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# A Prospective Study of the Impact of Hot Climate on Polytrauma Patients

**Mala Rani[1], Parshotam Lal Gautam[2], Gurpreeti Kaur[3], Sunil Katyal[4]**

[1]Senior Resident, Department of Anesthesiology, Goverment Medical College, Sector 32, Chandigarh, 160047, [2]Professor and HOD, Department of Critical Care and Liver Transplant, [3]Associate Professor, [4]Professor and HOD, Department of Anesthesiology, Dayanand Medical College and Hospital, Ludhiana, Punjab 141001, India.

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**Abstract**

*Background*: Climatic change is the biggest global health threat of the 21st century. It is widely recognized that extreme climatic conditions during summer months may constitute public health threat. Elderly persons, children & patients with chronic medical problems or poor physical reserves are particularly susceptible to heat related illness. Trauma is the overall leading cause of death in younger age group. Persons who are working outside in the fields are exposed to direct atmospheric heat via radiations from sun. The industrial workers get exposed to industrial pollution and high humidity levels which interfere with evaporation.

*Aims and Objectives*: We aimed to compare the incidence of complications and hospital stay in polytrauma patients during hot climate with comfortable temperature.

*Material and Methods*: A prospective study was undertaken to study the impact of hot climate on 100 polytrauma patients of age 20-70 yrs of either sex with moderate trauma (Trauma index score >8). Patients were grouped on the basis of peak outdoor temperature. Group I included the polytrauma patients when peak outdoor temperature ranged between 20-29°C (comfortable zone) and Group II included the polytrauma patients when peak outdoor temperature was >40°C. Fifty patients were enrolled in each group. To reduce the bias, inclusion and exclusion criterion were defined. Meteorological factors, patient characteristics, surgical procedures undertaken and other related data were noted.

*Results*: There was no statistically significant difference in relation to duration of hospital stay and complications among both groups. Mean duration of hospital stays (days) was 15.11±5.78 in group I and 17.14±7.61 in group II with p-value of 0.161. In group I, only 19 patients (38%) whereas in group II, 22(44%) patients had complications (p-value 0.271).

*Conclusion*: We did not find any statistically significant difference on hot climate as compared to comfortable temperature in 100 polytrauma adult patients. Four patients died during study period, one in group I and three in group II. All patients who died were high risk as per Shoe Maker's Risk Score and ASA physical status.

**Keywords**: Polytrauma; Peak outdoor temperature; Complications.

## Introduction

It is widely recognized that extreme hot climatic conditions during summer months may constitute a public health hazard.[1] Heat related illness may range from trivial heat injury to life threatening emergencies.[2] Future climate scenarios suggest the higher global mean temperatures could lead to marked changes in the frequency of temperature extremes. Climate change is the biggest global health threat of the 21$^{st}$ century.[3] Ambient mean temperature is increasing globally by 0.07°C per decade.[4] As there is gradual global warming, the

**Corresponding Author**: **Gurpreeti Kaur,** Associate Professor, Department of Anesthesiology, Dayanand Medical College and Hospital, Ludhiana, Punjab 141001, India.

**E-mail:** grewal.preeti@gmail.com

threat of intermittent heat wave on human life is increasing day by day. Epidemiological studies of mortality during summer in England, Belgium, USA, France, Czech, Spain and many other countries reported similar higher mortality during hot climate.[5-10]

Body temperature is regulated through a dynamic balance between heat production and heat loss. The regulatory mechanisms fail to work above the body temperature of 40°C or below 35°C resulting in multiorgan injury.[11] It has been reported that heat waves occurring in the spring or early summer often resulted in more deaths than heat waves occurring later in the summer.[12,13]

Epidemiological studies of heat related morbidity and mortality during heat wave suggest that elderly and young children are more vulnerable.[14] In our previous study conducted on elderly population during hot weathr found that hot and humid weather adversely affects the outcome in terms of prolonged hospital stay and complication rate in elderly surgical patients (>60 years).[2] Persons who are working outside in the fields are exposed to direct atmospheric heat via radiations from sun. The industrial workers get exposed to industrial pollution and high humidity levels which interfere with evaporation.

Although a lot of research have been carried out to evaluate effect of hot climatic conditions and its correlation with other medical conditions on morbidity and mortality yet only a few have been considered in trauma patients. Thus, we designed study to evaluate the impact of hot climatic conditions on perioperative complications and hospital stay in polytrauma patients during hot climatic conditions (peak outdoor temperature ≥40°C) and comfortable outdoor temperature (20°C-29°C).

## Materials and Methods

This study was conducted in the Department of Anesthesiology and Resuscitation in a tertiary care hospital after approval from the institutional ethics committee. Informed consent was taken from all the patients. A Total of 100 polytrauma patients were enrolled, aged 20-70 yrs of either gender with moderate trauma (Trauma index score>8) belonging to ASA grade I-IV undergoing or not undergoing any surgical procedures under Anesthesia irrespective of patient's characteristic and socio-economic status, divided into two groups of 50 patients each. Patients were grouped on the basis of peak outdoor temperature.

Group I – 50 Polytrauma patients when peak outdoor temperature ranging between 20-29°C.

Group II - 50 Polytrauma patients when peak outdoor temperature ranging >40°C.

Daily data was collected from meteorological department, Punjab Agricultural University to enrol patients. We considered peak ambient temperature at the time of hospital admission as our reference point. To minimize the bias due to medical problems and adaptation of body in the air conditionedenvironment, the exclusion criterion was designed as follows:

- Patients who were reported after 24 hours of hospital admission, minor trauma (trauma index score <8), living in regular air-conditioned atmosphere (more than 18 hours per day).
- Patients suffering from hyperthyroidism, hypothyroidism and malignant hyperthermia, taking drugs interfering with temperature regulation -β blockers, anticholinergics, phenothiazines or other neuroleptic drugs.

### *Environmental record*

Peak outdoor temperature, relative humidity and evaporation index was noted from Meteorological Department, Punjab Agricultural University, Ludhiana. Indoor temperature was noted in wards, where the patients were admitted. Humidex or heat index are the commonly used indices to study the effects of temperature and relative humidity. Heat index was derived from the above noted value with the formula given below:

Heat Index (HI)[9] or apparent temperature (AI)=

$$-42.379 + 2.04901523\,(Tf) + 10.14333127\,(RH) -0.22475541\,(Tf)\,(RH) - (6.83783\times10^{-3})\,(Tf^2) - ((5.481717\times10^{-2})\,(RH^2) + ((1.22874\times10^{-3})\,(Tf^2)\,(RH) + ((8.5282\times10^{-4})\,(Tf)\,(RH^2)) - ((1.99\times10^{-6})\,(Tf^2)\,(RH^2)$$

Tf = Temperature in Fahrenheit

RH = Relative humidity

All patients included in the study were assessed clinically for symptoms and signs of heat related illness, past history of medical problems, injury details, economical status and drug intake history including alternative medicine. Socioeconomic status of patient was assessed using Kuppuswamy's socioeconomic status scale.[15] Patient's risk stratification was done on basis of ASA physical status[16], trauma index score[17] and Shoemaker's risk criteria.[18] If patient was undergoing surgery, then nature of surgery, operative procedure, duration, blood loss or any other adverse event was also recorded. Routine investigations such as (hemoglobin, total leukocyte count, platelet count, packed cell volume, bleeding time, clotting time, prothrombin index, activated partial thromboplastin time, urine routine, random blood sugar, blood urea, serum creatinine, serum sodium, serum potassium, serum chloride, LFT, creatine phosphokinase and serum procalcitonin if done, chest X-rays etc) electrocardiogram were recorded. Any complications, sign of septicaemia (as evident from fever, increased WBC count or culture report), organ dysfunction during hospital stay were recorded along with the date and time of the episode. Outcome of patients was evaluated and compared in the form of incidence of complications, duration of hospital stays. Morbidity and clinical outcome variables were correlated with various risk factors and compared among both groups.

***Statistical analysis***

All the observations were noted in the proforma and analysed using student test, z-test & chi-square test for statistical significance. Stepwise multivariate regression analysis was used to compare the risk factors for morbidity.

## Results

One hundred patients were enrolled in study with 50 in each weather. Patients in both groups were comparable with regards to their demographic characteristics, socioeconomic status, risk stratification based on ASA physical status,Shoe Maker's Risk Score (Table 1). Average age among groups I and II was 38.18±13.37 and 37.86±11.16 respectively. There were more males (92%) in both groups belonging to middle socioeconomic class II & III (76% in group I and 64% in group II, Fig. 1). Most of patients in both groups belonged to ASA classes I & II (Fig. 2). In group I, there were 7 patients in class IV, 5 patients in class V and none in class I. In group II, there were 11 patients in class IV, 7 in class V and none in class I.

In our study most of patients suffered from moderate degree of trauma (TIS 7-15) 86% group 1 and 78% in group II with mean trauma index score of 12.42±2.70 and 13.76±3.09 in group I and group II respectively with p-value 0.023 (Fig. 3). 7 patients in group I and 11 patients in group II had higher Trauma Index Score of 16-25. Patients mostly belonged to low risk shoemaker's score. Most of patients underwent surgery in both groups (92% in group I and 96% in group II). There was statistically significant difference in peak temperature, relative humidity and heat index among both groups (Table 2, Fig. 4). In group I, mean peak temperature was 26.05±2.71°C. Whereasin group II, it was 40.94±1.53°C (p-value 0.000). Mean relative humidity (%) in group I was 87.92±13.13 as compared to 46.34±10.68 in group II (p-value 0.000). Mean heat index in group II was 131.40±9.23 as compared to 83.38±11.35 in group I (p-value 0.000) There was no statistically significant difference in haematological and biochemical parameters in both groups. 76% patients in group I received blood transfusion compared to 68% in group II with p-value of 0.373.

No statistical difference was found among both groups in relation to hospital stay. Mean duration of hospital stays (days) was found to be 15.11 ±5.78 in group I and 17.14±7.61 in group II with p-value 0.161(Fig. 5). We found that 44% patients had complications in group II as compared to 38% patients in group I with p-value of 0.271 (Fig. 6). It was further seen that there were more complications related to infection (12%) and acute renal failure (10%) in group II as compared to group I, 6% and 4% respectively. The incidence of tachycardia and hypotension was comparable in both groups. In group I, 6% patients and in group II, 4% suffered from respiratory distress. In group II, one patient had liver dysfunction.

There was no statistically significant difference in complications among both groups in relation to ASA status, socioeconomic status and trauma index score (Fig. 7,8,9). But patients belonging to lower, lower middle and upper lower socioeconomic classes (classes III, IV&V) were found to have higher complications.

Both groups were comparable in relation to mortality rate (2% in group I and 6% in group II with p-value of 0.162, Table 3) In group II, one patient had pulmonary embolism and one had myocardial infarction. Two other patients, one in each group died because of cardiorespiratory arrest related to high risk stratification in relation to poor ASA physical status and high trauma index score.

Multiple logistic regression analysis was used to compare patients on the basis of age, gender, different heat variables, trauma index score and other surgical risk factors. Trauma Index Score and blood transfusions were found to be the risk factor for predicting perioperative complications with p-value of 0.001 (Table 4)

**Table 1:** Comparison of demographic parameters and risk score among two groups

| Parameters | Group I | Group II | p-value |
|---|---|---|---|
| Age | 38.18+-13.37 | 37.86+- 11.16 | 0.897 |
| Male | 46(92) | 46(92) | NS |
| Female | 4(8) | 4(8) | NS |
| ASA I and II | 37(74) | 36(72) | 0.732 |
| Trauma index score | 12.42+- 2.70 | 13.76+-3.09 | 0.023 |
| Trauma index score 7-15 | 43(86) | 39(78) | |
| Trauma index score 16-25 | 7(14) | 11(22) | |
| Shoe Makers Risk Criteria Low Risk | 47(94) | 47(94) | NA |
| Shoe Makers Risk Criteria High Risk | 3(6) | 3(6) | NA |

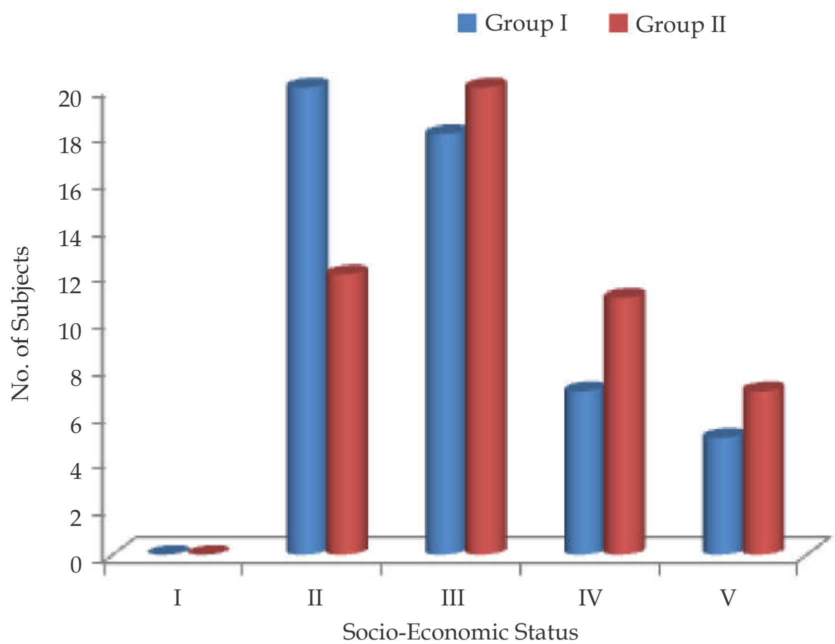


**Fig. 1:** Distribution of Subjects According to Socio-Economic Status

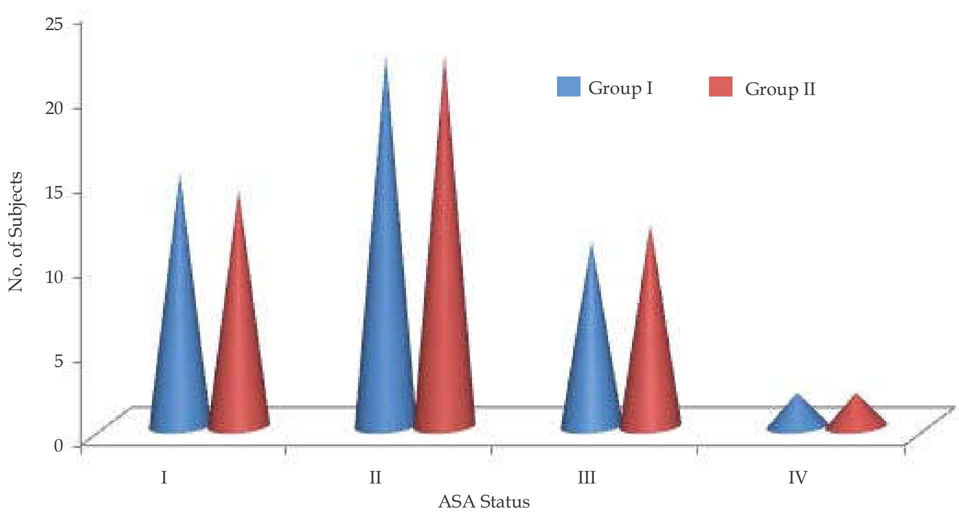


**Fig. 2:** Comparison of Subjects According to ASA Status

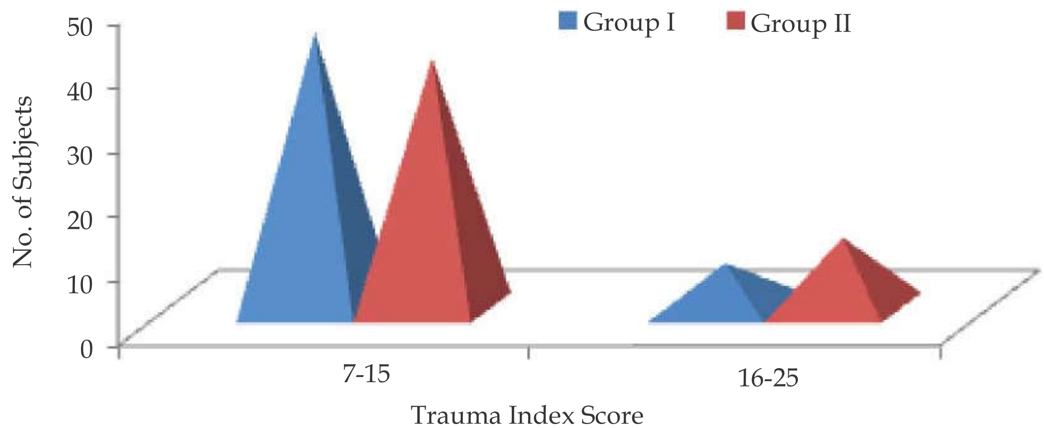


**Fig. 3:** Comparison of Subjects According Totrauma Index Score

**Table 2:** Comparison of Different Heat Variables

| Heat Variables | Group-I | Group-II | p-value |
|---|---|---|---|
| Peak Temperature(°C) | 26.05±2.71 | 40.94±1.53 | 0.000 |
| Relative Humidity (%) | 87.92±13.13 | 46.34±10.68 | 0.000 |
| Heat Index | 83.38±11.35 | 131.40±9.23 | 0.000 |

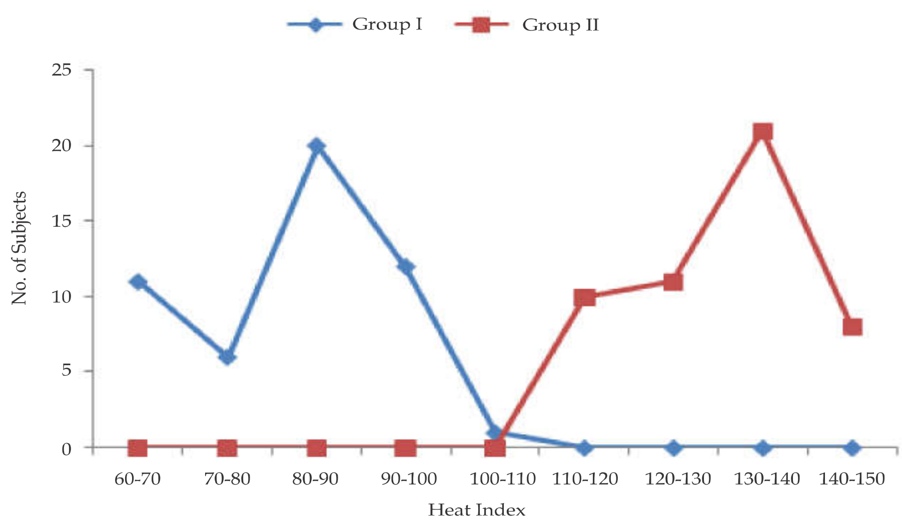


**Fig. 4:** Distribution of Subjects According to Heat Index

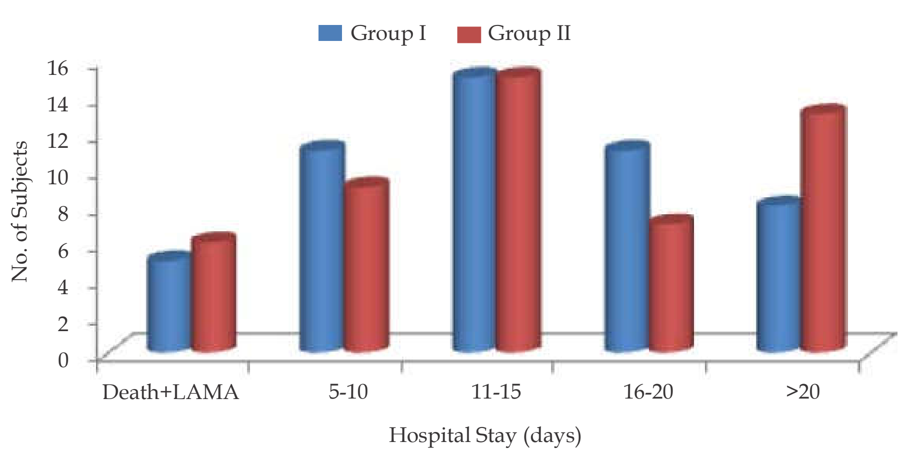


**Fig. 5:** Comparison of Subjects According to Duration of Hospital Stay (Days)

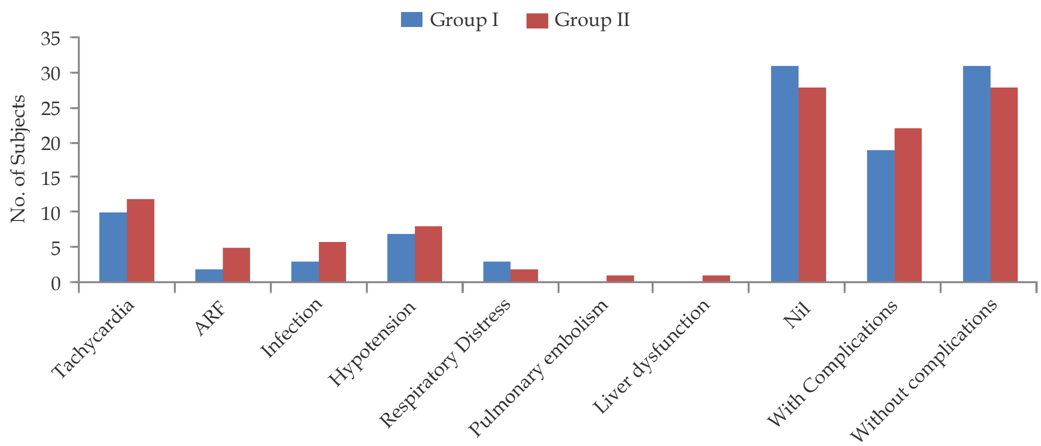


**Fig. 6:** Comparison of Subjects According to Complications among both Groups

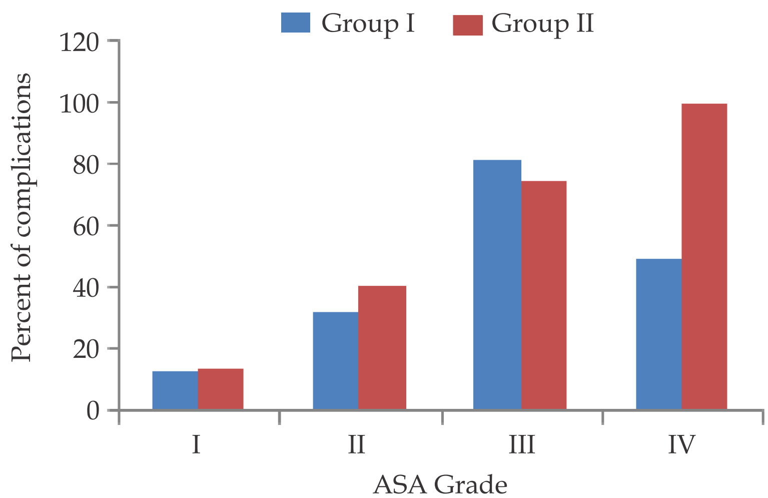


**Fig. 7:** Complications in Relation to ASA Status among both Groups

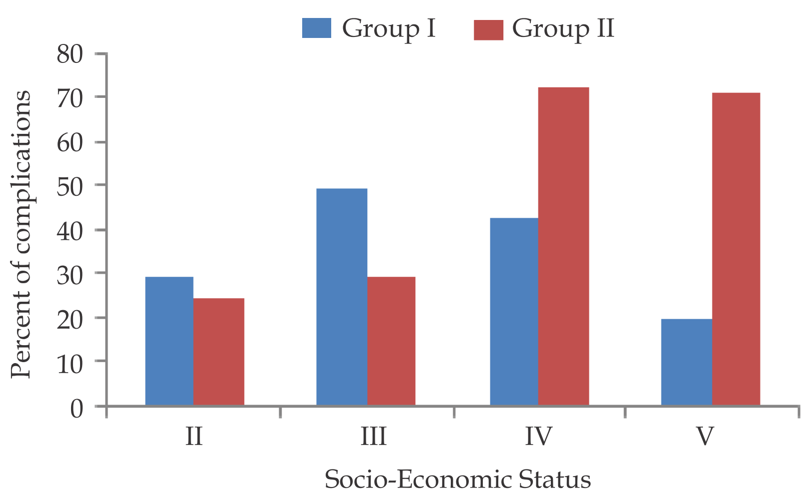


**Fig. 8:** Complications in Relation to Socio-Economic Status among both Groups

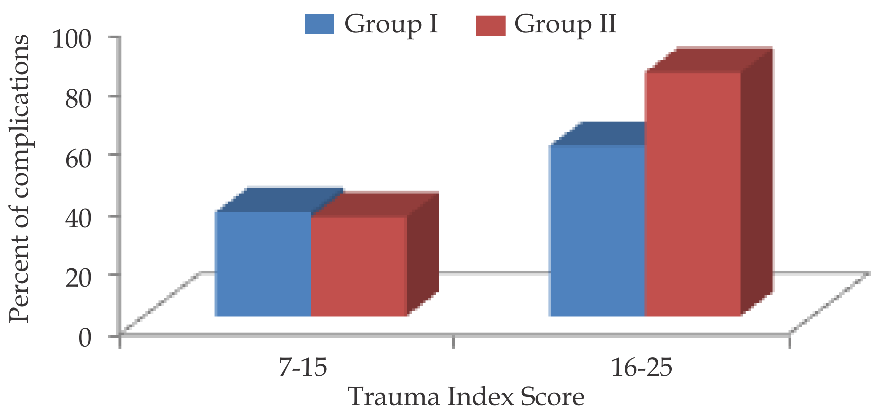


**Fig. 9:** Complications in Relation to Trauma Index Score among both Groups

**Table 3:** Details of Patients who Died During Hospital Stay

| | Group I | Group II | | |
|---|---|---|---|---|
| **Mortality Rate** | **2%** | **6%** | | |
| Age | 55 yrs | 45 | 65 | 46 |
| Sex | M | M | F | M |
| S.E Status | III | IV | IV | II |
| Peak Temp. | 27 | 40 | 42 | 42.6 |
| Peak Relative Humidity | 94 | 55 | 41 | 45 |
| Heat Index | 88.2 | 137.3 | 129.9 | 138.9 |
| Underwent Surgery(+/-) | + | + | + | + |
| ASA | III | IV | III | III |
| Trauma Index Score | 17 | 14 | 11 | 18 |
| Shoe Maker's Risk | HR | HR | LR | HR |
| p-value | 0.162 | | | |

**Table 4:** Factors Predicting Complications: Multiple Logistic Regression Analysis

| Variable | Ist Run Equaton | | Final Run Equation | |
|---|---|---|---|---|
| | **B** | **p-value** | **B** | **p-value** |
| Constant | -13.089 | 0.054 | -4.944 | 0.000 |
| Age (years) | -0.019 | 0.415 | | |
| Sex: M=2; F=1 | 0.310 | 0.783 | | |
| Peak Temperature | 0.271 | 0.323 | | |
| Peak Relative Humidity | 0.059 | 0.194 | | |
| Heat Index | -0.041 | 0.409 | | |
| Trauma Index Score | 0.308 | 0.004 | 0.298 | 0.001 |
| Duration of Procedure | -0.220 | 0.372 | | |
| Transfusion Yes=1, No=0 | 2.503 | .000 | 2.209 | 0.000 |

## Discussion

Global warming is emerging as a threat to the survival of human beings in the coming future. There are a number of epidemiological surveys to address the heat wave and heat wave-related morbidity and mortality.[6,18] In a study by Nakai S et al., the authors observed that heat-related deaths were more prone to occur during the day, with peak daily temperatures of >38°C, and the incidence of these deaths showed an exponential dependence on the number of hot days. In the last decade, numerous epidemiological studies related to heat wave appeared in the literature from Italy,[1,19] USA,[20–22] Japan[23] France,[24] Belgium[6] and many other countries.

Temperature, humidity, wind, evaporation and sunshine are the important climatic elements of environment which directly influences body's comfort and well-being.[25] Body produces heat as a result of cellular metabolism and also gains heat from the environment if the ambient temperature is higher than body temperature. Maintenance of body temperature is very complex. Evaporation is a primary way of heat loss when the environmental temperature is higher than that of the body.[24] Active sympathetic cutaneous vasodilatation increases the blood flow in the skin up to 8 L/min. In order to facilitate heat dissipation, there occurs reduced visceral perfusion, particularly in the intestine and kidneys as blood gets shunted from the central circulation to skin and muscles.[24]

As long as evaporation can remove the secreted moisture, it has a cooling effect but this process is restricted, resulting in uneasiness, discomfort and profuse sweating develops. Continuous active evaporation without adequate water intake poses a risk of dehydration and heat-related illness.[24]

Public health outcomes of hot weather and heat waves depends upon the level of exposure (frequency, severity and duration), population sensitivity as well as the ability to adapt to hot weather.[22] Furthermore, most deaths were reported either in children (<4 years) or (>70 years). Heat wave is prolonged period of excessively hot weather, which may or may not be accompanied by high humidity. It is one of the major causes of weather-related deaths. Heat wave as recommended by the glossary of meteorology is defined as: A period of abnormally and uncomfortably hot and usually humid weather. More realistically, the comfort criteria for any one region are dependent upon the normal conditions of that region.

Both groups were comparable on the basis of their demographic profile i.e. age and socioeconomic status. There were higher number of male patients 92% among both the groups in our study belonged to middle socioeconomic status scale.

Risk stratification was done on the basis of ASA physical status of the patient, trauma index score to compare the degree of trauma and shoemaker's surgical risk score. Both the groups were comparable on the basis of all these factors. Most of patients in our study suffered from moderate degree of trauma (TIS 7-15). 86% group 1 and 78% in group II with mean trauma index score of 12.42±2.70 and 13.76±3.09 in group I and group II respectively with p-value 0.023. Most of patients were belonged to ASA II among both groups. Patients mostly belonged to low risk shoemaker's score. Most of patients underwent surgery in both groups. Gautam et al. found more complications in patients with poor reserves through ASA status and Shoemaker's criteria in their study. Moreover, these patients had more complications when temperature and other heat variables were unfavourable. However, the power of study was low as sample size was small.[2] In our study group there were more young patients with a smaller number of high-risk patients. Hematological and Biochemical parameters were not statistically significant among both groups.

We found that 44% patients had complications in group II as compared to 38% patients in group I with p-value of 0.271. It was further seen that there were more complications related to infection (12%) and Acute Renal Failure (10%) in group II as compared to group I 6% and 4% respectively. Probably, high temperature and humidity led to dehydration compromising splanchnic circulation leading to translocation of bacteria from gut.[24] It may be high humidity and sweat resulting in infectious pockets in skin folds and leading to infections from breached skin due to trauma and intravascular catheters. However, we did not study the pattern and epidemiology of infections in our study. Semenza documented a higher incidence of acute renal failure during heat wave.[26] In group I, 6% patients and in group II 4% suffered from respiratory distress. In group II, one patient had liver dysfunction.

On further subgrouping, according to socioeconomic status as per Table (12), patients belonging to poor socioeconomic status (class IV and class V) in group II had higher complications than in group I. It corroborates the findings of McGeehin et al.,[7] Kuan-che Lu et al.[11] and Reid et al.[27] that poor socioeconomic status groups are more prone to side effects of hot weather despite their adaptation due to prolonged heat exposure. Lu KC and Wang reported that as heat loss is proportional to square of wind velocity, lower socioeconomic status populations are at a higher risk of heat related illnesses.[11] They also have poor air conditioning facility which is another risk factor for development of heat related diseases.[28] We did not record the exact demographics i.e. housing, type of urbanization etc.

No statistical difference was found among both group in relation to hospital stay. The mean duration of hospital stays (days) was found to be 15.11±5.78 in group I and 17.14±7.61 in group II. However in the previous study by our authors; Gautam et al, in elderly surgical patients there was prolonged duration of hospital stay in hot climate.[2] Probably the patients in our study tolerated heat stress better being young trauma victims.

Four (8%) patients in group I and three (6%) in group II were lost during follow up as they left hospital against medical advice. The mortality rate was 2% in group I and 6% in group II. In group II, one patient had pulmonary embolism, other had myocardial infarction. Two other patients, one in each group died because of cardiorespiratory arrest related to high risk stratification in relation to poor ASA physical status, high trauma index score. There was difficulty to attribute mortality in relation to heat related illness in these patients. However, High-risk patients with poor cardiorespiratory reserve are at a greater risk of complications. Inglis et al. also found seasonal variations in cardiac failure patients in the Australian population in the summer season.[29] Also, body's ability of thermoregulation is impeded when too much blood is diverted from vital organs to skin surface on exposure to high temperature, putting increased stress on vital organs like heart and lungs.[28]

On multivariate regression analysis comparing age, gender, various heat variables and trauma index score, it was found that trauma index score is an important risk factor for the development of periopearative complications. Trauma patients often have little or no unused reserves in cardiopulmonary function. Bhattacharya et al. (2001) studied significant positive relationship between maximum daily temperature and trauma admissions.[24] Patients who died, were high risk as per Shoe Maker's Risk Score and ASA physical status.

Our study is novel of its kind, because there is paucity of literature to compare. However, if we see the physiological adaptation of hot weather,[11,24] it becomes a supportive evidence that patients who have compromised cardiorespiratory reserves have higher rate of morbidity and thus would have poor surgical outcome in hot and humid weather.

Our study corroborates some of the findings of a previous study by Gautam et al., where authors found significantly higher number of perioperative complications and increased duration of hospital stay in high risk patients during hot weather. The difference probably lies in our study from previous results of Gautam et al., that in our study patients were young and in earlier published study patients were elderly having compromised cardiorespiratory reserves.

In our region, the change in weather is gradual as compared to the coastal regions. Whenever temperature is high, the evaporation index also goes up to counteract the effect of humidity, so there is better adaptation and acclimatization to climate. On the basis of results in our study, this aspect needs to be further explored by better study designs in a larger sample of population. We also recommend that prior to elective surgery patients should be stabilized in air-conditioned environment for some time for better outcome if possible.

Being a pioneer work, there were many limitations of our study. The major one being sample size was small to find out the relationship of complications with various variables and intragroup comparison. The patients were young, with an average age of 36-38 years with low Shoemakers risk criteria and surgical risk factors among both groups were not similar. Risk stratification variation in relation to ASA physical status, trauma index score needs to be adjusted to minimize the bias. Although both the groups were comparable but bias due to Trauma Index Score could not be ruled out. We did not include the vulnerable group categorically, except the age group. There is enough literature analysis on heat vulnerability factors.[6,31] Heat vulnerability varies spatially, on local, regional, national and international scales. Even within the same city, in addition to the regional difference in heat vulnerability, a higher vulnerability had been seen within the downtown areas of all cities compared with the suburban areas, regardless of the city's overall vulnerability. Our study design lacks control in the same period of year with acclimatization in air-conditioned weather for some time.

## Conclusion

It is well known that extreme hot climate adversely affects the health and high risk patients. We studied the impact of hot weather on young polytrauma patients. But we did not find any statistically significant difference in the complications, hospital stay and mortality among both groups i.e hot climate and comfortable temperature. Four patients who died during study were high risk as per Shoe Maker's Risk Score and ASA physical status. One patient belonged to group I and three patients belonged to group II. Thus, hot and humid weather has minimal impact on morbidity on young trauma patients. However, high risk surgical patients may be at added risk in hot climate.

***Prior publication***: Three

***Support***: Nil

***Conflicts of interest***: Nil

***Permissions***: Nil

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