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Assessment of Physiological Strain in Male Food Crop Cultivators due to Work and Exposure to Changeability in Thermal Conditions in Working Environments

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ABSTRACT
Paddy is grown all most all the states of India; and among them the focal state, West Bengal ranks first in the country in terms of paddy cultivating area and paddy production. Yet, the paddy cultivators constrained to work manually all through the day irrespective of disparity in working situation existing in the working environment. Moreover earlier studies reports that, physical work capacity and work-performance are getting affected due to adverse thermal conditions prevailing in the working environment in different occupations including agriculture. In this backdrop, an attempt has been made to assess the impact of thermal working environmental condition and workload on physiological strain in terms of indices of physiological strain in male food crop cultivators, exposed at high temperature from natural working environment during their regular working schedule. Physical and physiological parameter of the study participants was measured. Indicators of thermal working environmental condition were calculated. Indices of physiological strain of the study participants also calculated. Result of the present study indicated that environmental condition adjudged by select popular heat indices is above the recommended threshold value making the task strenuous for the human resources. Additionally, human resources are indeed subjected to strains, albeit to different degree, as adjudged by the indices of physiological strain.
Keywords: *cardiac cost, climate change, heat indices, food growers, thermal working environment, work performance*

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INTRODUCTION

India has a population of 1.21 billion, which accounts for more than 17% of world population i.e. 1 in every 6 - 7 human of this planet is an inhabitant of India [1]. But India has a land area of 328.7 million hectares which is 2.4% of the planet's land area; this is denoting a challenging spectrum in terms of per capita land availability. Besides that, Indian economy is basically agrarian in nature. Nearly two-thirds of its population depends directly on agriculture for its livelihood and sustenance. Nearly two-thirds of its population depends directly on agriculture for its livelihood and sustenance. Agriculture, the earliest occupations of mankind and still continues to play a significant role in the lives of people all over the world including India. Among the different agricultural food crops paddy is the most important in India. Moreover India has a long history of paddy cultivation. Globally, it stands first in paddy cultivation area and second in paddy production. West Bengal ('bowl of paddy') is the highest paddy producing state in India with a production of 15023.68 thousand tones. Paddy in West Bengal is grown in three cropping seasons autumn, winter and summer. These three seasons are named according to the season of harvest of the crop. Autumn or pre-kharif rice is known as 'Aus' in West Bengal. The pre-monsoon 'Aus', covers April to July in the northern region and May to September in the southern region of the state. The winter or monsoon paddy, known as 'Aman', is grown from June to December. The summer or dry season paddy is popularly known as 'Boro'. Paddy cultivation involves- ploughing (both dry land and wet land), transplanting (straight row and random), reaping, threshing (manual and automated) and parboiling [2]. Moreover, the agricultural work is most commonly seasonal, and during summer harvest, workers often spend long hours under hot and humid condition, performing arduous physical labour [3-5]. Moreover, adverse thermal environment at work is further being aggravated by the phenomenon of global warming which is affecting all walks of our life, including living and working environments, and in the process

creating health threats for millions of people worldwide. And there are reports that physical work capacity and work-performance are getting affected due to adverse thermal conditions prevailing in the working environment in different occupations [6-7] including agriculture [8-10]. Therefore in order to make sure health status, well being and thereby improving the work performance, the assessment of physiological strain in terms of indices of physiological strain is considered as an essential factor for the human resources engaged in outdoor occupations especially those who are engaged in different types of tasks during the period of paddy cultivating time [11-12]. In this backdrop the present study has been undertaken to assess the impact of thermal working environmental condition and workload on cardiac response profile in terms of indices of physiological strain in male food crop cultivators, exposed at high temperature from natural working environment during their regular working schedule, i.e. during parboiling task (a hydrothermal treatment of paddy followed by drying before milling for the production of milled parboiled rice, it could be done manually and mechanically both) during 'Aman' and 'Boro' type of paddy cultivating time.

MATERIAL AND METHODS

Before proceeding with the field study for obtaining data from the food crop cultivators, preliminary works involving selection of the location as detailed below was carried out. After getting permission from institutional human ethical clearance committee, male individuals (age range 24 - 36 years) permanently (>10y) residing in the Goghat II administrative Block, Arambagh Subdivision, and Hooghly District, were requested to take part in the study. Paddy cultivators having a minimum work experience of five years and no known history of or apparent illness (self reported) and regularly working for at least a period of six to six and half hours in the agricultural field and also voluntarily expressing their desire for being included in the study were only considered for random selection. Initially approached with a request to permit carrying out of the studies on the paddy cultivators engaged in manual parboiling task during the paddy cultivation time. After obtaining initial consent from the study participants, the study requirements were explained elaborately. Thus on obtaining prior informed consent the field study was initiated. Data were collected during October to middle of November (during the 'Aman' type of paddy cultivating period) and during the period March to April (during the 'Boro' type of paddy cultivating period). These data were presented in three spells i.e. morning [6.15 - 9 am] was referred to as spell 1 [S1], similarly around noon [9.30 - 10.00 am to about 1pm] was referred to as spell 2 [S2] and afternoon [2.30 pm - 4.30 pm] was referred to as spell 3 [S3]. It may be also mentioned that the data of individuals who were available for study during both the seasons were only considered for analyses. Data were collected from 37 adult male food crop cultivators (age range of 24 - 36 years) while they were taking part in manual parboiling task during 'Aman' and 'Boro' type of paddy cultivation. These data were tabulated as the data from manual parboiling group (PBG - A) and (PBG - B). After obtaining the consent, the name, age (year), ethnic background of the study participants was recorded to each individual in a pre designed schedule. Information for the assessment of socio economic status of the participants was recorded by using Kuppuswamy's socioeconomic scale [SES] [13]. Stature in cm and body weight in kg was measured using an anthropometric measurement set and a weighing scale, respectively. Body Mass Index (BMI) ($kg.m^{-2}$) was calculated from the measured stature and body weight (BW) data. Pre-work heart rate ($HR_{Pre\text{-}work}$) of the study participants was recorded and/or by using the Polar heart rate monitor and stopwatch before the individuals started their work and expressed in $beats.min^{-1}$. Pre work Systolic and diastolic blood pressure ($SBP_{Pre\ -\ work}$ and $DBP_{Pre\ -\ work}$) also recorded during the morning hours before the individuals started their working and/or by using an automated blood pressure monitor and sphygmomanometer in sitting condition and expressed in mm Hg. Heart rate was monitored using heart rate monitor (Polar) and data were recorded at a regular intervals during the activity period of paddy cultivators in three different spells and finally, the highest values of heart rates in each spell was presented as Peak heart rate (HR_{peak}), expressed in $beats.min^{-1}$ [14]. Net cardiac cost (NCC) was obtained [15] as the difference between working and pre-working heart rate of the study participants and was expressed in $beats.min^{-1}$. Peak estimated energy expenditure (EEE) of tasks was obtained [16] and was expressed in $kcal.min^{-1}$. The 'heaviness' of work was adjudged in terms of - peak heart rate (HR_{peak}) ($beats.min^{-1}$), net cardiac cost (NCC) ($beats.min^{-1}$), and peak estimated energy expenditure (EEE) ($kcal.min^{-1}$). In case of basic environmental parameter - Dry bulb (T_{DB}) and Wet bulb (T_{WB}) temperature were measured with the help of Hygrometer. The dry bulb temperature was recorded thereafter during the working hours in the agricultural field [17]. Wet Bulb Globe Temperature (WBGT) index was found out. Corrected Effective Temperature (CET) was determined from T_{DB}, $T_{WB,}$ $T_{G,}$ Air velocity (AV) from specified nomograms [18]. Discomfort index (DI) was determined from T_{DB}, T_{WB} values as follows [19]. The percentage of human resources dissatisfied because of thermal environment was ascertained for different spells in different paddy cultivating time as prescribed in ISO 7730:1994 [20]. The collected data were tabulated, analyzed

and were tested for significance with analysis of variance (ANOVA), as appropriate. As the thermal environmental conditions were assessed in terms of several indices, the correlation between them was found out. P value lower than 0.05 ($P<0.05$) was considered significant.

RESULTS AND DISCUSSION

General characteristics including age (year), ethnicity, SES, working experience (year) of the participants are presented in Table 1.

TABLE 1: GENERAL INFORMATION OF THE FOOD CROP CULTIVATORS

Variables	Values
Age (year)	26.9 ± 3.65
Ethnicity	Bengalee
SES	Lower middle
Working experience (year)	8.3 ± 1.05

Data presented as AM ± SD

The physical and physiological profile of in terms of their stature, body weight, BMI, $HR_{Pre\ work}$, and $SBP_{Pre\ work}$, $DBP_{Pre\ work}$ of the study participants are presented in Table 2.

TABLE 2: PHYSICAL AND PHYSIOLOGICAL PROFILE OF THE STUDY PARTICIPANTS

Variables	Values
Stature (cm)	155.7 ± 4.15
BW (kg)	54.0 ± 3.11
BMI ($kg.m^{-2}$)	20.8 ± 3.35
$HR_{Pre\text{-}work}$($beats.min^{-1}$)	70.0 ± 3.58
$SBP_{Pre\text{-}work}$ (mm Hg)	116.0 ± 7.80
$DBP_{Pre\text{-}work}$ (mm Hg)	76.0 ± 6.58

Data presented as AM ± SD

The food crop cultivators were fallen under 'normal weight' category as per mean BMI value as per classification given by WHO [21]. The mean BMI values of the food crop cultivators was in consonance with the findings of previous studies [22-25]

The environmental condition is adjudged in terms of three indicators of thermal environmental status- WBGT, CET, and DI are presented in figure 1.

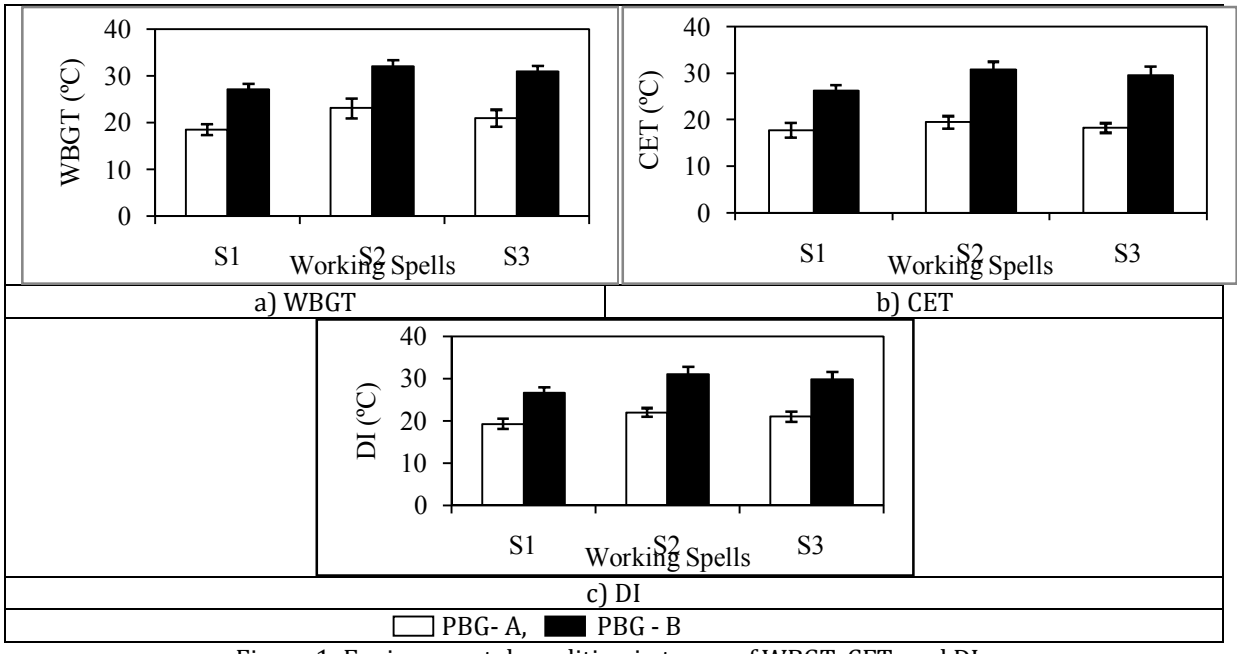


Figure 1: Environmental condition in terms of WBGT, CET, and DI

In case of PBG -A, the average values of WBGT index, during 'Aman' type of paddy cultivating time in S1, S2 and S3 working spells were 18.5°C, 23.1°C and 21.0°C respectively. There was no restriction recommended against carrying out the task. In case of PBG-B, the average WBGT values in S1, S2 and S3 working spells were 27.1°C, 32.1°C and 31.0°C. Of which in S2 working spell no work is ideally allowable

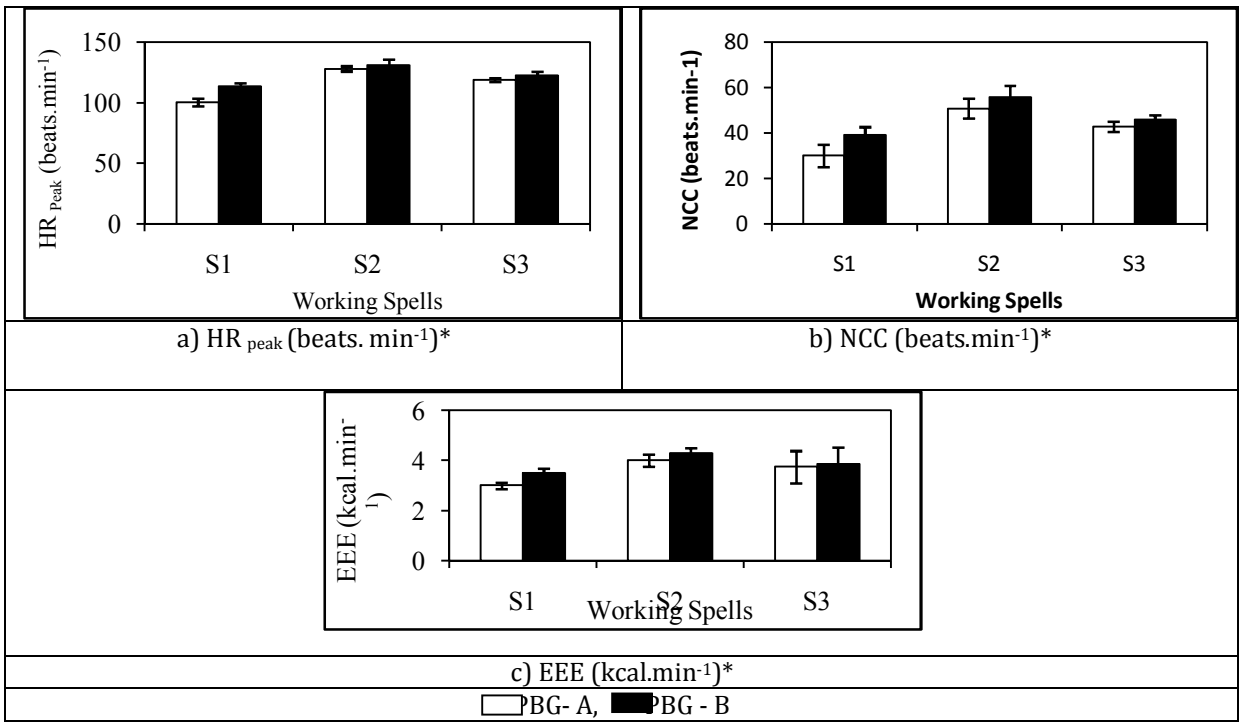
as per American Conference of Governmental Industrial Hygienists (AGIH) guideline [26-27]. Whereas in the S1 and S3 working spell for 'light' type of work, there is no restriction in terms of allocation of work in work-rest cycle; for 'moderate' type of work, upto 75% time each hour, work can be allocated in work rest cycle and for 'heavy' type of work, upto 50% time each hour, work can be allocated in work rest cycle. The average values of CET in case PBG- A were 17.8°C, 19.5°C and 18.3°C. There is no restriction for carrying out the task along the working spells i.e. in S1, S2 and in S3. In case of PBG- B, average values of CET in S1, S2 and S3 working spells were 26.3°C, 30.8°C and 29.5°C. Of which in the S1 working spell no restriction recommended against carrying out the task. During the S2 working spell upto 'light' category of work could be performed. In the S3 working spell upto 'moderate' category of work could be performed [28]. In case of PBG - A, the average DI values in S1, S2 and S3 working spells were 19.3°C, 22.0°C and 21°C. In S1, S2 and S3 there is no restriction recommended against the carrying out the task. Whereas in case of PBG-B, the average values of DI in S1, S2 and S3 working spells were 26.6°C, 31.0°C and 29.9°C. In the S1 working spell with average DI values of 26.6°C, the heat load is considered 'moderate' and individual can perform the physical work some difficulties. Whereas during the S2 and S3 working spell with the average DI values of 31.0 °C and 29.9°C heat load is considered as 'severe', and human resources engaged in physical work are at increased risk for heat illness [29]. The percentage of human resources during parboiling task who work in conditions exceeding permitted $WBGT_{max}$ and Met_{max} values calculated. It has been presented in table 3. It could be observed that in second and third spells in PBG - B, all the human resources work exceeding the limits, because of the extreme condition of the thermal environment prevailing in the parboiling task during 'Boro' type of paddy cultivation.

Table 3: PERCENTAGE OF HUMAN RESOURCES WORKING IN CONDITIONS EXCEEDING $WBGT_{MAX}$, AND MET_{MAX} VALUES

No of Individuals	**'Aman'**			**'Boro'**		
	Working Spells			**Working Spells**		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
37	nil	nil	nil	nil	100	85

Data presented as individuals (%)

Physiological strain in terms of HR_{peak} (beats. min^{-1}), NCC (beats.min^{-1}), and EEE (kcal.min^{-1}) has been presented in figure 2.



a) HR_{peak} (beats. min^{-1})*

b) NCC (beats.min^{-1})*

c) EEE (kcal.min^{-1})*

*P<0.05

Figure 2: Cardiac response profile of the study participants in terms of HR_{peak} (beats. min^{-1}) (a), NCC (beats.min^{-1}) (b), and EEE (kcal.min^{-1}) (c)

PBG - A individuals: In terms of HR_{Peak} (beats.min^{-1}) it is found that in the paddy cultivators belonging to PBG group, during the 'Aman' type of paddy cultivating time, the values varied from 96 - 104 beats.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during S2 and S3 it varied from 124 - 133 beats.min^{-1} and 113 - 121 beats.min^{-1} respectively. In terms of NCC, expressed in beats.min^{-1}, it is found that PBG individuals during the 'Aman' type of paddy cultivation, the values varied from 26 - 34 beats.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 46 - 54 beats.min^{-1} and 33 - 41 beats.min^{-1} respectively. In terms of EEE, expressed in kcal.min^{-1}, it is found that the values of EEE varied from 2.97 - 3.05 kcal.min^{-1} in the first working spell, i.e. in S1 spell, whereas during the S2 and S3 it varied from 3.97 - 4.09 kcal.min^{-1} and 3.71 - 3.80 kcal.min^{-1} respectively. CSI value varied from 27 - 35, 38 - 47 and 33 - 41 in the S1, S2 and S3 spell respectively.

PBG- B individuals: In terms of HR_{Peak} (beats.min^{-1}) it is found that in the paddy cultivators belonging to PBG group, during the 'Boro' type of paddy cultivating time, the values varied from 109 - 119 beats.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 126 - 135 beats.min^{-1} and 117 - 126 beats.min^{-1} respectively. In terms of NCC, expressed in beats.min^{-1}, it is found that PBG individuals during the 'Boro' type of paddy cultivation, it varied from 35 - 43 beats.min^{-1} in the first working spell, i.e. in S1 working spell whereas during the S2 and S3 it varied from 51 - 59 beats.min^{-1} and 41 - 49 beats.min^{-1} respectively. In terms of EEE, expressed in kcal.min^{-1}, it is found that the values of EEE varied from 3.47 - 3.55 kcal.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 4.26 - 4.34 kcal.min^{-1} and 3.81 - 3.89 kcal.min^{-1} respectively. CSI value varied from 33 - 42, 45 - 54 and 38 - 48 in the S1, S2 and S3 working spell respectively.

In terms of heaviness of workload for **PBG - A** individuals, the heaviness of workload in the S1 working spell has been adjudged as 'moderate', 'quite moderate' and 'moderate' respectively in terms of three indicators HR_{peak}, NCC, and EEE. In the S2 working spell the workload has been adjudged as 'heavy', in terms of HR_{peak}, NCC, and EEE. In S3 working spell the workload has been adjudged as 'heavy', 'rather heavy' and 'moderate' respectively in terms of three indicators HR_{peak}, NCC, and EEE. In case of **PBG - B** individuals, the heaviness of workload has been adjudged as 'heavy', 'moderate', and 'moderate' respectively in terms of three indicators HR_{peak}, NCC, and EEE. In the S2 working spell the workload has been adjudged as 'very heavy', 'heavy' and 'heavy' in terms of three indices of physiological strain- HR_{peak}, NCC, and EEE. In the S3 working spell the workload has been adjudged as 'heavy', 'rather heavy' and 'moderate' respectively in terms of HR_{peak}, NCC, and EEE.

The magnitudes of indicators of physiological strain were found to vary with the change of working spell. The environmental heat load might be one of the reasons for increased cardiovascular strain. The result of the present study showed that the manual parboiling task during 'Boro' type of paddy cultivation is more arduous in terms of the indices of physiological strain. The finding of the present study in consonance with the finding of earlier studies [30-32] carried out in male human resources occupationally engaged in different types of tasks during paddy cultivation time in the district of Hooghly that reports the unfavorable thermal environmental condition in working environment i.e. above the recommended threshold values, mostly prevalent during 'Boro' type of paddy cultivation, is making the task strenuous for the human resources engaged in paddy cultivation. Moreover, different tasks during paddy cultivating period - ploughing (dry and wet ploughing) [5, 8, 9, 32, 33, 34, 35], transplanting (manual) [36-37], reaping (manual) [3, 8, 37], threshing (by mechanized thresher and electrically driven paddy thresher) [10, 12, 30, 31], and manual parboiling [11] was strenuous; this is affirmed by the finding of the present study for the human resources primarily engaged in manual parboiling task during the 'Boro' type of paddy cultivation. Added to this the task manual parboiling task is arduous for the paddy cultivators in terms of heaviness of workload; hence, ergonomic interventions, including rescheduling of the work-rest cycle, frequent fluid intake to replace the water lost due to sweating, using PPDs to protect them from radiating heat may help reduce the heat stress of the agricultural workers, increase capability and thereby improved working efficiency.

CONCLUSION

From the present study, it may be concluded that, the agricultural task - paddy cultivation - is strenuous and has health implications for the human resources; moreover the manual parboiling task is more strenuous task; as indicated from the indicators of the physiological strain. Added to this, the thermal environmental conditions adjudged by the heat indices are not favorable, i.e. they are above the recommended threshold values, making the task arduous for the human resources primarily engaged in manual parboiling task during the 'Boro' type of paddy is cultivated. And cardiac strain in terms of indices of physiological strain also significantly higher during 'Boro' type of paddy cultivation compared to 'Aman' type of paddy cultivation. This may have serious implications in view of the fact that average ambient temperature is on the rise throughout the world leading to climate change and the challenges are

more in tropical country like India with huge number of people being involved in open sky livelihood earning in the unorganized sector.

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CONFLICT OF INTEREST
None

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