INORGANIC PHOSPHORUS OF HORSE SERUM

THE EFFECT OF AGE AND NUTRITION

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Relatively little information is available on the phosphorus content of horse blood. Abderhalden (1), in his pioneer investigations of 1898, analyzed the blood of two horses and reported 3.3 mg. of inorganic phosphorus per 100 ml. of serum. Robinson (2), using the method of Fiske and Subbarow, determined the inorganic phosphorus content of the blood of forty-four horses and found a range of 1.92 to 5.36 mg. per 100 ml. of serum with an average of 3.19, but did not indicate the age or breed of the animals from which the blood samples were obtained. The most complete work on the normal phosphorus values for mature horses is that of Kintner and Holt (3), who analyzed the blood of 69 horses and found a range of 2.63 to 5.00 mg. of inorganic phosphorus per 100 ml. of serum with an average of 3.55 mg. In a recent paper Dimock and Healy (4) report an average of 4.9 mg. of inorganic phosphorus per 100 ml. of serum obtained from four thoroughbred yearling fillies. They observed no significant change in the phosphorus content of the serum from overfed fillies that received, in addition to the standard diet, haliver oil and ultra-violet ray treatments.

Methods

The blood samples were obtained from 76 horses, varying in age from 118 days to 23 years. All of the animals used for the study of the normal phosphorus values had been on a standard diet for several months. This diet consisted of a limited amount of grain and green feed and a liberal allowance of good quality hay. Those under 10 months of age were not yet weaned. Mature horses grazed on a pasture devoid of green herbage were observed in order
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to ascertain if this nutritional régime affected the serum phosphorus. Except for three grade Arabians, all of the animals were pure-bred Arabian horses of similar lines of breeding. Consequently, the genetic variability, if such occurs, should be a minimum factor.

The blood was drawn from the jugular vein and the serum from the individual samples was separated from the corpuscles by centrifugation. The inorganic phosphorus was determined by the method of Youngburg and Youngburg (5). At frequent intervals simultaneous determinations were also made by utilizing the method of Fiske and Subbarow (6). This procedure served as a double check.

*Normal Phosphorus Values*—For the purpose of statistical analyses of the data, the animals are divided into age groups by years up to the time they reach maturity, when a more or less constant level for inorganic phosphorus of the serum is reached. The mean concentration of the inorganic phosphorus of the serum is recorded in Table I.

The mean value of $3.37 \pm 0.041$ mg. of inorganic phosphorus per 100 ml. of serum for mature animals is not significantly different from the average of 3.55 mg. reported by Kintner and Holt (3). The mean value of $4.41 \pm 0.092$ mg. of inorganic phosphorus per 100 ml. of serum for animals 1 to 2 years old is somewhat lower than the value of 4.9 mg. reported by Dimock and Healy (4) for horses of similar age but of a different breed.

**Correlation between Phosphorus and Age of Growing Animal**—Since the inorganic phosphorus content of the serum decreases with increasing age of the growing animal, a correlation study was

<table>
<thead>
<tr>
<th>No. of animals</th>
<th>Age</th>
<th>Inorganic P per 100 ml. serum</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Under 1</td>
<td>$5.23 \pm 0.130$ mg.</td>
<td>0.536</td>
</tr>
<tr>
<td>12</td>
<td>1-2</td>
<td>$4.41 \pm 0.092$ mg.</td>
<td>0.320</td>
</tr>
<tr>
<td>7</td>
<td>2-3</td>
<td>$4.29 \pm 0.146$ mg.</td>
<td>0.386</td>
</tr>
<tr>
<td>6</td>
<td>3-4</td>
<td>$3.64 \pm 0.141$ mg.</td>
<td>0.347</td>
</tr>
<tr>
<td>18</td>
<td>Over 4</td>
<td>$3.37 \pm 0.041$ mg.</td>
<td>0.176</td>
</tr>
</tbody>
</table>
made between these two factors. The data used in this computation represent the inorganic phosphorus values ranging from 3.16 to 6.20 mg. per 100 ml. of serum obtained from forty animals ranging in age from 118 days to 3 years and 10 months. By means of the equation of Wallace and Snedecor (7) for machine calculation of the correlation coefficient, we find that the derived $r = -0.768 \pm 0.066$. This high negative correlation means that with increasing age of the growing animal there is a decrease in the inorganic phosphorus content of the serum.

The regression line (Fig. 1) superimposed upon a familiar scatter diagram of the original data shows the estimated or average phosphorus values corresponding to varying ages. The regression line is immediately useful for estimating the inorganic phosphorus

![Fig. 1. Scatter diagram of relation between inorganic phosphorus content of the serum and age of the growing animal. The regression line shows the estimated or average phosphorus values corresponding to varying ages.](image-url)
content of the serum of other horses within the age range considered, and with similar breeding and environmental conditions. The estimated value may also serve as a standard of comparison for inorganic phosphorus values observed in growing horses subjected to abnormal environmental conditions, nutritional régimes, or in pathological cases.

Effect of Nutritional Régimes—During the summer and autumn months sixteen mature horses were grazed on hill pasture. Since the precipitation during the 4 months prior to executing this study was nil, the feed consisted almost entirely of dry forage plants. The inorganic phosphorus of the serum of the horses grazed on this pasture ranged from 2.45 to 2.91 mg. per 100 ml. of serum, with a mean of 2.63 ± 0.054; standard deviation 0.217. The animals grazed on dry forage showed markedly lower phosphorus values than the mature horses receiving an adequate diet and having a mean serum phosphorus of 3.37 ± 0.041 mg.; standard deviation 0.176. These differences are highly significant statistically and leave no doubt as to the effect of the nutritional régimes on the inorganic phosphorus content of the serum.

In order to ascertain if the hypophosphoremia\(^1\) was due to quantitative dietary differences, the sixteen horses were moved to an adjoining pasture with similar herbage not previously grazed during the year, as the former pasture had been, thereby insuring an abundant supply of feed. 14 days later blood samples were obtained from eight of the horses; the analyses showed no increment in the inorganic phosphorus content of the serum. This fact led us to suspect that the hypophosphoremia was probably due to the low phosphorus content of the forage plants on which the horses were grazed. The phosphorus and calcium contents of the three pre-dominating species of forage plants gathered from the ungrazed pasture at the time the horses were moved into it are reported in Table II.

Inspection of Table II shows that both of the wild oats species are considerably lower in phosphorus and calcium than is bur-clover. The bur-clover was less abundant than either of the wild oat species. A comparison of the data in Table II with a large number of analyses of the same species gathered from native pastures in various sec-

\(^1\) The term hypophosphoremia is used to denote an inorganic phosphorus content of the serum significantly below the normal.
tions of California, shows that the phosphorus values reported in Table II are more nearly comparable to the lower figures reported by Hart et al. (8), rather than with the normal values. The data indicate that the hypophosphoremia was due to the low phosphorus content of the herbage upon which the horses were grazed.

Recovery from Hypophosphoremia—Some indication as to the rapidity of recovery from the hypophosphoremia when the horses were changed to a different nutritional régime is obtained in the case of two animals. Two mature horses, selected at random from the sixteen head, were moved from the pasture and given a ration of 4 pounds of grain daily and a liberal allowance of good quality alfalfa and oat hay. When this change was made the inorganic phosphorus content of the serum was 2.45 and 2.91 mg. per 100 ml.

**TABLE II**

*Percentage Composition of Forage Plants*

<table>
<thead>
<tr>
<th>Species</th>
<th>Moisture</th>
<th>Calcium</th>
<th>Phosphorus</th>
<th>Ratio, Ca:P:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild oats (<em>Avena fatua</em>)</td>
<td>4.45</td>
<td>0.46</td>
<td>0.17</td>
<td>2.6</td>
</tr>
<tr>
<td>Slender wild oats (<em>Avena barbata</em>)</td>
<td>4.74</td>
<td>0.39</td>
<td>0.09</td>
<td>4.7</td>
</tr>
<tr>
<td>Bur-clover (<em>Medicago hispida</em>)</td>
<td>5.65</td>
<td>1.62</td>
<td>0.26</td>
<td>6.2</td>
</tr>
</tbody>
</table>

* Analyses for Ca and P on moisture- and silica-free basis.

respectively. 7 days later the inorganic phosphorus content of the serum of the first animal showed an increment from 2.91 to 3.29 mg. per 100 ml.; while 8 days later the second animal showed an increment from 2.45 to 3.33 mg. per 100 ml. of serum.

**SUMMARY**

1. There is a high negative correlation \( r = -0.768 \pm 0.066 \) between the age of the growing horse and the inorganic phosphorus content of the serum.

2. The inorganic phosphorus of the serum of the horse tends to approach a constant level at maturity. The level is, however, affected by an inadequate phosphorus intake.

3. Mature horses grazed on dry forage showed an inorganic phosphorus content of the serum significantly lower than that of horses receiving a limited amount of grain and green feed, and a liberal allowance of hay.
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4. Recovery from the hypophosphoremia was effected within 8 days after changing from a phosphorus-deficient to an adequate phosphorus intake.

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BIBLIOGRAPHY

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