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Original Research Article

Assessment of Heat Strain Among Workers in Steel Industry – a Study

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Keywords

Heat stress, WBGT, Heat strain, Hypertension, Exposure limits, Air temperature, core bodytemperature, & pulse rate.

A B S T R A C T

The impact of Heat on workers' Health in the steel industry has been examined in the present study. The main objective of the present study were to examine the effect of Heat stress on workers employed in steel plant by measuring physiological reactions of workers such as pulse rate and core body temperature and comparing the results with exposure limits recommended by ACGIH & other professional bodies. Secondary objective was to determine an association between air temperature at workplace & rise in core body temperature of workers during work. Out of 140 employees exposed to heat hazard, 101 employees are examined in this study. Study was done in important production units in steel plant having heat hazards such as Blast furnace Cast House, Steel Melting shop, Energy optimizing furnace, Ladle refining furnace, continuous casting machine and Rolling mills; reheating furnaces, roll table, cooling bed area. Workers were interviewed, examined & information was collected through questionnaire. Workers were not using Heat resistant coat or cool coats for thermal comforts. The maximum core body temperature after work was found 39.3 ^{0} C (Mean; 38.52 & S.D; 0.7). The maximum pulse rate of workers after work was found 120 beats/minute (Mean; 94.96 beats/minute, S.D; 13.11). The study indicate core body temperature of workers was found more than permissible exposure limit prescribed by ACGIH. This indicate the heat strain sustained by workers is significant whereas the pulse rate and Blood pressure was found normal & not exceeded the limits. In this study, correlation between air temperature at workplace & core body temperature rise was found significant. (r= 0.55, P = < 0.01)

Introduction

Steel making is basically a high temperature process. Steel workers are exposed to Heat stress particularly during hot summer months. The local climate (where the study steel plant is located is hot & humid & temperatures goes up to 43^0 C in summer. High levels of Heat stress are found in the steel industry especially at hot rolling area, casting platforms & near furnaces.In previous study made in this plant the thermal stress with WBGT levels of 28 ^{0}C to 34 ^{0}C was found at many production areas in this plant. At WBGT levels over 30 ^{0} C, the risk of incurring heat illness progressively increases with the level of risk being higher for the heavier physical work (Simon P.V.

1992). Excessive heat strain in the workplace can lead to heat related illness from headache, nausea, vomiting to severe form of heat stroke, which if untreated can leads to death.

The environmental heat stress (air temperature, Humidity, Radiant heat) combined with physical work causes heat strain among steel workers. Heat strain is defined as "the physiological impact of heat stress on the body, as expressed in terms of changes in core body temperature and compensating changes in the activity of physiological systems(heart rate, sweat rate, skin blood flow)" (Taylor 2005). Figure: 1 shows the interaction between heat stress & heat strain. It is evident that environmental heat stress increases the sweat rate, core body temperature & pulse rate among the employees exposed to heat hazard.

Because the humans are so highly variable, the only way to determine the true thermal strain is to measure the individual response to the heat hazard. In hot environment deep body temperature is measured & monitored as the best single gauge of heat strain. Konz recommends multiple measures such as heart rate, sweat rate in addition to deep body temperature.

In this study an attempt has been made to study the physiological changes (pulse rate, core body temperature & Blood pressure among employees exposed to heat hazard to assess heat strain sustained by workers. Further ambient temperature was also measured to know the extent of heat hazard at workplace.

a. **Air temperature**: The temperature of the air surrounding the human body which is representative of that aspect of the surrounding which determine heat flow between human body & the air. Air temperature is important in any assessment of thermal stress as it effects the convection heat transfer from the individual.

b. **Pulse rate:**Pulse Rate typically measured in beats/minute provides a guide to measure heat stress on the body. Pulse rate can be used as an effective measure of a Heat strain & this is due to the way in which the body responds to increased heat loads. Blood circulation is adjusted to move blood around the body to dissipate heat, this in turn results in an increased pulse rate.

   In humans the heart rate is highly variable but in most average adults a rate of 60 – 80 beats per minute is common. Under thermal stress higher than normal pulse rates are observed.

c. **Core body temperature:**Humans are warm blooded and whose biochemistry functions at an optimum temperature level (near 37 ^{0} C). Any deviation of a few degree from this temperature can have serious consequence. When the body is unable to cope with the hot environment, the body's heat gain exceeds body's capability to lose heat. As a result the inner body temperature rises increasing the risk of heat related illness. Thus core body temperature is very good indicator of heat strain on the body.

Materials and Methods

Study place: An integrated steel plant located near koppal

Study Design: Cross sectional study.

Study Period: May to July – 2014 (summer season).

Profile of workers, work load & work profile.

Profile of target group workers

Workers	101
Sex	100% men
Positions	Technicians, Gas cutters, Helpers
Status	Initially healthy
Employment	Full-time employees
Age	25-55 years
Work experience	More than 5 years
Work place	• Blast furnace cast house, • Steel making shop; - Energy optimizing furnace, - Ladle refining furnace, - Continuous casting machine. • Rolling mill section - Reheating furnaces

Out of 140 workers exposed to heat hazard, 101 workers participated in this study. Thus the response rate was 72.14 %. Written permission was obtained from thecompetent authority of the factory and cleared the study protocol.

Work profile

All subjects were industrial workers habitually exposed to heat stress in a hot environment in production unit such as Blast furnace cast house, Energy optimizing furnace, Rolling Mill area and continuous casting machines.

The factory works continuously round the clock in three shifts of eight hours each. Posting of worker in particular section was of permanent nature. The shifts of workers were changed on rotation every week. The clothing ensemble consisted of long thick cotton trousers & long sleeved shirts, safety boots, safety helmets and eye protection. Workforce were mobile. The workers worked intermittently for one to two hours three times with lunch break & rest. The workers were relatively well informed about the safety issues related to working in hot environment.

Work load

Work consist of tap hole launder preparation, lancing of oxygen at energy optimizing furnace & Blast furnace, mould level monitoring in casting platform of continuous casting machine, Gas cutting of hot blooms, Hot punching etc. These jobs are fall under category of light to moderate physical work (around 240 kcal/hour)

Questionnaire

The information such as age, height, weight, exposure period, task carried out, availability of cool rest room, drinking water, type of clothing etc.from employees with respect to Heat hazard problems was collected in a Performa designed for this purpose.

All the workers who participated in this study were examined in the factory occupational health centre periodically. Each worker was interviewed and examined.

Measurement of core body temperature

It is the temperature of body's internal organs. A clinical thermometer was used by placing it below tongue to measure the pyrogenic changes in body's temperature.

Clinical thermometer details:

- Make : OMRON MC-246
- Type : Digital Thermometer
- Measurement accuracy: $\pm$ 0.1 ^{0} C.
- Measurement Range : 32 to 42 ^{0} C

Procedure: The thermometerwas placed in the mouth under the tongue so that it rests to the root of the tongue and the minimum time two minutes time was waited before taking temperature measurement. Temperature was measured before starting work & soon after work.

Measurements of Air temperature

At work place was measured using OMRON MC-246 thermometer. Three measurements were taken at each workplace and average temperature was recorded.

Measurement of Pulse rate (heart rate) and Blood pressure

Pulse rate of employee exposed to heat hazard was measured before start of work and soon after work. The instrument used was AutomaticBlood pressure monitor OMRON HEM-7113 of OMRON make. This instrument measures Blood pressure(Systolic & diastolic) and pulse rate simultaneously & shows the result digitally.

- Measurement Range : Pressure: 0 to 299 mm/Hg
  Pulse: 40 to 180 beats/min.
- Accuracy: Pressure: $\pm$ 3mm Hg.
  Pulse: $\pm$5% of reading.
- Measurement method: Oscillometric method.
- Features: Simultaneous display of Systolic, Diastolic & pulse rate.

The workers were considered for high blood pressure when there is persistence elevation of systolic blood pressure to level of 140mm/Hg are higher & diastolic pressure at a level of 90 mm/Hg are higher. (Young and Laffrey 2006).

Body Mass index : Information regarding weight & height of workers exposed to hot environment were collected & body mass index calculated.

Medical examination files of workers exposed to heat and control group employees was studied in advance for analysis.

Statistical analysis

Data from completed questionnaire and field results were entered in Microsoft excel spread sheets & analyzed with the help of MINITAB statistical software package. Mean & standard deviation,& coefficient of co-relation were used for statistical analysis. Frequency distribution tables & percentage were used to summarize study data in tabular formats.

Heat Strain Limits

The results obtained with respect to body core temperature & pulse rate were compared with permissible exposure limits recommended by ACGIH.

As per ACGIH exposure limits, one or more of the following measures may mark excessive heat strain and an individual's exposure to heat stress should be discontinued when any of the following occur:

- Sustained (several minutes) pulse rate is in excess of 180 bpm (beats/minute) minus the individual's age in years (e.g. 180 – age).

- Body core temperature is greater than 38.5 ^{0} C for medically selected & acclimatized personnel or not greater than 38^{0}C for non-acclimatized workers.
- When there is symptom of sudden & severe fatigue, nausea, dizziness or light headedness. Ref:TLV BEI Book, ACGIH-2007.

The limits of heat strain are to be followed to monitor exposure to heat stress on an individual basis.The limits represent time to cease an exposure & allow for recovery.

Results and Discussion

Age group of Target group employees

Table 1 shows that the participants are from all age group. But the maximum number of workers are in the age group of 20-29 & 30-39 (total 76.23 %.). Age is one of the important factor while determining heat strain. The older a person is the more likely they are to suffer from the effect of heat; Particular consideration should be given to individuals over 45 years of age. It is not advisable to post persons over 50 years of age for strenuous jobs in hot environment. (BOHS). But 8% of workers were in the age group of 50 -60 years working in hot environment. For these employees there is a need to monitor the body core temperature, heart rate, rest pause etc. at workplace.

Weight & physical fitness.

Susceptibility to heat varies from person to person. Body weight and physical fitness are important factors for assessing heat strain. Those who are overweight & physically weak are more likely to experience ill effects of heat. Table.2 shows the details of Height, weight & Body mass index of target group employees.

Nearly 48.5 % of target group employees are classified as overweight and obese. These people require greater energy to perform a task.Hence higher metabolic heat is produced in the body. Bigger the persons lower the surface area – to – mass ratio, so the person's ability to dissipate heat is reduced. Fat is good insulator, which means that the fatter the person is, the less heat tolerant. It is established that persons with Body mass index 30 or more have less heat intolerance and there is a risk of heat stroke for these workers when they work in hot environment. (SIMRAC- Hand book of Occupational health practice -2001, Editor Dr. A.J. Keil block). Persons with obesity having more than 30 BMI needs to be closely monitored at workplace where heat hazard exist.

Core Body Temperature & Pulse rate

Table 3 shows the air temperature at workplace & details of body temperature, pulse rate & Blood pressure of workers measured individually during work in hot environment.

a. **Air temperature**:

The air temperature was measured at all workplaces having heat hazard. Air temperature is important in assessment of thermal stress as it affects the convection heat transfer from an individual. Minimum air temperature recorded at workplace was 34^0 C & maximum 39.4 ^{0} C (**Mean air temperature: 36.53 ^{0} C & standard deviation: 1.54**). Air temperature exceeding 35 ^{0}C can increase the heat load on the body.Air temperature indicates that there is a significant heat stress for employees working in hot environment.

b. Core body temperature:

Core body temperature was measured before & soon after work. Table 3 shows core body temperature of workers before start of work which was in the range of 35.7^0 C to 37.9 ^{0} C (Mean 37.0 ^{0} C & standard deviation: 0.535). The Core body temperature measured soon after work was in the range of 37.3^0 C to 39.3^0 C (Mean 38.52^0 C & standard deviation: 0.704). The maximum core body temperature rise was 2.4^0C. The rate of increase in core body temperature is a potential factor in the development of heat illness. (Hales JRS, Richard DAB- 1988) The commonly recommended limits for industrial hyperthermia are 38^0C or an increase of + 1^0C. The Maximum core temperature of body suggested by ACGIH is 38.5^0C for medically selected & acclimatized personnel; or not greater than 38^0C for non-acclimatized workers. It is found during study 53 workers out of 101(52.47 %) reached core body temperature more than 38.5^0C. This indicates more than 50% of employees working in hot environment are suffering from significant heat strain at workplace. The core body temperature rise up to 2.4 ^{0} C indicate the heat loss from the body was not adequate.

British occupational hygiene society (BOHS) recommends stoppage of work when the core body temperature increase is 1 ^{0} C in less than one hour. The limits prescribed by BOHS is core body temperature rise of 1.4 ^{0} C or core body temperature 38.5 ^{0} C whichever comes first .The work can be permitted when:

- Subjects are medically screened.
- They are acclimatized to heat.
- Continuing medical surveillance.
- Heart rate is monitored.
- The worker can be allowed to leave the work as he pleases.

Any increase of temperature of core body temperature above 39 ^{0}C work should be stopped immediately.

In this study there is rise of core body temperature to an extent of 2.4 ^{0} C and core body temperature exceeded 39 ^{0} C for 23 employees (23.07%).This calls for engineering measures such as thermal barriers, better ventilation to control heat hazard. Intermittent rest in cool room is required. More man coolers should be engaged to increase evaporation of sweat. Fluid intake should be encouraged & close monitoring of parameters such as pulse rate, sweat loss etc. to be monitored.

Association between air temperature & core body temperature rise:

An attempt was made in this study to determine the co-relation between air temperature at workplace & core body temperature rise. The co-relation was found significant with r=0.55 & P = < 0.01. It is to be noted that apart from air temperature other factors such as humidity, physical workload, sweat rate & type of clothing used also influence the rise in core body temperature. Further study in this regard is required.

c. Pulse Rate

Pulse rate is being considered as an effective measure of heat strain. Pulse rate indicated reaction to heat much sooner than body temperature response. Table 3 shows pulse rate of workers before start of work & soon after work. Pulse rate before start of work was found in the range of 67 to 99 beats/minute **(**Mean 82.24 &S.D: 8.23) and pulse rate soon after work was found in the range of 78 to 120 beats/minute (Mean 94.96 & S.D; 13.11). For 3 employees increase in pulse rate was found more than 30 beats/minute.

The limit with respect to pulse rate (sustained for several minutes) during work is 180 beats /minute minus the individual's age in years. (ACGIH: 2007 TLV BEI book) The pulse rates shown in the table 3 indicate no employee has crossed the exposure limits recommended by ACGIH.

d. Blood pressure.

Out of 101 target group workers, 8 were found with hypertension in the range of 140/90 to 161/89. The remaining were without hypertension problem. Rise in blood pressure during moderate to heavy work at any workplace is a common phenomenon. Similar rise in Blood pressure was also found among workers working in hot environment. No association between hypertension & hot environment was found in this study.

e. Medical reports of target group

No cases of heat stroke had been reported to the 24 hour on-site medical centre for past 10 years. Only skin rashes and superficial burns reported when workers were in contact with hot surface.

f. Workers Feed back

Feedback of employees with respect to heat related illness was obtained. According to feedback obtained from the workers through questionnaire, the following are the heat related problems faced by employees:

- Workers in Energy optimizing furnace, Blast furnace cast house & Continuous casting sections have complained of eye strain due to exposure to intense, yellow – infrared radiations from the furnace & molten metal. Usage of goggles to protect eyes against radiant heat, was found around 40%.
- 10% of workers complained of mild headache while working in hot environment.
- 5 out of 101 target group workers felt vomiting symptoms during attending hot work jobs.
- Nearly 50% of employees complained of discomfort with respect to usage of helmet, face shield, shoes & thick cotton uniform while working in hot environment. They have suggested to provide cool coats for thermal comforts.

Limitations

a. Measurement of core body temperature:

In this study for measurement of core body temperature, a clinical thermometer was used by placing it below tongue or in arm pit. For accurate measurement any one of the following methods are suggested.

- Inserting a thermometer 8 to 12 cms in to rectum.
- Inserting a wire thermometer through the nose or mouth & down to esophagus approximately at heart level.
- Having the subject swallow a radio – tele thermometer that can transmit temperature data to the outside.

The above methods generally meets with resistance from workers and their co-operation is difficult to get.

b. Assessment of Heat strain:

In this two important indicators core body temperature & pulse rate are measured & considered for assessment of heat strain. Other parameters such as sweat rate, dehydration & heart rate recovery etc. should also be considered for accurate assessment.

c. Association between air temperature at workplace & core body temperature rise was found significant. But the influence of other factors such as humidity, sweat rate, physical work load & type of clothing on core body temperature rise are not considered in this study.

Table.1 Age group of Target group employees

Sl. No.	Age group	No. of workers	Percentage %
01	20-29	39	38.61
02	30-39	38	37.62
03	40-49	16	15.84
04	50-60	08	7.92
	Total	**101**	

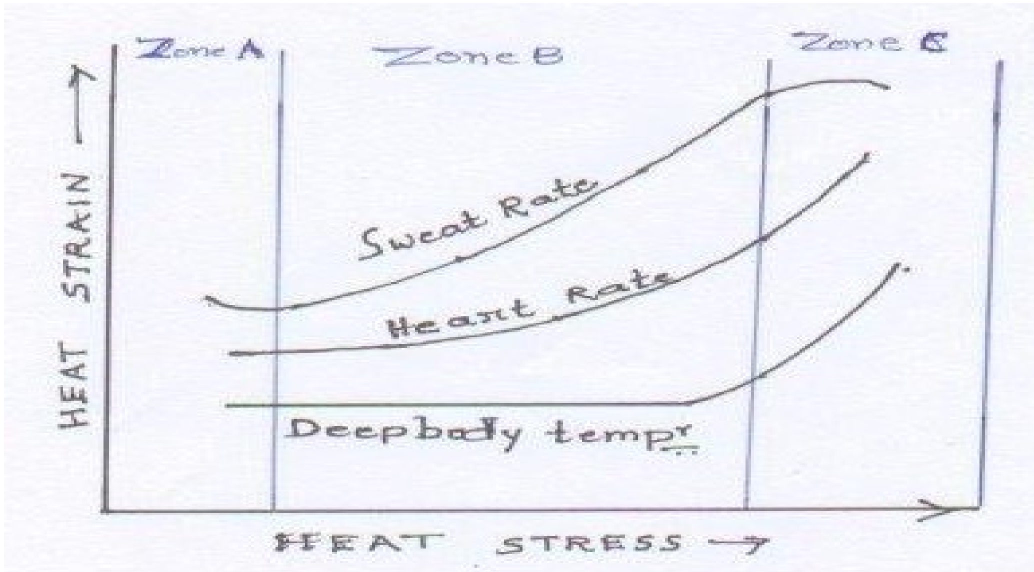
Table.2 Classification of Body mass index of workers exposed to hot work.

Sl.No.	Body mass index number	No. of workers	Percentage %
01	Underweight < 18.5	02	1.98
02	Normal 18.5 – 24.9	49	48.51
03	Overweight 25 – 29.5	41	40.59
04	Obesity >30	08	7.92
	Total	**101**	

Table.3 Details of Body temperature, Pulse Rate of workers exposed to Heat hazard & air temperature

	Air Temperature In ^{0}C	Body Temp. Before In ^{0}C	Body Temp. After In ^{0}C	Rise in Core body temp. In ^{0}C	Blood pressure before	Blood pressure after	Rise in Blood pressure	Pulse rate Before	Pule rate after	Rise in Pulse rate
n		101	101	101	101	101	101	101	101	101
Min	**34**	**35.7**	**37.3**	**0**	**110**	**108**	**01**	**67**	**78**	**00**
Max	**39.4**	**37.9**	**39.3**	**2.4**	**160**	**161**	**30**	**99**	**120**	**36**
Mean	**36.53**	**37.0**	**38.52**	**1.54**	**129.64**	**136.64**	**7.36**	**82.24**	**94.96**	**12.72**
S.D	**1.54**	**0.535**	**0.704**	**0.624**	**11.95**	**11.950**	**6.68**	**8.23**	**13.11**	**11.545**

Fig.1Relationship between Heat stress & Heat strain–Source: WHO



The conclusion in this study it was found that air temperature in many areas exceeds 35 0 C indicating heat stress in working environment. Heat stress is a potential health problem in steel plant. Study indicates rise in core body temperature of workers (up to 2.4 0 C) in hot environment which is potential risk factor in causing heat illness. Close monitoring of core body temperature and pulse rate is essential. Shortening the work period in shifts to avoid hyperthermia & intermittent rest in A/C room is suggested.

As workers suggested cool coats needs to be supplied to workers for thermal comfort. Engineering control measures such as installation of thermal barriers, improving ventilation, provision of A/C rooms are suggested for protection of employees from heat stress.

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