Assessment of cardiac response in paddy cultivators engaged in manual paddy transplanting task in Hooghly, West Bengal

Ayan Chatterjee1*, Neepa Banerjee1, Sandipan Chatterjee1 and Shankarashis Mukherjee1,2*

1HPAFU, Department of Physiology, University of Calcutta, Kolkata 700 009, India
2Public Health Analytics Unit, Department of Food and Nutrition, West Bengal State University, Kolkata 700 126, India

*Email: phauhpafu@gmail.com

ABSTRACT

During the different tasks in agriculture, which is one of the major occupations in India and also in the focal state of West Bengal, providing livelihood to a large number of our countrymen, the human resources are exposed to multiple environmental and occupational stressors that can contribute to adverse personal health outcomes. Moreover, in the agricultural work, workers often spend long hours under direct sun, in intense heat. In view of climate change becoming a reality due to global warming, and reports of adverse health consequences including performances getting affected in different occupational settings in different parts of world, a study has been undertaken. Thermal environmental condition was assessed in terms of Wet Bulb Globe Temperature (WBGT) Index, Corrected Effective Temperature (CET), Discomfort Index (DI) and Physiological Strain Index (PSI). To assess the effect of workplace heat exposure, workload and posture being adopted in their likely impact on performance, cardiac strain indicators like net cardiac cost (NCC), estimated energy expenditure (EEE) (kcal:min⁻¹), absolute cardiac cost (ACC) (beats:min⁻¹) and human physical drudgery index (HPDI) were estimated in male paddy cultivators involved primarily in manual straight row paddy transplanting task in southern parts of West Bengal. The result of the study indicated that human resources are indeed subjected to strains, albeit to different degree, as adjudged by the indicators of cardiac strain like Net Cardiac Cost (NCC), Estimated Energy Expenditure (EEE) (kcal:min⁻¹), Absolute Cardiac Cost (ACC) (beats:min⁻¹) and Human Physical Drudgery Index (HPDI), and thermal environmental condition was also assessed and found to be not conducive in terms of Wet Bulb Globe Temperature (WBGT) Index, Corrected Effective Temperature (CET), Discomfort Index (DI) and Physiological Strain Index (PSI).

KEYWORDS: Agriculture, WBGT, DI, PSI, cardiovascular strain

INTRODUCTION

Thermal comfort is that condition, which expresses satisfaction with the thermal environment. Alternatively, the zone of thermal comfort is the span of conditions where 80% of sedentary or slightly active persons find the environment thermally acceptable (Epstein and Moran, 2006). Whereas high temperatures and humidity provide discomfort sensations and sometimes heat stress. Therefore, the evaluation of the thermal sensation is often a crucial matter for outdoor working environments. Thermal sensation depends on the subject-environment heat transfer which is strictly related to subjective variables (metabolic rate and clothing thermo-physical properties) and four environmental variables (air temperature, mean radiant temperature, air velocity and relative humidity), according to the energy balance equation (Jendritzky et al., 2012). Since long, the temperature - humidity index (THI), and the wet bulb globe temperature (WBGT) were used for evaluating heat stress levels; and the predictive mean vote (PMV) was used for evaluating human thermal comfort.

Received 7 January 2020 | Accepted 20 March 2020 | Published online 31 March 2020


Acknowledgement

We are thankful to all the volunteers for their active participation in the study.

Copyright © Ayan Chatterjee, Neepa Banerjee, Sandipan Chatterjee & Shankarashis Mukherjee. 2020. NECEER, Imphal allows unrestricted use, reproduction, and distribution of this article in any medium by adequate credit to the author(s) and the source of publication.
Material and Methods

Present study was carried out on a group of human resources occupationally engaged in different agricultural tasks during the paddy cultivation. On obtaining individual consent and ethical clearance, the present study was carried out on 39 adult Bengalee males (age range 21-30 years), permanently residing in an and around village Badanganj, Block Goghat, District Hooghly (latitude 23°01'N to 22°39’N and longitude 88°30’E to 87°39’E) 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. The workers in the present study usually started their work around 6:00 a.m. and worked for about three hours in the first spell. Then, they are used to taking a break for breakfast for about half an hour and resume the work thereafter to continue in the second spell for about 3 – 3½ hours. Then they have a little longer break for about one and half to two hours to have bath, lunch and little rest, and usually start their third spell work at 3 p.m. to work for about 2 hours.

Recording of Basic Information

Information regarding their age (year), ethnicity, socio – economic status (SES) - assessed by using the Kuppuswamy’s socioeconomic scale (Ravikumar et al, 2013), working experience (year), and average working time (hr.day⁻¹) were recorded in a pre-designed schedule.

Assessment of Thermal Environmental Condition

Ambient temperature (T) (°C), wet bulb temperature (TWB) (°C), globe temperature (Tg) (°C) and natural wet bulb temperature (TNWB) (°C) were periodically noted during the working hours in the agriculture field. The values of wet bulb globe temperature (WBGT) (°C) (Dehghan et al, 2012), corrected effective temperature (CET) (°C) (Brake and Bates, 2002), discomfort index (DI) (ºC) (Epstein and Moran, 2006) and physiological strain index (PSI) (Moran and Pandolf, 1998) were found out.

Assessment of Physical and Physiological Parameters

Stature (cm) and body weight (BW) (kg) were measured using anthropometric measurement set and pre calibrated weighing scale respectively. Body mass index (BMI) and body surface area (m²) were calculated from the measured stature (cm) and body weight (kg) data. Somatotyping characteristics of the study participants were calculated (Carter and Heath, 1990). The pre work heart rate (HRPRE-work) (beats. min⁻¹), systolic and diastolic blood pressure (SBP, DBP) (mm Hg) were recorded using automated blood pressure monitor and/or sphygmomanometer in the morning hours before the individuals started working.

Assessment of Indicators of Physiological Strain

Physiological strain indicators - peak heart rate (HRpeak) (beats.min⁻¹) (Astrand and Rodhal, 1986), net cardiac cost (NCC) (beats.min⁻¹) (Chamoux et al, 1985), estimated energy expenditure (EE) (kcal.min⁻¹) (Ramanathan et al, 1967), absolute cardiac cost (ACC) (beats.min⁻¹) (Pancardo et al, 2015) and human physical drudgery index (HPDI) (Joshi et al, 2015) scores were found out, from the heart rates of the study participants recorded periodically during the work along the spells using heart rate monitor. The ‘heaviness’ of work was adjudged in terms of – peak Heart Rate (HRpeak) (beats.min⁻¹), Net Cardiac Cost (NCC) (beats.min⁻¹), estimated energy expenditure (EE) (kcal.min⁻¹), and ACC (beats.min⁻¹).

Postural Assessment

Different working postures adopted by the agricultural workers during the manual straight row transplanting task were analyzed

(Ghany et al, 2014; Heidari et al, 2015). The Physiological Effective Temperature (PET) and the Universal Thermal Climatic Index (UTCI) were used for evaluating thermal comfort and heat stress as well; both being in the temperature scale. PET, a thermal index that gives an estimation of the thermal sensation, the corresponding heat stress level and the Standard Effective Temperature (SET) index describes the relationship between thermal sensation and discomfort (Mohan et al, 2014; Banerjee et al, 2014). Earlier studies reported that, increase in local ET) and the Universal Thermal Climatic e years and ⁰ ± (Brake and Bates, 2002), discomfort index (ºC) (Epstein and Moran, 2006) and physiological strain index (PSI) (Moran and Pandolf, 1998) were found out.

Assessment of Physical and Physiological Parameters

Stature (cm) and body weight (BW) (kg) were measured using anthropometric measurement set and pre calibrated weighing scale respectively. Body mass index (BMI) and body surface area (m²) were calculated from the measured stature (cm) and body weight (kg) data. Somatotyping characteristics of the study participants were calculated (Carter and Heath, 1990). The pre work heart rate (HRPRE-work) (beats. min⁻¹), systolic and diastolic blood pressure (SBP, DBP) (mm Hg) were recorded using automated blood pressure monitor and/or sphygmomanometer in the morning hours before the individuals started working.

Assessment of Indicators of Physiological Strain

Physiological strain indicators - peak heart rate (HRpeak) (beats.min⁻¹) (Astrand and Rodhal, 1986), net cardiac cost (NCC) (beats.min⁻¹) (Chamoux et al, 1985), estimated energy expenditure (EE) (kcal.min⁻¹) (Ramanathan et al, 1967), absolute cardiac cost (ACC) (beats.min⁻¹) (Pancardo et al, 2015) and human physical drudgery index (HPDI) (Joshi et al, 2015) scores were found out, from the heart rates of the study participants recorded periodically during the work along the spells using heart rate monitor. The ‘heaviness’ of work was adjudged in terms of – peak Heart Rate (HRpeak) (beats.min⁻¹), Net Cardiac Cost (NCC) (beats.min⁻¹), estimated energy expenditure (EE) (kcal.min⁻¹), and ACC (beats.min⁻¹).

Postural Assessment

Different working postures adopted by the agricultural workers during the manual straight row transplanting task were analyzed

(Ghany et al, 2014; Heidari et al, 2015). The Physiological Effective Temperature (PET) and the Universal Thermal Climatic Index (UTCI) were used for evaluating thermal comfort and heat stress as well; both being in the temperature scale. PET, a thermal index that gives an estimation of the thermal sensation, the corresponding heat stress level and the Standard Effective Temperature (SET) index describes the relationship between thermal sensation and discomfort (Mohan et al, 2014; Banerjee et al, 2014). Earlier studies reported that, increase in local ET) and the Universal Thermal Climatic index (ºC) (Brake and Bates, 2002), discomfort index (ºC) (Epstein and Moran, 2006) and physiological strain index (PSI) (Moran and Pandolf, 1998) were found out.
with the rapid upper limb assessment (RULA) (McAtamney and Corlett, 1993) and rapid entire body assessment (REBA) (Hignett and McAtamney, 2000) methods.

Data and Statistical Analysis

Data were collected during the period of June to middle of July. The environmental and cardiovascular response data were collected at regular intervals during [6am - 9am], [9.30am - 1.00 pm] and [3pm - 5pm] respectively referred to as first (S1), second spell (S2) and third spell (S3). Obtained data were analyzed and presented graphically. 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

Basic characteristics including age (year), ethnicity, SES, working experience (year), average working time (hr.day) of the study participants are presented in Table 1. In the present study all the individuals were from Bengalee population and lower middle class as per SES status.

### Table 1. Basic profile of the study participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>25.2 ± 4.15</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Bengalee</td>
</tr>
<tr>
<td>SES</td>
<td>Lower middle</td>
</tr>
<tr>
<td>Working experience (year)</td>
<td>7.3 ± 1.15</td>
</tr>
<tr>
<td>Working time (hr.day)</td>
<td>6.8 ± 1.03</td>
</tr>
</tbody>
</table>

Heat index integrates personal, physiological, and thermal environment parameters into a single number for a “quantitative” assessment of the magnitude of exposure to heat. In the present study the thermal environmental conditions were assessed in terms of WBGT (°C), CET (°C), DI (°C) and PSI. And the thermal environmental status has been presented in terms of - WBGT (°C) (a), CET (°C) (b), DI (°C) (c) and PSI (d) are presented in Figure 1.

### Table 2. Physical and physiological profile of the study participants.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stature (cm)</td>
<td>159.5 ±5.16</td>
</tr>
<tr>
<td>BW (kg)</td>
<td>55.2 ± 5.11</td>
</tr>
<tr>
<td>BMI</td>
<td>21.1 ± 1.15</td>
</tr>
<tr>
<td>BSA (m²)</td>
<td>1.60 ± 0.071</td>
</tr>
<tr>
<td>Somatotyping Characteristics</td>
<td>Ectomorphic Mesomorph</td>
</tr>
<tr>
<td>HR_{Pre-work} (beats.min⁻¹)</td>
<td>71 ± 5.4</td>
</tr>
<tr>
<td>SBP_{Pre-work} (mm Hg)</td>
<td>119 ± 5.2</td>
</tr>
<tr>
<td>DBP_{Pre-work} (mm Hg)</td>
<td>80 ± 6.1</td>
</tr>
</tbody>
</table>

AM ± SD

The physical and physiological profile in terms of – stature (cm), BW (kg), BMI, BSA (m²), somatotyping characteristics, HR_{Pre-work}, SBP_{Pre-work} and DBP_{Pre-work} of the study participants are presented in Table 2.

### Figure 1. Comparison of Indicators of Thermal Environmental Status along the Working Spells; S1, S2, and S3

a) Comparison of WBGT (°C) Values along Spells

b) Comparison of CET (°C) Values along Spells

c) Comparison of DI (°C) Values along Spells

d) Comparison of PSI Values along Spells
In Figure 2, the cardiac response profile in terms of HR$_{peak}$ (beats. min$^{-1}$) (a), NCC (beats. min$^{-1}$) (b), EEE (kcal. min$^{-1}$) (c), ACC (beats. min$^{-1}$) (d), HPDI Score (e) of the study participants has been presented.

**Study on Workload**

In the present study the workload was assessed throughout the working spell by using the four indices of the physiological strain i.e. HR$_{peak}$, NCC, EEE and ACC.

Assessment of working posture during the straight row manual paddy transplanting task was assessed by using RULA and REBA postural assessment method. The postural score of different tasks during paddy cultivation time has been presented in Table 3.

**Discussion**

Agriculture being an open air occupation, the agricultural workers have to perform varieties of agricultural tasks like ploughing, transplanting, reaping, threshing and parboiling throughout the year during the paddy cultivating time, in most cases without help of mechanized devices. Moreover, in terms of Heart Rate recorded for the study participants, it can be mentioned that the participants are not having either bradycardia or tachycardia. In terms of BMI, the participants were in ‘normal weight’ category as per the classification given by WHO (WHO, 2000), which is not surprising as the individuals participating in the study were

<table>
<thead>
<tr>
<th>Posture Adopted by Agricultural Workers</th>
<th>RULA Score</th>
<th>REBA Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taking the bundle of seedlings and untying it.</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Making the bundle into two halves and gripping one half in one hand.</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Taking few seedlings by the right hand and planting them into soil. Left hand remained on the left thigh near the folded knee.</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>


In Figure 2, the cardiac response profile in terms of HR$_{peak}$ (beats. min$^{-1}$) (a), NCC (beats. min$^{-1}$) (b), EEE (kcal. min$^{-1}$) (c), ACC (beats. min$^{-1}$) (d), HPDI Score (e) of the study participants has been presented.
carrying out physical activities regularly; several previous studies demonstrated that, taking part regularly even in recreational physical activity in a planned and systematic manner reduced the chances of becoming overweight (Banerjee et al., 2015a; 2015b; Mukherjee et al., 2014a; 2014b; Mukherjee et al., 2013) and favorable somatotyping characteristic (Chatterjee et al., 2015d). Higher values of BMI have also been found to be associated with more chance of work related musculoskeletal disorder among sedentary workers (Chatterjee et al., 2015d; 2014). In terms of somatotyping characteristics, the individuals are found to belong to ectomorph-mesomorph category; this finding was in consonance with the finding of an earlier study among the human resources occupationally engaged in different agricultural task during ‘Aman’ type of paddy cultivation (Chatterjee et al., 2015e).

Adverse working conditions prevailing in the working environment restrict human resources to demonstrate their capabilities and attain full potential; to obtain the optimum work performance the assessment of working environmental condition is an essential factor. In terms of the thermal working environmental condition, the time weighted average values of WBGT index, one of the popular indicators of thermal environmental condition, along the spells were 28.5°C, 33.5°C and 31.9°C (Fig.1, a). In the present study the average CET value in along the spells were 26.0°C, 31.5°C and 29.0°C respectively (Fig.1, b). Another heat index, physiological strain index, adequately depicts the combined strain reflected by the cardiovascular and thermoregulatory systems. It has been found that during the first spell of the working hours, the calculated PSI value was 2.8 and hence, there is no restriction for carrying out any work. During the second and third spells of the working hours, the calculated PSI values were 4.1 and 3.3 respectively (Fig.1.d), i.e. during the second and third spells, no work is ideally allowable (ACGIH, 2008; WHO, 1969; Sohar et al., 1962). The environmental condition of the present study has been adjudged by four well known indicators of thermal environmental condition - WBGT, CET, DI and PSI; 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 DI (P < 0.05), WBGT and PSI (P<0.05), CET and PSI (P<0.05), CET and DI (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. The findings of the present study regarding the thermal working environmental condition was in consonance with the findings of the earlier studies in which human resources were engaged in different agricultural tasks during the paddy cultivation (Chatterjee et al., 2016a; 2016b).

Human activity depending primarily on the natural conditions, mainly temperature and rainfall involves various manual works like cultivating the soil, producing crops.Transplanting of paddy seedlings is mainly carried out during the months of June July i.e. in the beginning of the rainy season. During the transplanting of paddy seedlings task physiological strain of the male paddy cultivators have been assessed is assessed in terms of HR_{peak} (beats.min^{-1}), EEE (kcal.min^{-1}), NCC (beats.min^{-1}) and ACC (beats.min^{-1}). HR_{peak} (beats.min ) during work. It has been observed from the present study that in the first, second and third spells of the working hours the average values of HR_{peak}, one of the most important indicators of physiological strain, varied from 105-112 beats.min^{-1}, 122-125 and 115-118 beats.min^{-1} respectively (Fig.2, a). The findings of the present study in agreement with findings of earlier studies conducted on agriculture workers engaged in paddy cultivation (Chatterjee et al., 2020, 2019a). NCC (beats.min^{-1}) is found to vary from37-40 beats.min in first spell whereas at second and third spell it varied from 54-61 beats.min^{-1} and 45-52 beats.min^{-1} respectively (Fig.2, b). EEE is varied from 3.67-3.88 kcal.min^{-1}, 4.87-5.45 kcal.min and 4.55-4.67 kcal.min^{-1} in the first, second and third spell of the working hours respectively and second spell of the working hours (Fig. 2, c). The ACC (beats.min^{-1}) is found to vary in the first, second 38-42 beats.min^{-1}, whereas in the second and third spell of the working hours the ACC (beats.min^{-1}) is varied from 48-52 beats.min and 45-48 beats.min^{-1} respectively (Fig. 2, d). HPDI values are varied from 65-70, 75-80, and 70-75 in first second and third spell of the working hours (Fig. 2, e). This finding was in consonance with the finding of an earlier study conducted among the agricultural workers (Jena and Mohanty, 2014).

The workload was categorized by using the four indices of physiological strain i.e. HR_{peak}, NCC, EEE and ACC. In the first spell, the transplanting task is ‘moderate’, as assessed by three indicators of physiological strain, i.e., HR_{peak}, NCC and EEE, whereas the work is categorized as ‘moderate’ in terms of another indicator of physiological strain, ACC. In the second spell, the transplanting task has been considered as ‘heavy’, in terms of all four indicators of physiological strain, i.e., HR_{peak}, NCC, EEE and ACC. Where as in the last spell of the working hours i.e. in the third spell, the transplanting task has been considered as ‘heavy’, in terms of HR_{peak}, EEE and ACC; whereas ‘rather heavy’ (between ‘moderate’ and ‘heavy’) in terms NCC. Similar trends of results have been observed in the earlier studies among the agricultural workers engaged in different tasks during ‘Aman’ type paddy cultivation (Chatterjee et al., 2017a; 2017b). From the present study, it may be concluded that, the agricultural work – paddy cultivation is strenuous and has health implications for the human resources; moreover the manual transplanting task is strenuous, 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 transplanting task during the ‘Aman’ type of paddy is cultivating time. This finding also in tune with the earlier studies carried out among male agricultural workers in West Bengal (Chatterjee et al., 2018a; 2018b; 2019a; 2019b; 2019c; 2018c; 2018d; 2018e; 2019d).

Manual straight row paddy transplanting task performed by the agricultural workers were analyzed with the RULA and REBA to determine the postural strain and to categorize the potential harmfulness of the work posture. The posture scores of RULA and REBA indicate that, postures in different phases of transplanting
tasks, demand immediate attention. Thus it is clear that the agricultural workers adopt awkward postures at work and suffer from musculoskeletal disorders because they remain in such awkward postures for a prolonged period of time. The findings of the present study regarding the assessment of work posture in agreement with the findings of some previous studies (Ojha and Kwatra, 2014; Kar et al., 2012). The strenuous posture is one of the major problems in rice cultivation jobs. Moreover, transplanting of paddy seedlings is the most repetitive type long duration manual work performed in awkward bending posture under muddy and slippery workplace (Osborne et al., 2012). It is also observed from the result of the present study that, individuals experienced different degree of physiological strain. From the result of the present study, it may be observed that human resources engaged in manual straight row paddy transplanting task experience ‘moderate’ to ‘heavy’ category of workload in terms of indicators of physiological strain in the second spell of work that is at around noon with the sun is overhead, the ray path through the atmosphere being the shortest; continuation of the work in such adverse environmental condition may force the human resources for early termination of the work, resulting in decrease in work output. In the light of the observations presented, it may be mentioned that agriculture particularly being an open air work is strenuous, as adjudged in terms of so many indicators of physiological strain like HRpeak (beat.min⁻¹), NCC (beat.min⁻¹), EEE (kcal.min⁻¹), ACC (beat.min⁻¹), and the degree of difficulty is rising with adverse impacts due climate change caused among other by global warming being on the rise.

**Conclusion**

From the present study, it may be concluded that agricultural work in the of paddy cultivation (‘Aman’ type) is found to be strenuous, possibly due to the prevailing the environmental conditions existing in different spells along the day, the demand of the work, and posture that had to be adopted for carrying out the work in the manual straight row paddy transplanting as adjudged by the different indicators of the physiological strain. 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. Modification of work rest cycle including early starting and/or provision of motorized devices may be attempted in order to reduce the strain.

**References**

ACGIH, 2008. Threshold Limit Values and Biological Exposure Indices, Cincinnati, Ohio.


Chatterjee, A., Chatterjee, S., Banerjee, N., Santra, T., Chatterjee, S. & Mukherjee, S. 2018c. Assessment of Thermal Working Environmental Condition and Cardiac Response Indicators in...


Mukherjee, S., Banerjee, N., Chatterjee, S. & Chatterjee, S. 2014a. Effect of Practicing Select Indian Classical Dance Forms on Body Composition Status of Bengalee Females an


