

Impact of Variation in Thermal Working Environmental Condition on Cardiac Response Indices in Male Human Resources Engaged in Food Crop Cultivation Task

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Abstract: Climate change poses a serious threat worldwide including increase in temperature particularly in tropical countries and our country India is no exception to it. It has been also reported that the work performance of the human resources is also affected particularly those who were exposed to outdoor working environment. In this backdrop, the present study has been undertaken to assess the physiological strain in male food crop cultivators (age range 24-36 years) occupationally engaged in reaping tasks during food crop cultivation. Physical and physiological parameters are also recorded. Indicators of thermal environmental condition i.e. dry bulb temperature, and wet bulb temperature are also recorded during the working time. Results of the present study indicated unfavourable working environmental condition making the task more arduous for the human resources engaged in reaping task during 'Boro' type of paddy cultivation time as indicated from the indices of physiological strain.

Keywords: Environment modeling; Physiological cost of work; Climate change; Hooghly.

Introduction

India is an agriculture based country. As per the census 2011, population of India is 1.21 billion. In the focal state of West Bengal, paddy is the major food crop cultivated in different seasons named according to the harvest of the crop. Autumn or pre-kharif rice is known as 'Aus' in West Bengal. The pre-monsoon 'Aus' is grown from 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'. The sowing time of summer paddy is November to February and

harvesting time is March to May. The growing season for the crop sometimes overlaps with 'Aus' (Adhikari et al., 2012).

Paddy cultivation involves different tasks—ploughing, transplanting, reaping, threshing, and parboiling. Reaping or cutting is the first task in harvesting; depending on the crop's condition, and availability of human resources; it can be done either manually or mechanically. Earlier studies reported that physical work capacity and work-performance are getting affected due to adverse thermal conditions prevailing in the working environment in different occupations (Venugopal et al., 2016; Kjellstrom et al., 2016; Lucas et al., 2014; Lundgren et al., 2013; Mukherjee, 2015; Banerjee

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et al., 2014) including agriculture. (Chatterjee et al., 2019a, 2019b, 2019c, 2019d, 2018a, 2018b, 2018c, 2018d, 2018e). On the other hand, simultaneously, the situation, resulting from 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.

Over the last 100 years, the average temperature of the air near the Earth's surface has risen by a little less than 1°C ($0.74 \pm 0.18^\circ\text{C}$, or $1.3 \pm 0.32^\circ\text{F}$) and it is estimated to go up further by 1.8 to 4.0°C (estimated average 3.0°C) by 2100 AD depending on actions to limit GHG emissions (IPCC Fourth Assessment Report, 2007). The human resources who are exposed to excessive heat in course of their livelihood earning, especially in low and middle income tropical countries, are at highest risk in respect of their health and wellbeing (Kjellstorm et al., 2016). The situation in India (located at the north of the equator between 6°44' and 35°30' north latitude and 68°7' and 97°25' east longitude), with a 7517 km coastline, is no different from other less developed tropical countries. The unprecedented rise in average ambient temperature is posing a newer challenge to the working population (about 40% of the 1.2 billion strong Indian population), particularly those engaged in different unorganized sector. Therefore, the plight of the workers especially with regard to health, safety, welfare can be well imagined. In order to ensure health, well being and thereby improving the work performance, the assessment of cardiac response profile is considered as an essential factor for the human resources engaged in outdoor occupations (Chatterjee et al., 2018f, 2018g, 2017a, 2017b) especially those who are engaged in different type of tasks during the period of paddy cultivating time. In this backdrop, the present study has been undertaken to assess the effect of workplace heat exposure on cardiac response status in terms of indicators of physiological strain in male paddy cultivators primarily engaged in different task during 'Aman' and 'Boro' type of paddy cultivation.

Methodology

The area of the field study was comprised of villages under Fului Gram Panchayat, and Krishnaganj Gram Panchayat, Goghat II administrative Block, Arambagh Subdivision and Hooghly District (latitude 23°01' N to 22°39' N and longitude 88°30' E to 87°39' E) in West Bengal, India. The study design was approved by

the Institutional human ethical committee. The study was carried out on consenting human resources with no known chronic disease history (self-reported) and having a minimum working experience of three years and regularly working for a period of six to six and half hours per day on an average in the agricultural field. Data were collected during May to middle of November (during the 'Aman' type of paddy cultivating period) and during the period November 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 1 pm] 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 47 adult male food crop cultivators (age range of 24-36 years) while they were taking part in manual reaping task (also known as cutting, this is the first task of harvesting) during 'Aman' and 'Boro' type of paddy cultivation. These data were tabulated as the data from RGA during 'Aman' (RG - A) and RGA during 'Boro' (RG - B) manual reaping group. Information regarding their age (year), socio-economic status (SES) – assessed by using the Kuppaswamy's socio-economic scale (Ravikumar et al., 2013), and working experience (year) were recorded in a pre-designed schedule. Ambient temperature (T_a) (°C), wet bulb temperature (T_{WB}) (°C), globe temperature (T_g) (°C) and natural wet bulb temperature (T_{nwb}) (°C) were noted during the working hours in the agriculture field. The values of Wet bulb globe temperature (WBGT) (°C) (Heidari et al., 2015), corrected effective temperature (CET) (°C) (Brake and Bates, 2002), modified discomfort index (MDI) (°C) and predicted four-hour sweat rate (P_4SR) (l) (Epstein and Moran, 2006) were found out.

Anthropometric measurements—stature (cm) and body weight (kg) were measured using anthropometric rod and a pre calibrated weighing scale respectively. Somatometric indicator, BMI was calculated to measure the obesity status of the human resources. The pre-work heart rate ($\text{beats} \cdot \text{min}^{-1}$), pre-work systolic and diastolic blood pressure (mm Hg) were recorded in the morning hours before the individuals started working. Cardiac strain indicators in terms of peak heart rate (HR_{peak}) ($\text{beats} \cdot \text{min}^{-1}$) (Astrand and Rodhal, 1986), net cardiac cost (NCC) (Chamoux et al., 1985), estimated energy expenditure (EEE) ($\text{kcal} \cdot \text{min}^{-1}$) (Ramanathan et al., 1967) and cardio vascular strain index (CSI)

(Trites et al., 1993) were found out. The ‘heaviness’ of workload (e.g. light, moderate, heavy and very heavy) (Motamedzade and Azari, 2006) has also been adjudged in terms of HR_{peak} (beats.min⁻¹), NCC (beats.min⁻¹), and EEE (kcal.min⁻¹). Data have been presented in AM $\pm$ SD form. Obtained data were statistically analyzed to find out the significant differences among the indices of physiological strain in different working spells. 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 as significant.

Result and Discussion

Basic information in respect of age (year), socio-economic status, working experience (year) of the participants are presented in Table 1.

Table 1: Basic information of the study participants

Variables	Values
Age (year)	27.3 $\pm$ 3.72
Socio-economic status	Lower middle
Working experience (year)	7.3 $\pm$ 1.15

Data presented as AM $\pm$ SD

The physical and physiological parameters in terms of their stature, body weight, BMI, $HR_{Pre\ work}$, $SBP_{Pre\ work}$ and $DBP_{Pre\ work}$ of the study participants are presented in Table 2. The food crop cultivators were fallen under ‘normal weight’ category as per mean BMI value (WHO, 2000). The mean BMI values of the food crop cultivators was in consonance with the findings of previous studies which reports that practising different form of dancing in a methodical way (Banerjee et al., 2015a; 2015b; Mukherjee et al., 2014a, 2014b, 2013; Chatterjee et al., 2015d) help to maintain favourable body composition. Earlier studies also reports increase in the mean BMI value linked with work related musculoskeletal disorder difficulty (Chatterjee et al., 2015e, 2014).

Table 2: Physical and physiological parameters of the study participants

Variables	Values
Stature (cm)	15.8 $\pm$ 1.85
BW (kg)	55.4 $\pm$ 3.31
BMI	21.0 $\pm$ 4.55
$HR_{Pre-work}$ (beats.min ⁻¹)	70.0 $\pm$ 3.58
$SBP_{Pre-work}$ (mm Hg)	119.0 $\pm$ 10.80
$DBP_{Pre-work}$ (mm Hg)	74.0 $\pm$ 9.38

Data presented as AM $\pm$ SD

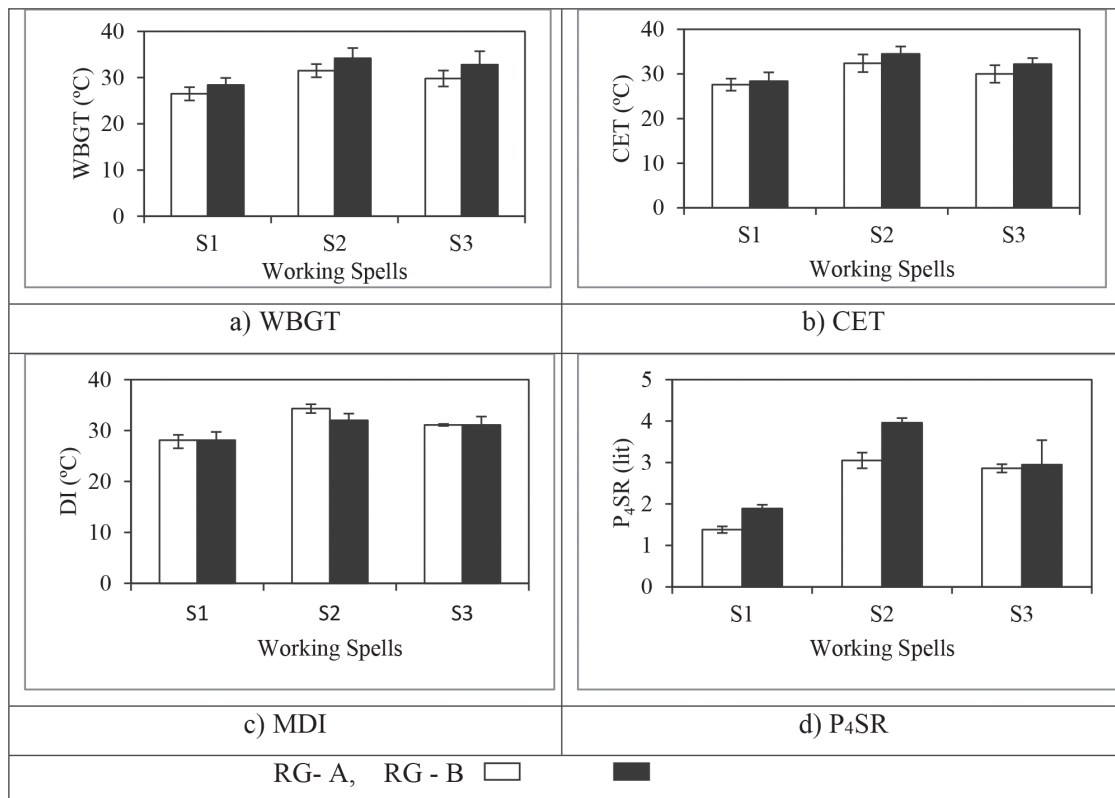


Figure 1: Environmental condition in terms of WBGT, CET, MDI and P₄SR.

The environmental condition adjudged in terms of four indicators of thermal environmental status, WBGT, CET, MDI and P_4SR are presented in Figure 1.

In case of reaping task, the average values of WBGT index, during 'Aman' type of paddy cultivating time in S1, S2 and S3 working spells were 26.5°C, 31.5°C and 29.8°C respectively. Of these, S2 (31.5°C) and S3 (29.8°C) spells 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 could 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. In the S1 at average WBGT index value of 26.5°C, there is no restriction recommended against carrying out the task.

During the 'Boro' paddy cultivation, time with the average WBGT index in S1, S2 and S3 working spells were 28.4°C, 34.5°C and 32.2°C. Of these, S2 (34.5°C) and S3 (32.2°C), no work were ideally allowable. In the S1 working spell with the average WBGT value 28.4°C 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 could be allocated in work rest cycle (ACGIH, 2008; 2016) and for 'heavy' type of work, upto 50% time each hour, work can be allocated in work rest cycle.

The average values, during 'Aman' paddy cultivating time, Corrected Effective Temperature (CET), along the working spells were 27.6°C, 32.4°C and 30.0°C. In the S2, with CET value of 32.4°C, upto 'light' type of work is allowable. And in S1 (with average CET value of 27.6 °C) and S3 (with average CET value of 30.0°C) spells, upto 'moderate' category of work could be carried out. During 'Boro' type of paddy cultivating time, average values of CET in S1, S2 and S3 working spells were 28.5°C, 34.5°C and 32.2°C. Of these, in the S2 (with average CET value 34.5°C) no work was ideally allowable (WHO, 1969). In S3 working spell (with average CET value 32.2°C) upto 'moderate' category of work and in S1 working spell upto 'light' category of work is allowable as per recommendation of WHO (WHO, 1969).

During the 'Aman' type of paddy cultivating time with an average MDI value in S1, S2 and S3 working spells were 25.0°C, 32.0°C and 31.1°C. Of these, in S2 and in S3 heat load is considered 'severe', and human resources engaged in physical work are at increased risk for heat illness. In S1, the head load is considered 'mild' and individual can perform physical work with some difficulties. During 'Boro' type of paddy cultivating time the average DI values in S1, S2 and S3 working spells

were 28.5°C, 34.3°C and 31.1°C. During S1, S2 and S3 heat load is considered 'severe', and human resources engaged in physical work are at increased risk for heat illness (Epstein and Moran, 2006; Sohar et al., 1962). During the 'Aman' type of paddy cultivating time, in second spell, limit in terms of P_4SR for acclimatized human resources clearly exceeded and for the third spell, it approaches the limit (McArdle et al., 1947).

Similar trends of result were found during the 'Boro' type of paddy cultivating time in S2 and S3 spells. The finding of the present study in terms of environmental condition was in consonance with the findings of earlier studies carried out among male paddy cultivators in West Bengal (Chatterjee et al., 2016a; 2016b; 2015a; 2015b; 2015c). The environmental condition of the present study has been adjudged by four well known indices of thermal environmental condition – WBGT, CET, MDI and P_4SR ; however the values of these four indices are indicating similar environmental status. This is further affirmed by significant positive correlation among these indices [WBGT and CET ($P < 0.05$), WBGT and MDI ($P < 0.05$), WBGT and P_4SR ($P < 0.05$), CET and P_4SR ($P < 0.05$), CET and MDI ($P < 0.01$)]. From the result of the present study it has been clearly observed that the individuals working in the agricultural field would feel very hot and uncomfortable most of the day time, especially at around noon, i.e. during the second spell.

RG-A Individuals

In case of cardiac response profile in terms of HR_{peak} (beats.min⁻¹), it is found that in the paddy cultivators belonging to RG group, during the 'Aman' type of paddy cultivating time, the values varied from 100-110 beats.min⁻¹ in the first working spell i.e. in S1 working spell, whereas during the S2 and S3 it varied from 119-129 beats.min⁻¹ and 111-120 beats.min⁻¹ respectively. In terms of NCC, expressed in beats.min⁻¹, it is found that RG individuals during the 'Aman' type of paddy cultivation, the values varied from 30-39 beats.min⁻¹ in the first working spell i.e. in S1 working spell whereas during the S2 and 3 it varied from 39-49 beats.min⁻¹ and 35-44 beats.min⁻¹ respectively. It is found that the values of EEE varied from 2.96-3.07 kcal.min⁻¹ in the first working spell i.e. in S1 working spell, whereas during the S2 and S3, the magnitude of working environmental temperature and the workload may contribute additional threat to the human resources. It varied from 3.92-4.04 kcal.min⁻¹ and 3.50-3.60 kcal.min⁻¹ respectively. The values of CSI varied from 28-37, 41-50 and 33-42 in the S1, S2 and S3 spells respectively.

RG-B Individuals

In terms of HR_{peak} (beats.min⁻¹), it is found that in the paddy cultivators belonging to RG group, during the ‘Boro’ type of paddy cultivating time, the values varied from 115-125 beats.min⁻¹ in first working spell i.e. in S1 working spell, whereas during the S2 and S3 the value varied from 127-136 beats.min⁻¹ and 121-130 beats.min⁻¹ respectively. In terms of NCC, expressed in beats.min⁻¹, it is found that RG individuals during the ‘Boro’ type of paddy cultivation, it varied from 30-40 beats.min⁻¹ in the first working spell i.e. in S1 working spell whereas during the S2 and S3 it varied from 47-56 beats.min⁻¹ and 38-49 beats.min⁻¹ respectively. In terms of EEE, it is found that the values varied from 3.14-3.22 kcal.min⁻¹ in the first working spell, i.e. in S1 working spell, while during the S2 and S3, it varied from 4.73-4.84 kcal.min⁻¹ and 3.60-3.69 kcal.min⁻¹ respectively. The CSI values varied from 33-42, 48-58 and 39-48 in the S1, S2 and S3 working spell respectively. The variation in HR_{peak} , NCC, and EEE increases as the working environmental temperature increases and the working environmental condition

i.e. second spell of the working hours also adjudged as unfavourable as indicated from the observed values of different environmental heat indices. Significant differences also exist between indices of physiological strain according to the working spell.

High temperatures and humidity provide discomfort sensations and sometimes heat stress. Moreover, discomfort and heat stress affect the performance of the human resources and may lead to serious health problems. The impact on human function and health in work situation is ‘neglected’ effect of global climate change. The potential health risks and work performance reductions due to climate change are substantial; this is in tune with the finding of earlier study (Mukherjee, 2015).

Cardiac response status of the study participants in terms of indicators of physiological strain are presented in Figure 2.

The heaviness of the work carried out is assessed in terms of different indicators of physiological strain viz. HR_{peak} (beats.min⁻¹), NCC (beats.min⁻¹), and EEE (kcal.min⁻¹). For reaping task, during the ‘Aman’ type

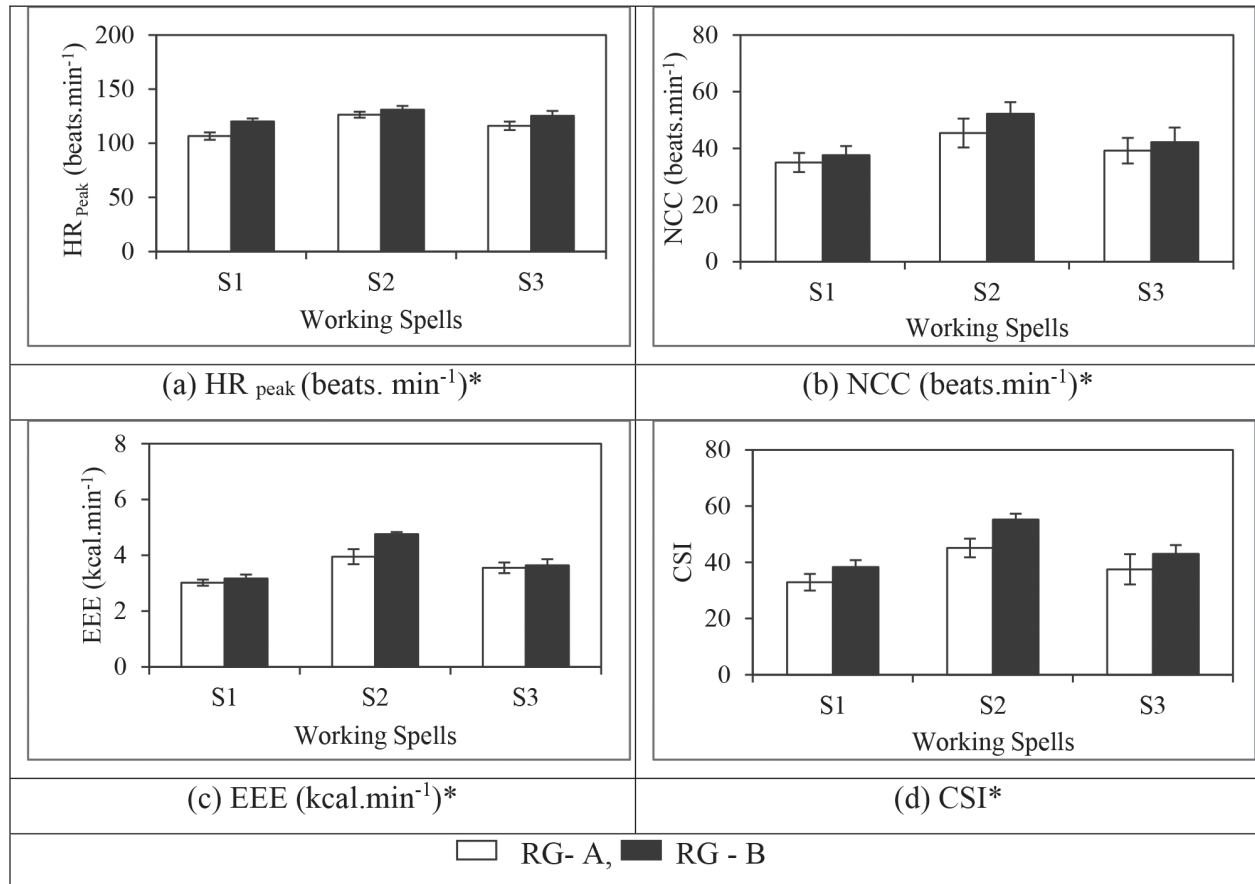


Figure 2: Cardiac response profile of the study participants in terms of HR_{peak} (beats.min⁻¹) (a), NCC (beats.min⁻¹) (b), EEE (kcal.min⁻¹) (c) and CSI (d).

of paddy cultivating time, the heaviness of workload in the S1 working spell has been adjudged as 'moderate' in terms of three indicators HR_{peak} , NCC and EEE. In the S2 working spell the workload has been adjudged as 'heavy', 'rather heavy' and 'moderate' in terms of HR_{peak} , NCC, and EEE. In S3 working spell the workload has been adjudged as 'heavy', 'moderate' and 'moderate' respectively in terms of three indicators HR_{peak} , NCC, and EEE.

During 'Boro' type of paddy cultivating time, 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 strains 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. A comparison has been made between present study and an earlier study; it was noted that the strain was much higher for agricultural workers than that of the car assembly workers and steel plant workers. Such variation of the CSI among different group of industrial workers might be due to difference in the degree of severity of job, environmental conditions and also duration of activity (Pari et al., 2012).

From the result of the present study, it was clearly observed that the individuals working in the agricultural field would feel very hot and uncomfortable most of the daytime, especially at around noon during S2 working spell during 'Boro' type of paddy cultivating time. The finding of the present study is in consonance with the finding of an earlier study conducted among the paddy cultivators occupationally engaged in threshing task during 'Aman' type of paddy cultivation (Chatterjee et al., 2018g, 2018h). This is further affirmed by the finding of the present study carried out during the 'Boro' type of paddy cultivation. From the present study it may be concluded that physiological strain was significantly higher in RG-B individuals compared to the RG-A individuals.

Conclusion

From the present study, it may be concluded that, the paddy cultivation is arduous and has health implications for the human resources. The thermal environmental conditions adjudged by the heat indices are not favourable, i.e. they are above the recommended

threshold values, making the task strenuous for the paddy cultivators. From the present study it may be also concluded that the physiological strain was significantly higher during 'Boro' type of paddy cultivation. With climate change due to global warming becoming a reality, agriculture being an open sky task, there is the need to modification of the work rest cycle to reduce the work stress factor. Added to this, motorized devices should be provided in order to reduce cardiac strain.

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