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A study on Human Comfort of some places in India

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ABSTRACT. An attempt has been made for making a study of human comfort of 27 stations in India using the strain chart of Lee. Using the mean monthly temperature and vapour pressure data of these stations, climograms were drawn on the strain chart and comfort for each individual month of the year, of the stations is determined.

1. Introduction

The important climatic factors that come into consideration of human comfort or discomfort are temperature, humidity, radiation and wind. The problem is to get a quantitative estimate of the relative strain which these climatological factors bring about upon the body's metabolism and heat regulating mechanism. Attempts have been made to represent different ranges of cooling power of the atmosphere in terms of human sensation. Malhotra (1955) defined the environmental comfort zone in warm and humid atmospheres. Lee (1958) put forward a strain formulation for the study of human comfort. Banerji (1959) approached the problem of the definition of the comfort zone using the condition of ventilation. Subrahmanyam and Sivaramakrishnaiah (1964) made a study of the comfort zones of India and the neighbourhood using the method of Lee.

2. Theory

Lee has suggested a formulation, based partly on heat transfer mechanisms, partly on observations of the way in which the human body evinces strains of various kinds as conditions get progressively hotter and using the same, he prepared a strain chart for a man acclimatized, doing moderate work, with moderate air movement, and wearing normal clothing. From such a chart the significance for that man of any combination of temperature and vapour pressure can be read off in terms of strain index number. The strain to the individual, of any given temperature and vapour pressure, is given by the value of the sloping strain line running through that point. The significance of the strain value can be determined from the following list —

None comfortable below : $1\frac{1}{2}$–3
Most comfortable at : 4–$4\frac{1}{2}$
None comfortable above : 6–$8\frac{1}{2}$

The above strain ranges for different degrees of comfort are given by the author as shown below for the purpose of present study —

Below $1\frac{1}{2}$: discomfort
$1\frac{1}{2}$–3 : poor comfort
3–4 : comfortable
4–$4\frac{1}{2}$: most comfortable
$4\frac{1}{2}$–6 : comfortable
6–$8\frac{1}{2}$: poor comfort
above $8\frac{1}{2}$: discomfort

3. Material

The present study is aimed at making a study of the comfort, for each individual month of the year, of some selected places in India, using the above mentioned strain chart of Lee. The climatic data of 27 selected stations were used for the present study. Mean temperatures and vapour pressures, for twelve months, of these stations were collected from the publications of the India Meteorological Department (1953) and are given in Table 1. Using the temperature, vapour pressure data, climograms were drawn on the strain chart, and comfort, for each individual month of the year, of each station was determined from the strain ranges for different degrees of comfort given above. Fig. 1 is the strain chart of Lee on which climograms for New Delhi and Bangalore were superimposed and months were also indicated.

4. Discussion

1. *New Delhi* (714 ft asl) — It is comfortable in April and most comfortable in October. Conditions of discomfort prevail from May to September, and November to February due to high and low temperatures respectively.

2. *Bangalore* (3021 ft asl) — It is comfortable from March to October and most comfortable in June. Conditions of poor comfort prevail from November to February, the zone of poor comfort being on the low temperature side of the comfort zone.

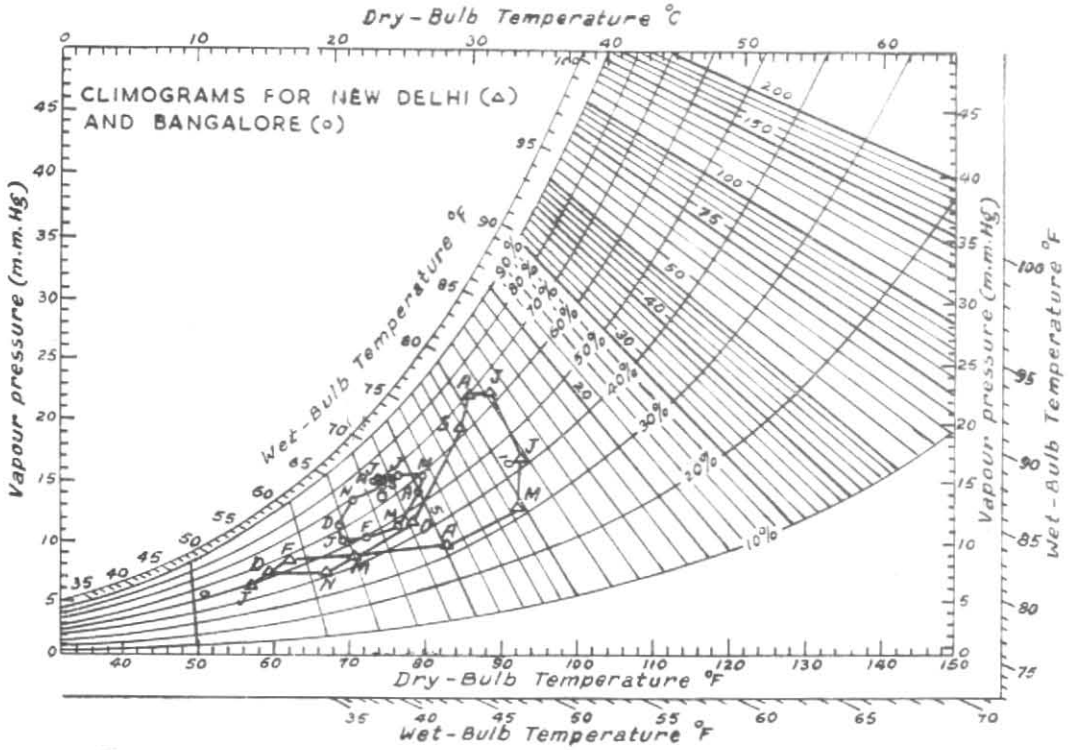

Fig. 1. Thermal Strain Chart — In relation to atmospheric temperature and vapour pressure

3. *Bombay* (37 ft asl) — It is comfortable in February and November and most comfortable in January and December, but it experiences conditions of discomfort from April to October due to warm wet conditions. Conditions of poor comfort prevail in March, the zone of poor comfort being on the high temperature side of the comfort zone.

4. *Mahabaleswar* (4534 ft asl) — The place situated at a height of 4534 ft in Western Ghats is comfortable in April and May, but it experiences conditions of discomfort from July to September and November to February due to low temperatures. Conditions of poor comfort prevail in March, June and October, the zone of poor comfort being on the low temperature side of the comfort zone.

5. *Ahmedabad* (163 ft asl) — March and November are comfortable months, but conditions of discomfort prevail from May to September because of high temperatures. It experiences conditions of poor comfort in April and October, and from December to February, the corresponding two zones of poor comfort being on the high and low temperature side of the comfort zone respectively.

6. *Bhopal* (1643 ft asl) — It is comfortable in April and October and most comfortable in September. Conditions of discomfort prevail in January and December due to low temperatures, but the discomfort in June is attributed to high temperatures. It experiences conditions of poor comfort in May, July and August, and February, March and November, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

7. *Abu* (3945 ft asl) — The place situated at an altitude of 3945 ft is comfortable in May and July and most comfortable in June, but it experiences conditions of discomfort from November to March because of low temperatures. Conditions of poor comfort prevail in April and from August to October, the zone of poor comfort being on the low temperature side of the comfort zone.

8. *Leh* (11,529 ft asl) — The place located at a height of 11,529 ft in the Himalayan Range experiences conditions of discomfort throughout the year, and the conditions particularly in winter are unbearably cold and dry producing maximum discomfort.

9. *Srinagar* (5205 ft asl) — It is comfortable in July and August, and it experiences conditions of discomfort from October to May, but the conditions in winter are unbearably cold and dry causing maximum discomfort. Conditions of poor comfort prevail in June and September, the zone of poor comfort being on the low temperature side of the comfort zone.

10. *Lucknow* (371 ft asl) — October is the comfortable month. Conditions of discomfort from May to September, and December to February, are due to high and low temperatures respectively. It experiences conditions of poor comfort in March and November, the zone of poor comfort being on the low temperature side of the comfort zone.

TABLE 1
Climatic Data

S. No.	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	New Delhi (28°35′N, 77°12′E, Ht. 714 ft)	56·9	62·0	71·0	82·2	91·8	92·5	87·7	85·7	84·5	78·4	67·5	59·4
		7·8	10·5	10·9	12·6	17·1	22·9	30·5	29·6	25·6	15·3	9·9	9·6
2	Bangalore (12°58′N, 77°35′E, Ht. 3021 ft)	68·8	72·8	77·4	80·8	80·1	75·5	73·5	73·5	73·7	73·7	70·5	68·2
		13·8	13·8	14·4	17·9	19·9	20·6	20·5	20·4	20·4	20·1	17·9	15·0
3	Bombay (18°54′N, 72°49′E, Ht. 37 ft)	75·0	75·3	79·1	82·6	85·4	83·6	81·1	80·6	80·6	82·2	81·0	77·7
		19·3	19·9	22·9	27·0	29·5	31·0	30·7	29·6	29·5	28·3	23·8	20·2
4	Mahabaleswar (17°56′N, 73°40′E, Ht 4534 ft)	65·8	67·8	72·5	75·8	74·3	66·5	63·9	63·6	64·3	67·8	66·4	64·6
		10·6	9·9	10·9	13·8	17·0	20·8	20·2	18·7	19·8	16·6	12·3	10·5
5	Ahmedabad (23°02′N, 72°35′E, Ht. 163 ft)	71·2	73·9	82·3	89·2	93·0	91·4	85·8	83·4	84·3	85·0	79·1	73·0
		8·4	9·5	10·1	13·1	20·5	27·6	29·2	27·7	26·4	17·6	12·2	9·7
6	Bhopal (23°16′N, 77°25′E, Ht. 1643 ft)	64·6	68·7	76·6	85·3	91·7	87·4	79·9	78·7	79·0	77·0	69·4	64·3
		8·9	8·9	7·7	7·8	12·2	22·8	26·9	26·0	14·6	15·5	11·6	9·7
7	Abu (24°36′N, 72°43′E, Ht. 3945 ft)	58·3	60·6	68·8	76·3	79·5	76·1	70·7	68·2	70·0	71·8	65·8	60·5
		6·3	7·0	7·5	8·3	12·8	20·2	22·6	21·2	19·4	11·4	8·2	7·9
8	Leh (34°09′N, 77°34′E, Ht. 11,529 ft)	18·7	21·7	32·6	42·9	50·4	57·8	63·4	62·8	55·8	44·6	33·6	24·0
		1·6	1·7	2·7	4·2	4·4	6·1	9·0	9·6	6·4	3·9	2·8	1·8
9	Srinagar (34°05′N, 74°50′E, Ht. 5,203 ft)	32·7	36·8	47·0	55·7	64·0	71·4	76·1	75·0	68·5	62·2	46·7	37·9
		5·3	6·0	7·5	10·0	13·0	15·7	19·6	19·0	13·9	9·5	6·5	5·6
10	Lucknow (26°52′N, 80°56′E, Ht. 371 ft)	60·5	65·0	75·7	86·1	91·9	91·0	86·0	84·6	84·2	79·0	69·0	61·6
		11·0	11·8	11·4	12·7	19·7	27·2	32·4	32·5	30·3	22·2	14·8	11·7
11	Calcutta (22°32′N, 85°20′E, Ht. 21 ft)	67·1	71·6	80·7	86·2	86·6	85·5	84·3	83·7	84·0	81·5	74·0	67·2
		14·5	16·2	21·0	26·5	31·2	33·0	33·1	33·0	32·5	28·4	20·0	15·2
12	Dehra Dun (30°19′N, 78°02′E, Ht. 2239 ft)	55·1	58·0	66·8	76·3	83·1	83·9	80·2	78·7	77·2	71·6	63·3	56·9
		9·1	9·4	9·7	10·2	13·6	21·3	27·8	27·8	24·1	16·9	12·0	9·6
13	Shillong (25°34′N, 91°53′E, Ht. 4921 ft)	49·5	52·4	60·6	65·6	66·6	68·8	70·0	69·6	68·0	62·9	56·1	50·8
		9·4	9·7	9·7	12·6	17·5	20·3	20·9	20·8	19·9	17·1	13·1	10·5

Note — The first and the second rows against each station show temperature in °F and vapour pressure in mb respectively

TABLE 1 (*contd*)

S. No.	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14	Chanda (19°58′N, 79°18′E, Ht. 634 ft)	70·3	75·0	82·9	90·7	94·7	89·8	82·1	81·3	81·7	79·0	72·2	67·7
		13·4	13·5	12·9	15·2	15·6	24·1	27·9	27·9	27·9	23·4	18·1	14·5
15	Jagdalpur (19°05′N, 82°02′E, Ht. 1815 ft)	66·1	71·3	79·3	85·0	88·1	83·1	77·4	77·1	77·6	75·5	69·5	64·3
		13·0	14·5	15·1	18·2	20·3	25·0	26·3	26·4	26·4	22·8	17·3	13.6
16	Chandbali (20°47′N, 86°44′E, Ht. 20 ft)	69·7	74·4	82·2	87·7	88·3	86·8	83·2	83·4	83·6	81·3	74·8	69·0
		16·3	19·6	23·8	28·0	31·6	32·8	32·3	32·5	32·2	29·1	21·2	16·3
17	Madurai (9°55′N, 78°07′E, Ht. 437 ft)	77·1	79·9	83·9	87·3	88·4	87·6	86·6	85·9	84·9	82·4	79·9	77·5
		20·5	20·4	20·9	25·2	24·6	22·3	21·8	23·0	23·8	25·5	25·0	22·5
18	Coimbatore (11°00′N, 76°58′E, Ht. 1341 ft)	75·4	78·7	82·8	85·1	84·0	80·4	78·9	79·2	79·8	79·2	77·2	75·2
		17·8	17·6	18·5	23·2	25·9	24·3	23·7	23·9	24·5	24·1	22·5	20·1
19	Mercara (12°25′N, 75°44′E, Ht. 3781 ft)	67·2	69·8	72·9	73·8	72·3	67·7	65·4	65·6	66·8	68·9	67·8	66·3
		15·1	15·1	16·1	20·3	21·8	20·9	20·4	20·3	20·2	19·3	17·8	15·3
20	Kurnool (15°50′N, 78°04′E, Ht. 923 ft)	75·0	79·8	86·0	91·3	92·8	87·3	83·4	82·4	82·6	81·2	76·9	73·6
		14·3	13·8	13·6	17·6	19·6	23·0	23·6	24·0	24·0	21·8	17·8	15·4
21	Trivandrum (8°29′N, 76°57′E, Ht. 200 ft)	80·3	81·0	83·1	83·7	83·1	80·2	79·1	79·6	80·4	80·1	79·6	80·4
		24·4	25·6	27·6	30·0	30·7	29·1	28·2	28·2	27·9	28·5	28·0	25·8
22	Miraj (16°49′N, 74°41′E, Ht. 1817 ft)	71·9	74·7	80·1	84·6	85·9	80·1	76·3	76·1	76·1	77·6	73·9	70·5
		12·5	13·0	14·6	18·6	22·2	24·4	24·5	24·0	23·2	19·4	16·0	13·4
23	Madras (13°04′N, 80°15′E, Ht. 51 ft)	76·2	78·4	81·9	86·8	91·5	90·4	87·8	86·4	85·6	82·6	78·7	76·5
		22·8	24·3	26·6	29·8	29·3	26·4	26·5	27·2	28·9	28·6	26·7	23·8
24	Hyderabad (17°26′N, 78°27′E, Ht. 1778 ft)	71·7	75·9	82·6	87·8	91·4	84·9	80·0	78·9	78·8	78·0	73·4	70·0
		15·2	15·3	16·2	20·2	21·6	24·7	24·8	24·8	25·1	20·8	16·9	14·8
25	Nagpur (21°09′N, 79°07′E, Ht. 1022 ft)	70·7	75·1	83·3	90·9	95·7	89·6	81·9	81·2	82·3	80·6	73·7	69·5
		11·5	11·7	11·5	13·2	14·7	24·3	27·5	26·8	25·9	19·1	14·1	12·1
26	Kargil (34°34′N, 76°08′E, Ht. 8800 ft)	18·6	19·6	31·2	47·3	59·5	67·7	75·2	74·4	66·5	49·0	39·9	27·1
		2·2	2·2	3·5	5·9	7·5	9·0	11·6	11·1	8·2	5·2	4·1	3·1
27	Gauhati (26°11′N, 91°45′E, Ht. 182 ft)	62·8	65·9	73·1	77·8	80·0	82·7	84·0	84·2	82·8	79·0	71·4	64·2
		14·9	15·3	16·6	21·3	27·1	30·9	32·6	32·6	31·4	27·1	20·9	16·8

Note—The first and the second rows against each station show temperature in °F and vapour pressure in mb respectively

11. *Calcutta* (21 ft asl) — November is the comfortable month. It experiences conditions of discomfort from April to September due to high temperatures followed by high humidities. Conditions of poor comfort prevail from December to February, and in March and October, the corresponding two zones of poor comfort being on the low and high temperature sides of the comfort zone respectively.

12. *Dehra Dun* (2239 ft asl) — The place situated at a height of 2239 ft in the Siwalik Range is comfortable in April, May and September, but it experiences conditions of discomfort from November to March because of very low temperatures. Conditions of poor comfort prevail from June to August, the zone of poor comfort being on the high temperature side of the comfort zone.

13. *Shillong* (4921 ft asl) — The place located at an altitude of 4921 ft in Khasi hills experiences conditions of poor comfort from May to September, the zone of poor comfort being on the low temperature side of the comfort zone. Conditions of discomfort prevail from October to April due to low temperatures.

14. *Chanda* (634 ft asl) — February, March and October are comfortable months whereas conditions of discomfort prevail in April, May and June because of hot conditions. It experiences conditions of poor comfort from July to September, and November to January, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

15. *Jagdalpur* (1815 ft asl) — It is comfortable from July to October and most comfortable in March. It experiences conditions of discomfort in May because of hot conditions, but the discomfort in January and December is due to low temperatures. Conditions of poor comfort prevail in April and June, and November and February, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

16. *Chandbali* (20 ft asl) — It is comfortable in February and November, but it experiences conditions of discomfort from April to October because of warm wet conditions. Conditions of poor comfort prevail in January and March, the corresponding two zones of poor comfort being on the low and high temperature sides of the comfort zone respectively.

17. *Madurai* (437 ft asl) — It is comfortable from December to February, but it experiences conditions of discomfort from April to September due to high temperatures. Conditions of poor comfort prevail in March, October and November, the zone of poor comfort being on the high temperature side of the comfort zone.

18. *Coimbatore* (1341 ft asl) — It is comfortable in January and November and most comfortable in February and December, but it experiences conditions of discomfort in April and May because of high temperatures. Conditions of poor comfort prevail in March and from June to October, the zone of poor comfort being on the high temperature side of the comfort zone.

19. *Mercara* (3781 ft asl) — The place situated at an altitude of 3781 ft in the Western Ghats experiences conditions of poor comfort throughout the year, the zone of poor comfort being on the low temperature side of the comfort zone.

20. *Kurnool* (923 ft asl) — It is comfortable in November and January and most comfortable in February, but it experiences conditions of discomfort from April to June because of high temperatures. Conditions of poor comfort prevail in March and from July to October, the zone of poor comfort being on the high temperature side of the comfort zone.

21. *Trivandrum* (200 ft asl) — It experiences conditions of poor comfort from June to February, the zone of poor comfort being on the high temperature side of the comfort zone. Conditions of discomfort prevail from March to May due to warm temperatures coupled with the oceanic effect.

22. *Miraj* (1817 ft asl) — It is comfortable in February, March and from July to November. It experiences conditions of poor comfort from April to June, and in January and December, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

23. *Madras* (67 ft asl) — It is comfortable from December to February, but it experiences conditions of discomfort from April to October due to high temperatures coupled with the oceanic effect. Conditions of poor comfort prevail in November, the zone of poor comfort being on the high temperature side of the comfort zone.

24. *Hyderabad* (1778 ft asl) — It is comfortable in February, March and October, but it experiences conditions of discomfort from April to June because of hot conditions. Conditions of poor comfort prevail from July to September, and in January and December, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

25. *Nagpur* (1022 ft asl) — March and October are comfortable months, but in May and June, it experiences conditions of discomfort because of hot conditions. Conditions of poor comfort prevail in April, July, August and September,

and from November to February, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

26. *Kargil* (8800 ft asl) — The apparent poor comfort in July and August, of the place situated at an altitude of 8800 ft in the northern Himalayan Range is due to warm temperatures and moderate humidities and the discomfort from April to June and in September and October are due to low temperatures. It is unbearably cold and dry from November to March and therefore, has maximum discomfort.

27. *Gauhati* (182 ft asl) — April is the comfortable month. It experiences conditions of discomfort from June to September due to warm wet conditions, but the discomfort in January, February and December is due to low temperatures. Conditions of poor comfort prevail in May and October, and March and November, the corresponding two zones of poor comfort being on the high and low temperature sides of the comfort zone respectively.

Lee prepared the strain chart for a man doing moderate work, with moderate air movement, and wearing normal clothing. The formula upon which this chart is based enables similar calculations to be made for other degrees of activity, types of clothing, and rates of air movement. Although radiation is one of the important factors in the consideration of human comfort, it has not been taken into account by Lee as the equivalence between incident radiation and net heat load are still under examination. Once the equivalence is established, however, radiant energy can easily be incorporated in the formula. The strain chart has got some limitations in its application to Indian conditions. Firstly, it is based upon the reactions of only partially experienced people to short exposures to heat. Application to people continuously living in hot climates is made uncertain by the inadequacy of present knowledge on long-term effects. Continued exposure involves elements of both improved adaptation and cumulative deterioration, the nature and relative significance of which have been insufficiently studied. Secondly, the strain chart is based on European clothing. Therefore, it is not strictly applicable to Indian conditions. However, in the absence of a similar chart, taking into account Indian conditions, perhaps there is no other alternative than to make use of Lee's chart.

Climatic studies in relation to human comfort are very important from the view point of developing climatic health resorts. In some of the western countries, namely, U.S.A. U.K., West Germany and U.S.S.R., studies in this direction have been undertaken by some of the specialised institutes. In West Germany, a number of climatic health resorts have been developed whose climates are not only comfortable, but also helpful in curing some human diseases such as cardiac and circulatory diseases, severe forms of bronchial as thama, adaption diseases, sleeplessness and nervous diseases. It will be highly rewarding if scientific research is encouraged to make a study of the climatic conditions existing at several places in India from the view point of human comfort so that suitable places might be developed as climatic health resorts.

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