THE INFLUENCE OF ULTRA-VIOLET RADIATION ON THE WEIGHT OF ADULT RABBITS, NORMAL AND SYPHILITIC

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During the course of an experiment previously reported (1), it was noted that rabbits exposed to ultra-violet radiation under certain conditions did not appear to be in as good physical condition as animals living in an environment from which all light was excluded and were more susceptible to intercurrent infections. With these facts in mind, the experiment was repeated with a view to determining the influence of ultra-violet irradiation on body weight, the chemical composition of the blood, and susceptibility to intercurrent infections of normal and syphilitic animals and on the reaction to syphilitic infection. The present paper will be limited to a report of the results obtained for body weight and susceptibility to intercurrent infections.

Material and Methods

In the experiment to be reported, 60 male rabbits between 6 and 8 months of age were used. The animals were divided into 6 comparable groups of 10 each, and from the beginning of the experiment on November 27, 1928, until June 15, 1929, these animals were kept in a room from which all light was excluded. They were caged separately, and fed the routine diet of hay, oats, and cabbage. The temperature of the dark room was satisfactorily maintained at 70° to 75°F. and the humidity varied with that of the outside air. The animals were weighed at weekly intervals.

Beginning December 5, 1928, 30 animals, listed as Groups II, IV, and VI were exposed for an hour each day to the unfiltered radiations of a quartz-mercury arc lamp (80 volts, 4.2 amperes) at a distance of 4.5 meters. The doors of the cages were open to permit free access of light but no depilatory measures were used and at no time throughout the experiment could there be detected evidence of derma-

titis, conjunctivitis, or any other inflammatory process which might be attributed to the action of ultra-violet radiation. The other animals, Groups I, III, and V, remained in the dark room throughout the experiment. Group I served as a control for Groups III and V, and Group II, as the control for Groups IV and VI.

A summary of experimental procedures, according to groups, is given in the following table:

Group	Number of animals	Dark room	Ultra-violet irradiation started	Inoculated with <i>T. pallidum</i>	Termination of experiment
I	10	Nov. 27, 1928	Dec. 5, 1928	Dec. 18, 1928	June 15, 1929
II	10	Nov. 27, 1928			June 15, 1929
III	10	Nov. 27, 1928	Dec. 5, 1928	Dec. 18, 1928	June 15, 1929
IV	10	Nov. 27, 1928		Dec. 18, 1928	June 15, 1929
V	10	Nov. 27, 1928		Jan. 24, 1929	June 15, 1929
VI	10	Nov. 27, 1928	Dec. 5, 1928	Jan. 24, 1929	June 15, 1929

All animals received some light from two other sources. For a brief period each day a 30 Watt amber tinted Mazda lamp was used in the dark room for cleaning cages, feeding, and making certain necessary observations. The animals were also exposed to diffuse filtered sunlight for a brief period once every 2 weeks when they were brought into the laboratory for bleeding purposes. During the remaining time all animals were kept in the dark room.

The mean values contained in Tables I to VI inclusive have been smoothed by the formula $\frac{a + 2b + c}{4}$ and are presented in the graphs (Text-figs. 1 to 3) in terms of per cent variation from a standard mean value, using for this purpose 2200 gm.

RESULTS

The results of the observations made in this experiment are presented in the form of tabulated summaries, Tables I to VIII, which are supplemented by a series of graphs, Text-figs. 1 to 3.

TABLE I
Gross Body Weight. Normal Dark Room

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1940	-260	-11.8
Dec. 6	2043	-167	- 7.6
Dec. 12	2088	-113	- 5.1
Dec. 20	2132	- 82	- 3.7
Dec. 28	2121	- 61	- 2.8
Jan. 5	2182	- 21	- 0.9
Jan. 12	2232	+ 17	+ 0.8
Jan. 18	2222	+ 32	+ 1.5
Jan. 25	2253	+ 59	+ 2.7
Feb. 5	2309	+105	+ 4.8
Feb. 9	2350	+154	+ 7.0
Feb. 16	2409	+199	+ 9.0
Feb. 22	2431	+186	+ 8.8
Mar. 6	2273	+117	+ 5.3
Mar. 16	2290	+ 94	+ 4.3
Mar. 23	2325	+114	+ 5.2
Mar. 29	2315	+ 88	+ 4.4
Apr. 6	2197	+ 33	+ 1.5
Apr. 14	2225	+ 25	+ 1.1
Apr. 19	2262	+ 61	+ 2.8
Apr. 27	2295	+ 98	+ 4.5
May 11	2342	+138	+ 6.3
May 17	2355	+103	+ 4.7
May 25	2162	- 1	0
June 1	2120	- 58	- 2.6
June 8	2167	- 37	- 1.7
June 15	2200	0	0
Group mean.....	2231	+ 31	+ 1.4

Dec. 6 to Jan. 25—14.5.

Mean gain—13.2.

Final net gain—11.8.

TABLE II
Gross Body Weight. Normal Ultra-Violet

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1865	-335	-15.7
Dec. 6	1970	-194	- 8.8
Dec. 12	1998	-150	- 7.0
Dec. 20	2084	-133	- 6.0
Dec. 28	2103	- 77	- 3.5
Jan. 5	2216	- 10	- 0.4
Jan. 12	2228	+ 34	+ 1.5
Jan. 18	2265	+ 46	+ 2.1
Jan. 25	2236	+ 59	+ 2.6
Feb. 5	2322	+ 75	+ 3.4
Feb. 9	....	....	....
Feb. 16	2220	+104	+ 4.7
Feb. 22	....	....	....
Mar. 6	2453	+186	+ 8.8
Mar. 16	2420	+106	+ 4.8
Mar. 23	....	....	....
Mar. 29	....	....	....
Apr. 6	....	....	....
Apr. 14	2031	- 63	- 2.9
Apr. 19	....	....	....
Apr. 27	2065	-133	- 6.0
May 11	2109	- 81	- 3.6
May 17	2193	- 31	- 1.3
May 25	2180	- 47	- 2.1
June 1	2059	- 98	- 4.5
June 8	2112	-114	- 5.2
June 15	2063	-137	- 6.2
Group mean.....	2152	- 48	- 2.2

Dec. 6 to Jan. 25—18.3.

Mean gain—13.5.

Final net gain—9.5.

TABLE III

Gross Body Weight. Dark Room. T. pallidum Inoculated on December 12, 1928

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1902	-197	- 8.9
Dec. 6	1955	-119	- 5.4
Dec. 12	2180	- 98	- 4.5
Dec. 20	2000	- 63	- 2.9
Dec. 28	2230	+ 31	+ 1.3
Jan. 5	2240	+ 27	+ 1.2
Jan. 12	2342	+168	+ 7.6
Jan. 18	2387	+174	+ 7.9
Jan. 25	2357	+193	+ 8.8
Feb. 5	2397	+211	+ 9.6
Feb. 9	2422	+211	+ 9.6
Feb. 16	2405	+230	+10.5
Feb. 22	2415	+247	+11.2
Mar. 6	2485	+230	+10.5
Mar. 16	2405	+213	+ 9.7
Mar. 23	2425	+214	+ 9.7
Mar. 29	2417	+213	+ 9.7
Apr. 6	2400	+245	+11.2
Apr. 14	2425	+274	+12.4
Apr. 19	2470	+298	+13.5
Apr. 27	2500	+327	+14.9
May 11	2500	+321	+14.8
May 17	2567	+240	+10.9
May 25	2450	+108	+ 4.8
June 1	2295	+ 25	+ 1.1
June 8	2215	+ 6	+ 0.2
June 15	2200	0	0
Group mean.....	2333	+133	+ 6.0

TABLE IV

Gross Body Weight. Ultra-Violet. T. pallidum Inoculated on December 12, 1928

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1852	-248	-11.2
Dec. 6	1900	-183	- 8.7
Dec. 12	2017	-101	- 4.6
Dec. 20	2065	-132	- 6.0
Dec. 28	2127	- 87	- 4.3
Jan. 5	2135	- 56	- 2.4
Jan. 12	2180	- 21	- 0.9
Jan. 18	2212	+ 12	+ 0.5
Jan. 25	2245	+ 40	+ 1.8
Feb. 5	2260	+ 41	+ 1.8
Feb. 9	2212	+ 14	+ 0.6
Feb. 16	....	....	....
Feb. 22	2175	- 24	- 1.1
Mar. 6	....	....	....
Mar. 16	2134	- 66	- 3.0
Mar. 23	2093	- 87	- 3.9
Mar. 29	2142	- 67	- 3.0
Apr. 6	2156	- 53	- 2.4
Apr. 14	2134	- 71	- 3.2
Apr. 19	....	....	....
Apr. 27	....	....	....
May 11	2090	-108	- 4.9
May 17	....	....	....
May 25	....	....	....
June 1	2053	-147	- 6.7
June 8	....	....	....
June 15	....	....	....
Group mean.....	2115	- 85	- 3.9

TABLE V

Gross Body Weight. Dark Room. T. pallidum Inoculated on January 24, 1929

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1932	-268	-12.2
Dec. 6	2162	-178	- 8.1
Dec. 12	2222	+ 15	+ 0.7
Dec. 20	2255	+ 56	+ 2.4
Dec. 28	2295	+ 91	+ 4.1
Jan. 5	2325	+130	+ 5.9
Jan. 12	2380	+174	+ 7.9
Jan. 18	2412	+212	+ 9.6
Jan. 25	2447	+245	+11.1
Feb. 5	2477	+274	+12.4
Feb. 9	2497	+303	+13.8
Feb. 16	2542	+305	+13.9
Feb. 22	2442	+254	+11.5
Mar. 6	2387	+208	+ 9.5
Mar. 16	2417	+204	+ 9.4
Mar. 23	2395	+191	+ 8.7
Mar. 29	2357	+130	+ 5.9
Apr. 6	2312	+128	+ 5.8
Apr. 14	2332	+127	+ 5.8
Apr. 19	2332	+146	+ 6.6
Apr. 27	2391	+163	+ 7.5
May 11	2339	+148	+ 6.7
May 17	2322	+103	+ 4.7
May 25	2230	+ 50	+ 2.3
June 1	2218	+ 44	+ 2.0
June 8	2290	+ 90	+ 4.1
June 15	....	.....	.....
Group mean.....	2335	+135	+ 6.1

TABLE VI

Gross Body Weight. Ultra-Violet. T. pallidum Inoculated on January 24, 1929

Date	Group mean	Smoothed net variation	Per cent variation
<i>1928-29</i>	<i>gm.</i>	<i>gm.</i>	
Nov. 30	1922	-258	-11.5
Dec. 6	2061	-168	- 7.6
Dec. 12	2086	- 96	- 4.2
Dec. 20	2183	- 39	- 1.7
Dec. 28	....	....	....
Jan. 5	2194	- 2	- 0.1
Jan. 12	2222	+ 22	+ 1.0
Jan. 18	2250	+ 48	+ 2.2
Jan. 25	2269	+ 75	+ 3.4
Feb. 5	2303	+ 81	+ 3.7
Feb. 9	2250	+ 68	+ 3.1
Feb. 16	2272	+ 69	+ 3.1
Feb. 22	2266	+ 65	+ 3.0
Mar. 6	2267	+ 69	+ 3.1
Mar. 16	2277	+ 74	+ 3.4
Mar. 23	....	....	....
Mar. 29	2275	+ 45	+ 2.0
Apr. 6	....	....	....
Apr. 14	....	....	....
Apr. 19	2155	+ 40	+ 1.9
Apr. 27	....	....	....
May 11	....	....	....
May 17	2025	- 48	- 2.2
May 25	....	....	....
June 1	2002	-148	- 6.7
June 8	1922	-212	- 9.6
June 15	....	....	....
Group mean.....	2168	- 32	- 1.5

TABLE VII
Per Cent Gain from Initial Weight

Dark room				Ultra-violet			
Group	Jan. 25, 1929	Mean	Final	Group	Jan. 25, 1929	Mean	Final
I	16.1	15.0	13.4	II	19.9	15.4	10.6
III	24.8	22.6	15.1	IV	21.2	14.2	10.8
V	26.6	20.8	18.5	VI	18.1	12.7	0.0

TABLE VIII

Dark room		Ultra-violet	
Group	Survivals	Group	Survivals
I	10	II	6
III	10	IV	8
V	9	VI	9

TEXT-FIG. 1

TEXT-FIG. 2

TEXT-FIG. 3

DISCUSSION AND CONCLUSIONS

In taking up the discussion of the results recorded above, attention should be directed to the fact that in these experiments the only light of any consequence which was received by the irradiated animals was that derived from the quartz mercury lamp. These experiments differ, therefore, from others in which animals receiving unfiltered or diffuse filtered sunlight are given an additional ultra-violet irradiation. A further condition to which attention should be called is the fact that during the course of these experiments, there was a marked deterioration of the lamp used, so that the energy delivered during the latter part of the experiment was much less than at the beginning. It is regretted that the actual change and the rate of decrease can not be given accurately. But throughout the entire period of the experiment, all animals lived in a room from which all extraneous light was excluded, the only environmental variation being the exposure of Groups II, IV, and VI to ultra-violet radiation for an hour each day at a distance of 4.5 meters.

Considering the results for normal animals first, it will be seen by a comparison of the figures for body weight that from the beginning of the experiment on November 30, 1928, until January 25, 1929, both Groups I and II showed a gradual increase in body weight. Following this, the dark group exhibited a rather sharp increase in weight reaching a maximum on February 16. The increase in the ultra-violet group of animals was more gradual, their maximum weight being attained on March 6. From these high values both groups showed a loss in weight, the group exposed to ultra-violet radiation losing more than animals living in total darkness. After March 16 and throughout the remainder of the experiment, the general level of body weight of the ultra-violet group was below that of the dark group. The latter group exhibited a secondary increase in weight during the first week of May, this same increase being reflected in the ultra-violet animals although at a much lower level. From these levels, both groups decreased in weight, the ultra-violet animals showing a more gradual decline while the dark group showed a slight increase in weight during the last 2 weeks of the experiment.

The difference between the two groups of animals with respect to

susceptibility to intercurrent disease (Table VIII) is in agreement with the results obtained for body weight. This is clearly shown by the occurrence of 4 deaths among the irradiated animals and none among those which received no ultra-violet light. Postmortem examination showed that death was due in all cases to pneumonia.

The effects of irradiation on syphilitic rabbits were essentially the same as on normal animals. The animals of Groups III and IV (Tables III and IV; Text-fig. 2) were inoculated with the Nichols strain of *T. pallidum* on December 24, 1928. All other conditions were the same as for Groups I and II. Except for the values obtained on December 12, at which time both groups coincided, the gross body weights for animals exposed to ultra-violet radiation was far below that maintained by animals living in total darkness. On May 6, there was a difference of 20 per cent between the mean values obtained for these two groups of animals. While the course of syphilis in the two groups of animals was moderately severe, yet no deaths were recorded as resulting from the specific infection. However, at the end of the experiment, all animals of Group III were alive while 2 died in Group IV, deaths being due to pneumonia.

The animals in Groups V and VI were inoculated on January 24, 1929, with the same strain of *T. pallidum* as were Groups III and IV. In general, it can be stated that the syphilitic infection in these animals was less severe than that found in Groups III and IV. The mortality rate from non-specific infection was the same in both Groups V and VI.

From the beginning of the experiment until December 6, the animals in Group VI showed a higher gross body weight than those in Group V, but from this time on the animals in Group VI maintained a level below that of Group V. In these two groups of animals, it will be noted that the difference in weight is not as great as that found to exist between Groups III and IV.

If the gain in weight is calculated in per cent of the original or first recorded weights (Table VII), essentially the same results are demonstrable. At the end of the first 7 weeks of the experiment, January 25, 1929, the animals in Group II showed a greater per cent gain in weight than did the control animals in Group I. It will also be noted that the mean per cent gain was slightly higher for animals exposed to ultra-violet radiation than for those animals in the dark room. The final

weight for the ultra-violet group was less than for those animals in the dark room. In the 4 other groups the per cent gain was less in animals exposed to ultra-violet light than in those remaining in total darkness; in Group VI the final weight was exactly the same as the original.

Another factor which influences all calculations is the mortality rate among these 6 groups of animals (Table VIII). Seven deaths occurred among animals remaining in the dark room. The deaths in each group were due to pneumonic infections.

SUMMARY AND CONCLUSION

In summarizing the results obtained for these 6 groups of animals, the following conclusions may be drawn:

Normal rabbits living in total darkness and exposed to ultra-violet radiation at regular intervals showed a more rapid rate of increase in weight than animals living under the same condition, but after an initial period of rapid increase, the irradiated animals maintained a lower body weight than those living in the dark.

Under the same conditions, animals inoculated with *T. pallidum* and exposed to ultra-violet light maintained a lower weight than the corresponding control groups living in total darkness.

Furthermore, the mortality rate from pneumonic infection was found to be greater in animals exposed to ultra-violet radiation than in those living entirely in the dark.

It is evident, therefore, that, under the conditions given, ultra-violet radiation was detrimental rather than beneficial.

BIBLIOGRAPHY

1. Harnes, A. R., *J. Exp. Med.*, 1929, **49**, 859.