e-ISSN: 0975-5160, p-ISSN: 2820-2651

Available online on www.ijtpr.com

International Journal of Toxicological and Pharmacological Research 2023; 13(7); 112-118

Original Research Article

Analysis of Cooling Curves Obtained from the Human Corpses where Time since Death is Known

Siva Kameswara Rao V.[1], Ananda Kumar L.[2], Jaffar Hussain A.P.[3], Balamanigandan R.[4]

[1]Associate Professor, Department of Forensic Medicine, Siddhartha Medical College, Vijayawada, Andhra Pradesh, India

[2]Associate Professor, Department of Forensic Medicine, Govt. Medical College, Nandyal, Andhra Pradesh, India

[3]Assistant Professor, Department of Forensic Medicine, Guntur Medical College, Guntur, Andhra Pradesh, India

[4]Postgraduate Student, Department of Forensic Medicine, Guntur Medical College, Guntur, Andhra Pradesh, India

Received: 20-04-2023 / Revised: 21-05-2023 / Accepted: 25-06-2023

Corresponding author: Jaffar Hussain A.P

Conflict of interest: Nil

Abstract:

A physical change that may occur in a corpse after death would be heat exchange from the body to the surrounding environment. An attempt has been made by the investigators to analyse the cooling curves obtained from the human corpses where time since death is known. A total of 100 human corpses selected for the study. The study was conducted in typical winter season from October to December of the year 2013. During the process of recording, ambient temperature remains almost same on every day of the study period and it was 27°C-28° C. On average, it took18-20 hours for the thin built bodies to reach the ambient temperature, whereas 20-22 hours for moderately built bodies and for thick built bodies 22-24 hours. The cooling curves obtained by applying observed data, is of more or less double exponential sigmoid one. It is observed that the process of cooling retarded in its earlier stages, represented by a flat portion in its upper most part, signifying the occurrence of a lag period in the earlier stages of cooling, known as "temperature plateau". Followed by a plateau, the investigators observed that a steeper portion of the cooling curve having two different components of variable lengths on the curve, representing different phases of cooling during the process of reaching the equilibrium with the ambient temperature. The initial rate of cooling in most of the cases is to be 0.5ºc/hour rising to 1ºC/hour during the period of maximum cooling. The average rate of cooling/hour has been estimated as 0.5ºC.

Key words: Core Temperature, Conduction, Convection, Radiation, Temperature Plateau.

Introduction

A remarkable physical change that may occur in a corpse after death would be heat exchange from the body to the surrounding environment provided there might have been temperature gradient existed between the body and the environment.

The cooling of the body after death is a complex process, which does not occur at the same rate throughout the body[1]. Cooling occurs from the surface of the body to the surroundings due to temperature difference between the body and surroundings[1]. Basically there are four types of heat exchange mechanisms through which heat will be lost from the body namely conduction, convection, radiation and evaporation[2]. During life, heat is constantly transferred from one body part to other by conduction as well as convection[2]. After death, this occurs only through conduction. Heat loss from the body parts which are in direct contact with the supporting surface occurs through conduction; whereas the body parts which are not in direct contact with the surface lose heat through convection[2]. Radiation is the physical process through which all bodies radiate heat. Radiation is fastest during the initial few hours, when the body is hot after death, then after body loses heat mainly by conduction[2]. Only a small fraction of heat is lost by evaporation of fluids from the body, the effect of which is incalculable2. A temperature gradient is formed soon after death between the surface to the core of the body with core being warmer. Core temperature is the temperature of the

viscera which is higher than the surface temperature[2].

The cooling pattern of human corpse does not obey the Newton's law of cooling which was thought by earlier investigators, which states that the rate of heat loss from the object is directly proportional to the temperature gradient existed between the object & surroundings.

The cooling curve pattern is adequately described by a double exponential formula and the shape of the curve is a sigmoid one.

The uppermost part of the cooling curve in all observed cases was flattened for variable length, which was physically determined, signifying the phenomenon of "Post mortem Temperature plateau". The calculated temperature plateau in all observed cases varies from 2-4 hours, depending on the original body temperature at the time of death. The body temperature at the time of death largely influenced by Mode & Cause of death. It is observed that in all violent, unnatural deaths the body temperature recorded is considerably high and remained constant for a significant time period.

Following the plateau, a steeper portion of the cooling curve noted having two different components of variable length i.e. the sloping part and the linear part. These two phases of cooling mainly depends on the original body temperature at the time of death.

Materials and Methods

In this study a total of 100 human corpses were taken to analyse the cooling curves obtained from them where time since death is known. Of the 100 cases, 50 were males and another 50 were females. The study was conducted for a period of 3 months in the winter season from October to December of the year 2013. The winter season is ideal for studying the cooling pattern of the human corpse because ambient temperature is always less than body temperature which is unlike in summer where ambient temperatures recorded are always far high than the body temperature[3,4]. All these cases are collected from the Acute Medical Care unit of the Osmania General Hospital who were admitted and undergone treatment as Medico Legal Cases and sent to the mortuary for autopsy. The corpses are categorically divided into Thin, Moderate and Thick depending on their Body Size and their Body Mass Index[3,4]. (Table1 & 2) The investigators personally attended theAcute Medical Care unit of the Osmania General Hospital and recorded the temperature of theAcute Medical Care unit (ambient temperature) of the hospital and rectal temperatures of the corpses, at the moment of death, before declaring death by the duty doctor to the patient attenders. From then the monitoring of the corpse was supervised by the investigators in the process of shifting from the ward to the mortuary, in order to avoid much delay in shifting the corpse by the ward attenders so that corpse may not be laid down in two different room temperatures (i.e. ward and mortuary)[3,4].

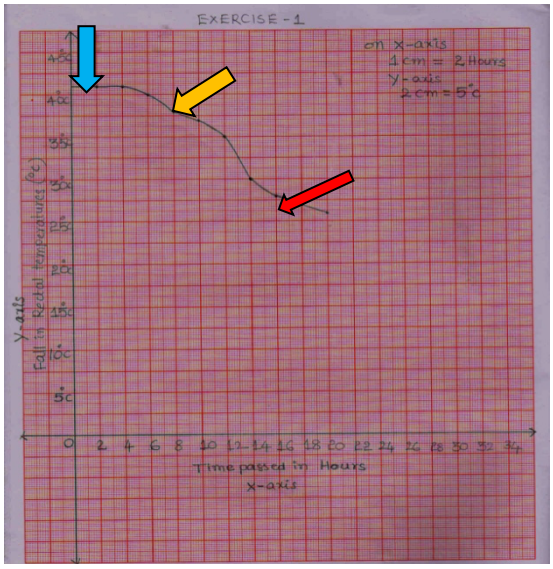
After admission to the mortuary, the name, sex, age, height & built, weight, Medico Legal Case Number & In patient Number, date and time of death, cause of death were recorded. Then the bodies were stripped, made naked, placed over the mortuary table in prone position with both upper limbs lying side by the body. Thermometer (chemical), graduated from 0o to 50^{o} C was inserted into the rectum of the corpse by keeping the buttocks wide apart, such that at least 10cms of it from its tip should be there in the rectum[3,4]. The chemical thermometer, as such kept there undisturbed, and readings are taken after 5mts interval, the time being required for its stabilization[3,4]. From then serial recording of the rectal temperature readings at an hourly interval made by the investigator without disturbing the corpse and thermometer[3,4]. The initial time of recording the ambient and rectal temperatures were noted and tabulated[3,4]. Likewise, serial recording at an hourly interval of rectal and ambient temperatures taken and tabulated. Informed consent was taken from the deceased′s attenders for the same. Institutional ethics committee gave no objection certificate for the project.

Observations

In total 100 cases were studied, of the 100 cases 50 were males and another 50 were females. The Cause of Death varied from Road Traffic Accidents – Major (60), Burns (10), Asphyxial deaths (10), Poisoning (10) and Natural deaths (10).

- The shape of the cooling curve observed is more (or) less double exponential sigmoid one. (Fig1&2)
- Human corpse did not follow the "Newtonian principle" of cooling to reach the ambient temperature.
- The uppermost part of the cooling curve showed flat portion in all cooling curves signifying the occurrence of "Temperature plateau".
- "Post-mortem temperature plateau" is of variable period, ranging from 2-4 hours in all observed cases, which is proportional to the body temperature at the time of death which in turn depends on the Mode & Cause of death. (Fig 3)
- Following the plateau, a steeper portion of the cooling curve noted having two different components of variable length i.e., the sloping part and the linear part.

- The duration of the sloping part on the curve is proportional to the original body temperature at the time of death. (Fig 4)
- The duration of the linear part on the curve is proportional to the original body temperature at the time of death. (Fig 5)
- It is observed that rate of cooling per hour varied from 0.3 – 0.6º C, the average being 0.5ºC. (Fig 1).



Fall in rectal temperature in °C

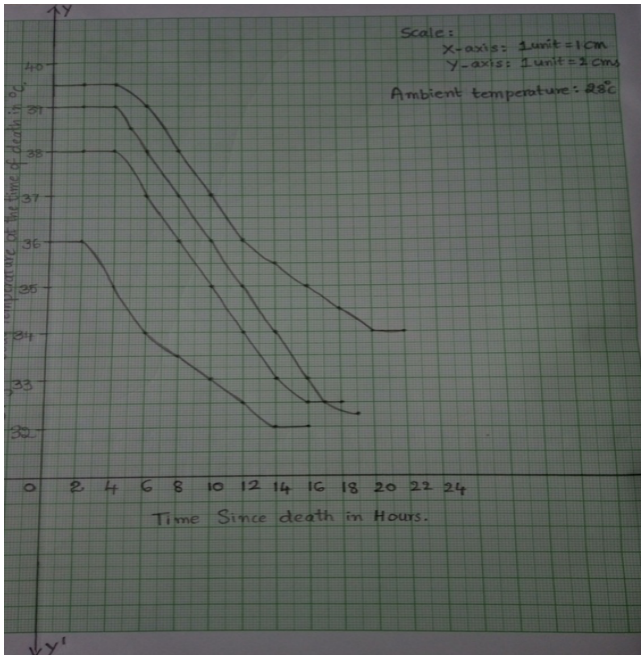
Time passed in Hours

Figure 1: Cooling curve showing different components

Solid arrow pointing **"Temperature Plateau"**

Solid arrow pointing **"Sloping part"**

Solid arrow pointing **"Linear part"**



Original body temperature at the time of death in

Time since death in hours

Figure 2: cooling curves obtained at different body temperatures at the time of death

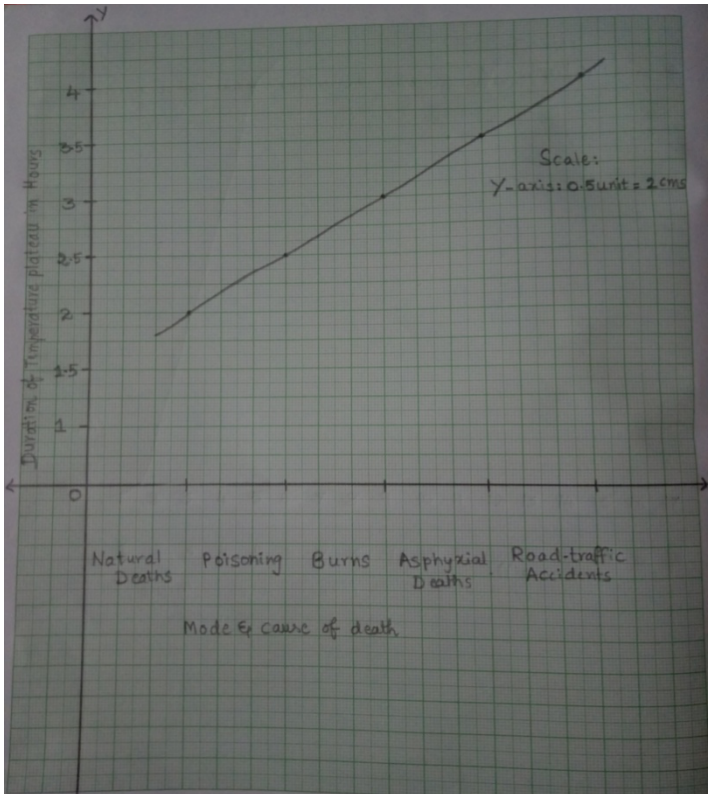
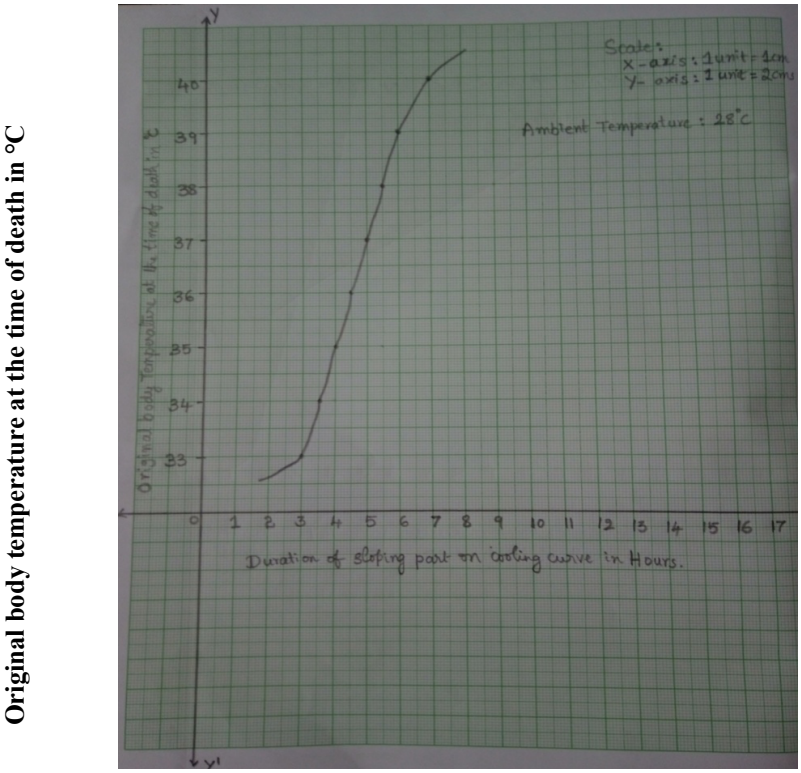
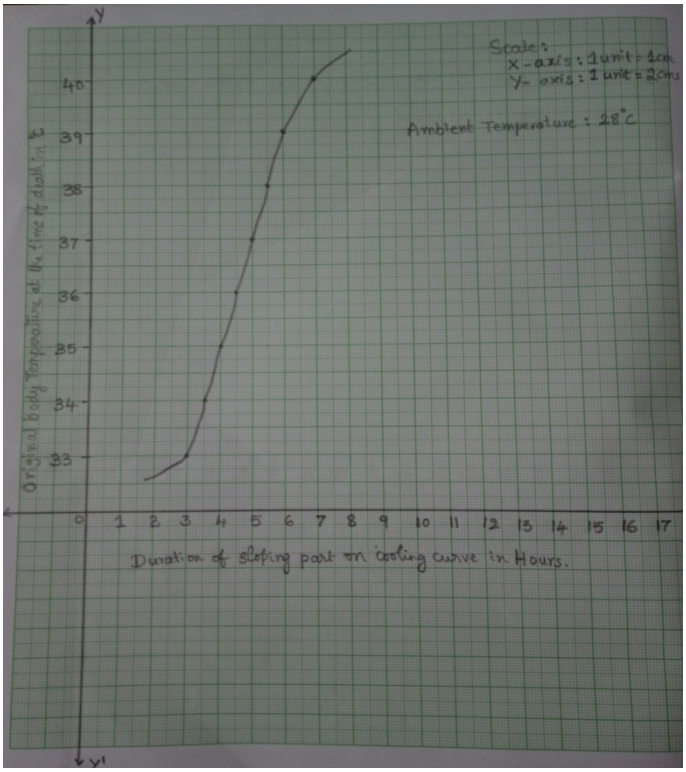


Figure 3: Effect of Mode & Cause of death on duration of temperature plateau of cooling curve



Duration of sloping part on cooling curve in Hours

Figure 4: Effect of original body temperature on the sloping part of the cooling curve



Original body temperature at the time of death in °C

Duration of sloping part on cooling curve in Hours

Figure 5: Effect of original body temperature on the linear part of the cooling curve

Table 1: Body Size among different Age groups (male)

Age groups in yrs.	Thin	Moderate	Thick	Total (n=50)
20-29	3	3	4	10
30-39	4	3	3	10
40-49	5	3	2	10
50-59	5	4	1	10
60-69	6	2	2	10
Total	23 (46%)	15(30%)	2(24%)	50(100%)

Table 2: Body Size among different Age groups (female)

Age groups in yrs.	Thin	Moderate	Thick	Total (n=50)
20-29	5	4	1	10
30-39	2	5	3	10
40-49	2	4	4	10
50-59	1	3	6	10
60-69	4	4	2	10
Total	14 (28%)	20(40%)	16(32%)	50(100%)

Discussion

To study the cooling patterns of the human corpses, it is ideal to choose winter season of the year, where the body temperature is always significantly high than the ambient temperature.

During the process of recording rectal temperatures, the ambient temperature was almost remained more or same for the entire 3 months of study period and it was 27°C-28°C. The rectal temperatures recorded from the selected human corpses varied from 36°C-39°C. All the cases selected were died due to unnatural deaths of varied etiology showing significant rise in body temperature at the time of death. The elevated body temperature recorded from all the corpses signifying the occurrence of post-mortem caloricity probably due to violence & exertion they faced at the time of death. On average, it took18-20 hours for the thin built bodies to reach the ambient temperature, whereas 20-22 hours for moderately built bodies and for thick built bodies 22-24 hours. The shape of the cooling curve of a human corpse is of great importance as it is inevitably the basis on

which all post mortem temperature investigations were made. The human body cools in a manner adequately described mathematically by the double exponential formula. The cooling curve obtained from the observed data of the investigators show more or less double exponential one. It is observed that the process of cooling is retarded in its earlier stages represented by a flat portion in upper most part of the cooling curve in all observed cases, signifying the occurrence of a lag period in the earlier stages of cooling, known as "temperature plateau", determined physically by the variable period of 2-4 hours in all cases[5,6]. The duration of plateau largely depends on the original body temperature at the time of death which is considerably high in violent unnatural deaths[5,6].

The phenomenon of temperature plateauwas due to delay in establishment of temperature gradients and the continuation of metabolic processes that do not cease at the moment of death but continue for a short period after clinical death, responsible for production of heat at cellular level, which maintains the plateau[5,6].

Followed by a plateau, the cooling curve shows a steeper part, having two different components of variable lengths i.e., the upper sloping part of variable length and the lower linear part of variable length. The upper sloping part of the cooling curve represents the period of quickest cooling; whereas the lower linear part corresponds to period of slowest cooling[7].

The part of the cooling curve that is of forensic use is the sloping one, which represents the period of fast cooling[7].

Conclusion

- The cooling of a human corpse does not follow the Newton's law of cooling and it is adequately described by a double exponential formula, and the shape of the curve is a sigmoid one[7].
- The initial stages of cooling reported a "lag period", known as temperature plateau for a variable length on the cooling curve; the calculated period of plateau on the curve is 2-4 hours in all observed cases.
- The steeper part of the cooling curve shows two different components of variable length i.e., the upper sloping and lowers more (or) less linear part[7].
- The duration of the sloping part on the curve is proportional to the original body temperature at the time of death[7].
- The duration of the linear part on the curve is proportional to the original body temperature at the time of death [7].
- The initial rate of cooling to be 0.5o C/ hour and reaches the 10C/hour during the period of maximum cooling.
- The rate of cooling varied from 0.3–0.6oC/ hour the average being 0.50C / hour.
- With such a small rate of fall in temperature, it is not advisable to estimate the time since death, based on the cooling process of the body[8,9,10].
- The average rate of fall in temperature thus obtained is during winter season, hence the applicability of this data to the temperature based – time estimation methods are restricted to winter season only[8,9,10].

Conflict of interest: None

Funding agencies: None.

References:

1. KS Narayan Reddy – The essentials of Forensic Medicine and Toxicology. 31stEd.Suguna Devi K, Hyderabad.p141-2.
2. Anil Aggrawal - Essentials of Forensic Medicine and Toxicology. 1st ed. Avichal Publishing Company, Delhi. 118: 1-6.
3. Knight B. The evolution of methods for estimating the time of death from body temperature. Forensic Sci. Int. 1988; 36: 47-55.
4. https://secure.jbs.elsevierhealth.com/ Retrieved on 25.5.18.
5. Lundquist F. Physical and chemical methods for the estimation of the time of death. Acta Med. Leg Soc 1956: 9: 205-13. https://www.ncbi.nlm.nih.gov/pubmed/13434819Retrieved on 25.5.18.
6. Nokes L, Hicks B, Knight B. The post-mortem temperature plateau – fact or fiction. Med. Sci. Law 1985; 25: 263-4.
7. https://www.ncbi.nlm.nih.gov/pubmed/4068955, Retrieved on 25.3.18.
8. Hutchins G. Body Temperature is elevated in the early post-mortem period. Hum. Pathol. 1985: 16: 560 -1.
9. https://www.ncbi.nlm.nih.gov/pubmed? Retrieved on 25.3.18.
10. Marshall T, Hoare F. Estimating the time of death - the rectal cooling after death and its mathematical representation. / Forensic Sci. 1962; 7: 56-81.
11. https://ci.nii.ac.jp/naid/10024171927 Retrieved on 24.4.18.
12. James W, Knight B. Errors in estimating time since death. Med. Sci Law1965; 5:111-16.
13. http://journals.sagepub.com/doi/abs/10.1177/002580246500500210?journalCode=mslaRetrieved on 24.4.18.
14. Joseph A. Schiekele A. A General method for assessing factors controlling post-mortem cooling. J Forensic Sci 1970: 15: 364 - 91.
15. https://ci.nii.ac.jp/naid/10007369876/ Retrieved on 25.5.18.

16. Lyle H, Cleveland F. Determination of the time since death by heat loss. J. Forensic Sci. 1956, 1: 11-24.

17. https://ci.nii.ac.jp/naid/10024171932/Retrieved on 25.5.18.