THE EFFECT OF LIGHT ON CREATININE AND CREATINE EXCRETION AND BASAL METABOLISM.*

BY MARIETTA EICHELBERGER.

(From the Nutrition Laboratory of the Department of Home Economics of the University of Chicago, Chicago.)

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The object of this investigation was twofold: to determine the effect of light on the hourly excretion of creatinine and creatine in the urine, and to determine the effect of light on basal metabolism.

Part I. Creatinine and Creatine.

LITERATURE.

Thus far, Hoogenhuyze and Best (1) have been the only investigators found who have worked on the influence of light on the formation of creatinine. The light which they used was from 88 incandescent lamps of 16 candle power each, placed along the four sides of a wooden cabinet lined with zinc. The subject was placed in the cabinet for ½ hour with only his head out of the opening at the top. The temperature of the interior of the cabinet, when closed, varied from 40-50°C but could be reduced to 35° or 36°C. by opening one of the sides and fanning the air vigorously. Light exposures for ½ hour with and without heat increased the creatinine excretion, but when the light was intercepted by sheets of asbestos, the temperature remaining the same, the creatinine was either not increased at all or increased to only a slight extent. Averages of their figures show an excretion before light exposure of 1.488 gm. of creatinine, apparently for the 24 hours, as compared with 1.767 gm. with light at a temperature of 50°C. Without light, but with the same temperature, 50°C., the excretion became 1.550 gm. per 24 hours as against 1.807 gm. with cooled light. It is to be regretted that they did not give more details of their work.

In the above experiments the whole body was exposed to the light rays, but later these same workers sought to find whether there was any influence...
from the exposure of only a part of the body to the Roentgen rays. They used instead of normal individuals, two patients afflicted with Banti's disease, two with leukemia, and two with sarcoma of the thigh, and exposed the afflicted parts of the bodies to the radiation. They give no figures of their results but state that after the exposure the total quantity of creatinine was increased, and when there was any creatine in the urine this was diminished after the exposure.

In still later experiments with two individuals, after 3 days on a creatinine-creatine-free diet, the average 24 hour creatinine excretion was 0.876 gm. for one patient and 0.954 gm. for the other. Creatine was not found. After 2 days exposure to the sun the figures were 0.989 for the former and 1.106 for the latter. They cite especially the fact that the creatinine immediately made a small jump and afterward remained practically constant for the duration of the experiment (4 weeks).

**EXPERIMENTAL.**

**Sources of Light.**—The sources of light used in these investigations were sunlight and a carbon arc known as the "Pan Ray Arc" manufactured by the Atlas Electric Devices Company, Chicago. This lamp is of the flame type burning with an inch and a half to a 2 inch arc and running on a potential of 110 volts with a direct or alternating current of 32 amperes. The white flame carbons used are impregnated with rare earth fluorides, 25 per cent of which is cerium. These carbons give a spectrum rich in ultra-violet. The spectrophotograph shows very bright lines in the region of 247 to 253\(\mu\mu\), only weak ones from 279 to 281\(\mu\mu\), and an abundance from 288 to 570\(\mu\mu\).

The richness of this light in ultra-violet radiation from 290\(\mu\mu\) to much longer wave-lengths makes the spectrum from this carbon arc similar to that obtained from the sun which has a short wave-length limit of 291\(\mu\mu\), but in addition it contains an abundance of shorter wave-lengths.

**General Procedure.**—The creatinine and creatine determinations were made on normal women during the morning hours after their

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1 Special acknowledgment is made to the Atlas Electric Devices Company of Chicago for the use of the Pan Ray Arc. For the kindness of this loan, the gift of carbons, and cooperation of Mr. H. S. Thayer in the operating of the lamp, the author wishes to express her indebtedness and most sincere appreciation.

2 The author is indebted to Mr. V. D. Snyder for making the spectrophotograph.
customary breakfasts and while engaged in the usual activities connected with laboratory work. Two young girls, aged 10 and 11 respectively, also acted as subjects. Many of the determinations were on one subject, M. E., thus more easily eliminating variables than with one experiment each on a number of people. These individuals were not restricted in diet as breakfast only was involved and that varied little in one individual from day to day.

The subjects were exposed to the sunlight for 1 hour during the summer and early autumn months, June, July, August, September, and October, and to the carbon arc for 50 minutes at a distance of 6 to 7 feet during the winter months, December, January, February, and March. All irradiations were given in the morning hours between 9 and 11. The exposures to the sun were made on a roof free from all shadows, while those to the carbon arc were made within a small adequately heated metabolism laboratory.

Subjects exposed to the sun wore ordinary summer underclothes and a thin white voile dress with a rather low neck and usually with short sleeves. Later when artificial light was substituted for sunlight, the subject wore only light underwear, leaving the arms and shoulders bare. But for this change and that of the longer urine collection period after exposure, the procedure was the same as it was for the sunlight irradiation.

Erythema was more marked after exposure to the carbon arc than to the sun, but even with the artificial light did not occur for 1 or 2 hours. M. E. found that after several successive days of irradiation the erythema became less severe and gradual bronzing took place. M. C. and M. M. who were exposed only on single isolated days noticed practically no pigmentation.

The bladder was emptied 1 hour after breakfast and thereafter hourly collections of urine were made and analyzed for creatinine and creatine. Collections were made for 1 or 2 hours before exposure to the sun and from 2 to 5 hours afterward.

The determination of creatinine and creatine by the Folin (2) method was first carried out on a known solution of creatinine and creatine containing 1 mg. of creatinine and 0.2 mg. of creatine. Upon analysis an average of 1.19 mg. of total creatinine was accounted for, with a range in six experiments of from 1.19 to 1.21 mg.

The creatinine and creatine used for this preliminary work and
for the standard was obtained from the Special Chemicals Company, Highland Park, Illinois.

The creatine was determined in hourly samples of urine collected for the creatinine determinations by Folin's (2) method, using a 250 cc. Pyrex Erlenmeyer flask, distilled water instead of the tap water as suggested by Folin, and boiling till concentrated to 20 gm.

The data obtained are given in the tables showing creatinine determinations.

**DISCUSSION.**

*Creatinine.*—In 38 creatinine determinations on samples of urine collected directly after an hour of sunlight irradiation, and in 18 determinations on similar samples from carbon arc light exposure, it was found in every case that the excretion of creatinine was higher for the hour of exposure than for the hour following. In some cases, but not in all, it was also higher than for the preceding hour; that is, the irradiation hour showed a peak in creatinine excretion. This was true when the preceding hour was spent quietly working (standing or sitting) in the laboratory, but not always when it was spent in exercise. Even as little as a brisk 15 minute walk during the hour previous to the irradiation, or just before, had as much effect on increasing the creatinine as had the irradiation, or even more. This increase has already been shown by Schulz (3), McLaughlin and Blunt (4), and others.

The results obtained are presented in Tables I to IV. In Tables I and II are included those results obtained from the exposure to sunlight and the carbon arc when the irradiation hour was preceded by 1 or 2 non-exercise hours. With some of the cases, collection of urine was begun to include an earlier exercise period so that the latter cases of these tables show both an exercise and an irradiation peak.

With the carbon arc light the diminution of creatinine after irradiation was always present, but the increased excretion for the period of irradiation over the previous hour was not as pronounced as it had been with sunlight. This may have been due to the fact that the period of exposure was 10 minutes shorter for the carbon arc light than for the sunlight, or to the lesser intensity of this artificial light in spite of its more intense heat at so close range, or to qualitative differences in the two spectra.
Tables III and IV show the effects of irradiation by means of sunlight and the carbon arc respectively directly after exercise. The decreased excretion of creatinine usually lasted for at least 2 to 4 hours after irradiation. In the case of sunlight, the observa-

**TABLE I.**

*Irradiation by Sunlight Preceded by Non-Exercise Period.*

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of determinations</th>
<th>Extremes of variations of:</th>
<th>Light period over fore period.</th>
<th>Light period over after period.</th>
<th>Average of entire period.</th>
<th>Average of all after periods.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>M. M.</td>
<td>5</td>
<td></td>
<td>7.2</td>
<td>1.8</td>
<td>6.3</td>
<td>1.5</td>
</tr>
<tr>
<td>M. E.</td>
<td>3</td>
<td></td>
<td>3.9</td>
<td>1.7</td>
<td>5.8</td>
<td>-0.0</td>
</tr>
<tr>
<td>E. N.</td>
<td>3</td>
<td></td>
<td>4.2</td>
<td>1.6</td>
<td>10.0</td>
<td>-5.5</td>
</tr>
<tr>
<td>Lila</td>
<td>3</td>
<td></td>
<td>4.5</td>
<td>1.2</td>
<td>5.2</td>
<td>3.0</td>
</tr>
<tr>
<td>Dorothy</td>
<td>2</td>
<td></td>
<td>3.0</td>
<td>0.7</td>
<td>4.2</td>
<td>4.1</td>
</tr>
</tbody>
</table>

**TABLE II.**

*Irradiation by Carbon Arc Preceded by Non-Exercise Period.*

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of determinations</th>
<th>Extremes of variations of:</th>
<th>Light period over fore period.</th>
<th>Light period over after period.</th>
<th>Average of entire period.</th>
<th>Average of all after periods.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Maximum</td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>M. E.</td>
<td>4</td>
<td></td>
<td>3.7</td>
<td>-0.1</td>
<td>8.7</td>
<td>2.7</td>
</tr>
<tr>
<td>M. C.</td>
<td>1</td>
<td></td>
<td>3.4</td>
<td>3.4</td>
<td>6.8</td>
<td>0.8</td>
</tr>
<tr>
<td>M. M.</td>
<td>1</td>
<td></td>
<td>5.0</td>
<td>5.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

...tions were not continued past the period of decreased creatinine excretion, but after exposures to the carbon arc observations were made till the creatinine excretion returned to the normal level. This time required from 3 to 5 hours. That is, irradiation caused
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an immediate increased excretion of creatinine for that hour of exposure and a definite decreased excretion which persisted for 3 to 4 hours and then returned to the level observed before irradiation.

When the experiments were repeated on the subjects indoors,

**TABLE III.**

Irradiation by Sunlight Preceded by Exercise Period.

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of determinations</th>
<th>Extremes of variations of:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Light period over fore period.</td>
<td>Light period over after period.</td>
</tr>
<tr>
<td>M. E.</td>
<td>10</td>
<td>12.6</td>
<td>-5.2</td>
</tr>
<tr>
<td>Lila</td>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Dorothy</td>
<td>2</td>
<td>-0.5</td>
<td>-1.7</td>
</tr>
</tbody>
</table>

**TABLE IV.**

Irradiation by Carbon Arc Preceded by Exercise Period.

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of determinations</th>
<th>Extremes of variations of:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Light period over fore period.</td>
<td>Light period over after period.</td>
</tr>
<tr>
<td>M. E.</td>
<td>9</td>
<td>2.7</td>
<td>-2.8</td>
</tr>
<tr>
<td>M. C.</td>
<td>1</td>
<td>-1.8</td>
<td>-1.8</td>
</tr>
<tr>
<td>M. M.</td>
<td>1</td>
<td>-1.9</td>
<td>-1.9</td>
</tr>
</tbody>
</table>

or in the shade outdoors, on a day of similar temperature to that of the sunlight exposure, no such increased creatinine excretion was observed but rather a constant excretion for the morning hours under observation.

The results suggest a close parallelism to those obtained by
Fontes and Yovanovitch (5). These investigators found that the total nitrogen eliminated was greater in a light room than in a dark room. They gave an average total nitrogen excretion for a period of 6 hours as 3.77 gm. when the subject was awake in the dark. When the subject was awake in the light the average excretion became 5.33 gm. for this period. In the same way, the excretion of nitrogen was 3.83 gm. when the subject was asleep in the dark and 4.73 gm. when he was asleep in the light. Thus it is they conclude that the absence of light is evidently responsible for the diminished nitrogen metabolism in sleep.

During the months of September and October and also during the latter part of August, irradiation by the sun caused little or no effect on the creatinine excretion. These observations are recorded in Table V.

TABLE V.
Irradiation by Autumn Sunlight.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Extremes of variations of:</th>
<th>Light period over</th>
<th>Light period over</th>
<th>Average of</th>
<th>Average of</th>
<th>Average of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of determinations.</td>
<td>fore period.</td>
<td>after period.</td>
<td>period.</td>
<td>period.</td>
<td>period.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximum. mg.</td>
<td>Minimum. mg.</td>
<td>mg.</td>
<td>mg.</td>
<td>mg.</td>
</tr>
<tr>
<td>M. E.</td>
<td>9</td>
<td>1.8</td>
<td>-5.3</td>
<td>5.8</td>
<td>-1.6</td>
<td>48.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>46.9</td>
<td></td>
<td>44.8</td>
</tr>
</tbody>
</table>

Dorno (6) and Hess (7) have brought out the fact that the ultraviolet content of the sun in the region of 295 to 313\mu\mu is greatest during the morning hours of the summer months, June, July, and August, reaching a maximum in July. Inasmuch as some of the September days were as hot as the summer days and even more humid, it is evident that heat was not the causative factor in this increased excretion followed by a decreased excretion of creatinine, but rather the quality of light emitted during these months.

Creatine.—Creatine was found to be excreted by all three women all the time except during two periods by E. N. With M. E., on whom most of the determinations were made, the creatine ranged from 0.7 to 11.5 mg. per hour. The continuous excretion
of creatine observed by McLaughlin and Blunt (4) in their women is thus paralleled. These investigators do not attempt to give any reason for the constantly occurring creatine, but they do say that perhaps as suggested by Howe, Mattill, and Hawk (8) these relative high creatine values were caused by the unusual large quantities of water taken in hourly (200 cc.). In our experiments the intake of water was reduced to 100 cc. per hour and still the rather high and continuous excretion persisted. Nor is it probable that this constant excretion of creatine was due to strain as ascribed by Stearns and Lewis (9). One subject (M. E.) was working steadily in the laboratory, but inasmuch as the work required no special time for completion, she went about it in a rather leisurely way, being conscious of no strain in accomplishing it. In fact, she states that she felt more relaxed during these months of sunlight irradiation than at any other time.

Part of the creatine may possibly have been caused by taking of milk. During these months M. E. was taking at least a pint of milk per day, with one cup or about 240 cc. for breakfast. The creatine in cow's milk as observed by Denis and Minot (10) shows an average of 2.4 mg. per 100 cc. of milk. This would involve a total intake of 6.0 mg. of creatine at breakfast. But inasmuch as results show a much higher total excretion of creatine for the morning hours, in some cases as much as 18 mg. in 3 hours, it is evident that this creatine came from some other source. It might also be well to state that this subject was not eating a high protein diet, never taking meat more than once per day and then only in moderate amounts.

The children also excreted creatine constantly and in surprisingly large amounts. The maximum creatine excretion per hour was 10.2 mg. for Dorothy and 13.5 mg. for Lila. The average excretion for each per hour, over a period of 4 hours was 6.3 and 7.8 mg. respectively. It is not probable that this creatine could have come from a high protein intake for these children were on a rather high carbohydrate, medium protein intake at the time of these experiments.

These results obtained with sunlight show nothing definite as to its influence on creatine during or after irradiation. In some cases there was a slightly diminished excretion of creatine and in other cases a slight increase, while in still other cases the excretion
remained the same. Similar results were obtained with the young girls used in the experiments. This is contrary to the findings of Hoogenhuyze and Best (1) who, although they quote no figures, observed that when creatine was present it was always diminished after irradiation.

Because of this apparent lack of effect of sunlight on creatine excretion further observations on the creatine content of the urine after the carbon arc exposures were not made.

Part II. Basal Metabolism.

LITERATURE.

Clark (6) makes the following statement with respect to the effect of light on metabolism.

"Light exerts some influence on body metabolism, as is shown by a number of results indicating a change in amount of CO₂ expired, a change in rate and depth of respiration, and an increased rate of growth in the light compared to the dark. However, no results definite enough to review at any length are reported in this field. Since ultraviolet light is a powerful oxidizing and reducing agent it seems strange that it does not produce more marked changes in metabolism than it does. The small penetration of the chemically active rays is of course our protection against them. As far as the change in CO₂ output is concerned, it is visible light and ultraviolet light greater than 330μμ which is responsible for the effects reported so far, as the animals experimented on were always exposed to light under glass."

McConnell and Yagloglou (11) found that carbon dioxide produced and oxygen consumed increased with exposure to high or low temperature. They hold that there is a zone within which basal metabolism should be measured since the metabolic rate is increased when the temperature of the environment exceeds the body temperature. Those (12) holding a contrary view maintain that if external heat could be substituted for chemical processes in the body then the tropical temperature should reduce these fundamental metabolic changes to a low level in comparison with that which is obtained in the temperate zone, and so far climate or temperature differences have never been regarded as altering the metabolism of man in any noticeable degree.

In 1920, Ozorio de Almeida (13), a Brazilian physiologist, announced on the basis of studies made on ten white men and an equal number of negro laborers—using the Tissot gasometer—that the inhabitants of warm climates have a basal metabolism as low as 30 calories per square meter of body surface per hour. By some (12) this work was discredited unless it be "assumed that certain much discussed endocrine functions are notably disturbed by life in the tropics," and also because Eijkman (14) has confirmed his early work on the metabolic rate of white and colored persons in
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Java, reporting the usual figures—about 40 calories per hour. On the other hand, Du Bois rather accepts the findings of Ozorio de Almeida, attributing the low results to the limited muscular activity of subjects in such hot climates. That the small amount of muscular activity was the contributing cause was demonstrated by the fact that one subject increased his basal metabolism upon increased muscular activity.

Hill and Campbell (15) have shown that children crippled with surgical tuberculosis and lying fixed in splints in bed and more or less nude, gave a much higher basal metabolism after graduated exposure to open air and heliotherapy. However, these children also showed an increased weight and so a greater basal metabolism, but, when allowance was made for weight the rise in metabolism caused by heliotherapy was insignificant compared with that caused by exposure to open air.

EXPERIMENTAL.

Procedure.—The basal metabolism determinations were made in the winter months during the morning hours, on nine women students in the Nutrition Laboratory, six of whom were graduate students, and two young men, one a University instructor and the other a business man. All except one young woman (E. W.) who had a slight goiter were normal and healthy.

The Sanborne type of the Benedict respiration apparatus, an old machine converted according to Roth (16), was used to determine the oxygen consumption and therefrom the basal metabolism was computed. In general the procedure of the Nutrition Laboratory for determining the oxygen consumption was followed (17, 18). However, methods of recording data, technique, and the like were modified more according to the methods of Roth (19). After attaching the subject to the apparatus, kymographic tracings were made of the oxygen consumption over periods of 10 minutes each. Tests for tightness and for the presence of unabsorbed carbon dioxide in the spirometer were made each day.

After two 10 minute observations, checking within less than 5 per cent, usually within less than 3 per cent, had been made for the control basal rate, the carbon arc light described previously was used to irradiate the subject for 20 minutes. Then with the light still shining on him, two more 10 minute observations of oxygen consumption were made, usually involving a total light exposure of 45 to 50 minutes at a distance of 6 to 7 feet. During the whole of this irradiation period the subject lay quiet and re-
laxed. Just as in the case of creatinine determinations, the subject removed top clothing, leaving the arms and shoulders bare.

**DISCUSSION.**

The irradiation had no appreciable effect upon the basal metabolism. Of the eighteen studies made, an increase of 5.7 per cent occurred in one case, but the majority of the determinations fell within 3 per cent or less above or below those of the non-irradiated period.

It was also observed that neither the pulse rate nor the rate of respiration, as averaged from those of a 4 minute period, was changed by the light exposure, nor do the kymographic tracings show any difference in the depths of respirations during each period.

The negative findings from this work are rather striking, especially since Clark (6) in discussing the work of a group of investigators suggested that light influenced the amount of carbon dioxide expired and caused a change in the rate and depth of respirations. Likewise Rollier (20) in his study of tuberculosis, held that light absorbed by the blood changed it into a receptacle of radiant energy which hastened the intracellular process of oxidation and reduction.

It might be well to mention that while all subjects were considered normal because their basal metabolism fell within 10 per cent of Benedict's predicted values yet all except three of these women were 6 to 10 per cent below that predicted.

**SUMMARY.**

The creatinine and creatine excretion of three normal women and two children as affected by the irradiation from sunlight was observed during 3 summer months and 2 autumn months. Similar observations were made with the carbon arc light during the winter months.

A study was also made of the effect of irradiation by the carbon arc on the basal metabolism of nine normal women and two men.

The experimental observations seem to justify the following conclusions.

1. Light from the sun and from the carbon arc increased the
creatinine excretion for the hour of irradiation and then decreased
the excretion of creatinine for several hours, after which the ex-
cretion finally returned to the level obtained before the irradiation.
2. Irradiation by sunlight had no effect on the creatine excre-
tion of normal women or of the children studied. Creatine was a
constant component of both the urines.
3. Exercise increased the hourly creatinine excretion, in some
cases to a higher degree than did irradiation.
4. Autumn sunlight did not increase the creatinine excretion
as much as the sunlight of the summer months.
5. Irradiation had no immediate effect upon basal metabolism.
6. There is no apparent relation between the effect of irradia-
tion on creatinine excretion and the basal metabolic rate.

It is a pleasure to take this occasion to express grateful appre-
ciation to Dr. Katharine Blunt for her constant interest and help-
ful suggestions in all of the work undertaken.

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