[Journal of Criminal Law and Criminology](https://scholarlycommons.law.northwestern.edu/jclc)

Volume 46 | Issue 4 Article 12

1956

Post-Mortem Temperature and the Time of Death

G. S. W. De Saram

G. Webster

N. Kathirgamatamby

POST-MORTEM TEMPERATURE AND THE TIME OF DEATH

G. S. W. DE SARAM, G. WEBSTER, AND N. KATHIRGAMATAMBY

G. S. W. de Saram, O.B.E. is professor of legal medicine, University of Ceylon. Professor de Saram was formerly pathologist in the General Hospital, Colombo, Ceylon, and has received special training in forensic medicine at the University of Edinburgh under Sir Sidney Smith, at the Metropolitan Police Laboratory, London, and the Medico-Legal Department, Cairo. He and Mr. Webster have collaborated on several articles that have appeared in this Journal.

G. Webster is a research technician in the Department of Forensic Medicine, University of Ceylon.

N. Kathirgamatamby holds a Master of Science degree from the University of Ceylon in the field of mathematics and has served as visiting lecturer in mathematics at this university for the last two years. He has also studied the fields of statistics and actuarial science at the University of London.—EDITOR.

The study of the cooling rate of dead bodies appears to have been first reported in 1863 by Taylor and Wilks (1). They recorded the temperature, "by placing the exposed bulb of a thermometer on the skin of the abdomen" in one hundred cases from the Guy's Hospital wards, and published their results as the maximum, minimum, and the average findings over 2–3 hour intervals after death up to a maximum of 12 hours. Seydeler (2) had carried out investigations by 1869, and Taylor (3) refers to Goodhart and also Burman who fixed the average rate of cooling at 1.6°F per hour and to Niderkorn who fixed a more rapid rate. Mueller (4) quotes Hofmann, Max Richter, Merkel, Bournville, and Brites who stressed the need for care in the use of these figures in forensic work.

Mann and Brend (5), Webster (6), Simpson (7), Smith and Fiddes (8), Modi (9), Glaister (10), Gordon Turner & Price (11), Lyon (12), Kerr (13), Schwarz & Heidenwolf (14) all confirm the view that various factors influence the rate of post-mortem cooling. Sir Sydney Smith (15), after observing the temperature at two-hourly intervals in some four hundred bodies, failed to construct any useful cooling curves, and refers to similar results obtained by others.

It is curious, however, that as late as 1921, Vaughan (16) recommends the sense of touch as a means of determining "the approximate time of death with a fair degree of accuracy". This he estimates by gauging with the hand the temperature differences of ten imaginary segments into which he divides the lower extremities of the body.

The fall of temperature in a body after death is the result of a process of heat loss. Of all processes, in whatever field, it may be said that they are the results of certain causes, and that the speed of these processes are either accelerated or reduced by certain modifying factors. The cause of the heat loss is generally explained by the unequal temperature levels obtaining between the body and its environment. This is universally true of all inanimate bodies which have a temperature higher than their surroundings.

In fact, it was recognised by at least 1894 that post-mortem cooling rate "is nearly proportional to the difference between the body and the surrounding medium; so that the rate of cooling becomes slower as its temperature approximates to the surrounding medium". The heat loss itself is, as generally recognised, effected through the modes of radiation, conduction, and convection.

Any generalisation, therefore, regarding the cooling rate of dead bodies such as an average hourly rate of fall proceeds on two assumptions, *viz.*:

1. That the modifying factors, in respect of the bodies after a consideration of which such a general rate is fixed, will act with similar effect, and to a similar degree, in any other body; and

2. That whatever other or different modifying factors, that may obtain in respect of the body under view, are of no substantial importance.

Granted that these assumptions are correct, then one is able to say quite accurately that as other bodies fall at this speed, therefore the particular body under investigation would fall at a similar speed.

In actual practice, however, the use of a generalised formula such as:

$$\frac{\text{(normal temp.) } 98.4°\text{F}^{1} - \text{rectal temp. at time of examination}}{\text{the generalised rate of temp. fall per hour}} = \text{number of hours after death}$$

does not result in that degree of accuracy which is often desirable.

In applying the above formula the influence of the generally accepted factors modifying heat loss through radiation, conduction, and convection are assessed, so to say, empirically according to the experience of the observer.

Some of the principle factors which modify heat loss in this way in bodies exposed to the air are:

1. The condition of the surrounding atmosphere, *viz.*, body-atmosphere temperature difference, humidity, air currents, etc.

2. The condition of the body, *viz.*, disease, body weight, surface area, and dampness.

3. The nature and extent of the clothing on the body.

Object of Investigation

Having defined the chief modifying factors, we have attempted to investigate:

1. Whether, in the circumstances in which these investigations were conducted, these factors do in fact influence the fall of temperature.

2. Whether it will be possible to obtain a more accurate knowledge of the degree to which each of these modifying factors influence the cooling rate from the data obtained in this investigation.

3. Whether a more precise generalisation as to the time of death than obtains at present may possibly be arrived at.

[1] Some workers use an initial temperature of 98.6°F, (Moritz (17), Ford (18)).

Methods

Our investigation has been carried out in respect of a total of 41 bodies of executed prisoners—36 in Colombo[2] and 5 in Kandy.[3]

In order to limit, as far as possible, the modifying factors, both in respect of their number and in respect of their degree of operation, we have attempted to reduce, to the very minimum, the differences in the conditions of investigation of one experiment from those of another.

Except in the case of the Kandy bodies which necessarily differed, in respect of the place of examination and transport, from those experimented upon in Colombo, the conditions of study were, as far as possible, identical in all the cases, for:

1. This investigation has been restricted to the same type of body, i.e., those of prisoners who had been in normal health and under the same living conditions, diet, time of meals, muscular exertion, etc., up to the time of execution.
2. The weight and height of each prisoner was recorded by the Prison Medical Officer on the day previous to the execution.
3. Execution by hanging was effected at 8.00 a.m. on the respective days.
4. The body was detached from the suspending rope when the Prison Medical Officer was satisfied that the pulse at the wrist (by palpation) and the heart-beat (by auscultation) had ceased—a period of not more than 10 to 15 minutes.
5. In Colombo, the bodies, clothed in their prison garments (thick cotton overalls), were then laid on an adjoining metal-topped table, and an immediate examination of the upper cervical vertebrae and spinal cord was made by the Prison Medical Officer, through an incision on the back of the neck. Also, in most of the cases, an Ophthalmic Surgeon removed either the corneae or the eye balls for corneal grafting.

Transport

6. At the expiry of 1 to 1½ hours, the body, in its prison clothes and covered with a thin linen cloth, was placed on a wire stretcher and transferred, at the entrance of the execution-room-cum-mortuary, to a covered motor hearse halted 8 to 10 feet from the mortuary table.
7. The body was transported thus, a distance of less than half mile, to the threshold of the laboratory 3 to 6 feet from which the hearse was drawn up, on arrival. The body, still covered, was then conveyed on the stretcher a distance of 90 feet along the corridor inside the laboratory building, to the room where it was transferred from the stretcher to the cement floor in which position all further investigations were made.

This room (19 ft. x 17 ft.) is on the ground floor of a three-storeyed building and is covered at a height of 18 feet by the reinforced concrete floor of the story above. It has one outside and three inside walls, one of which separates the room from the

[2] The laboratory at Colombo is situated about 22 feet above mean sea level. The annual mean temperature in Colombo is 80.6°F and the annual mean humidity is 77% and 90% for day and night respectively. (19).

[3] Kandy, a town about 60 miles from Colombo as the crow flies, is situated in the lower reaches of the hill country at an elevation of 1674 feet above mean sea level. The annual mean temperature is 76.3°F and the annual mean humidity is 72% and 90% for day and night respectively. (19)

adjoining laboratory. This wall reaches only to a height of 13 feet thus leaving a gap 5 ft. x 19 ft. at the top. In this short wall is a door 8 ft. 4 ins. x 2 ft. 8 ins. which was kept constantly closed, except when it was opened for the purpose of making each half hour observation. The windows and fan lights occupy a space of 10 ft. x 10 ft. on the outside wall, but these were kept closed throughout the investigation.

The bodies were in the prison clothes throughout each investigation except the 15 nude bodies (Table I) which were stripped of their clothes immediately on arrival in the laboratory. (Each of the 5 bodies examined at Kandy was carried, as soon as it was detached from the rope, a distance of 190 yards in a wooden coffin with lid to the prison mortuary where, after removal of the prison clothes, it was immediately placed on a metal-topped table.)

Temperature observation

8. Immediately after the examination of the cervical cord referred to above, the temperature was read with a standard chemical thermometer inserted into the rectum to a depth of 3 to 4 inches, through an incision in the overalls. The first reading was taken at the end of five minutes, the thermometer being kept *in situ* for subsequent half-hourly readings. It was removed immediately before the transport of the body. On the arrival of the body in the room of the laboratory the thermometer was reinserted into the rectum. The thermometer reading was taken five minutes later and half-hourly temperatures were recorded thereafter with the thermometer *in situ* (see footnote, Table I), the atmospheric temperature being recorded at the same time. The humidity was recorded at three hourly intervals with an Aspirated Hygrometer.

9. The Kandy bodies were all examined nude in the prison mortuary from the time of arrival to 4 p.m. of the particular day. The temperature readings, etc., were recorded in the same way as in the Colombo bodies. The Prison mortuary is a single-roomed building, the internal measurements of which are 7½ ft. x 5½ ft. x 7 ft. high with a tiled roof and cement floor. There are four ventilation tiles on the roof, and five ventilation grills each 1 ft. 8½ ins. covered with wire mesh, at floor level in three walls of the building. The single door and window of the room which were partially covered with wire mesh panes were kept closed throughout the period of the observations, the door being opened only to permit entry and exit from the room for the making of observations.

Results

Our results are shown in Table I.

Examination of Results

1. *The moment of death:* The pulse and heart beat ceased in all cases within 15 minutes of the time of execution, (Kerr (13) gives 15 and 20 minutes for such cases), the heart continuing to beat for 3 to 5 minutes after the pulse had ceased. The moment of death has therefore been fixed at 8.15 a.m.

2. *The initial temperature:* In those bodies where the initial readings at death were recorded, the temperature of the rectum varied between 97.8°F and 100.8°F with a

TABLE I*

Case No.	Date	1st Reading of Rectal Temp.	Time of 1st Reading of Rectal Temp.	Rectal Temp. at 9 a.m.	Temp. Drop at 9 a.m.	Rectal Temperatures at 10 a.m.	11 a.m.	12 noon	1 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.	7 p.m.	8 p.m.	Room Temp. in Laboratory Min. (Of Four Readings)	Max.	Avg.	Humidity Percentage in Laboratory Min. (Of Four Readings)	Max.	Avg.	Age	Height	Weight	Surface Area	Whether Clothed or Nude
			a.m.																				yrs.		lbs.	Sq. cms.	
1	17.1.53	98.0	9.20	—	—	98.0	96.5	95.0	94.2	93.6	93.0	92.0	91.2	90.8	90.0	89.5	81.0	83.5	82.4	Not recorded			52	5′ 1″	112	14,760	Clothed
2	28.1.53	97.8	9.45	—	—	97.7	96.8	95.8	94.8	94.1	93.3	92.7	91.9	91.1	90.4	89.9	79.0	82.0	80.3	"	"		45	5′ 5″	152	14,600	Clothed
3	29.1.53	98.5	9.30	—	—	98.3	97.5	96.5	95.8	95.0	94.2	93.5	92.8	92.2	91.4	90.5	80.0	82.0	81.0	"	"		35	5′ 3″	130	16,100	Clothed
4	22.4.53	98.3	9.30	—	—	Body not available																					
5	23.4.53	98.5	9.30	—	—	98.3	97.6	96.8	96.0	95.2	94.5	93.7	93.0	92.2	91.7	91.0	85.5	86.9	86.2	"	"		20	5′ 6″	132	16,760	Nude
6	4.7.53	99.5	8.10	—	—	Body not available																					
7	7.7.53	98.5	8.12	97.8	0.7	97.2	96.5	95.9	95.3	94.7	93.9	93.3	92.7	92.1	91.5	91.0	83.5	85.5	84.3	"	"		38	5′ 8″	131	17,060	Nude
8	8.7.53	100.0	8.15	100.0	0	99.0	98.4	97.6	96.8	95.9	95.1	94.4	93.7	93.0	92.4	91.8	84.0	85.0	84.5	"	"		39	5′ 3″	120	15,560	Nude
9	10.7.53	99.0	8.15	99.0	0	97.3	96.4	95.5	94.9	94.3	93.6	92.8	92.1	91.5	90.8	90.3	84.0	85.5	84.5	"	"		30	5′ 7″	131	16,890	Nude
10	8.8.53	100.0	8.25	100.0	0	98.2	97.3	96.2	95.3	94.6	93.9	93.1	92.4	91.7	91.0	90.4	85.5	86.0	85.9	"	"		26	5′ 0″	112	14,580	Nude
11	27.8.53	100.5	8.20	100.5	0	99.5	98.5	97.6	96.8	96.2	95.4	94.8	94.2	93.6	93.0	92.6	87.5	88.5	88.0	"	"		24	5′ 5″	115	15,630	Nude
12	12.9.53	98.0	8.20	97.8	—	Body not available																					
13	17.9.53	100.2	8.15	100.2	0	98.8	97.8	96.9	96.2	95.5	94.8	94.0	93.4	92.8	92.2	91.7	86.0	86.5	86.4	"	"		36	5′ 0″	104	14,140	Clothed
14	9.1.54	99.0	8.15	98.8	0.2	97.0	95.5	94.3	93.5	92.7	91.8	90.9	90.1	89.4	88.6	88.0	81.8	82.0	82.0	81.0	84.0	82.6	29	5′ 7″	144	17,580	Clothed
15	16.1.54	99.2	8.20	98.8	0.4	97.5	96.4	95.4	94.4	93.4	92.5	91.5	90.8	90.0	89.5	88.8	81.0	81.5	81.2	69.3	73.0	71.1	27	5′ 6″	112	15,630	Clothed
Kandy 16†	27.1.54	98.0	8.30	98.0	0	96.8	95.5	94.5	93.5	92.5	91.8	90.8	—	—	—	—	74.8	81.5	79.0	71.0	73.2	72.4	32	5′ ¼″	106	14,300	Nude
17	25.2.54	99.0	8.20	98.0	1.0	Body not available																					
18	9.4.54	100.2	8.20	100.2	0	99.5	98.5	97.5	96.6	95.9	95.2	94.5	93.8	93.2	92.6	92.1	86.0	86.9	86.5	78.0	82.4	79.6	35	5′ 3″	112	15,110	Clothed
19	28.5.54	100.2	8.25	100.0	0.2	99.2	98.5	97.8	97.0	96.1	95.3	94.7	94.0	93.5	92.8	92.1	85.2	86.2	85.7	74.0	77.0	76.0	22	5′ 3½″	133	16,350	Clothed
20	8.6.54	100.8	8.30	100.5	0.3	99.9	98.9	97.9	97.1	96.5	96.0	95.1	94.5	94.0	93.4	92.8	86.8	87.5	87.1	70.5	73.5	72.4	22	5′ 4″	136	16,610	Clothed
Kandy 21†	25.6.54	99.0	8.30	99.0	0	97.9	96.3	95.2	94.0	93.0	92.0	91.0	—	—	—	—	77.9	82.0	80.2	58.5	66.5	63.7	22	5′ 3½″	103¼	14,690	Nude
22	29.6.54	100.8	8.23	100.6	0.2	99.9	99.0	98.2	97.4	96.6	96.0	95.3	94.9	94.1	93.5	92.6	86.8	87.6	87.1	66.0	70.0	67.9	24	5′ 7″	139	17,320	Clothed
23	30.6.54	98.8	8.23	98.8	0	97.8	97.0	96.2	95.5	95.0	94.5	93.9	93.3	92.8	92.0	91.1	86.1	87.5	86.8	64.0	70.0	67.3	34	5′ 3″	131	16,140	Clothed
24	2.7.54	99.8	8.22	99.4	0.4	98.6	97.9	97.0	96.2	95.5	94.9	94.2	93.7	93.0	92.3	91.5	86.0	87.1	86.5	67.0	68.0	67.4	23	5′ 3″	129	16,040	Nude
25	6.7.54	99.5	8.30	99.0	0.5	98.0	96.5	95.5	94.6	93.9	93.1	92.3	91.8	91.0	90.3	89.8	84.5	84.7	84.6	69.0	72.0	70.8	28	5′ 3¼″	112	15,150	Nude
Kandy 26†	8.7.54	99.2	8.30	99.0	0.2	97.2	95.8	94.5	93.5	92.5	91.6	90.8	—	—	—	—	76.8	79.8	78.7	65.0	74.0	69.3	20	5′ 3¼″	110	15,030	Nude
27	29.7.54	100.6	8.30	100.5	0.1	99.8	98.6	97.6	96.6	95.7	95.0	94.1	93.2	92.6	92.0	91.3	85.8	86.3	86.0	70.0	72.7	71.7	30	5′ 7″	118	16,150	Nude
28	4.8.54	99.2	8.19	99.2	0	98.1	97.1	96.3	95.3	94.6	93.8	93.0	92.3	91.8	91.0	90.1	83.5	84.5	84.0	75.5	82.0	78.7	24	5′ 6″	130	16,650	Nude
29	12.8.54	99.8	8.25	99.6	0.2	98.2	97.5	96.5	95.4	94.6	93.8	93.0	92.2	91.6	91.0	90.3	83.5	84.1	83.9	83.1	84.1	73.9	19	5′ 5″	121	15,970	Nude
30	18.8.54	100.8	8.20	100.8	0	99.2	97.8	96.5	95.3	94.5	93.9	92.9	92.0	91.2	90.5	90.0	84.3	84.8	84.5	70.0	73.0	72.3	21	4′ 11″	111	14,350	Nude
31	26.8.54	99.2	8.25	98.8	0.4	97.1	95.8	94.9	94.0	93.4	92.7	92.0	91.5	91.0	90.3	89.9	84.8	85.2	85.0	72.0	74.0	73.0	54	5′ 2″	107	14,650	Clothed
32	4.9.54	100.2	8.25	100.1	0.1	98.6	97.2	96.1	95.1	94.7	93.9	93.0	92.3	91.7	91.0	90.3	84.9	85.2	85.0	71.0	73.5	72.0	26	5′ 5″	132	16,580	Nude

33	21.9.54	100.0	8.20	99.5	0.5	98.2	96.6	95.8	94.8	93.9	92.9	92.2	91.5	90.9	90.2	89.8	84.5	85.0	84.8	70.0	74.0	72.4	18	5′ 4″	110	15,170	Clothed
34	22.9.54	99.2	8.20	98.6	0.6	97.9	96.9	96.0	95.0	94.1	93.3	92.5	91.9	91.1	90.5	89.8	83.8	84.6	84.1	72.0	73.0	72.4	24	5′ 6″	117	15,920	Nude
35	30.9.54	99.8	8.27	99.8	0	98.0	96.9	96.0	95.0	94.2	93.6	93.0	92.2	91.7	91.0	90.3	84.0	85.0	84.6	69.5	73.0	70.3	40	5′ 5″	117	15,750	Clothed
36	21.10.54	99.7	8.25	99.7	0	98.1	96.7	95.2	94.0	93.0	91.8	91.0	90.0	89.4	88.6	88.0	80.5	82.2	81.4	78.3	78.5	78.5	38	5′ 4″	115	15,460	Nude
37	22.10.54	99.5	8.30	99.5	0	98.8	97.8	96.6	95.3	94.4	93.4	92.6	91.8	91.0	90.2	89.5	81.5	82.0	81.8	79.0	81.0	80.3	28	5′ 4″	121	15,800	Clothed
Kandy 38†	3.11.54	99.1	8.30	99.0	0.1	98.4	97.2	96.2	95.1	94.4	93.6	92.5	—	—	—	—	79.0	82.0	80.0	58.5	69.5	65.6	23	5′ 5¾″	136½	16,950	Nude
39	6.11.54	99.6	8.30	99.6	0	98.2	97.0	95.8	94.8	93.7	92.8	91.8	91.0	90.1	89.5	88.9	82.0	83.1	82.6	78.0	83.5	79.6	35	5′ 5″	111	15,400	Clothed
Kandy 40†	26.11.54	99.1	8.30	99.0	0.1	97.8	96.8	95.8	94.9	94.1	93.3	92.8	—	—	—	—	76.2	83.5	80.7	56.0	64.0	59.3	22	5′ 2¾″	121½	15,590	Nude
41	22.12.54	98.8	8.25	98.8	0	97.8	96.8	95.8	94.8	93.8	92.9	92.0	91.2	90.4	89.8	89.0	79.2	80.3	79.9	81.0	85.0	82.3	50	5′ 3½″	121	15,700	Clothed

* All temperatures recorded were by Standard Chemical Thermometers except in the case of Nos. 5 to 15 and No. 18 where the temperatures recorded in the Laboratory were on a Cambridge Electrical Recorder. The first readings, both at the Prison Mortuary and at the Laboratory were taken only after the thermometer remained *in situ* for at least 5 minutes. Both room and rectal temperatures were recorded half hourly although only the hourly readings are shown in this Table.

† These bodies were examined at Kandy.

The minimum, maximum and average room temperatures and humidity shown on the Table are those of three readings recorded in the Prison Mortuary where the tests were carried out. Each of these bodies were available only till 4 p.m.

TABLE II

										Average for 34 cases
Drop at 9 a.m.	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	1.0°F	0.18°F
No. of cases	16	4	5	1	3	2	1	1	1	

mean of 99.6°F. Cullumbine (20) fixes the mean rectal temperature at 99.8°F for males in this country.

3. *The lag period:* We found that there is a stagnation or, at any rate, a lag in the fall in temperature between 8.15 a.m. (the temperature at death) and 9 a.m. in all cases where these observations were made. In the 34 cases shown in Table II, zero occurs with maximum frequency, and the average is 0.18°F.

In view of this we are satisfied that, in general, the loss of temperature during the first 45 minutes after death is hardly significant and that the time lag we have noticed, before rectal cooling definitely sets in, may be fixed at 45 minutes. This lag is in agreement with Schwarz and Heidenwolf's (14) findings that the rectal temperature does not commence to fall immediately after death; and, as graphically explained by them, that it is necessary for the body surface to first drop in temperature and establish a temperature gradient before cooling can effect the internal body temperature. There is also every likelihood of metabolism generating body heat for sometime after somatic death.

4. *The period 9.00 a.m. to 8.00 p.m.:* Once the lag period is over, the temperatures of almost all the bodies, where temperatures have been recorded for the full period, show (Table I) a rapid fall over the first few hours gradually slowing from then onwards as the body temperature approximates to that of the atmosphere. But some reference should be made to the first hour immediately after the lag period, *viz.*, 9 to 10 a.m. It is unfortunate that all the Colombo bodies had to be transported during just this period as the question that the increased rate of fall between 9.00 a.m. and 10.00 a.m. was attributable to the process of transport itself might possibly arise. All the Kandy bodies, however, in which there was no question of such transport at all, show a rapid rate of temperature fall from 9 a.m. to 10 a.m.

Analysis of Results

The general trend of our temperature curves subsequent to the lag period supports the accepted view that the body-room temperature difference does have a significant bearing on the cooling rate. We have therefore classified our results in groups of similar initial body-room temperature difference as shown in Table III which also indicates the maximum and minimum temperatures observed by us for three-hourly periods up to twelve hours after death, a method somewhat similar to that adopted by Taylor (21). It is evident that there is a marked variation in temperature fall even among bodies in the same group.

We have analysed the data on the basis of certain established physical concepts. During life the human body loses its excess heat to the surrounding atmosphere in a threefold manner:

1. by evaporation of moisture from the lungs in respiration, and from the skin by

TABLE III

Case No.	Weight	Surface Area	Average Room Temp.	Difference between Body and Room Temp. Calculated from 99.6°F	Temperatures at 11 a.m.	Temperatures at 2 p.m.	Temperatures at 5 p.m.	Temperatures at 8 p.m.	Highest Temperatures Recorded at 11 a.m.	Highest Temperatures Recorded at 2 p.m.	Highest Temperatures Recorded at 5 p.m.	Highest Temperatures Recorded at 8 p.m.	Lowest Temperatures Recorded at 11 a.m.	Lowest Temperatures Recorded at 2 p.m.	Lowest Temperatures Recorded at 5 p.m.	Lowest Temperatures Recorded at 8 p.m.
	lbs.	*sq. cms.*	*°F.*													
11	115	15,630	88.0	11.6	98.5	96.2	94.2	92.6								
20	136	16,610	87.1	12.5	98.9	96.5	94.5	92.8								
22	139	17,320	87.1	12.5	99.0	96.6	94.9	92.6	99.0	96.6	94.9	92.8	97.0	95.0	93.3	91.1
23	131	16,140	86.8	12.8	97.0	95.0	93.3	91.1								
18	112	15,110	86.5	13.1	98.5	95.9	93.8	92.1								
24	129	16,040	86.5	13.1	97.9	95.5	93.7	91.5								
13	104	14,140	86.4	13.2	97.8	95.5	93.4	91.7								
5	132	16,760	86.2	13.4	97.6	95.2	93.0	91.0	98.6	96.1	94.0	92.1	97.3	94.6	92.4	90.4
27	118	16,150	86.0	13.6	98.6	95.7	93.2	91.3								
10	112	14,580	85.9	13.7	97.3	94.6	92.4	90.4								
19	133	16,350	85.7	13.9	98.5	96.1	94.0	92.1								
31	107	14,650	85.0	14.6	95.8	93.4	91.5	89.9								
25	112	15,150	84.6	15.0	96.5	93.9	91.8	89.8								
32	132	16,580	85.0	14.6	97.2	94.7	92.3	90.3	97.2	94.7	92.3	90.3	95.8	93.4	91.5	89.8
33	110	15,170	84.8	14.8	96.6	93.9	91.5	89.8								
35	117	15,750	84.6	15.0	96.9	94.2	92.2	90.3								
9	131	16,890	84.5	15.1	96.4	94.3	92.1	90.3								
8	120	15,560	84.5	15.1	98.4	95.9	93.7	91.8								
30	111	14,350	84.5	15.1	97.8	94.5	92.0	90.0								
28	130	16,650	84.0	15.6	97.1	94.6	92.3	90.1	98.4	95.9	93.7	91.8	96.4	94.1	91.9	89.8
29	121	15,970	83.9	15.7	97.5	94.6	92.2	90.3								
7	131	17,060	84.3	15.3	96.5	94.7	92.7	91.0								
34	117	15,920	84.1	15.5	96.9	94.1	91.9	89.8								
39	111	15,400	82.6	17.0	97.0	93.7	91.0	88.9								
1	112	14,760	82.4	17.2	96.5	93.6	91.2	89.5								
14	144	17,580	82.0	17.6	95.5	92.7	90.1	88.0	97.8	94.4	91.8	89.5	95.5	92.7	90.1	88.0
37	121	15,800	81.8	17.8	97.8	94.4	91.8	89.5								
15	112	15,630	81.2	18.4	96.4	93.4	90.8	88.8								
3	130	16,100	81.0	18.6	97.5	95.0	92.8	90.5	97.5	95.0	92.8	90.5	96.4	93.0	90.0	88.0
36	115	15,460	81.4	18.2	96.7	93.0	90.0	88.0								
Kandy 40	121⅓	15,590	80.7	18.9	96.8	94.1	—	—								
2	152	17,600	80.3	19.3	96.7	94.1	91.9	89.9								
Kandy 21	103¼	14,690	80.2	19.4	96.3	93.0	—	—	97.2	94.4	91.9	89.9	96.3	93.0	91.2	89.0
Kandy 38	136⅓	16,950	80.0	19.6	97.2	94.4	—	—								
41	121	15,700	79.9	19.7	96.8	93.8	91.2	89.0								
Kandy 16	106	14,300	79.0	20.6	95.5	92.5	—	—	95.8	92.5	—	—	95.5	92.5	—	—
Kandy 26	110	15,030	78.7	20.9	95.8	92.5	—	—								

sweat, and by *insensible perspiration* (a passive seeping of water through the epidermis) (22).

2. by conduction and convection to the surrounding atmosphere, and
3. by radiation to the surrounding surfaces.

Evaporation has been found to be fairly constant in the living body in surroundings which have an effective temperature below about 86°F (23). Whether the same holds good in a dead body by the possible seeping of moisture through the epidermis is open to question. We would, however, anticipate a marked reduction of moisture evaporation with the cessation of respiration and circulation. In addition, loss of heat by conduction to the material on which the body is lying will be a mode of heat loss under the conditions of our investigation.

Radiative, convective, and conductive cooling are dependent on the temperature of the body surface and are independent of any internal processes in the body except in so far as they affect the temperature of the body surface.

Cooling by convection is known to follow a relation of the form:

$$C = k_c V^{\frac{1}{2}}(T_s - T_a)$$

where C is the rate of convective cooling.

k_c is a constant dependent on the shape and posture of the body and the physical processes involved.

V is the velocity of the surrounding air.

T_s is the mean temperature of the body surface.

T_a is the temperature of the surrounding air.

Radiation obeys the Stefan-Boltzmann law given by

$$R = K(T_s^4 - T_w^4)$$

where R is the rate of radiative cooling.

K is a constant dependent on the radiation surface.

T_s is the mean temperature of the body surface in degrees absolute.

T_w is the mean equivalent radiation temperature of the surrounding surfaces in degrees absolute.

When T_w is constant and the difference between T_s and T_w is not large, the law approximates to the form

$$R = K_r(T_s - T_w)$$

where $K_r = 4KT_w^3$ is another constant.

In this form, T_s and T_w need not be referred to the absolute scale of temperature.

Conductive cooling too follows a linear relation of the form

$$D = K_d(T_s - T_w)$$

where D is the rate of conductive cooling,

K_d is a constant dependent on the conductive medium and

T_s and T_w are as defined earlier.

Under these circumstances, radiative, convective, and conductive cooling together follow a law of the form

$$R + C + D = K_r(T_s - T_w) + K_c(T_s - T_a) + K_d(T_s - T_w)$$

where $K_c = k_c V^{\frac{1}{2}}$ and is constant if air movement is held constant.

If we make the further assumption that the atmosphere and the surrounding surfaces are at the same temperature, i.e., $T_a = T_w$ the relation reduces to the form

$$R + C + D = K_o(T_s - T_a)$$

where $K_o = K_r + K_c + K_d$

These considerations suggest that an appropriate theoretical model with which to examine the fall in body temperature in our data on postmortem cooling would be of the form

$$\tau = \alpha' + \beta\theta'$$

where τ is the rate of fall in body temperature.
α' and β are constants.
θ' is the temperature difference between the body surface and its surroundings.

The rectal temperature is perhaps the most convenient single measure of the overall body temperature. When continuity of heat flow is established, a fall in rectal temperature will with sufficient accuracy represent the drop in overall body temperature. The rectal temperature will, however, over-estimate the skin temperature. Provided the difference between rectal temperature and skin temperature remains reasonably constant and small, compared with the difference between the skin temperature and the atmospheric temperature, the effect of replacing the skin temperature by the rectal temperature would be to produce a shift in the value of the constant α'. The form of the relationship would not be altered, for,

$$\begin{aligned}\tau &= \alpha' + \beta\theta' \\ &= \alpha' + \beta(T_s - T_a) \\ &= \alpha' - \beta(T_r - T_s) + \beta(T_r - T_a) \text{ where } T_r \text{ is the rectal temperature.} \\ &= \alpha + \beta\theta \\ \text{where } \alpha &= \alpha' - \beta(T_r - T_s) \\ \theta &= (T_r - T_a)\end{aligned}$$

From our data we have computed the hourly drop in rectal temperature and the corresponding mid-hourly difference between the rectal temperature and the atmospheric temperature. A graphical representation of these figures confirmed the linear relationship we had expected between the two measurements. In each case we estimated statistically the best linear relationship.

We have given the estimates of α and β so obtained in Table IV. It was found that α is small compared with $\beta\theta$ for most of the range of cooling considered, but as the effect of evaporation shows itself in the magnitude of α', which is substantial, we must conclude that evaporation as a factor in post-mortem cooling is by no means small. Any variations in it however have not been large enough to disturb the linear trend of the cooling law.

We believe that the surface area of the body and the weight are also factors on which the cooling rate depends. Using as our criteria the ratio $\frac{\text{Surface Area}}{\text{Weight}}$ (which we termed the "size factor") together with humidity we attempted to assess the extent of their influences on the cooling rate, but we were not able to draw any definite conclusions.

Estimates of α and β show variations from body to body. This is as it should be. For, the rate of temperature fall is dependent on the magnitude of the body surface exposed to cooling and on the thermal capacity of the body. The rate of evaporative

TABLE IV

Observed Rectal Temperatures as Compared With Estimated Temperatures Using the Formula $\alpha + \beta\theta = ke^{-\beta t}$

Case No.	Estimated Values of α	Estimated Values of β	Estimated Values of $p = \frac{\alpha}{\beta}$	Observed and Estimated	At Time 10 a.m.	11 a.m.	12 noon	1 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.	7 p.m.	8 p.m.
1	−0.188	0.104	−1.81	Obs.	98.0	96.5	95.0	94.2	93.6	93.0	92.0	91.2	90.8	90.0	89.5
				Est.	99.2	97.7	96.4	95.2	94.1	93.1	92.2	91.4	90.7	90.1	89.5
2	0.203	0.043	4.72	Obs.	97.7	96.8	95.8	94.8	94.1	93.3	92.7	91.9	91.1	90.4	89.9
				Est.	97.6	96.7	95.8	94.9	94.1	93.3	92.6	91.9	91.2	90.5	89.9
3	0.236	0.041	5.76	Obs.	98.3	97.5	96.5	95.8	95.0	94.2	93.5	92.8	92.2	91.4	90.5
				Est.	98.2	97.3	96.4	95.6	94.8	94.0	93.2	92.5	91.8	91.1	90.5
5	0.178	0.064	2.78	Obs.	98.3	97.6	96.8	96.0	95.2	94.5	93.7	93.0	92.2	91.7	91.0
				Est.	97.7	96.8	96.0	95.2	94.5	93.8	93.2	92.6	92.0	91.5	91.0
7	−0.005	0.057	−0.09	Obs.	97.2	96.5	95.9	95.3	94.7	93.9	93.3	92.7	92.1	91.5	91.0
				Est.	96.5	95.8	95.1	94.5	93.9	93.3	92.8	92.3	91.9	91.4	91.0
8	0.002	0.068	0.03	Obs.	99.0	98.4	97.6	95.8	95.9	95.1	94.4	93.7	93.0	92.4	91.8
				Est.	99.0	98.1	97.2	96.3	95.5	94.8	94.1	93.5	92.9	92.3	91.8
9	0.056	0.071	0.79	Obs.	97.3	96.4	95.5	94.9	94.3	93.6	92.8	92.1	91.5	90.8	90.3
				Est.	97.1	96.2	95.3	94.5	93.8	93.1	92.5	91.9	91.3	90.8	90.3
10	0.136	0.084	1.62	Obs.	98.2	97.2	96.2	95.3	94.6	93.9	93.1	92.4	91.7	91.0	90.4
				Est.	98.5	97.3	96.3	95.3	94.4	93.6	92.8	92.2	91.5	90.9	90.4
11	0.047	0.085	0.55	Obs.	99.5	98.5	97.6	96.8	96.2	95.4	94.8	94.2	93.6	93.0	92.6
				Est.	99.5	98.5	97.6	96.8	96.0	95.3	94.7	94.1	93.6	93.1	92.6
13	0.083	0.074	1.12	Obs.	98.8	97.8	96.9	96.2	95.5	94.8	94.0	93.4	92.8	92.2	91.7
				Est.	98.7	97.8	96.9	96.1	95.3	94.6	93.9	93.3	92.7	92.2	91.7
14	−0.015	0.093	−0.16	Obs.	97.0	95.5	94.3	93.5	92.7	91.8	90.9	90.1	89.4	88.6	88.0
				Est.	97.0	95.6	94.4	93.3	92.4	91.5	90.6	89.9	89.2	88.6	88.0
15	0.076	0.072	1.05	Obs.	97.5	96.4	95.4	94.4	93.4	92.5	91.5	90.8	90.0	89.5	88.8
				Est.	97.9	96.7	95.5	94.5	93.5	92.6	91.7	90.9	90.1	89.5	88.8
18	0.145	0.068	2.13	Obs.	99.5	98.5	97.5	96.6	95.9	95.2	94.5	93.8	93.2	92.6	92.1
				Est.	99.6	98.6	97.7	96.8	96.0	95.2	94.5	93.8	93.2	92.6	92.1
19	0.492	0.022	22.36	Obs.	99.2	98.5	97.8	97.2	96.1	95.3	94.7	94.0	93.5	92.8	92.1
				Est.	99.2	98.4	97.6	96.9	96.1	95.4	94.7	94.0	93.4	92.7	92.1
20	0.106	0.069	1.54	Obs.	99.9	98.9	97.9	97.1	96.5	96.0	95.1	94.5	94.0	93.4	92.8
				Est.	99.9	99.0	98.1	97.2	96.5	95.7	95.1	94.4	93.9	93.3	92.8
22	0.481	0.028	17.20	Obs.	99.9	99.0	98.2	97.4	96.6	96.0	95.3	94.9	94.1	93.5	92.6
				Est.	99.9	99.1	98.3	97.5	96.7	96.0	95.3	94.6	93.9	93.2	92.6
23	0.606	0.009	67.30	Obs.	97.8	97.0	96.2	95.5	95.0	94.5	93.9	93.3	92.8	92.0	91.1
				Est.	97.8	97.1	96.4	95.7	95.1	94.4	93.7	93.1	92.4	91.7	91.1
24	0.571	0.017	33.60	Obs.	98.6	97.9	97.0	96.2	95.5	94.9	94.2	93.7	93.0	92.3	91.5
				Est.	98.6	97.9	97.1	96.4	95.6	94.9	94.2	93.5	92.8	92.2	91.5
25	−0.041	0.099	−0.42	Obs.	98.0	96.5	95.5	94.6	93.9	93.1	92.3	91.8	91.0	90.3	89.8
				Est.	97.9	96.7	95.6	94.6	93.7	92.9	92.1	91.4	90.9	90.3	89.8
27	0.217	0.072	3.02	Obs.	99.8	98.6	97.6	96.6	95.7	95.0	94.1	93.2	92.6	92.0	91.3
				Est.	100.0	98.9	97.8	96.8	95.8	94.9	94.0	93.3	92.6	92.0	91.3
28	0.501	0.030	16.70	Obs.	98.1	97.1	96.3	95.3	94.6	93.8	93.0	92.3	91.8	91.0	90.1
				Est.	98.1	97.2	96.3	95.4	94.6	93.8	93.0	92.2	91.5	90.8	90.1
29	0.400	0.039	10.30	Obs.	98.2	97.5	96.5	95.4	94.6	93.8	93.0	92.2	91.6	91.0	90.3
				Est.	98.3	97.3	96.4	95.6	94.7	93.9	93.1	92.4	91.7	91.0	90.3
30	−0.056	0.105	−0.53	Obs.	99.2	97.8	96.5	95.3	94.5	93.9	92.9	92.0	91.2	90.5	90.0
				Est.	99.2	97.8	96.5	95.4	94.4	93.4	92.6	91.8	91.2	90.6	90.0
31	−0.222	0.122	−1.82	Obs.	97.1	95.8	94.9	94.0	93.4	92.7	92.0	91.5	91.0	90.3	89.9
				Est.	97.2	96.1	95.0	94.1	93.2	92.5	91.8	91.3	90.8	90.3	89.9
32	0.089	0.083	1.07	Obs.	98.6	97.2	96.1	95.1	94.7	93.9	93.0	92.3	91.7	91.0	90.3
				Est.	98.5	97.4	96.3	95.3	94.4	93.6	92.8	92.1	91.5	90.9	90.3
33	−0.151	0.119	−1.27	Obs.	98.2	96.6	95.8	94.8	93.9	92.9	92.2	91.5	90.9	90.2	89.8
				Est.	98.3	97.0	95.7	94.7	93.7	92.8	92.1	91.4	90.8	90.3	89.8
34	0.279	0.058	4.78	Obs.	97.9	96.9	96.0	95.0	94.1	93.3	92.5	91.9	91.1	90.5	89.8
				Est.	98.0	97.0	96.0	95.0	94.2	93.3	92.5	91.8	91.1	90.4	89.8
35	0.226	0.618	0.37	Obs.	98.0	96.9	96.0	95.0	94.2	93.6	93.0	92.2	91.7	91.0	90.3
				Est.	98.3	97.3	96.3	95.4	94.5	93.7	92.9	92.2	91.5	90.9	90.3
36	−0.166	0.107	−1.55	Obs.	98.1	96.7	95.2	94.0	93.0	91.8	91.0	90.0	89.4	88.6	88.0
				Est.	96.1	94.9	93.8	92.7	91.8	91.0	90.3	89.6	89.0	88.5	88.0
37	0.309	0.052	5.94	Obs.	98.8	97.8	96.6	95.3	94.4	93.4	92.6	91.8	91.0	90.2	89.5
				Est.	98.9	97.6	96.5	95.5	94.5	93.5	92.6	91.8	91.0	90.2	89.5
39	0.161	0.075	2.15	Obs.	98.2	97.0	95.8	94.8	93.7	92.8	91.8	91.0	90.1	89.5	88.9
				Est.	98.3	97.1	95.9	94.7	93.7	92.8	91.9	91.0	90.3	89.6	88.9
41	0.350	0.041	8.54	Obs.	97.8	96.8	95.8	94.8	93.8	92.9	92.0	91.2	90.4	89.8	89.0
				Est.	97.4	96.4	95.4	94.5	93.6	92.8	91.9	91.2	90.4	89.7	89.0

heat loss is influenced by the vapour pressure of the moisture in the atmosphere, while the rate of convective heat loss is influenced by the air movement in the atmosphere. These will vary from day to day but, as the linear trend indicates, we may with sufficient accuracy assume each to be constant for the duration of each experiment.

It is of interest to know how far the estimates of the rectal temperature, using the cooling relation containing the values of α and β as determined, correspond to the actual observations made. In each of the experiments the room temperature was reasonably constant throughout its duration. When room temperature is constant $\tau = -\frac{d\theta}{dt}$ and the cooling law may be written as $-\frac{d\theta}{dt} = \alpha + \beta\theta$ where t represents the measure of time.[4] This has a solution of the form

$$\alpha + \beta\theta = ke^{-\beta t} \quad \text{where } k \text{ is a constant.}$$

(e is the exponential constant 2.718 ···)

We have computed the expected values of the rectal temperature on the basis of the observed average room temperature, starting from the final rectal temperature observed and working backwards.

Instead of using the mean of the observed values, we have chosen to start from the final temperatures observed, because, in practice, any similar estimation would have to be effected with the use of the reading available to us. It is possible that our method of estimation may not give as good a fit as by using the mean. Table IV sets out our results and furnishes a comparison of the observed and expected rectal temperatures. The reader will note from the results that apart from cases Nos. 1 and 36, the rest of the cases present a remarkably close fit and the error is less than 1°F.

We may therefore for all practical purposes assume a relation of the form $\alpha + \beta\theta = ke^{-\beta t}$ for the rectal temperature of a body cooling under the conditions we have assumed. These are:

1. the room and atmospheric temperature, and the air movement in the atmosphere remain constant and

2. the body has remained in the same position and environment during the whole period of cooling.

We shall examine the cooling law further to see whether it will help us to determine the time of death of a body whose previous history as regards its rectal temperature is unknown, but whose cooling has closely conformed to the conditions indicated above. If θ_0, θ_1, and θ_2 are values of θ corresponding to value t_0, t_1, and t_2 respectively of t, we may deduce algebraically from the cooling law that

$$\frac{\log(\theta_0 + p) - \log(\theta_1 + p)}{\log(\theta_1 + p) - \log(\theta_2 + p)} = \frac{t_0 - t_1}{t_1 - t_2} \qquad \text{(A)}$$

where $p = \frac{\alpha}{\beta}$.

[4] $\frac{d\theta}{dt}$ is termed the derivative of θ with respect to t and represents the rate of increase of θ with time at the instant t.

If p is small compared with θ_0, θ_1, and θ_2, we have the approximation

$$\frac{\log \theta_0 - \log \theta_1}{\log \theta_1 - \log \theta_2} = \frac{t_0 - t_1}{t_1 - t_2} \tag{B}$$

The relations (A) and (B) suggest a means of estimating the time of death. If we have knowledge of two values of θ say θ_1 and θ_2 of the body at two instants of time t_1 and t_2 at a reasonable distance apart, we may obtain the time t_0 corresponding to another value θ_0 using relation (A) with an estimate of p, or using relation (B) if p is negligible.

We have applied this technique to estimating the instant of death of our experimental bodies assuming:

1. that the period of initial temperature lag was 45 minutes.
2. the initial rectal temperature was (a) observed temperature (b) 99.6°F.

We considered t_1 at points of time 2 p.m. and 4 p.m. respectively and took 4 hours as the interval of time between t_1 and t_2.

Our procedure was as follows: We satisfied ourselves that the room temperature during the period of cooling was reasonably constant and then determined the average room temperature. We obtained the rectal temperature at the particular time t_1 chosen and, by substracting the average room temperature, determined the value of θ_1 of the "Body–Room" temperature difference corresponding to t_1. Similarly we determined θ_2 corresponding to time t_2 which we took as 4 hours after t_1. We obtained the value of θ_0 on the basis of the observed initial rectal temperature. Considering p as negligible, we used formula (B) and obtained the value of t_0. Allowing for cooling lag, the time $t_0 - 45$ represented the estimated time of death and $t_1 - t_0 + 45$ gave us the estimated period of postmortem cooling prior to time t_1. It will be noticed that there are a few cases for which p is large, and for which the use of formula (B) would not be strictly valid. However, our results in those cases, obtained with the use of this formula, appear to be satisfactory.

We repeated the procedure for all the experimental bodies on the basis of an initial rectal temperature of 99.6°F. The results are set out in Table V.

Formula (B) by the very nature of its derivation, by neglect of p from formula (A), is biased towards giving a later time of death than formula (A). The extent of the bias is dependent on the relative magnitude of p with regard to the other values θ_0, θ_1, and θ_2. This bias is evident on examining the averages of our results in Table V. We have endeavoured to correct this bias by giving p an arbitrary value of 2. Our results repeating the same procedure but using formula (A) and $p = 2$ are also given in the same table. The value of 2 was chosen as it proved to reduce the bias and bring the averages to values around the expected figure of 8.15 a.m.

Our formula has enabled us to obtain reasonably good estimates of the time of death, as will be evident from the figures for the mean and standard deviation shown in Table V. It will be noticed however, that the 4 p.m. estimates both in regard to the actual initial observed temperatures and the fixed initial temperature of 99.6°F differ materially from the expected value of 8.15 a.m. in the cases numbered in italics (Table V). We would explain this as being due to an unduly high rate of cooling during the 4 p.m. to 8 p.m. segment of the cooling curve. The value of p in four of

TABLE V

Case No.	Time of Death Estimated with Formula (B) using				Time of Death Estimated with Formula (A) using the Arbitrary Value of 2 for p, and using			
	Observed initial temperature and temperatures observed at		An initial temperature of 99.6°F and temperatures observed at		Observed initial temperature and temperatures observed at		An initial temperature of 99.6°F and temperatures observed at	
	2 p.m.	4 p.m.	2 p.m.	4 p.m.	2 p.m.	4 p.m.	2 p.m.	4 p.m.
1	—	—	7.17 a.m.	7.31 a.m.	—	—	6.58 a.m.	6.57 a.m.
2	—	—	7.47	8.20	—	—	7.35	8.01
3	—	—	8.10	9.27	—	—	7.59	9.11
5	—	—	9.19	10.03	—	—	9.01	9.28
7	8.55 a.m.	9.04 a.m.	7.53	8.04	8.42 a.m.	8.39 a.m.	7.35	7.32
8	9.04	9.22	9.25	9.42	8.52	8.59	9.15	9.22
9	8.35	9.01	8.07	8.34	8.18	8.28	7.46	7.57
10	8.29	9.32	8.46	9.46	8.05	8.48	8.24	9.06
11	8.50	9.01	9.37	9.47	8.28	8.18	9.20	9.12
13	8.31	8.38	9.01	9.07	8.11	7.58	8.44	8.33
14	8.14	8.41	7.51	8.20	7.54	8.04	7.29	7.40
15	8.29	7.54	8.14	7.37	8.15	7.24	7.58	7.05
18	8.48	9.13	9.20	9.43	8.31	8.41	9.05	9.14
19	9.01	9.39	9.13	10.09	8.24	9.14	9.01	9.47
20	8.23	8.54	9.34	9.59	8.05	8.21	9.22	9.34
22	8.28	10.06	9.39	11.01	8.10	9.38	9.28	10.40
23	8.22	11.04	7.33	10.33	8.02	10.34	7.07	9.57
24	8.27	10.11	8.38	10.19	8.08	9.40	8.20	9.49
25	8.12	8.31	8.08	8.27	7.49	7.48	7.45	7.43
27	9.00	9.42	9.45	10.22	8.42	9.08	9.31	10.04
28	8.33	9.51	8.13	9.35	8.18	9.24	7.56	9.06
29	8.26	8.54	8.35	9.03	8.09	8.23	8.19	8.33
30	8.22	8.59	9.08	9.43	8.00	8.20	8.51	9.09
31	7.01	7.19	6.41	7.00	6.29	6.24	6.07	6.02
32	8.24	9.01	8.50	9.24	8.03	8.21	8.32	8.48
33	8.07	7.54	8.23	8.10	7.41	7.03	7.59	7.22
34	8.38	9.12	8.20	8.56	8.20	8.38	8.00	8.19
35	7.10	9.08	7.20	9.16	6.46	8.33	6.58	8.42
36	8.20	8.22	8.24	8.25	8.02	7.46	8.06	7.50
37	8.56	9.24	8.51	9.20	8.44	9.02	8.39	8.57
39	8.54	8.46	8.54	8.46	8.37	8.11	8.37	8.37
41	8.52	8.59	8.16	8.24	8.42	8.40	8.05	8.02
Mean	8.29	9.05	8.32	9.09	8.10	8.31	8.15	8.38
Standard Deviation	28 mins.	44 mins.	45 mins.	56 mins.	31 mins.	49 mins.	48 mins.	61 mins.

these cases will also be seen to be unduly high—a result which is again attributable to this high rate of cooling.

Our experiments were carried out under ordinary room conditions prevailing over a period of two years. Although we have limited to the very minimum the differences in the conditions of one experiment from another, the variations in the temperature fall are such as to be expected where artificial control of the conditions have not been exercised.

Summary

1. The cooling rate of 41 executed prisoners were investigated under, as far as possible, identical conditions except for a group of five bodies which were examined in Kandy and which necessarily differed, as regards transport and place of examination, from the remainder which were examined in Colombo.

2. The body–room temperature difference has been found to have a definite bearing on the cooling rate.

3. In addition to the generally accepted processes through which heat is lost, *viz.*, radiation, convection, and conduction, the influence of evaporation on the fall of temperature in a dead body has been found to be an important additional factor which is in agreement with the view of Strassmann (24). Increased evaporation tends to hasten the cooling rate.

4. In view of the limited scope of our experiments it was not possible to draw any definite conclusions as to the extent of the influence of the surface area and weight of the body (size factor), and the humidity of the atmosphere.

5. The thick cotton overalls in which some of the bodies were clothed do not appear to have significantly influenced the cooling rate.

6. It is submitted that the time of death be estimated, not, as at present, by a generalised formula where the influence of modifying factors are assessed, so to say, empirically, but by the use of a formula which in itself embodies the influence of these factors.

7. The formula we suggest, will operate with similar accuracy under conditions conforming to our assumptions, namely, that the factors influencing the cooling rate remain consistent in their effect on the body throughout the period of cooling.

8. The time of death can be assessed by means of this formula with reasonable accuracy if the first observation is made within eight hours after death. Thereafter the accuracy of the estimation of the time of death diminishes.

ACKNOWLEDGEMENTS

We are grateful to Mr. C. P. D. W. Jayasinha, Dr. H. V. J. Fernando, and Mr. L. G. P. Weera ratne of our Department for valuable technical assistance; Mr. G. V. F. Wille, Commissioner of Prison and Probation Services, and his staff in charge of judicial executions at Colombo and Kandy, and the Prison Medical Officers; Dr. D. T. E. Dassanayake and Mr. R. D. Kreltsheim, Director and Assistant Director, respectively, of the Department of Meteorology; Mr. S. Thangarajah, Lecturer in Mathematics, Government Training College; and Mr. John de Saram, LL.M. (Yale) for their assistance and encouragement which helped materially in the development and completion of this paper.

REFERENCES

1. Taylor & Wilks, Guy's Hospital Reports, 1863, p. 184, cited by Taylor (3).
2. Seydeler, Cited by Mueller (4).
3. Taylor, Alfred Swaine, The Principles and Practice of Medical Jurisprudence, edited by Thomas Stevenson, fourth edition, Vol. 1, 1894, p. 46.
4. Mueller, B., Dtsch. Z. gerichtl. Med., Vol. 28, (1937) p. 172. Dtsch. Z. gerichtl. Med., Vol. 29, (1938) p. 158.
5. Mann, J. Dixon and Brend, William A., Forensic Medicine and Toxicology, sixth edition, 1922, p. 34.
6. Webster, Ralph W., Legal Medicine and Toxicology, 1930, p. 75.
7. Simpson, Keith, Science Progress, Vol. XXXIV, (1946) p. 719.
8. Smith, Sir Sydney and Fiddes, Frederick Smith, Forensic Medicine, ninth edition, 1949, p. 19.
9. Modi, Jaising P., A Textbook of Medical Jurisprudence and Toxicology, tenth edition, 1949, p. 118.
10. Glaister, John, Medical Jurisprudence and Toxicology, ninth edition, 1953, p. 128.

11. GORDON, I., TURNER, R., and PRICE, T. W., MEDICAL JURISPRUDENCE, third edition, 1953, p. 410.
12. GREVAL, S. D. S., LYON'S MEDICAL JURISPRUDENCE FOR INDIA, tenth edition, 1953, p. 139.
13. KERR, DOUGLAS J. A., FORENSIC MEDICINE, fifth edition, 1954, pp. 57 & 162.
14. SCHWARZ, F., AND HEIDENWOLF, H., INT. CRIM. POL. REV., No. 73 (1953) p. 339.
15. SMITH, SYDNEY, FORENSIC MEDICINE, eighth edition, 1945, p. 19.
16. VAUGHAN, E. M., JOUR. AM. MED. ASSOC., Vol. 76, (1921) p. 608.
17. MORITZ, ALAN R., ANNALS OF WESTERN MEDICINE AND SURGERY, Vol. 6, (1952) pp. 302-304.
18. FORD, RICHARD, JOURNAL OF CRIMINAL LAW, CRIMINOLOGY, AND POLICE SCIENCE, Vol. 43, (1953) p. 672.
19. Information supplied by the Surveyor General's Department and the Department of Meteorology.
20. CULLUMBINE, H., CEYLON JOUR. MED. SCI. (D), Vol. VI, (1949) p. 1.
21. SMITH, SYDNEY, COOK, W. G. H., and STEWART, C. P., TAYLOR'S PRINCIPLES AND PRACTICE OF MEDICAL JURISPRUDENCE, tenth edition, Vol. 1, 1948, p. 177.
22. BEST, C. H., and TAYLOR, N. B., THE LIVING BODY, third edition, 1953, p. 414.
23. WINSLOW, C. E. A., TEMPERATURE: ITS MEASUREMENT AND CONTROL IN SCIENCE AND INDUSTRY, (issued by the American Institute of Physics), 1941, pp. 509-21.
24. STRASSMANN, GEORGE, LEGAL MEDICINE, edited by R. B. H. Gradwohl, 1954, p. 133.