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THE PHYSIOLOGICAL STUDY ON THE EFFECTS OF EXPOSURE TO LOW TEMPERATURE ON THE GROWING CHICKS

I. Especially on the Variation of Body Temperature

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Abstract

White Leghorn male chicks were employed in the experiment, and raring places with following thermal conditions were set, namely, (1) a brooder kept under the temperature of 38°C at first and with decrease finally 31°C, (2) the room under uncontrolled temperature (28°C to 15°C during the experiment), and (3) a temperature-controlling chamber controlled to 5°C.

The chicks were divided into 4 groups. Those in Group 1 were kept in the brooder throughout the experiment. Those in Group 2 were transferred to the chamber from the brooder just before the measurement, and kept there for 3 days for the measurement. Those in Group 3 were done in the same way to the room from the brooder and kept there for 3 days during the measurement. And, those in Group 4 were moved from the brooder to the room and, after being kept there for 1 week, transferred to the chamber and kept there for 3 days during the measurement.

1. The chicks in Group 1 were rared in the usual way and they grew up normally in the brooder, and they increased with growth in body weight. The regression equation of growth curve is expressed as follows:

$$\log y = 0.03561x + 1.5569,$$

where x shows the age (days) and y body weight (grams), and correlation coefficient is 0.9955 between x and log y.

2. The chicks in Group 1 increased in body temperatures with growth, and the age-body temperature curve can be expressed as a following equation:

$$y = 42.20 - 2.1614\ e^{-0.1072x},$$

where x shows the age (days) and y body temperature (°C), and correlation coefficient is −0.8548 between x and log (42.20-y)

3. The influence of low environmental temperature on the chicks in Group 2 was considerably large, that is, all of the chicks aged 1 week were dead within 20 hrs after the exposure to 5°C, but it became smaller gradually with growth and with the development of homeothermic functions. They decreased in body weight and body temperature when exposed to 5°C, but with growth the influence became smaller with the development of homeothermic fuctions, and they might maintain their body temperatures normally constant even under such a low temperature.

Introduction

In mammals thermoregulatory mechanisms are generally considered to begin to functionate within 2 or 3 days after birth. A pig can withstand a 2-hr exposure to cold (a temperature of about 3°C) as early in life as 12 hrs after birth; if it has not recently been suckled, its ability to withstand cold is not good even at 48 hrs[11,14]. The newborn rat's thermoregulatory capacity is in any case exceeded at environmental temperature below 30°C[2,11,21]. Above these temperatures,

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if it is fed, it shows the homeothermic type of response to cooling of the environment in that its metabolic rate increased; if it is not fed, or if it is kept at lower temperatures, it behaves like a poikilotherm, because its ability to produce heat does not satisfy the environmental thermal demand. At the other extreme of thermoregulatory capacity in the reindeer calf, *Raniger tarandus*, which shows a high level of cold-resistance.[8,15,16,17,22,23] The domestic calf also shows a remarkable degree of independence of the environment,[18] and the lamb has a body temperature close to the mature level within an hour or so of birth[1].

In birds[4], especially in fowl chicks, thermoregulatory mechanisms take 2 or 3 weeks after hatching to begin to functionate and they should be kept in a brooder at about 100 °F (about 38.8 °C) during about first 3 weeks after hatching.

It is, by DAWSON and HUDSON's survey, of limited utility to specify a single, characteristic body temperature for a bird, since thermal level is strongly influenced by such factors as time of day, activity, and ambient temperature. Birds of many orders when inactive at moderate ambient temperature in the waking phase of their daily cycle, have body temperatures falling between 40°C and 43°C[4,12], a higher range than the 36°C to 39°C or 40°C commonly associated with higher eutherian mammals[5]. However, species representing the orders *Sphenisciformes* (penguins) 37.0°C - 39°C; *Struthioniformes* (ostrich) 39.2°C; *Casuariiformes* (emu and casuaries) 38.8°C - 39.2°C; and *Apterygiformes* (kiwis) 37.8°C - 39.0°C, virtually all show body temperatures in this mammalian range. In addition, certain members of the orders *Caprimulgiformes* (goatsuckers and allies), 37.6°C - 42.4°C and *Apodiformes* (hummingbirds and swifts) have body temperatures of less than 40°C under the conditions previously specified.

MCNAB[9] suggests that the relatively low body temperature of the penguins, ratites (ostrich, emu and casuaries), kiwis, and *procellariiform* birds are reflections of large size; he interprets his compilation of data on an extensive array of birds to indicate, with certain exceptions, the existence of a loose, inverse correlation between body temperature and weight. However, smaller members of certain of these orders have body temperatures below 40°C, and large birds of other orders exceed this figure.[9,12]

SCHOLES and HUTT[19] reported that body temperature of newly hatched chicks rises from about 38°C - 39°C in the first day, through about 40°C in the second day, and about 41°C in the third day, and a exact temperature depends on the time of day measured. And FRONDA[7] reported that normal body temperature of the fowls was 41.7°C ranging between 40.6°C and 43.0°C. SCHOLES and HUTT[19], showing age-body temperature curves of the chicks brooded at 28°C and 35°C, reported that these two curves tended to go together with increasing age, and this could be considered as an index of homeothermic stabilization.

In this experiment white leghorn male chicks were raised under the temperatures of 38°C - 31°C (in a brooder), of 28°C - 15°C (in a room of our laboratory), and of 5°C (in a temperature-controlling chamber) to investigate a physiological variation of their body temperatures.

Materials and Methods

White Leghorn male chicks, a total of 398 heads, were employed in this experiment, and they were fed with a commercial formula feed and fresh water ad libitum. They were kept in a brooder under about 38°C soon after hatching, and then they were divided into 4 groups and were transferred to be exposed to each temperature at the first day of each week of age, and were stayed there during succeeding 3 days for the measurement. The chicks in Group 1 were kept under 38°C - 31°C in the brooder through all the experiment. Those in Group 2 were under 5°C in the temperature-controlling chamber. Those in Group 3 were kept under uncontrolled room temperature. And, those in Group 4 were kept under uncontrolled room temperature for 1 week just before the transference to the chamber of 5°C. The numbers of chicks employed were 140, 98,

Table 1. Body Weight by Group (Body weight: grams, No.: heads)

Age (days)	Group 1				Group 2				Group 3				Group 4			
	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.
0	35.56		0.3655	25												
1	36.16		0.5706	25												
2	39.56		0.5718	25												
3	44.44		0.4764	25												
4	47.44		0.7418	25												
5	51.64		0.9830	25												
6	62.20	*100.00*	0.7265	54	64.03	*100.00*	0.9318	29	63.34	*100.00*	0.8031	47				
7	67.12	*107.91*	1.2090	33	[All chicks were dead within				62.33	*98.41*	0.8840	43				
8	73.67	*118.44*	1.6492	24	20 hrs after the exposure.]				68.49	*108.13*	1.0252	35				
9	73.67	*118.44*	1.8652	21					77.81	*122.84*	1.1361	27				
10	86.57		1.8652	21												
11	94.48		1.6675	25												
12	98.28		1.3970	25												
13	108.60	*100.00*	2.1585	43	120.40	*100.00*	2.2834	35	118.74	*100.00*	1.7343	47	111.21	*100.00*	2.8863	19
14	125.30	*115.38*	2.8881	27	105.16	*87.34*	2.3967	19	124.70	*105.02*	2.0678	47	106.69	*95.94*	2.6057	19
15	133.89	*123.29*	3.4574	18	114.80	*95.35*	3.4570	10	135.74	*114.32*	2.1864	38	113.58	*102.13*	2.8243	12
16	133.24	*122.69*	3.0983	21	122.60	*101.83*	5.7061	5	145.00	*122.12*	2.6219	29	121.80	*109.52*	3.8000	5
17	141.40		2.4576	25												
18	149.76		2.2047	25												
19	176.21		2.7588	34												
20	181.65	*100.00*	2.1943	43	180.46	*100.00*	2.1764	39	184.19	*100.00*	3.5042	27	182.05	*100.00*	4.0487	20
21	193.92	*106.75*	3.0586	24	165.42	*91.67*	2.2996	38	190.93	*103.66*	4.0692	27	177.70	*97.61*	3.8142	20
22	209.80	*115.50*	4.6987	15	179.08	*99.24*	3.4098	25	200.00	*108.58*	4.8595	18	192.17	*105.56*	6.0913	12
23	216.77	*119.33*	4.6232	13	188.73	*104.58*	3.1114	15	208.75	*113.33*	6.1572	12	197.00	*108.21*	4.9092	5

[Remark] *: The figures in italic letter show the recovery rate to the initial value at 2 hrs after the exposure in every week of age.

Table 2. Body Temperature by Group (Body temperature: °C, No.: heads)

Age (days)	Group 1				Group 2				Group 3				Group 4			
	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.	Mean	*R. R.**	S. E.	No.
0	38.35		0.0935	25												
1	39.86		0.0691	25												
2	39.07		0.1098	25												
3	40.78		0.0351	25												
4	41.06		0.0259	25												
5	40.98		0.0253	25												
6	41.48	*100.00*	0.0662	41	38.58	*100.00*	0.5231	27	41.02	*100.00*	0.0840	47				
7	41.32	*100.34*	0.1205	33	[All chicks were dead within				40.96	*99.85*	0.1023	43				
8	41.59	*101.00*	0.0635	24	20 hrs after the exposure.]				40.95	*99.83*	0.1068	35				
9	41.55	*100.90*	0.0811	25					41.10	*100.20*	0.1129	27				
10	41.52		0.0657	21												
11	41.70		0.0497	25												
12	41.44		0.0469	25												
13	41.93	*100.00*	0.0606	27	40.21	*100.00*	0.3306	35	41.58	*100.00*	0.0804	47	41.34	*100.00*	0.1509	19
14	41.77	*99.62*	0.0497	27	39.98	*99.43*	0.6629	16	41.20	*99.09*	0.0739	47	40.17	*97.17*	0.2816	19
15	41.98	*100.12*	0.0579	18	40.63	*101.04*	0.3976	9	41.71	*100.31*	0.0561	38	41.01	*99.20*	0.2207	12
16	41.81	*99.71*	0.0676	21	41.12	*102.26*	0.2653	5	41.58	*100.00*	0.0634	29	41.38	*100.10*	0.1067	5
17	41.64		0.0493	25												
18	41.86		0.0369	25												
19	41.89		0.0698	34												
20	41.93	*100.00*	0.0717	18	41.68	*100.00*	0.0747	39	41.83	*100.00*	0.0700	27	41.80	*100.00*	0.0596	20
21	42.02	*100.21*	0.0583	24	40.46	*97.07*	0.1366	36	41.76	*99.83*	0.0504	27	40.93	*97.92*	0.1752	20
22	42.09	*100.38*	0.0608	15	41.32	*99.14*	0.0947	25	41.82	*99.98*	0.0817	18	41.57	*99.45*	0.1010	12
23	41.62	*99.26*	0.0703	6	41.70	*100.05*	0.1287	15	41.68	*99.64*	0.1122	12	41.58	*99.47*	0.2083	5

[Remark] *: The figures in italic letter show the recovery rate to the initial value at 2 hrs after the exposure in every week of age.

121 and 39 heads for Groups 1, 2, 3 and 4, respectively.

The chicks were measured on body weight, body temperature (rectal temperature was measured with a thermister as the body temperature), the amounts of feed and water taken, heart rate and respiratory rate, on the living bodies, and after these measurements they were sacrificed and were determined on the following items: enumeration of red blood cells by THOMA-ZEISS method[20], the area of red blood cell (the area was calculated from the measurement of the major and minor axes of the cell with a ocular micrometer), and chemical properties of blood constituents.

Because this paper deals chiefly with the variation of body temperature by low environmental temperature, the details on the amounts of feed and water taken, on the heart rate, on the respiratory rate, on the enumeration of red cells, on the areas of the red cells, etc., are kept inevitably for the next paper.

Results and Discussion

Body Weight

In group 1: The chicks in Group 1 were rared in a brooder under about 38°C - 31°C throughout the experiment, and they increased in body weight linearly except in the first 3 or 5 days (see Table 1.). The regression equation of age-body weight curve is expressed as follows:

$$\log y = 0.03561\, x + 1.5569,$$

where x shows the age (days) and y body weight (grams), and correlation coefficient is 0.9955 between x and log y.

In Group 2: The measurement with the chicks in Group 2, which were transferred from the brooder to the chamber of 5°C, was made at 1-, 2- and 3- week of age. But the chicks aged 1 week were dead from the low environmental temperature of the chamber within 20 hrs. In Group 2, the 2- and 3-week old chicks did not differ in the change of body weight so much from that in other groups (see Table 1.). They decreased in body weight by 4.5 % to 8.3 % 20 hrs after the transference to the chamber, but they recovered 2 days later, and, more 1 day later, exceeded the weight found at 2 hrs after the transference. The chicks aged 6-week decreased a little in body weight 20 hrs after the transference, but they recovered 2 days later, and then they increased in body weight at a similar rate to that in Group 1. As mentioned above, they always decreased in body weight after 20 hrs of the transference to the chamber. The chicks seemed to use their energy to maintain them against the low temperature. Furthermore, the decrease in the amounts of feed taken appears to be one of the important reasons for the decrease in body weight.

The rate of decrease became smaller with growth, and the recovery also became faster with growth (Table 1.). The chicks aged 6-week were not hardly affected by the low environmental temperature of 5°C.

In Group 3: The chicks, in Group 3, were transferred from the brooder to the room under uncontrolled temperatures. The chicks aged 1-week decreased a little in body weight 20 hrs after the movement to the room (Table 1.), and they began to increase, showing, 3 days later, almost the same values as those in Group 1. Those aged 2-week increased in body weight in parallel to those in Group 1. Those aged 3-week did not decrease in body weight al all, but daily gains of body weight were a little smaller than those in Group 1, and those aged 6-week increased with a similar rate to those in Group 1.

As mentioned above, the chicks in Group 3 always increased in body weight with a similar rate to those in Group 1, and the difference of Group 3 from Groups 2 and 4 was remarkable. Thermoneutral temperature is considered to be 7°C to 10°C below the rectal temperature[3], and comfortable temperature intervals for the chicks is considered around 20°C[10,13], therefore, the temperature of the room (28°C - 15°C, during the experiment) was probably comfortable for the chicks in Group 3.

In Group 4: The chicks in Group 4 were moved from the brooder and kept in the room under uncontrolled temperature for 1 week before the transference to the cham-

ber of 5°C. The chicks aged 2-week decreased in body weight 20 hrs after the transference to the chamber, and then they increased (in Table 1.). The body weight varied with a similar pattern to that of those in Group 2. The chicks aged 3-week decreased in body weight a little 20 hrs after the transference to the chamber and the decrease was a little low as compared with that of those in Group 2, and then they increased. Those aged 6-week decreased in body weight a little 20 hrs after the transference to the chamber, and then they increased abruptly. As those were kept in the room under uncontrolled temperature for 1 week before the transference, they might withstand against the low environmental temperature by cold acclimatization. Therefore, in those aged 3-week, the decrease in body weight became smaller than that of those in Group 2, and those aged 6-week were not affected at all, but in those aged 2-week, as the homeothermic mechanism looked not to develop yet, body weight varied with a similar pattern to that of those in Group 2.

Body Temperature

In Group 1: The chicks in Group 1 rised in body temperature with growth from the day of hatching to 7-day old, from 38.35°C to 41.32°C. Then they continued to rise, and the rate of rise fell down and became stable gradually. Until 23-day of age body temperature was measured, and the highest was 42.09°C at 22-day of age, and the temperature became steady between 41.5°C and 42.0°C (see Table 2.).

The growing curve of body temperature was expressed as follows:

$$y = 42.20 - 2.1614\ e^{-0.1072x},$$

where x shows the age (days) and y body temperature (°C), and the correlation coefficient is −0.8548 between x and log (42.20-y).

FRONDA[7] reported that body temperature in normal chicks was 41.7°C ranging between 40.6°C and 43.0°C. A curve of body temperature by age in the chicks brooded at 35°C was shown by SCHOLES and HUTT[19]. The curve of body temperature in the chicks in Group 1 has a trend similar to that by SCHOLES and HUTT[19]. And, in this experiment, body temperature reached an adult level by about 10 days of age.

In Group 2: In 1-week old chicks in Group 2 body temperature fell down to 38.58°C 2 hrs after the transference to the chamber (Table 2.), and all of them were dead within 20 hrs after the exposure. In 2-week old chicks body temperature fell down to 40.21°C 2 hrs after the exposure as seen in Table 2. (at that time that of those in Group 1 was 41.93°C in average), and 20 hrs after the exposure the body temperature was 39.98°C. Then it began to rise, but it did not reach that of those in Group 1 even 3 days later. In 3-week old chicks the variation of body temperature showed a pattern similar to that of 2-week old chicks, and although it did not fall down so much 2 hrs after the exposure, it fell down to 40.46°C 20 hrs after the exposure, and it recovered 3 days later.

In this experiment, a temperature of 5°C looked to be too severe for the chicks. The influence of this temperature on 1- and 2-week old chicks was heavier than on 3-week old chicks, especially on those aged 1-week the influence was so severe that they could not maintain their body temperature above the fatal level and were dead within 20 hrs after the exposure. From the result a thermoregulatory function does not work enough until 2 or 3 weeks of age. FAIRFIELD[6] showed that infant rats withstand against lower body- and environmental-temperature than did adult rats, and that the capacity to keep a constant body temperature improves with growth.

In Group 3: The chicks aged 1-week, in Group 3, were always lower than that of those in Group 1, and they did not change so much for 2 hrs after the movement to the room from the brooder. Those aged 2-week decreased in body temperature to 41.20°C 20 hrs after the exposure, but recovered to 41.71°C 2 days later. Those aged 3-week were always higher than 41.5°C in body temperature, and they did not change so much in comparison with that of those in Groups 2 and 4.

In Group 4: The chicks, in Group 4, were moved from the brooder to the room of uncontrolled temperatures and were stayed for

1 week before the transference to the chamber of 5°C. The chicks aged 2-week did not decrease so much 2 hrs after the transference to the chamber, and the temperature became 40.17°C 20 hrs after the exposure and was a little higher than that of those in Group 2. Then the temperature increased, but it did not reach that of those in Group 1. In those aged 3-week body temperature showed a pattern similar to that of those aged 2-week, but the temperature recovered to 41.57°C 2 days after the transference to the chamber.

It is thought by the authors that the effect of being kept under the uncontrolled room temperature for 1 week just before the exposure appeared, to some extent, on the thermal activities of the chicks exposed to a further lower temperature.

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低温環境が発育中のヒナに及ぼす影響について

Ⅰ．とくに体温の変動について

下田与四雄・湯本章人・井上正人・住友恒和

要　約

白色レグホン種，雄ビナ398羽を用い，3種類の温度環境，(1)育すう器内（最初約 38°C，しだいに減温し最終的には31°C），(2)常温の飼育室内（28°Cないし15°C），および(3)恒温室（5°Cに調節）のもとで飼育した。実験ビナは4群に分けた。第1群は終始育すう器内で飼育，第2群は1，2および3週令のはじめの3日間ずつ育すう器から恒温室に移して飼育，第3群は同様な操作で同じ期間を常温の室内で飼育，および第4群は1および2週令のヒナを予じめ1週間ずつ常温室で飼育したものを2および3週令のはじめの3日間ずつを恒温室に移して飼育した。なお各々のヒナは爾余の期間は育すう器内で飼育され，上記の3日間の各種測定に際し3分の1ずっと殺され血液成分の検索に供された。

次の知見を得た。

1．3週余を育すう器内で飼育された第1群のヒナの体重成長について次の回帰方程式を得た。

$$\log y = 0.03561x + 1.5569$$

ただし，x：日令，y：体重（グラム）　かつ x と log y との間の相関は0.9955であった。

2．第1群のヒナにおける日令 — 体温曲線の方程式は次のとおりであった。

$$y = 42.20 - 2.1614e^{-0.1072x}$$

ただし，x：日令，y：体温(摂氏)　かつ x と log (42.20-y) との間の相関は−0.8548であった。

3．1週令のヒナは 5°C の低温環境が酷し過ぎたようで，いずれも恒温室に移した後20時間以内にへい死した。第2週令以後には同様の条件でへい死するものは皆無であった。あらかじめ室温に7日間おいた後に低温処理をおこなったものではある程度の温度順化が認められた。