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RESEARCH ARTICLE

Effect of WBGT on physiological cost of operation for agricultural workers in southern Rajasthan

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ABSTRACT

Heat stress is a condition that is caused by worker over-exposure to the high temperature work environments often found in outdoor agriculture operations. Wet bulb globe temperature (WBGT) is a measure of heat stress especially when it is above 27 °C. Considering the range of temperatures prevalent in the Rajasthan state of India during the months of May and June, agricultural operations during these months and the associated heat stress on the agricultural workers, this study was designed to ascertain the effect of WBGT on physiological cost of operation for agricultural workers. Southern Rajasthan was selected to conduct this study. Different WBGT of 28°C, 29°C, 30°C, 31°C and 32°C were selected for this study. The study conducted on twelve farm workers reveals that WBGT induces heat stress on the bodies of workers. The resting, working and delta heart rates and resting and working oxygen consumption rates of workers increased with increase of WBGT from 28 ºC to 32 ºC. The resting hear rate, working heart rate and ΔHR was found increasing linearly with wet Bulb globe temperature with higher correlation. Resting and working OCR were also having increasing linear relationship with wet bulb globe temperature.

KEY WORDS : WBGT, Physiological cost, Operation, Agricultural workers

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INTRODUCTION

India has the second largest population in the world, with 121 million people comprising 623.7 million males and 586.5 million females, according to the provisional 2011. On the basis of usually working persons in the principal status and subsidiary status, for every 1000 people employed in rural and urban India, 679 and 75 people are employed in the agriculture sector.

Still in the country most of the agricultural operations are being performed by manual labour. From starting to the end of the cultivation famer have to work under sun. High drudgery and low income is the main hurdle in agricultural production. Ploughing (June, July, October and April), sowing (July-August, October –November and March- April), intercultural operations (August, April – May), Harvesting (September – October, March-April and May-June) are the main agricultural operations which are being performed mostly by small hand tools in hot sunny days.

India is characterised by strong temperature variations in different seasons ranging from mean temperature of about 10°C in winter to about 32 °C in summer season (33) The temperatures start to increase all over the country in March and by April, the interior parts of the peninsula record mean daily temperatures of 30-35 °C. Central Indian land mass becomes hot with daytime maximum temperatures reaching about 40°C at many locations. Many stations in Gujarat, North Maharashtra, Rajasthan and North Madhya Pradesh exhibit high day-time and low night-time temperatures during this season. Analysis of data for the period 1901-2009 suggests that annual mean temperature for the country as a whole has risen by 0.56 ^{0}C.

Humans live their entire lives within a very small, fiercely protected range of internal body temperatures. The maximal tolerance limits for living cells range from about 0°C (ice crystal formation) to about 45°C (thermal coagulation of intracellular proteins); however, humans can tolerate internal temperatures below 35°C or above 41°C for only very brief periods of time. High environmental temperature, high humidity, strenuous exercise or impaired heat dissipation may cause a variety of heat disorders. They include heat syncope, heat oedema, heat cramps, heat exhaustion and heat stroke as systemic disorders, and skin lesions as local disorders.

Considering the range of temperatures prevalent in the Rajasthan state during the months of May and June, agricultural operations during these months and the associated heat stress on the agricultural workers, this study was designed to ascertain the effect of WBGT on physiological cost of operation for agricultural workers. Southern Rajasthan was selected to conduct this study.

EXPERIMENTAL PROCEDURE

A study was conducted to obtain the effect WBGT on physiological cost of operation of the farm workers. Total 12 farm workers were selected to measure the effect of wet bulb globe temperature on human body during weeding operation. The farm workers selected from the 50 the percentile of the anthropometric criteria and physical strength. Selected subjects are having agriculture as their main source of livelihood. All the subjects selected are not having the habits of chewing tobacco and taking any type of liquor. Subjects are between 20 - 40 years of age. The weeding operation was performed both in morning and evening shifts. In morning the time of operation was kept from 9 AM to 1 PM and in evening 3 PM to 5 PM. For the assessment of physiological effect due to heat stress condition the subjects were asked to perform the weeding operation continuously for one hour.

The study was conducted in southern Rajasthan in the month of May 2009. Intercultural operation like weeding was selected for this study as it was performed in the month of 15th May to 15th June. The temperature is at peak with very low humidity. The average temperature is ranges between 35°C to 43°C which causes high heat stress conditions.

Different WBGT of 28°C, 29°C, 30°C, 31°C and 32°C were selected for this study. The impact on heart rate and oxygen consumption were recorded at different WBGT. Weeding operation with the help of *Khurpi* (weeding hand tool) in green gram was carried by all 12 farm workers simultaneously. The OCR (Oxygen consumption rate) was recorded with the help of K4b^2 (computerized ambulatory Metabolic System, Cosmed, Italy) while heart rate was measured by polar heart rate monitor.

Subject selection :

For the study 12 farm workers representing average population of the region were selected. The subjects were medically examined in the supervision of physician. Subjects with abnormality in blood pressure, vision, resting heart rate or any chronically disease were not selected to participate in the study. All are regular farm workers generally working in their on agricultural farm.

WBGT conditions :

Wet bulb globe temperature (WBGT), was recorded with the help of heat stress monitor (Quest Temp. 36, Made Swan Envirotech). It was observed that in summer for a clear sky (without cloud cover) the WBGT was observed varying from 28^{o}C to 32^{o}C from morning to evening. Such types of days were selected, on the basis of data available from Indian Meteorological Department, weather forecasting.

Measurement of physiological parameter :

Measurement of heart rate (HR) and oxygen consumption rate (OCR) were carried for weeding operation in summer moong crop. Subjects were asked to carry the weeding operation with the help of *Khurpi*. Five ranges of the

WBGT *viz.*, 28°C, 29 °C, 30 °C, 31 °C and 32 °C were selected. Both the values of HR and OCR were average of one hour operation. ΔHR was calculated by following equation:

aHR=Working HR- Resting HR

Subjects were suggested to drink sufficient normal water during the work. Before each operation sufficient rest is provided to prohibit the residual effect.

EXPERIMENTAL FINDINGS AND ANALYSIS

Heat stress and physiological responses of twelve male farm workers were assessed for weeding operation in *Zaid* moong at Intalikhera village of Salumber block of Udaipur district. The days were selected after visiting the current satellite images hosted on the website *www.imd.gov.in* of Indian Meteorological Department, Government of India, Pune. Also the forecast statement issued by Indian Meteorological Department was considered to see the clear sky.

These experiments were conducted for five WBGT of 28 ºC, 29 ºC, 30 ºC, 31 ºC and 32 ºC. Mean values of thermal parameters of twelve workers were calculated from the observations and the mean value table of heart rates with WBGT is shown below in Table 1.

Table 1: Mean values of heart rates with WBGT

Treatments	Resting HR mean	Working HR mean	Delta HR mean
28 ºC WBGT	73.50	88.16	14.66
29 ºC WBGT	75.23	91.16	15.93
30 ºC WBGT	77.74	94.92	17.18
31 ºC WBGT	79.56	97.55	17.98
32 ºC WBGT	80.83	100.25	19.41
GM	77.37	94.41	17.03
S.E.±	1.07	1.29	0.27
C.D. (P=0.01)	4.042	4.858	1.035
CV	4.79	4.72	5.57

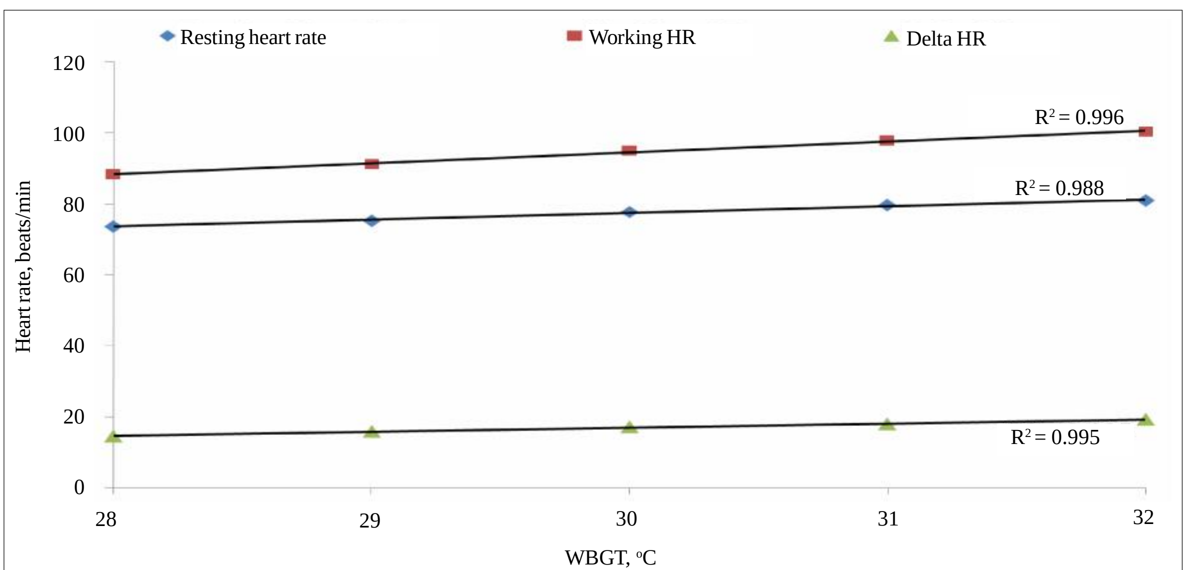

Fig. 1 : Variation of heart rates with WBGT

It can be seen that Resting HR varied from 73.50 beats/min at WBGT of 28 °C to 80.83 beats/min at WBGT of 32 °C. Working HR varied from 88.16 beats/min at WBGT of 28 °C to 100 .25beats/min at WBGT of 32 °C. ΔHR varied from 14 beats/min at WBGT of 28 °C to 19 beats/min at WBGT of 32 °C. Resting, working and delta heart

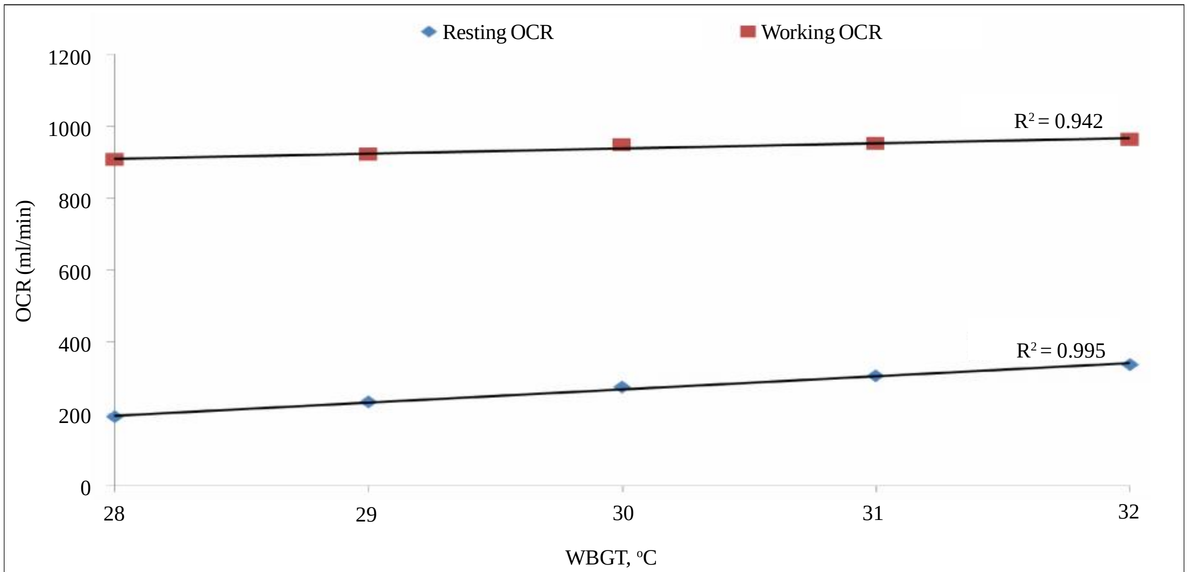

Fig. 2 : Variation of OCR with WBGT

Table 2 : ANOVA for heart rate with WBGT

Sr. No.	Character	Treatments	Error
1.	Resting HR	109.50083**	13.759439
2.	Working HR	281.1865**	19.875195
3.	Delta HR	40.249**	0.90151514

** indicates significance of value at P=0.01

Table 3 : Mean values of oxygen consumption rates with WBGT

Treatments	Resting OCR mean	Working OCR mean
28 °C WBGT	191.2917	907.5833
29 °C WBGT	232.4667	921.4417
30 °C WBGT	273.9000	948.2834
31 °C WBGT	306.3250	951.3500
32 °C WBGT	337.2083	963.6584
GM	268.2383	938.4633
S.E.±	14.0260	13.3887
C.D. (P=0.01)	52.9449	50.5392
CV	18.11	4.94

Table 4 : ANOVA for oxygen consumption rate with WBGT

Sr. No.	Character	Treatment	Error
		[4]	[55]
1.	Resting OCR	40319.734**	2360.748
2.	Working OCR	6421.7947*	2151.0866

* and ** indicate significance of values at P=0.05 and 0.01, respectively

rates were observed to increase with increase in WBGT. This increase was due to heat stress which was induced due to increase in WBGT.

Statistical analysis of the data was carried out to find out the significance of effect of WBGT on heart rate. ANOVA table of heart rates and their variance with WBGT is given in Table 2.

It can be seen from the ANOVA table that resting, working and delta heart rates of subjects significantly increase with 2 ºC increase in WBGT at 1 per cent level. The difference of CD at 1 per cent level is observed in the mean values with 2 ºC increase in WBGT.

Mean values of oxygen consumption rates at resting and working conditions were calculated from the observations and they are given in Table 3. OCR value was the average of one hour operation.

It can be seen that resting OCR varied from 191 ml/min at WBGT of 28 °C to 337 ml/min at WBGT of 32 °C. Working OCR varied from 907 ml/min at WBGT of 28 °C to 963 ml/min at WBGT of 32 °C.

Resting and working oxygen consumption rates were observed to increase with increase in WBGT. This increase was due to heat stress which was induced due to increase in WBGT. As the heart rate increased, oxygen consumption rate also increased.

Statistical analysis of the data was carried out to find out the significance of effect of WBGT on oxygen consumption rates. ANOVA table of oxygen consumption rates and their variance with WBGT is given in Table 4.

It can be seen from the ANOVA table that resting OCR of subjects significantly increase with 2ºC increase in WBGT at 1 per cent level while working OCR of subjects significantly increase with 2ºC increase in WBGT at 5 per cent level. The difference of CD at 1 per cent level is observed in the mean values with 2 ºC increase in WBGT in resting OCR while the difference of CD at 5 per cent level is observed in the mean values with 2 ºC increase in WBGT in working OCR .

Conclusion :

The study conducted on twelve farm workers reveals that WBGT induces heat stress on the bodies of workers. The resting hear rate, working heart rate and ΔHR was found increasing linearly with wet bulb globe temperature with higher correlation. Resting and working OCR were also having linear relationship with wet bulb globe temperature.

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