The Effect of Diet on the Blood Pressure and Heart Rate of Normal Dogs

Protein and Carbohydrate


Trained standardized dogs were fasted until the blood pressure declined to the stable fasting level and were realimented with isocaloric diets high in protein (horse meat) or in carbohydrate (rice or cracker meal). Realimentation was at low maintenance or luxus consumption levels of caloric intake. At the former level, there was no difference between the diets, but at the latter level, the systolic blood pressure and pulse rate were higher on the carbohydrate diet, while the diastolic pressure was normal or low. Preliminary fasting was necessary to obtain a prolonged effect of the carbohydrate diet. Meat appears to antagonize carbohydrate.

A REVIEW of the pertinent literature on the effects of nutrition on blood pressure1 has disclosed the following: (a) Blood pressure tends to rise and fall with body weight both in normotensive and hypertensive human subjects and dogs, the effect being more pronounced on the systolic than on the diastolic pressure. (b) Increasing or decreasing the protein intake nearly always fails to cause corresponding elevation or depression of the blood pressure of normotensive or hypertensive human subjects or dogs. On the other hand, in normotensive or hypertensive rats, the blood pressure tends to vary directly with the protein content of the diet. (c) The effect of carbohydrate and fat has been the subject of fewer studies but the conclusions are that they have no effect or that they effect blood pressure only if they increase body weight. (d) Increasing or decreasing the sodium intake elevates or depresses the blood pressure in some, but not all, cases of human hypertension. In general, the sodium intake has little or no effect on the blood pressure of normal or hypertensive dogs. In both normal and experimentally hypertensive rats, increasing the sodium intake elevates the blood pressure. Since the rat appears to behave differently from human subjects and dogs with respect to the effect of sodium and protein, broad generalizations based on the effect of diet on the blood pressure of rats appear unwarranted.

In all of the studies analyzed in the above review, it appeared that in investigating the effects of the three primary food materials it has been customary to begin with a normally nourished animal on a presumably adequate diet and either to substitute an unbalanced diet, high in the particular food material to be studied, or to make an isocaloric replacement of the food material under study, in an adequate, mixed diet. In either case the animal was adequately or well nourished. Previous studies by Wilhelm and Mann2,3 suggested that the metabolic mill may possess the property of momentum, hence when it is running at high speed it may not immediately reflect changes corresponding to a change in the type or quantity of fuel ingested. For this reason, in the present studies, the animals were fasted before administering each experimental diet.

Preliminary studies on fasting4 have shown that the behavior of the blood pressure and pulse rate of fasting dogs (water ad libitum) can be divided into two stages: first, a stage...
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characterized by wide but gradually diminishing fluctuations; and second, a low stable level characterized by only small daily variations. The degree of fluctuation and the length of stage I are proportional to the height of the previous nutritional level and is surprisingly constant in repeated fasts on the same dogs. Beginning the experimental diets from the stable fasting level of blood pressure, thus has the advantage of giving a very constant control base line, which is the minimal nutritional level of blood pressure.

Selye has shown that fasting is an effective alarming stimulus which also renders the animal more sensitive to all other alarming stimuli. Because of the sensitivity of the fasting animal it may show effects from the different types of food materials which are potential but which may be masked in the well-nourished animal.

METHODS

Ten well-trained, standardized dogs (four males and six females) were used in the various phases of these experiments. Except as indicated, the animals were fasted until the blood pressure reached the low stable fasting level before administration of each experimental diet.

The high protein diet consisted of raw, ground, horse meat and the high carbohydrate diets consisted of either cracker meal or boiled white rice, flavored and moistened with a 30 per cent aqueous solution of Difco beef extract.*

No vitamins were administered during fasting or when the animals were receiving the raw meat diet, but when they were receiving the cracker meal or rice diet, one tablespoon of Brewers yeast and one multivitamin capsule were administered daily. Addition or withdrawal of the vitamins did not alter the blood pressure of dog I when on the luxus consumption diet of cracker meal.

Both the high carbohydrate and the high protein diets were fed at two levels of intake; namely, the low maintenance level and the luxus consumption level. The diets were approximately isocaloric with additional allowance for the specific dynamic action. When the low maintenance diets were fed at the end of a period of fasting, further weight loss was stopped, but there was no gain in weight. By definition, the luxus consumption diet was twice the low maintenance diet, unless otherwise stated, and resulted in a progressive gain in weight.

In the calculating the calorie intakes, 4 calories per gram was used for both the meat and carbohydrate diets. Thirty per cent additional meat and five per cent additional rice or cracker meal were allowed for the specific dynamic action. When the first low maintenance or luxus consumption diet was calculated for any dog, these calorie intakes were used throughout the entire period of study on that dog. It is realized that the calculation of the calorie intakes was only approximate, but since the same values were used throughout, comparisons are valid.

Blood pressure was determined six days each week by the auscultatory method of Allen. The mean of at least 10 consecutive readings was considered to be the blood pressure level for that day. The animals were fed between 2 and 3 p.m. and the blood pressure and pulse rates determined 16 to 18 hours later; an effort was made to keep this time schedule reasonably constant.

RESULTS

Figure 1 shows a complete set of experiments on dog I (Nell) obtained over a period of two and one-half years. The order and the season in which the various diets were administered was purposely varied in the different dogs in order to avoid possible dietary conditioning and seasonal influences.

The following features illustrated in figure 1 deserve special emphasis:

(A) The control blood pressure and pulse rate on the kennel diet of "Nutrena" before the experiments were started (1) were 127/62-73, while a similar control at the end of all experiments (18) gave values of 132/58-75. Thus it is evident that these prolonged and rather severe dietary stresses caused no permanent change in the level of blood pressure when the animals were fed the usual kennel diet. This fact was also established on three other dogs.

(B) The blood pressures and pulse rates during the eight fasting periods (2, 4, 6, 8, 10, 12, 14, and 16)* in description of figure 1 the numbers refer to the various periods which are labeled from 1 to 18 at the bottom of the figure.
12, 15, 17)* were almost identical. The mean values were 87/38-51.

(C) The blood pressures and pulse rates after realimentation with the low maintenance diets of meat, carbohydrate (cracker meal), and Nutrena dog food (3, 5, 9)* were of the same order of magnitude. When the values on the low maintenance diets of protein or carbohydrate were compared on the three dogs approximately the same as on the three low maintenance diets.

(E) The luxus consumption diets of cracker meal or rice (13, 14, 16)* gave much higher values for systolic blood pressure and pulse rate than an isocaloric diet of meat.

(F) A luxus consumption diet composed of one-half meat and one-half cracker meal (7)* gave systolic pressures and pulse rates which

studied on these diets, there were no consistent or significant differences between the effects of protein or carbohydrate on blood pressure or pulse rate. However, all three dogs were in much better condition on the low maintenance diet of cracker meal than on an isocaloric diet of horse meat, hence, the latter diets were continued for much shorter periods of time.

(D) The blood pressures and pulse rates on the luxus consumption diet of meat (11)* were higher than the isocaloric diet of meat but lower than an isocaloric diet of cracker meal or rice.

(G) A luxus consumption diet of cracker meal was continued for 90 days (13).* The mean blood pressure and pulse rate averaged 155/55-95 and showed no tendency to decline. At the end of 90 days an isocaloric diet of boiled rice was substituted for the cracker meal, without an intervening fast, and continued for 18 days (14)* during which the

* See preceding footnote.
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The mean blood pressure and pulse rate were 157/57-85. Since it was possible that this might have been due to the phenomenon of momentum, the animal was fasted until the blood pressure reached the stable fasting value and the luxus consumption of rice given for a period of 77 days during which the blood pressure and pulse rate averaged 102/67-87 (16).*

(H) After the blood pressure and pulse rate had reached the high levels characteristic of the luxus consumption diet of carbohydrate, the amount ingested could be materially reduced without a significant decrease in blood pressure. For example, for 43 days the animal ingested 405 Gm. of cracker meal daily and the mean blood pressure and pulse rate were 154/53-108. The cracker meal was then reduced to 243 Gm. and for 30 days on this amount the mean values were 157/55-81. In another experiment the animal ingested 405 Gm. of rice daily for 31 days and the mean values were 157/60-82. The intake of rice was then reduced to 369 Gm. and for 24 days the values were 167/76-94. In both instances the reduced diets were low luxus consumption amounts since they were maintenance diets for body weights considerably above the control weights. This observation was recently confirmed on another dog in which the daily intake of rice was reduced from 610 to 410 Gm., with practically no change in blood pressure. This phenomenon is considered to be an example of momentum of the metabolic mill as it influences blood pressure.

Figure 2 shows the luxus consumption diets on dog II (Bess). It is seen that the luxus consumption diet of meat gave the lowest systolic pressure, and an isocaloric diet of cracker meal gave the highest. An isocaloric diet of one-half meat and one-half cracker meal was intermediate. When 25 Gm. of salt were added daily to the luxus consumption diet of cracker meal, the mean values were 157/55-81. In another experiment the animal ingested 405 Gm. of rice daily for 31 days and the mean values were 157/60-82. The intake of rice was then reduced to 369 Gm. and for 24 days the values were 167/76-94. In both instances the reduced diets were low luxus consumption amounts since they were maintenance diets for body weights considerably above the control weights. This observation was recently confirmed on another dog in which the daily intake of rice was reduced from 610 to 410 Gm., with practically no change in blood pressure. This phenomenon is considered to be an example of momentum of the metabolic mill as it influences blood pressure.

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![Figure 2: Luxus consumption diets on dog II (Bess). Base lines represent the mean values for the initial kennel diet control; F, the fasting values preceding each diet.](http://circres.ahajournals.org/)

*See preceding footnote.
meal the mean blood pressure was significantly higher than without the salt (P < 0.01; D < 0.01; pulse no difference).

As shown in figure 2, body weight did not reach the control value until the 63-71 day period, whereas the systolic blood pressure on the cracker meal diets with and without salt reached the maximal value in eight days when body weight was still far below normal. After the 18-26 day period the curves for body weight were practically identical with all diets in spite of the marked differences in systolic blood pressures. Similar results on other dogs demonstrate clearly that differences in body weight are not the direct or sole cause of the differences in the blood pressure on the different diets.

The upper part of table 1 gives a summary of the mean values and standard deviations on the luxus consumption diets of meat and carbohydrate and the significance of the differences between them. The blood pressure was consistently higher on the carbohydrate diet, the increase being more marked in the systolic than in the diastolic pressure. Differences in pulse rate were less consistent.

The fact that a luxus consumption diet composed of one-half meat and one-half cracker meal gave mean blood pressure values which were intermediate between luxus consumption diets of either food material alone suggested

**TABLE 1.—Differences between and Significance of Mean Values of Systolic (S), Diastolic (D) Pressures and Pulse Rate (P) on Luxus Consumption Carbohydrate and Isocaloric Meat Diet, after a Preliminary Fast**

<table>
<thead>
<tr>
<th>Dog</th>
<th>Luxus Consumption Carbohydrate</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Luxus Consumption Protein</th>
<th>Difference</th>
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<tr>
<td></td>
<td>S</td>
<td>D</td>
<td>P</td>
<td>S</td>
<td>D</td>
<td>P</td>
<td>S</td>
<td>D</td>
<td>P</td>
</tr>
<tr>
<td>I</td>
<td>(1) 156±11*</td>
<td>(1) 54±7.2</td>
<td>(1) 96±10.2</td>
<td>108±13.3</td>
<td>54±8.3</td>
<td>67±11.5</td>
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<td>+31</td>
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<tr>
<td>Nell</td>
<td>(2) 161±13.8</td>
<td>(2) 67±11.5</td>
<td>(2) 89±11.5</td>
<td>98±7.0</td>
<td>54±4.4</td>
<td>91±8.6</td>
<td>+37</td>
<td>+14</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>II</td>
<td>(1) 138±8.2</td>
<td>(1) 64±3.2</td>
<td>(1) 91±6.6</td>
<td>107±8.0</td>
<td>54±4.5</td>
<td>103±11.4</td>
<td>+30</td>
<td>+16</td>
<td>&lt;.01</td>
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<tr>
<td>Boss</td>
<td>(2) 150±10.8</td>
<td>(2) 72±7.1</td>
<td>(2) 91±8.7</td>
<td>127±9.7</td>
<td>52±9.2</td>
<td>121±16.4</td>
<td>+22</td>
<td>+6</td>
<td>&lt;.01</td>
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<tr>
<td>III</td>
<td>143±15.1</td>
<td>76±6.6</td>
<td>104±17.1</td>
<td>127±15.1</td>
<td>52±9.2</td>
<td>121±16.4</td>
<td>+22</td>
<td>+6</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Blackie</td>
<td>146±10.9</td>
<td>57±6.8</td>
<td>104±17.7</td>
<td>127±9.7</td>
<td>52±9.2</td>
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<td>+6</td>
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<tr>
<td>IV</td>
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<td>75±8.4</td>
<td>139±11.8</td>
<td>57±8.9</td>
<td>70±12.0</td>
<td>+32</td>
<td>-5</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>V</td>
<td>160±8.3</td>
<td>56±6.2</td>
<td>94±10.4</td>
<td>122±9.0</td>
<td>58±7.1</td>
<td>85±14.7</td>
<td>+18</td>
<td>-2</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Brownie</td>
<td>162±11.2</td>
<td>65±7.3</td>
<td>98±13.6</td>
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<td>67±7.9</td>
<td>111±15.1</td>
<td>123±12.1</td>
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<td>+51</td>
<td>+8</td>
<td>&lt;.01</td>
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<td>VII</td>
<td>155±8.9</td>
<td>67±7.9</td>
<td>111±15.1</td>
<td>123±12.1</td>
<td>58±8.8</td>
<td>98±17.3</td>
<td>+51</td>
<td>+8</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>VIII</td>
<td>156±10.0</td>
<td>52±7.7</td>
<td>75±8.4</td>
<td>139±11.8</td>
<td>57±8.9</td>
<td>70±12.0</td>
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<td>-5</td>
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<td>Shad</td>
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<td>56±6.2</td>
<td>94±10.4</td>
<td>122±9.0</td>
<td>58±7.1</td>
<td>85±14.7</td>
<td>+18</td>
<td>-2</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>VII</td>
<td>154±8.9</td>
<td>67±7.9</td>
<td>111±15.1</td>
<td>123±12.1</td>
<td>58±8.8</td>
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<td>+51</td>
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<td>57±8.9</td>
<td>70±12.0</td>
<td>+32</td>
<td>-5</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Hound</td>
<td>146±10.9</td>
<td>57±6.8</td>
<td>104±17.7</td>
<td>127±9.7</td>
<td>52±9.2</td>
<td>121±16.4</td>
<td>+22</td>
<td>+6</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Dog I (Nell): 1—cracker meal; 2—rice.

Dog II (Boss): 1—cracker meal; 2—cracker meal + 25 Gm. salt.

* Standard deviation.

As shown in figure 3, body weight did not reach the control value until the 63-71 day period, whereas the systolic blood pressure on the cracker meal diets with and without salt reached the maximal value in eight days when body weight was still far below normal. After the 18-26 day period the curves for body weight were practically identical with all diets in spite of the marked differences in systolic blood pressures. Similar results on other dogs demonstrate clearly that differences in body weight are not the direct or sole cause of the differences in the blood pressure on the different diets.

The upper part of table 1 gives a summary of the mean values and standard deviations on the luxus consumption diets of meat and carbohydrate and the significance of the differences between them. The blood pressure was consistently higher on the carbohydrate diet, the increase being more marked in the systolic than in the diastolic pressure. Differences in pulse rate were less consistent.

The fact that a luxus consumption diet composed of one-half meat and one-half cracker meal gave mean blood pressure values which were intermediate between luxus consumption diets of either food material alone suggested
that there may be an antagonistic effect between meat and carbohydrate on blood pressure. In order to test this hypothesis, the following experiment was performed on five dogs. The animals were fasted until the pressure reached the stable fasting level and the luxus consumption diet of cracker meal or rice was given and continued for 90 days; then, without an intervening fast, the diet was changed to an isocaloric diet of meat. In all instances the pressure began to decrease rather promptly and within 10 to 16 days reached a new low level at which it became stable (figure 3 and table 1).

Because of the importance of this finding it was repeated about one year later on dogs VI, VII and VIII by another observer. Dogs VI and VII showed an almost identical response. Dog VIII showed a much slower and less pronounced fall in systolic pressure which, however, was highly significant (P < 0.01) while there was a rise in diastolic pressure.

particularly the systolic, and the pulse rate rose promptly above the mean values on the kennel diet, but that on about the fourteenth to sixteenth day, the values, except the pulse rate on dog IV, declined and approached the mean values for the kennel diet. Thus, the preliminary fast is in some way necessary to maintain the high values characteristic of the luxus consumption diet of carbohydrate.

The same dogs were again placed on the kennel diet for about 35 days and the various factors stabilized at the control values. With-

**Fig. 4.** Effect on four dogs of changing from the kennel diet to a luxus consumption diet of cracker meal without an intervening fast. Values ± the kennel diet control. Zero base lines are values on kennel diet.
out a preliminary fast they were placed on the luxus consumption diet of meat. Figure 5 shows that the systolic and diastolic blood pressures remained at or below the control kennel diet levels. Pulse rates rose above the control values. From this it is evident that the tendency for the luxus consumption diet of meat to result in a low blood pressure is not dependent upon a preliminary fast.

Since Difco beef extract was added to the cracker meal and rice diets but not to the meat it was necessary to eliminate it as a factor in the results. The following findings indicate that it was not responsible: (1) It was added to the low maintenance diets of cracker meal, and in general these gave about the same blood pressure and pulse rates as the isocaloric low maintenance diets of meat or Nutrena which did not contain beef extract. (2) In the experiment on dog II (fig. 2), beef extract was added to the luxus consumption diet of meat in about the same amount as in the luxus consumption diet of cracker meal from the 63-71 to the 90-98 day periods but it did not elevate the blood pressure above the periods in which it was not added.

When different dogs were placed on the luxus consumption diets of carbohydrate, certain individual differences were noted. First, the rapidity of the elevation of the systolic pressure to the plateau level was often very rapid as shown in figure 2, or it might require from three to four weeks of gradual elevation to attain the high plateau value. Second, having reached the high plateau value the level was maintained with only moderate daily variations, but in one dog the daily fluctuations were very large (80-280 mg. Hg). Low blood sugar and very rapid pulse rates were sometimes associated with the low values. Third, 1 dog out of 10 (a female Dalmatian) has shown what appears to be adaptation to the diet. The blood pressure first rose in the usual manner but after approximately 62 days it began to fall slowly and finally reached the control level in spite of the fact that the dog was eating well and was greatly overweight. It remained at the low level for 28 days longer at which

![Graph](https://example.com/graph.png)
time certain changes were instituted in an attempt to discover the mechanism of the adaptation.

**Discussion**

Clinical literature stresses the importance of obesity as the prime factor in the elevation of blood pressure by diet, whereas the present studies show that in the dog, under the conditions of these experiments, the composition of the diet rather than body weight is the important factor. However, since there was no consistent or significant difference between the effects of protein or carbohydrate on blood pressure when fed at the low maintenance level, it is obvious that other factors, in association with the composition of the diet, were of paramount importance in bringing out the difference between the effects of these two food materials. The additional factor is the dietary load or stress. Ingle, Selye, and others have emphasized the harmful metabolic effects of overeating and the present experiments emphasize another aspect of this problem.

Two findings show that dietary stresses of the type and duration used here caused no permanent changes in the mechanisms maintaining normal blood pressure and heart rate. First, the elevated values were promptly reduced by fasting and the stable fasting levels showed no tendency to become progressively elevated. Second, on all dogs the blood pressures and pulse rates on the kennel diet were practically the same at the end of the long series of dietary stresses as they had been before starting them.

The effects were more marked on systolic than on diastolic pressure, a fact which has been noted by other investigators on human subjects and on dogs given high caloric mixed diets. This could be the result of increased cardiac output.

As shown in figure 1, there was some evidence suggesting that the diastolic pressure was gradually becoming elevated with repeated dietary stresses; there is the remote possibility that this represents a very early stage of a hypertension of dietary origin. Many more experiments of much longer duration would be necessary to settle this point.

The high carbohydrate diet was fed once daily and we have observed low blood sugar, very rapid pulse and convulsions 16 to 18 hours after the single feeding. An abrupt drop in blood pressure has in some instances preceded the low blood sugar and convulsions. This tendency to late postprandial hypoglycemia could result in stimulation of the pituitary-adrenal system.

Schroeder has reported that certain sulfhydryl compounds will reduce the blood pressure in experimental and clinical hypertension. The possibility of such compounds being a factor in the hypotensive effect of meat must be considered.

When 25 Gm. of sodium chloride were added to the luxus consumption diet of carbohydrate (fig. 2) a significant elevation of blood pressure occurred. Previous studies showed that when a similar amount of salt was added to the kennel diet (no preceding fast) for periods from 5 to 205 days there was no consistent or physiologically significant elevation of blood pressure of four dogs. The luxus consumption carbohydrate diet and the preliminary fast may be responsible for the difference.

Regarding the accuracy of the indirect method for determining blood pressure used in these studies, attention should be called to the fact that an outstanding authority on hemodynamics believes that the method agrees with direct readings to within ±10 mg. Hg. Since we are interested in relative and not absolute values, this agreement is satisfactory if the error remains reasonably constant. A large amount of evidence collected during the past five years leads us to believe that this is true when an experienced experimenter uses highly trained dogs. Another factor which tends to reduce the error is the large number of readings which are averaged to give the mean pressure for one experimental period. The luxus consumption period often lasted about 90 days during which 10 or more readings were made on each of 78 dogs, hence the mean for an experimental period is based on approximately 780 readings.

**Summary**

1. When dogs which had been fasted until the blood pressure declined to the stable fasting level were realimented with low mainte-
nance diets (60 calories per square meter of body surface per hour for 24 hours) high in protein (horse meat) or in carbohydrate (cracker meal), the blood pressure and pulse rate rose promptly but moderately above the fasting levels, but there was no consistent or significant difference between diets high in protein or in carbohydrates.

2. When similarly fasted dogs were realimented with similar diets at the luxus consumption level of intake (twice the low maintenance level), there was a marked difference in the effects of the high protein and high carbohydrate diets. The high protein diet caused elevation of blood pressure of the same order of magnitude as the low maintenance diets, while the high carbohydrate diets caused a marked and highly significant elevation of systolic blood pressure. Pulse rates showed similar but less consistent differences. A luxus consumption diet of one-half meat and one-half cracker meal gave blood pressure elevations between the luxus consumption high carbohydrate and high protein diets.

3. If animals on the regular kennel diet were changed to the luxus consumption diets without a preliminary fast, the high carbohydrate diet caused a temporary rise in blood pressure and pulse rate which returned to the kennel diet level in about two weeks, whereas the high protein diet caused either no elevation or an actual fall below the kennel diet level. The preliminary fast was, therefore, necessary to obtain a maintained blood pressure elevation with the high carbohydrate diet, but was not essential for the opposite effect of the high protein diet.

4. If the blood pressure was elevated by the high carbohydrate diet given after a preliminary fast, and an isocaloric high protein diet substituted without an intervening fasting period, the blood pressure immediately began to decrease and within a few weeks reached the low level characteristic of the high protein diet.

5. Differences in body weight were not the factors responsible for the difference between the luxus consumption high protein and high carbohydrate diets.

6. There was no clear cut evidence that these rather severe dietary stresses caused any permanent change in the mechanisms maintaining normal blood pressure and pulse rate.

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