± 1.9B</td>
<td>1.32 ± 0.11A</td>
<td>69.3 ± 3.2B</td>
<td>1387 ± 62B</td>
</tr>
<tr>
<td>Spinal column</td>
<td>WM</td>
<td>1.14 ± 0.08</td>
<td>810 ± 105</td>
<td>3574 ± 249A</td>
<td>55.6 ± 3.4AB</td>
<td>1.31 ± 0.10B</td>
<td>111 ± 7AB</td>
<td>2433 ± 173</td>
</tr>
<tr>
<td>Bone</td>
<td>MWL</td>
<td>1.17 ± 0.10</td>
<td>757 ± 93</td>
<td>3797 ± 324A</td>
<td>56.8 ± 4.5A</td>
<td>1.66 ± 0.29AB</td>
<td>119 ± 13A</td>
<td>2555 ± 210</td>
</tr>
<tr>
<td></td>
<td>SWL</td>
<td>0.95 ± 0.05</td>
<td>767 ± 87</td>
<td>2775 ± 192B</td>
<td>45.5 ± 2.5B</td>
<td>2.00 ± 0.14A</td>
<td>85 ± 5B</td>
<td>2013 ± 153</td>
</tr>
</tbody>
</table>

1. Data are means ± se, n = 8 for WM and MWL and n = 9 for SWL. Means with different letter superscripts differ significantly (Duncan's test, P < 0.05).
2. Content of both kidneys was determined.
Leggett (1993) has described a detailed kinetic model of lead metabolism that includes two compartments for hepatic lead uptake and retention. One compartment takes up lead from the plasma much more rapidly, storing it with a half-life of days. The second compartment stores higher concentrations of lead with a half-life of years. If these kinetically defined compartments have anatomical correlates, weight loss may preferentially reduce the mass of the short-lived compartment. This could result in a higher liver lead concentration due to retention of mass of the long-lived compartment.

Kidney lead and calcium concentrations of rats tend to vary considerably (Bogden et al. 1992 and 1995). Although the rats with substantial weight loss had the highest concentrations, these concentrations were not significantly greater than those of the weight maintenance group due to the considerable range of concentrations in each of these groups.

The relatively high iron concentrations found in several organs of rats that were losing weight have been previously described in animals not exposed to lead, and appear to be due to conservation of total body iron stores (Conrad et al. 1967, Furugouri 1973, Sturgeon and Shoden 1964). This is supported by the fact that the total iron content of the liver in the present study was not affected by weight loss while the total hepatic contents of calcium, copper, magnesium, and zinc were lowest in the SWL rats.

The rats in the present study had considerable body lead burdens due to their exposure to lead ending 4 wk before initiation of weight loss and 8 wk before organ harvesting. Concerns about the impact of weight loss on lead metabolism in people should be greatest for those who have experienced past occupational or environmental lead exposures, including those who lived in inner cities as children (Bogden et al. 1974, Crocetti et al. 1990). Inner city children, especially African-Americans, have generally had greater environmental exposures than those living in suburban areas (Crocetti et al. 1990).

Weight loss can have beneficial effects on risk factors for chronic diseases such as hypertension and diabetes, but may paradoxically be associated with increased mortality (Pamuk et al. 1992). Weight loss causes loss of intracellular electrolytes such as magnesium, and this is thought to contribute to the cardiac dysrhythmia and fatal outcomes sometimes resulting from severe weight loss diets (Callaway 1988). The known loss of intracellular electrolytes is consistent with our findings on organ calcium, copper, magnesium, and zinc content, which decreased in several organs with weight loss. It is possible that the increase in liver lead reported here may also contribute to the adverse hepatic effects associated with weight loss (Fris et al. 1987, Hoy et al. 1994).

The organs most sensitive to lead toxicity are the kidneys, central and peripheral nervous systems and hematopoietic system, with the liver being much more resistant to the toxic effects of lead (Tsuchiya 1979). Thus, the diversion of lead to the liver during weight loss may protect against the toxicity that would occur due to lead accumulation in the first-named organs. Because lead is a ubiquitous component of the natural environment and is present in the organs of all animals, it is possible that a mechanism for handling of lead by the liver during starvation evolved to protect organs more susceptible to lead toxicity.

The current study demonstrates a unique impact of weight loss on liver lead concentrations. Elucidation of mechanisms responsible for this effect will require further investigation. The study also demonstrates that there are considerable differences among organ metals in their response to weight loss.

LITERATURE CITED


