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Thermal stress and violence in India & Pakistan: investigating a new explanation of the Kerala model

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Kerala is widely praised as being relatively developed, compared with other parts of India. Several theories have been put forward to explain why Kerala is successful, such as matrilineal descent, rice farming, and female education. This paper offers a new explanation for Kerala's success, combining four hypotheses:

{A} parts of India (at certain times of year) have extreme temperatures;
{B} extreme temperatures generate stress hormones, to keep body temperatures in safe limits;
{C} stress hormones make humans violent;
{D} (male) violence, or the threat of it, restricts female autonomy.

Kerala has mild temperatures; but many parts of India and Pakistan have very hot summers and cold winters. Where temperatures exceed about 32°C or go below about 15°C, murders seem to increase. Sex-related crime appears to increase about 25°C, which may indicate the effects of testosterone. The level of female autonomy is correlated with thermal stress. Hence, female autonomy in Kerala may be more developed than elsewhere in India, because temperatures in Kerala do not produce stress hormones (and hence violence).

India is a land of dramatic contrasts. There are hot, dry desert areas in western India, whereas parts of eastern India have the highest rainfall on earth. There are also north-south differences: northern India has cold winters; north-central India has very hot summers; and southern India (especially near the coasts) has mild climates. Describing India, Crowther et al. (1990) wrote "The heat towards the end of the hot season is like a hammer blow; you feel listless and tired and tempers are short. It's said to be the time of year when murders and suicides take place".

There is evidence that temperature extremes are associated with violence (Anderson & Anderson, 1984): "Field studies clearly show that heat increases aggression" (Anderson, 1989); temperature-induced violence includes domestic violence (Anderson, 1989; Rotton & Cohn, 2001). Violence and murders increase in heat waves (Mathur, 1994). Annual crime variations are not all due to seasonal hunger: extreme temperatures are more strongly linked to violent crimes (murder, assault and rape) than to non-violent crimes (such as theft) (Anderson, 1987).

Many observers consider Kerala more developed than the rest of India. Kerala's successes include long life expectancy, low infant mortality, and female autonomy; these achievements seem more impressive given Kerala's poverty by Indian standards (Rajan, Sudha & Mohanachandran, 2000). This is called the 'Kerala model of development', but the definition of this "model" differs between authors. Alexander (2000) claims that Kerala has less tendency for "female suppression, low well-being and high fertility" found elsewhere in India. This paper proposes a new explanation for Kerala's success: most of northern India has more hostile temperatures than Kerala; hostile temperatures, via stress hormones, lead to violence; and in parts of India where violence is widespread, women tend to be more subjugated.

Section 1: Previous Explanations for Kerala's Success

Many writers have discussed why Kerala is more successful than the rest of India. Some writers report evidence of a north/south divide in India, in which Kerala is an example of the greater female autonomy in southern India. I now summarise some theories which attempt to explain the success of Kerala/southern India.

Matrilocalism refers to women who, after marriage, remain in or near their parents' home, in patrilocalism, men live with/near their parents after marriage. Matrilocal marriages, common in South India give married women a social support system (Lessinger, 1989). A northern Indian woman, in contrast, often moves to her husband's house on marriage and she is thrown among complete strangers on marriage (Karve, 1965). However, matrilocal marriage may be an effect, rather than a cause, of female autonomy.

Matrilineal descent refers to inheritance, in which land and other property are passed on via female relatives. Ramotra (1997) divides India into three areas: a rigid patrilineal system in northern India; a less rigid system in most of south India; and matrilineal descent in Kerala. But matrilineal descent does not ensure real power for women: in a matrilineal society, a woman cannot decide who inherits her husband's property.

Islam: "It is sometimes asserted that the low ritual status of women in the North is due to six centuries of Muslim rule" (Maloney, 1974). Karve (1965) argues that the patrilineal, patrilocal family existed about 1000 BC, "more or less as it exists today. Neither the Muslim nor the British rule was able to modify the structure". If the north/south divide preceded Islam, then Islam cannot fully explain female subordination in north India.

Rice farming: Lessinger (1989) claims that the relative freedom of women in southern India results from rice-growing, which depends heavily on female labour. Sen (1985) disagrees, arguing that paid female agricultural workers predominate in areas where fine grains (rice and wheat) are <u>not</u> grown. Mathur (1994) claims that rice farming benefited women in northern India more than in southern India.

Female jobs: some writers suggest female employment (partly) explains Kerala's success. Misra (2000) points out that Kerala has a low rural female employment rate, so female employment is not a convincing explanation of Kerala women's greater autonomy.

Education: Ramotra (1997) wrote that "among the Indian women the mass illiteracy is the major limiting factor in raising their status". Female education levels are better in Kerala than the rest of India; but female education does not guarantee female autonomy: for example, Kerala's high level of female education has not led to greater female employment (Misra, 2000).

Socialism: If Kerala women's autonomy is due to education, we need to know why girls in Kerala are well-educated. Some writers praise Kerala's socialist governments, but others give credit to the church school system. Alexander (2000) wrote "travelers and officials have long noted the higher status of women in Kerala", referring to a report from 1875, so Kerala's success seems to have preceded socialism.

These theories (and others not reported here) attempt to explain the success of Kerala & southern India, but no theory has achieved widespread acceptance. I now suggest a new hypothesis.

Section 2: A New Explanation for Kerala's Success

This paper offers a new explanation for the achievements of Kerala/southern India, by combining four hypotheses (each published before; but as far as I am aware, this is the first publication to combine them).

Hypothesis {A} – there are extreme temperatures in parts of the Indian subcontinent. To assess if a climate is stressful, note the distinction between annual average temperature, and temperature variation over a year. Mean annual temperatures are shown in Chart 4 below: these temperatures seem pleasant, given that preferred temperatures as 24^oC or 25^oC at Rae Bareli (Uttar Pradesh); 26^oC at Bhiwani (Haryana); and 30 or 31^oC at Roorkee (Uttar Pradesh) (Matthews & Nicol, 1995). However, annual average temperatures are not the whole story: temperatures vary over the year. For example, temperatures in Cochin (Kerala) vary pleasantly between 23 and 31^oC; whereas Delhi temperatures fall to 7^oC, and rise to 41^oC (India Tourist Office, 2002).

Hypothesis {B} - extreme temperatures cause production of stress hormones: Strain occurs if temperature and other stresses "exceed the body's tolerance threshold" (Mawson, 1999); survival in hostile temperatures requires a strong biological reaction, to maintain the core of the body within narrow temperature limits. Temperature extremes, like other forms of stress, cause the human body to release stress hormones, such as adrenaline (also called epinephrine) and noradrenaline (also called norepinephrine). Stress hormones help humans survive hostile temperatures (for example, adrenaline affects heartbeat and blood flow); but they have side-effects – for example, adrenaline prepares a human to run from, or use aggression towards, a threat. Noradrenaline is linked to anger (Kemper, 1990). I use the term 'stress hormones' to include adrenaline, noradrenaline, and other aggression-related hormones. Extreme cold can raise noradrenaline levels in the blood (Sramek et al., 2000; Frank et al., 1997); extremely hot conditions increase adrenaline and/or noradrenaline (Jezova et al., 1994; al-Hadramy, 1988). Testosterone levels also vary with temperature (Kukkonen-Harjula et al., 1989).

Hypothesis {C} - stress hormones lead to violence: Medical researchers have established links between stress and violence (Anderson, 1987; Anderson, 1989; Anderson & Anderson, 1984). This evidence indicates that women & men have similar biological reactions to thermal stress; but most murderers in India are men (Dreze & Khera, 2000). It seems plausible that such behaviour differs because of (childhood) socialisation; if so it may be possible to reduce violence by using anger management. "A large number of murders are committed in the heat of passion or in state of high emotionalism" (1987); Ahuja described 64% of Indian murders studied as 'situational'. "The most common homicide situation starts when the parties to the fatal interaction are involved in arguments and altercations, often over matters that might appear relatively trivial to many people" (Ahuja, 1987). A trivial incident leading to murder may indicate the influence of stress hormones (in which humans react more aggressively than is appropriate).

Hypothesis {D} - a culture of violence harms female autonomy. Domestic violence is a major problem in Pakistan and India. Noble & Dutt (1982) report a 'subculture of violence' in north-central India. Dreze & Khera (2000) refer to a culture of violence "in certain cities, such as Patna and Lucknow". Kerala, and southern India generally, have lower rates of violent crime than the rest of India (Dreze & Khera, 2000; Nayar, 1975).

Visaria (1999) cites a study of Tamil Nadu, which found about 37% of women experienced violence. Violence seems more prevalent in northern India: in a study of a Punjab village, three-quarters of scheduled caste women reported regular beatings. In Gujarat, "two-thirds of women surveyed reported some form of psychological, physical, or sexual abuse" (Visaria, 1999). Burney (1999) reports that between 70% and 90% of women in Pakistan experience domestic violence. This suggests violence is more widespread in Pakistan and northern India than in southern India, but the figures are not comparable because of different definitions of violence. I have not found comparable data to assess if domestic violence is more widespread in some parts of India than in others; hence, I use murder rates as a proxy for the prevalence of violence.

Dreze & Khera (2000) claim, "there is a strong link of some kind between gender relations and criminal violence (not just violence against women, but violence in the society as a whole)". Violence, or the threat of it, gives men power within their household (Bhattacharya, 2000). In Uttar Pradesh (north India), women obey their husbands because of the threat of violence. Agarwal (1988) reports a respondent saying "To avoid conflict I accept his decisions". If violence is widespread, men's greater physical strength suggests that men will tend to have more control than women. Another way violence could limit female autonomy is 'Purdah' practices, such as women not being permitted to leave home without their husband or other male relative. Purdah (widespread in northern India) may have arisen to protect women living in violent areas, but Purdah limits women's freedom.

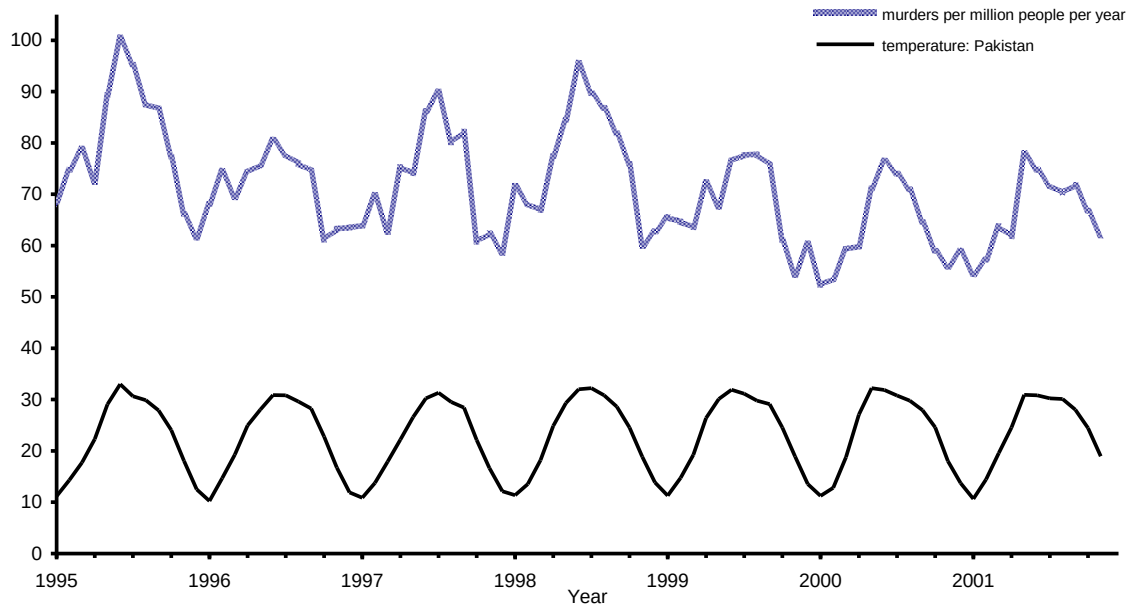
My hypothesis ({a}, {B}, {C} and {D} together) suggests that extreme temperatures cause violence, and hence female subordination. The following sections test this claim.

Section 3: Temperature Variations in Pakistan over time

How pleasant a particular temperature "feels" depends on many factors, including humidity, air movement, clothing and work intensity. I experimented with using humidity data to calculate effective temperature, but humidity data is less widely published than temperature data, so I use simple 'dry-bulb' temperatures for this paper. I calculate a 'murder rate' per million people per year, using census data (using geometric interpolation to estimate the population for each month), and adjusting for differing numbers of days per month.

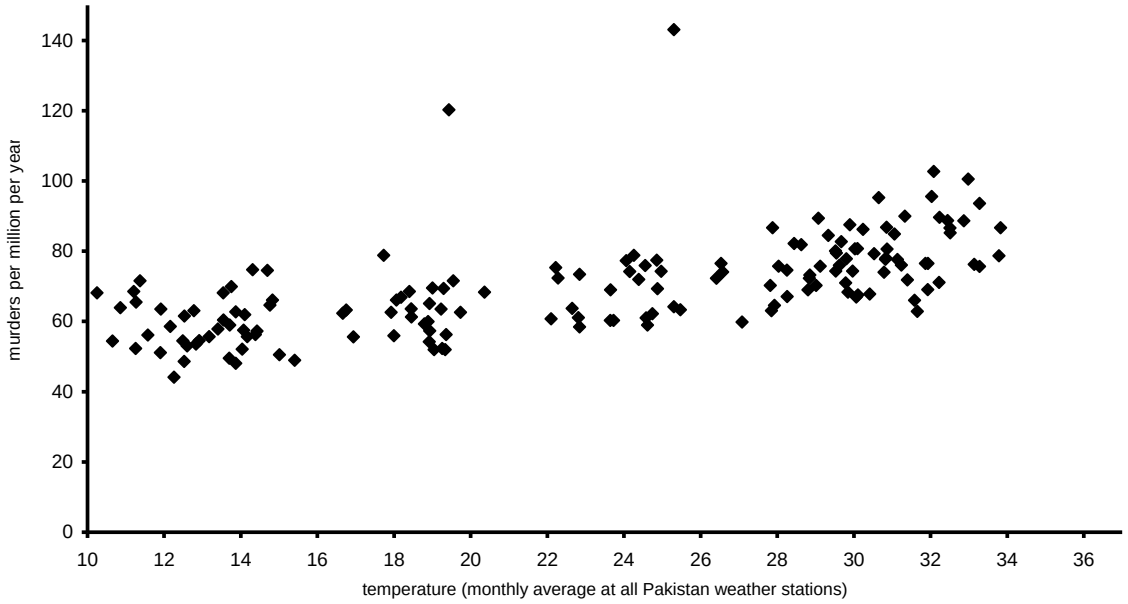
I begin with time-series data, to assess the claim (implied by hypotheses {A}, {B} and {C} above) that murder rates rise in extreme temperatures. Monthly data on murders in India is difficult to obtain, so I use data for Pakistan. Chart 1 reports average monthly temperatures from January 1995 to November 2001, using data from (Federal Bureau of Statistics, various). To deal with missing data, I calculated averages of "max" and "min" temperatures in Punjab, Sindh, NWFP and Baluchistan (for all reported weather stations); then use populations of each province to find the weighted average temperature. This estimate of Pakistan's national average temperature conceals local variation. I calculated the murder rate (per million people, per year) from (Federal Bureau of Statistics, various), and display it on Chart 1.

CHART 1: murder rate and temperature in Pakistan: monthly data



Time-series data shown in Chart 1 indicate a striking pattern: murders in Pakistan are more common in summer months, when temperatures are high. Chart 1 also hints that the murder rate also increases in the coldest months. Hence Chart 1 supports hypotheses {A}, {B} and {C}: extreme temperatures appear to cause murder. This pattern has been observed before, but not (as far as I am aware) in Pakistan.

CHART 2: murder rates versus temperature in Pakistan



To examine links between temperature and murder rates, Chart 2 is a X-Y graph, which uses the same data as Chart 1 but beginning in 1986 (I have a gap in 1987-8: some editions of the 'Monthly Statistical Bulletin' are missing in the library I used). In Chart 2, temperature (rather than time) is on the horizontal axis. The murder rate in Chart 2 shows a positive trend, increasing from about 60 (at 14^oC) to about 80 (at 32^oC). I discuss this below.

Turning from Chart 2 (for Pakistan) to India, Chart 3 is the equivalent for Rajasthan (which I consider the most reliable monthly crime data I could obtain for India). I use data for January 1964 to December 1972 from (17, up to the 1972 edition – there may be more published data, from editions not in my local libraries). The fact that Rajasthan is adjacent to Pakistan is coincidental. For chart 3, I use monthly temperature for 1946 to 1962 (Salmon, 1996): daily temperature measurements at 8.30 and 17.30 were averaged by Government of India.

CHART 3: murders and temperature in Rajasthan: monthly data

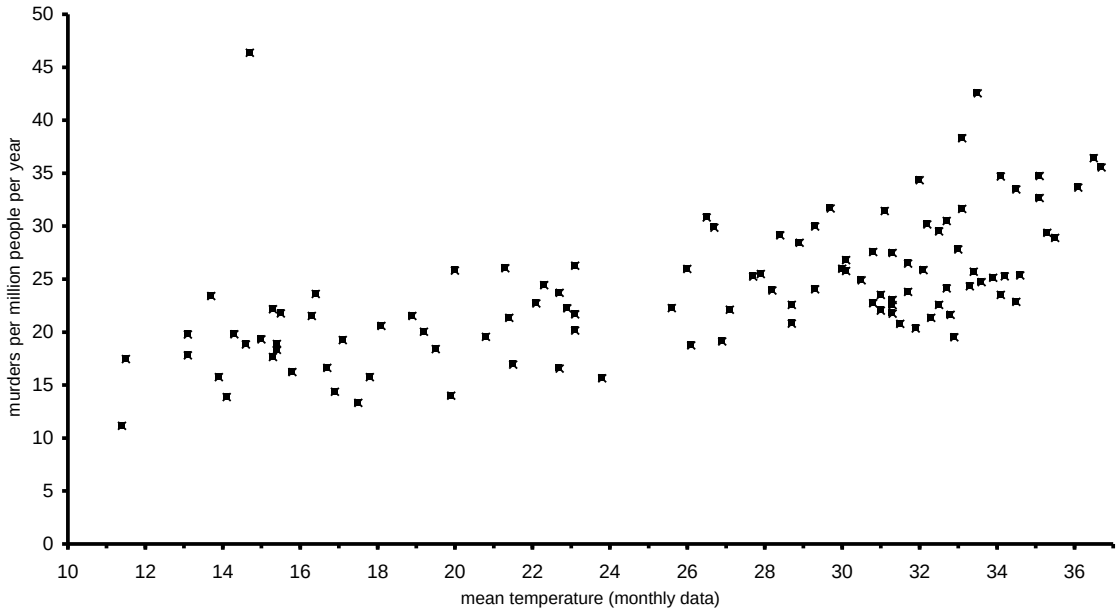


Chart 3 (for Rajasthan) suggests a similar pattern to Chart 2 (for Pakistan): murders are more likely to occur when temperatures are high. Hence chart 3 offers support to hypotheses {A}, {B} and {C}. However, the exact relationship between temperature and murder rate may not be a simple straight line – it would be desirable to verify these findings using more data.

Bruck (1989) claims that "During submaximal work the core temperature increase is nearly independent of ambient temperature over a wide range ($15^{o} - 35^{o}C$)" which suggests humans are most comfortable in this range. Humphreys (1995) claims human preferred temperatures range from $17^{o}C$ to $33^{o}C$. This is consistent with charts 2 and 3, which suggest slight rises in murder rates below about $15^{o}C$ and above about $32^{o}C$. We might expect a sudden rise in stress where air temperature is near (or above) normal blood temperature, $37^{o}C$ (Bruck, 1989), because the body can no longer rely on convection to dissipate heat: even when resting, humans generate heat due to heartbeat and other biological processes.

Charts 2 and 3 seem similar, but note the vertical axis: both charts show the number of murders per million, and there are many more murders in Pakistan than in Rajasthan, at any temperature. I cannot explain this difference: Indian law distinguishes between 'murder' and 'culpable homicide', but there are too few culpable homicides (relative to the number of murders) to explain this difference between Rajasthan and Pakistan.

Section 4: Regional variations in violent crime across India

To calculate murder rates for each Indian state, I calculate the average number of murders for 1994 to 2000 inclusive for India (Central Statistical Organisation, 1999; National Crime Records Bureau, 1997, and later editions), and for 1995 to 1998 in Pakistan (Federal Bureau of Statistics, various). I divide the average number of crimes for these three years, by 1995 populations to create Chart 2. Temperature data for Chart 4 are from (India Tourist Office, 2002); where temperatures are not reported for a state, I use adjacent states – excluding Lakshadweep islands, which (I suspect) may have very different temperatures to mainland India. The use of annual average temperatures for Chart 4 may be misleading – in most parts of India and Pakistan, the temperature varies from one month to another. Monthly data for each state would be preferable, if it can be obtained.

CHART 4: variations of murder rates with mean temperature: Indian states

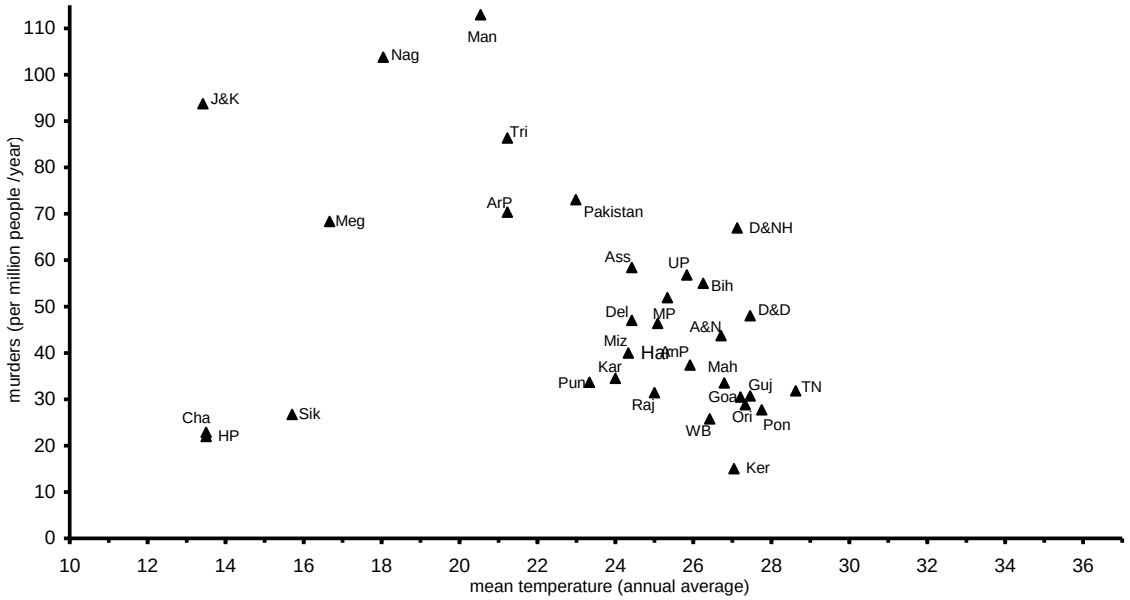


Chart 4 suggests a strong link between murder and temperature: high murder rates are generally in areas of greater thermal stress, which supports hypothesis {A}, {B} and {C}. But Chart 4 indicates that murders tend to rise when temperatures are between about 15 and 27^oC. This seems to be the opposite to the impression in Charts 2 and 3 above, in which murders tend to increase when temperatures are outside the comfortable range of about 15 to 32^oC. I discuss this issue below.

Section 5: Thermal stress

Finally, I consider the effect of thermal stress on development. As stated earlier, Kerala (and southern India generally) has more female autonomy than northern India. I now investigate hypothesis {D}, that low stress/violence partly explains Kerala's successful development. I use Ramotra's (1997) index of female status, which is based on female literacy, female urbanisation, female employment (fraction of total employment), women in non-agricultural work (fraction of all employed women), and females as a proportion of male population. The use of Ramotra's index to assess female status in arbitrary – but my research suggests that other indices, such as the Gender-related Development Index, give similar results.

There seems to be little similarity between time-series data (Charts 2 & 3, for Pakistan & Rajasthan) and cross-section data (Chart 4, for India). I cannot explain this difference. There are many factors not studied in this paper, such as acclimatisation; perhaps future research will shed light on this. For this paper, I treat Chart 4 as the best indicator of thermal stress, because it seems most closely related to Ramotra's index (see below). I now calculate a measure of thermal stress, based on Chart 4, assuming there are three types of violence-inducing temperatures (cold; testosterone; and hot). I use the following algorithm to estimate thermal stress:

temperature	**stress at temperature t**
if t is above 28^oC	stress = 22(t - 28)
if t is 23 to 28^oC	stress = 36(28 - t)/(28 - 23)
if t is 12 to 23^oC	stress = 36(t - 12)/(23 - 12)
if t is below 12^oC	stress = 11(12 - t)

The above parameters 28^oC, 23^oC, 12^oC, 22, 36 and 11 are crude estimates, which I estimated subjectively from Chart 4 and then modified (using iteration) in order to make Chart 5 below as highly-correlated as possible. More data is needed to be able to make reliable estimates, and future researchers may find better ways to estimate thermal stress. This algorithm models thermal stress as a W shape, where the left-hand-side of the W applies to temperatures below 12^oC: for every degree lower than 12^oC, thermal stress increases by 22 units. The number 36 represents the height of the middle part of the W. Temperature 23^oC represents the temperature at which the middle point of the W occurs. 28^oC represents the point at which temperatures begin to rise on the right-hand side of Chart 4.

CHART 5: thermal stress and development level, by state, India

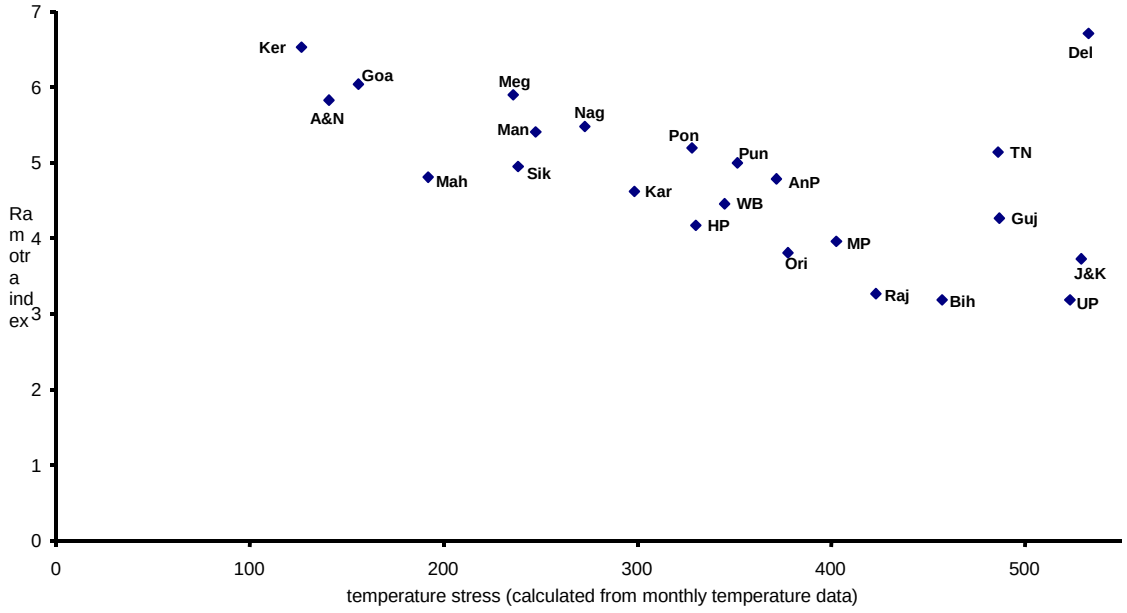


Chart 5 indicates a clear correlation between Ramotra's index, and my index of thermal stress defined above, although Delhi is an 'outlier' (I do not know why). Parts of India with high thermal stress tend to have low female autonomy, according to Ramotra's index; this suggests that thermal stress explains Kerala's success, supporting hypothesis {D}. Thermal stress may partly explain why south Indian states have more female autonomy than other parts of India. In Chart 5, Kerala is one of the most 'developed' states according to Ramotra's index, whereas Pakistan (like northern India) is near the low-status end of the female autonomy spectrum. The 'Kerala model' is sometimes called the "Kerala-Sri Lanka" model; Sri Lanka's mild climate and low murder rate (not shown in Chart 5) is consistent with hypotheses {A}, {B}, {C} and {D}. The most pleasant climates tend to be near the southern tip of the Indian subcontinent; the most hostile climates are in north-central India, far from sea but near the Himalayas (Salmon, 1996) – for example, Patna has India's highest murder rate.

The tendency for progress towards feminist aims in low-thermal-stress areas (such as Kerala) is consistent with the view that domestic violence causes women's subordination. But the mechanism is unclear - perhaps female status is low in high-thermal-stress areas because women defer to men to avoid violence; or perhaps Purdah (common in violent areas) subordinates women.

Conclusion

This paper brings together ideas which may explain women's higher status in Kerala (and southern Indian generally).

This paper is based on four hypotheses:
{A} parts of India (and Pakistan) have extreme temperatures;
{B} in extreme temperatures, humans produce stress hormones;
{C} stress hormones cause aggression/violence;
{D} violence creates a culture in which women have low status.

Hypotheses {A}, {B}, and {C} are all fairly well established in previous research. The existence of extreme temperatures in India is not controversial, and links between extreme temperatures and violence are known to criminologists. The role of stress hormones as an intermediate force between thermal stress and violence is difficult to assess, but hypothesis {B} is not central to this paper (provided the link between temperatures and violence is accepted). It is known that Kerala has a mild climate, and a low crime-rate. The fourth hypothesis may be controversial: does violence cause low female status, or are both violence and patriarchy the result of other forces such as education?

Visaria (1999) wrote "many [women] felt that if they listened quietly, their husband's abuse might die down. If instead a woman defended herself or responded angrily, the confrontation usually worsened and could escalate to physical violence". Female submissiveness seems a rational response to (threatened) male violence, but has unfortunate side effects: if women always defer, their influence in household decision-making is reduced. Where women have little power, female education is a low priority. A vicious circle.

In my view, this paper provides fairly persuasive evidence of links between temperature and violence, but the exact connections are unclear. I suggest the following patterns:

- murders are associated with hot temperatures, especially where air temperature is near or above blood temperature (37^{o}C);
- murders increase at very low temperatures – perhaps below about 12^{o}C;
- there seems to be a peak in violent (especially sex-related) crime, at about 23 or 25^{o}C; I suggest tentatively that this may be due to testosterone.

Overall, I suspect there may be a W-shaped pattern in thermal stress: stress is lowest at about 12^{o}C, or at about 28^{o}C. Murder rates may be raised by noradrenaline at temperatures below about 12^{o}C; by testosterone about 25^{o}C; and by adrenaline and/or noradrenaline above about 28^{o}C. The results in this paper are tentative, and need further research.

I studied data published by many countries for this research; the Indian and Pakistani governments were far better than any other country I studied. At the risk of sounding ungrateful, I would like even more crime data (preferably downloadable from websites): ideally, the Indian government would supply data (by state) on a monthly basis, and the Pakistani government would supply (monthly) data by province. I hope governments in other countries will follow India & Pakistan's lead. I suggest researchers avoid studying data based on small samples. For example, Karachi's monthly crime & temperature data for 1957 to 1965 is published (Federal Bureau of Statistics, various); thankfully, only about six murders per month occurred in Karachi; but this small number of cases makes Karachi data less reliable as a data source than (for example) Pakistan as a whole. More reliable results can be obtained by averaging data for many years.

If further research confirms links between thermal stress and violence, governments must do all they can to protect victims. People can learn to control aggression (Roy, 2000; Delahunt & Mellsop, 1987; Kemper, 1990). The cheapest solution is education – all schools could teach pupils (who are potential future victims) about anger management, problems of extreme temperatures, and use of counseling & offering a cooling drink to calm their partner (Mawson, 1999; Baron & Bell, 1976).

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