ASSESSMENT OF PHYSIOLOGICAL STRAIN IN MALE FOOD CROP CULTIVATORS ENGAGED IN MANUAL THRESHING TASK IN A SOUTHERN DISTRICT OF WEST BENGAL

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Original scientific paper
Received: February 16th, 2020
Accepted: March 25th, 2020
HAE-1938
https://doi.org/10.33765/thate.10.4.2

ABSTRACT

The impact of rise in ambient temperature is not confined to output; it has an impact on the work performance of human beings associated with occupational activities in informal sector, especially those carried out in the open field under the sky. The agricultural workers are constrained to work manually all through the day irrespective of disparity in working situation existing in the working environment. Hence, there is an urgent need to study the cardiac performance status in terms of indicators of physiological strain of the human resources. In this backdrop, the present study has been undertaken to assess the degree of physiological strain in male food crop cultivators' (age range 24 - 36 years) engaged in manual threshing (separating the grains from the rice straw by manually - by hand i.e. beating method) during paddy cultivation time. Moreover the magnitude of physiological strain was significantly higher ($P < 0.5$) during "Boro" type of paddy cultivating time. The result of the study indicated that human resources are indeed subjected to strains, albeit to different degree, as adjudged by the indicators of physiological strain.

Keywords: *agriculture, wet bulb globe temperature (WBGT), heart rate, cardiovascular strain, workload*

INTRODUCTION

The agriculture sector plays a pivotal role for sustainable growth and development of the Indian economy. Besides that, agriculture sector employs nearly half of the workforce of the country. Agriculture being an open air task, the agricultural workers has to perform different tasks throughout the year even in a single day, irrespective of variation in the thermal working environmental condition, including the disparity of thermal environmental status [1, 2]. Rice (*Oryza sativa* L.) is a plant belonging to the family of

grasses, Gramineae. It is one of the major food crops of the world and forms the staple diet of about half of the world's population. The global production of rice has been estimated to be at the level of 650 million tonnes. Asia is the leader in rice production accounting for about 90 % of the world's production. Among the Asian countries, India has a long history of rice cultivation [3 - 5]. Globally, it stands first in rice area and second in rice production. Paddy is grown all most all the states in India. Paddy cultivation involves ploughing, transplanting, reaping, threshing and parboiling. Most of the tasks in paddy cultivation is seasonal, and during summer harvest, workers often spend long hours under direct sun, in intense heat, performing arduous physical labour [4, 5]. And the earlier studies reported that physical work capacity and work-performance are getting affected due to unfavourable thermal conditions prevailing in the working environment in different occupations including agriculture [6]. The risks of excessive heat exposure are greater in tropical developing countries where large work forces perform manual and heavy tasks for long periods under very hot and humid conditions with minimal access to cooling intervention; India, being a tropical country is no exception to it. Additionally, it has also been reported 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. Hence, an increase in ambient temperature, a major determinant of thermal aspect of working environment, may have some impact on the occupational health profile on the individuals working in the open - air non-mechanized agricultural field daily for a considerable period of time. Therefore, different tasks performed by agricultural workers not only demand considerable time and energy but also sources of drudgery for the agricultural workers [3, 5, 6]. In this backdrop the present study has been undertaken to assess the cardiac response status in terms of indices of physiological strain in male food crop cultivators' while engaged in manual (beating the panicles on a hard or wooden surface) threshing task during "Aman" (the winter or monsoon paddy, known as "Aman", is grown from June to December) and "Boro" (the sowing time of summer paddy of "Boro" paddy is November to February and harvesting time is March to April) type of paddy cultivation time.

EXPERIMENTAL

Study area: Human resources engaged in paddy cultivating task in Arambagh subdivision in the district of Hooghly were approached for the present study, the protocol of which was approved by the Institutional human ethical committee.

Study population, inclusion and exclusion criteria: 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. The individuals who were carrying out manual threshing task during "Aman" (i.e. during October - middle of November) and "Boro" (i.e. during March - middle of April) type of paddy cultivation was considered for participation in the study. Data were obtained from 36 adult male paddy cultivators (age range of 24 - 36 years) while they were taking part in manual threshing task during "Aman" type of paddy cultivation; it constituted the threshing group A (TG-A). Data were again collected from 33 male individuals while they were taking part in manual threshing task during "Boro" type of paddy cultivation; it constituted the threshing group B (TG-B).

Recording of basic information: Information regarding their age (year), socio – economic status (SES) - assessed by using the Kuppuswamy's socioeconomic scale [7], and average working experience (year) were recorded in a pre-designed schedule.

Assessment of thermal environmental condition: Ambient temperature (T_a) (ºC), wet

bulb temperature (T_{WB}) (ºC), globe temperature (T_g) (ºC) and natural wet bulb temperature (T_{nwb}) (ºC) were noted during the working hours in the agriculture field. The values of wet bulb globe temperature (WBGT) (ºC), corrected effective temperature (CET) (ºC), discomfort index (DI) (ºC) and predicted four hour sweat rate (P_4SR) (lit) were determined.

Assessment of physical and physiological parameters: Anthropometric measurements – stature (cm) and body weight (kg) were measured using anthropometric measurement set and a pre calibrated weighing scale respectively. Body mass index (BMI) was calculated. The heart rate $_{pre-\ work}$ ($HR_{Pre-work}$) (beats.min^{-1}), pre - work systolic ($SBP_{Pre-work}$) and diastolic ($DBP_{Pre-work}$) blood pressure (mm Hg) was recorded using automated blood pressure monitor and/or sphygmomanometer in the morning hours before the individuals started working.

Assessment of indicators of cardiac strain: Cardiac strain indicators in terms of peak heart rate (HR_{peak}) [8], net cardiac cost (NCC) (beats.min^{-1}) [9], estimated energy expenditure (EEE) (kcal.min^{-1}) [10], and cardio vascular strain index (CSI) [11] were determined.

Assessment of heaviness of workload: The "heaviness" of work has also been adjudged in terms of HR_{peak}, NCC, and EEE. The environmental and cardiac response data were collected at regular intervals during morning (6.15 - 9.00 am), around noon (10.00 am - 1 pm) and afternoon hours (3.00 - 5.00 pm) respectively referred to as first, second and third spell (S1, S2 and S3).

Data and statistical analysis: Data have been presented in AM ± SD form. Obtained data were analysed and presented graphically. Analysis of variance (ANOVA) was performed. As the thermal environmental conditions were assessed in terms of several indices, the correlations between them were found out. P value lower than 0.05 ($P < 0.05$) was considered significant.

RESULTS AND DISCUSSION

General characteristics of both groups are presented in Table 1. There is no significant difference in respect of age (years), SES, and working experience (year).

Table 1. General characteristics of study participants

Variables	TG-A	TG-B
Age (years)^	26.8 ± 2.12	27.0 ± 2.61
SES^	Lower Middle	Lower Middle
Working experience (year)^	7.8 ± 0.89	7.7 ± 0.68

AM ± SD, ^ns

The physical and physiological variables of the study participants are presented in Table 2. TG-A and TG-B individuals do not differ significantly in terms of their stature (cm), body weight (BW) (kg), BMI (kg.m^{-2}), $HR_{Pre-work}$ (beats.min^{-1}), $SBP_{Pre-work}$ (mm Hg), and $DBP_{Pre-work}$ (mm Hg).

Table 2. Physical and physiological characteristics of the study participants

Variables	TG-A	TG-B
Stature (cm)^	163.0 ± 4.11	162.2 ± 2.85
BW (kg)^	54.8 ± 5.17	55.2 ± 5.05
BMI (kg.m^{-2})^	20.5 ± 1.17	21.0 ± 4.02
$HR_{Pre-work}$ (beats.min^{-1})^	69.0 ±5.19	70.4 ± 4.17
$SBP_{Pre-work}$ (mm Hg)^	118.0 ± 5.19	117.4 ± 5.11
$DBP_{Pre-work}$ (mm Hg)^	72.0 ± 7.01	71.7 ± 6.11

AM ± SD, ^ns

The mean values of BMI of TG-A and TG-B individuals are 20.5 kg.m^{-2} and 21.0 kg.m^{-2}; which indicated that, the participants were in "normal weight" category as per the classification given by World Health Organization (WHO) [12]. This finding is not surprising as the human resources participating in the present study were carrying out manual threshing tasks during paddy cultivation time, as earlier studies observed that, individuals taking part regularly even in different form of

recreational physical activity in a planned and systematic way have beneficial role in achieving favourable body composition, enhancing fitness and hence facilitate maintaining a normal BMI [13 - 16]. Higher values of BMI have also been found to be associated with more chance of work related musculoskeletal disorder among sedentary workers [17, 18].

The environmental condition in terms of three indicators of thermal environmental status - WBGT, CET, DI and P_4SR are presented in Figure 1.

In case of TG-A individuals, the average values of WBGT index, during "Aman" type of paddy cultivating time in S1, S2 and S3 working spells were 19.0 °C, 22.2 °C, and 20.0 °C respectively. There was no restriction recommended against carrying out the task. In case of TG-B individuals i.e. during "Boro" paddy cultivating time the average WBGT values in S1, S2 and S3 working spells were 27.1 °C, 35.6 °C, and 34.4 °C respectively; ideally, no work would be allowed under conditions recorded during S2 and S3 as per American Conference of Governmental Industrial Hygienists (ACGIH) guideline [19]. Whereas in the S1 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, up to 75 % time each hour, work can be allocated in work rest cycle and for "heavy" type of work, up to 50 % time each hour, work could be allocated in work rest cycle [20]. The average values, during "Aman" paddy cultivating time, of corrected effective temperature (CET), along the spells were 17.3 °C, 20.4 °C, and 19.3 °C. There is no restriction for carrying out the task along the working spells i.e. in S1, S2, and S3 working spells. During "Boro" type of paddy cultivating time, average values of CET in S1, S2, and S3 working spells were 28.2 °C, 32.1 °C, and 31.1 °C respectively, out of which in the S2 (with average CET value 32.1 °C) no work would ideally be allowed. In S3 (with average CET value 31.1 °C), up to "light" category of work could be allowable [21, 22]. During the "Aman" type of paddy cultivating time with an average DI values in S1, S2, and S3 working spells were 19.5 °C, 23.7 °C, and 21.0 °C.

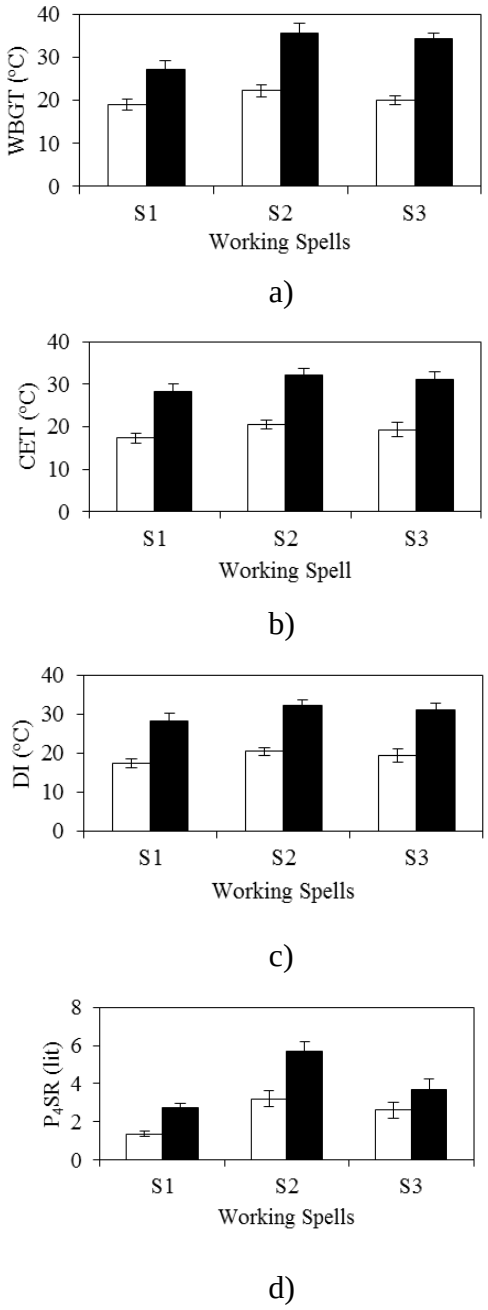

Figure 1. Thermal environmental status along the working spells: a) WBGT, b) CET, c) DI, d) P_4SR (□ TG-A, ■ TG-B)

There was also no restriction of carrying out the task throughout the working spell. During "Boro" type of paddy cultivating time the average DI values in S1, S2 and S3 were 26.0 °C, 31.5 °C and 30.5 °C. During S2 and S3, heat load is considered "severe", and human resources engaged in physical work are at

increased risk for heat illness. In S1 working spell with average DI values of 26.0 °C, the heat load is considered "moderate" and individuals can perform the physical work some difficulties [23, 24]. During the "Boro" paddy cultivating time the limit in the S2 and S3 working spell in terms of P_4SR for acclimatized human resources is clearly exceeded [25]. The environmental condition of the present study has been adjudged by four well known indicators of thermal environmental condition - WBGT, CET, DI 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 DI ($P < 0.05$), WBGT and P_4SR ($P < 0.05$), CET and P_4SR ($P < 0.05$), 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. Moreover, the global climate change is increasing and average temperatures are becoming more extreme. This is of great significance in various locations of India which already remain hot in most months of the year; this also directly affects the occupational health status and the work output of the human resources engaged in different type of outdoor occupational task. With continuation of work for long time in such adverse environmental condition, especially during the "Aman" and "Boro" type of paddy cultivation, and particularly during the second and third spell of the working hours, there is a risk of different degrees of physiological strain among the study participants.

Cardiac response profile of the study participants adjudged by using strain indicators, i.e. by using HR_{Peak} (beats.min^{-1}), NCC, EEE and CSI. The results of the physiological strain in terms of HR_{peak}, NCC, EEE and CSI for the TG-A and TG-B individuals have been presented in Figure 2.

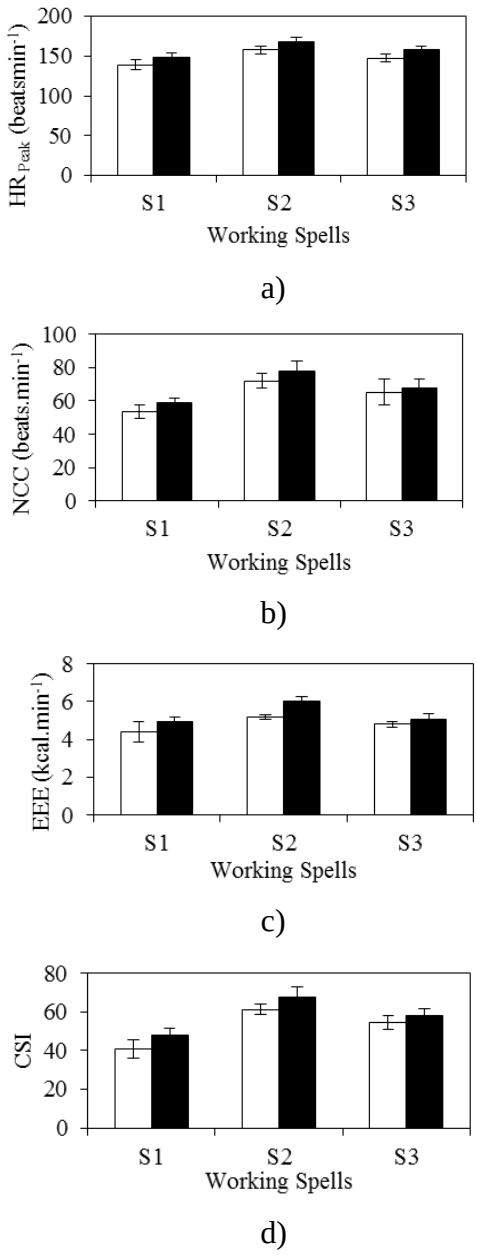

Figure 2. Comparison of cardiac response status in terms of different indicators of physiological strain along working spells: a) HR_{Peak}, b) NCC, c) EEE, d) CSI (□ TG-A, ■ TG-B)

In case TG-A individuals, in terms of HR_{Peak} (beats.min^{-1}), it is found that in the paddy cultivators during the "Aman" type of paddy cultivating time, the values varied from 135 - 144 beats.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 153 - 162 beats.min^{-1}, 143 - 152 beats.min^{-1} respectively. In terms of NCC, expressed in beats.min^{-1}, it is found that during the "Aman" type of paddy cultivation, the values varied from 49 to 58 beats.min^{-1} in

the first working spell, i.e. in S1 working spell whereas during the S2 and S3 it varied from 65 to 78 beats.min^{-1} and 61 - 69 beats.min^{-1} respectively. In terms of EEE, expressed in kcal.min^{-1}, it is found that the values of EEE varied from 4.35 to 4.43 kcal.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 5.15 to 5.25 kcal.min^{-1} and 4.78 to 4.86 kcal.min^{-1} respectively. CSI value varied from 38 - 47, 57 - 66 and 50 - 59 in the S1, S2 and S3 respectively.

In case of TG-B individuals, in terms of HR_{Peak} (beats.min^{-1}), it is found that in the paddy cultivators during the "Boro" type of paddy cultivating time, the values varied from 144 to 153 beats.min^{-1} in the first working spell, i.e. in S1 working spell, whereas during the S2 and S3 it varied from 163 - 172 beats.min^{-1} and 152 - 161 beats.min^{-1} respectively. In terms of NCC, expressed in beats.min^{-1}, it is found that, during the "Boro" type of paddy cultivation, the values varied from 54 to 63 beats.min^{-1} in the first working spell, i.e. in S1 working spell whereas during the S2 and S3 it varied from 74 - 81 beats.min^{-1}, 63 - 71 beats.min^{-1} respectively. In terms of EEE, expressed in kcal.min^{-1}, it is found that the values of EEE varied from 4.90 to 5.02 kcal.min^{-1} in the first working spell, i.e. in S1 spell, whereas during the S2 and S3 it varied from 5.97 to 6.06 kcal.min^{-1} and 4.91 - 5.02 kcal.min^{-1} respectively. The CSI value varied from 37 to 47, 57 – 66, and 50 - 60 in the S1, S2 and S3 spell respectively.

In terms of workload for TG-A individuals, i.e. during the "Aman" type of paddy cultivating time, the heaviness of workload in the S1 working spell has been adjudged as "very heavy", "heavy" and "heavy" respectively in terms of three indicators HR_{peak}, NCC, and EEE. In the S2 working spell, the workload has been adjudged as "extremely heavy", "heavy" and "heavy" in terms of HR_{peak}, NCC, and EEE. In S3 working spell the workload has been adjudged as "very heavy", "heavy" and "heavy" respectively in terms of three indicators HR_{peak}, NCC, and EEE.

In case of TG-B individuals i.e. during "Boro" type of paddy cultivating time, the heaviness of workload has been adjudged as "very heavy", "heavy", and "heavy" respectively in terms of three indicators HR_{peak}, NCC, and EEE. In the S2 working spell the workload has been adjudged as "extremely heavy", "heavy" and "very 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 "extremely heavy", "heavy" and "heavy" respectively in terms of HR_{peak}, NCC, and EEE. The finding of the present study was in consonance with the finding of an earlier study carried out among male paddy cultivators in Maharashtra [26]. It was observed that the human resources experienced highest degree i.e. "extremely heavy" degree of physiological strain while engaged in manual paddy threshing task compared with the other task during paddy cultivation period - ploughing (dry and wet ploughing) [1, 2, 27 - 30], transplanting (manual) [2, 3, 31, 32], threshing (by mechanized thresher and electrically driven paddy thresher) [4, 6, 33, 34] and reaping (manual) [35 - 37] parboiling [5]. Moreover, manual threshing during "Boro" type of paddy cultivation is more strenuous task compared to the others tasks during the paddy cultivating time in terms of the physiological strain. 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 HR_{Peak} (beats.min^{-1}), NCC (beats.min^{-1}), EEE (kcal.min^{-1}), and CSI, the degree of difficulty is rising with adverse impacts due climate change caused among other by global warming being on the rise. The strain has been found to be more in TG-A individuals, compared to the TG-B counterparts. Moreover, the workers were ignorant about the balance between work ability and job demand which could be attributed to the lack of awareness on health and safety issues. Moreover, the socioeconomic status compelled the workers to be least concerned for their health and working situation.

CONCLUSION

From the present study it may be concluded that the agricultural work - paddy cultivation – is a strenuous task. Moreover, the thermal environmental conditions adjudged by the heat indices are not favourable, i.e. they are above the recommended threshold values, making the task laborious for the human resources. It may be also mentioned that physiological strain was significantly higher in threshing - B (TG-B) individuals, i.e. during "Boro" type of paddy cultivating time compared to their age matched threshing - A (TG-A) counterpart. Since agriculture is an open sky occupation and manual threshing is one of the strenuous tasks in paddy cultivation, there is a need for simultaneous attempt to use more human factor designed devices than absolutely being dependent on manual effort.

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Acknowledgements

We are thankful to all volunteers for their participation.