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Assessment of Physiological Strain in Male Cultivators Engaged in Mechanized Paddy Threshing Task Using Two Different Types of Threshers

Abstract **: Agriculture in India is a vital sector as it not only takes care about the nutritional requirement of more than 1.2 billion strong populations but also provides millions with earning opportunity. In the wake of climate change, both agricultural produce output and the performance of the human resources associated with agriculture are estimated to suffer. In this backdrop, a study has been undertaken to assess the physiological strain mainly in terms of cardiac response indicators to assess the extent of strain in male agricultural human resources engaged threshing (the process of loosening the edible part of cereal grain (or other crop) from the scaly, inedible chaff that surrounds it) in paddy cultivation. It has been found that the strain is significantly more when aid of an electrically driven paddy thresher is not taken. This has implication that in the wake of climate change when more rise and consequent more strain on human resources are expected, it will be better to use at least to some reasonable extent mechanized devices to combat the adverse thermal condition induced strain of the human resources for continuation of work on field without compromising on the quality of performance.**

Keywords: Physiological cost of work, climate change, workload, agriculture, paddy, threshing

Global climate change, which includes both changes in mean weather conditions and the frequency and intensity of extreme weather events[1], is changing the pattern of occupational heat stress risks over time. Human resources in tropical and subtropical regions involved in heavy physical work outdoors or indoors, without effective cooling, are at are particularly at high risk[2]. In low and middle-income tropical countries where heat stress is a problem, rapid urbanization and the cash economy may cause human resources to do heavy labor for long period under hot and humid conditions. This is especially true for those who have challenging socio economic status. These human resources are resultantly exposed to excessive heat due to sheer economic compulsion especially those who have low socioeconomic status. As a result, these workers are exposed to excessive heat[3-4]. Therefore, protecting workers against health and safety risks of heat stress in hot workplaces is necessary in him all sease. In this regard, a heat stress assessment by the valid tools like heat stress indices is a requirement. The concept of heat stress index as well as heat exposure assessment plays a fundamental role in integrating knowledge of human responses to the heat load in a way, which can be used to specify safe working conditions[5]. These indices can generally be categorized into one of three groups: "rational indices", "empirical indices", or "direct indices". Direct indices, such as Wet Bulb Globe Temperature (WBGT) and Discomfort Index (DI), are built on direct measurements of environmental variables[6-7]. There are other indices for assessing heat stress and predicting physiological reactions to heat, such as Predicted Four Hour Sweat Rate (P_4SR), Predicted Heat Strain (PHS), DI and Cumulative Heat Strain Index (CHSI), Universal Thermal Climate Index (UTCI)[5-9]. The International Standard Organization (ISO) recommended the WBGT index for estimating the heat stress on workers in hot environments in ISO 7243[10] and predicted heat strain (PHS) model for predicting human physiological responses (the sweat rate and the internal core temperature) in hot environments for occupational groups in ISO7933[11]. Climate change has become a reality, posing a serious threat to the health of the general population[12-17]and adding to the risk of occupational heat stress, having significant ramifications for the large workforce employed in different occupations[18-22]. Predicted changes in ambient temperatures and humidity as part of local climate change have also been forecast to cause occupational health and work output concerns[12-13]. Heat stress is estimated to lead to decreased work performance[18] by triggering the body's natural response to reduce physical work intensity and internal heat generation and also through deliberate efforts to adhere to heat stress exposure limits[18-19]. The impact of rise in ambient temperature is not confined to agricultural output; it has an impact on the work performance of human being associated agriculture as occupational activities[23-25]. Pedal threshing in paddy cultivation requires both leg and hand coordination and consumes 25 % of the total energy utilized in paddy cultivation[26]. Therefore, assessment of physiological strain is considered as an essential factor for understanding endurance and workloads of threshing task, the process of loosening the edible part of cereal grain (or other crop) from the scaly, inedible chaff that surrounds it. In this backdrop a study has been undertaken to assess the physiological strain experienced by male agricultural workers primarily engaged in paddy threshing task using a mechanized thresher dependent on human effort and

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compare it with the human resources of comparable age from similar location and background engaged in similar type of task but using electrically driven automated paddy thresher.

Methodology : The present study was carried out villages in Goghat II region in Arambagh, Hooghly, (latitude 23º01´20"N 22º39´32"N, longitude 88º30´15"E 87º30´20"E). Data from human resources volunteering to take part in the study on being explained the study objectives and requirements with no known chronic disease history (self - reported) and having a minimum working experience of three years, regularly working on an average for at least a period of slightly more than six hours in the agricultural field were collected. 33 adult male agricultural workers (age range of 21 – 30 years) primarily engaged in paddy threshing task using only mechanical only type of paddy thresher and 37 male agricultural workers, of comparable age group, from same locality and same background engaged in similar task using electrically driven automated paddy thresher respectively constituted the threshing group 1 (TG1) and threshing group 2 (TG2). TG1 operators, in the first phase, use equipment which has a moving drum type rough surface, kept on rotation by an operator who uses his/her foot for the purpose of pressing, while he/she stands on the other foot. For the TG2 operators, the electrically driven equipment does not need any continuous effort on the part of the human resources in form of pressing the lever; hence the operator does not need to stand on one leg for a long time and is not required to press the lever to keep it operational. The agricultural workers of the present study usually start their work around 6.00 a.m. and work for about three hours in the first spell. Then, they generally take a break for breakfast for about half an hour and resume the work thereafter to continue the work in the second spell for about 2½ -3 hours. Then they have a little longer break for about one and half to two hours to have bath, lunch and little rest. They generally start their third spell work at 3 p.m. and work for about 2 hours. During the working time the agricultural workers usually put on a full sleeve cotton shirt and trouser, sometime they use goggles to protect their eyes during threshing task.

Information regarding their age (year), marital status, socio – economic status (SES) - assessed following the Kuppuswamy's socioeconomic scale[27], working experience (year), and average working time (hr.day^{-1}) were recorded in a pre-designed schedule. Temperature in ºC of the dry bulb (T_{DB}), wet bulb (T_{WB}), globe (T_g) and natural wet bulb (T_{nwb}) were noted during the working hours in the agriculture field. The values of wet bulb globe temperature (WBGT) [28-29], and discomfort index (DI) [6] were found out. Anthropometric parameters - stature (cm) and body weight (kg) were measured using anthropometric measurement set and a pre calibrated weighing scale respectively. Body mass index (BMI) and body surface area (BSA) (m^2) were calculated from measured stature and body weight data. Somatotyping characteristics of the participants were calculated[30]. The resting heart rate (beats. min^{-1}), systolic and diastolic blood pressure (mm Hg) were recorded in the morning hours before the individuals started working. Estimated maximum age related heart rate (beats.min^{-1})[31], $HR_{Average}$ (beats.min^{-1}), heart rate reserve (HRR) (beats)[32] was calculated. Indicators of physiological strain in terms of peak heart rate (HR_{peak}) (beats.min^{-1})[33-34], NCC (beats.min^{-1})[35], estimated energy expenditure (EEE) (kcal.min^{-1})[36], total cardiac cost of work (TCCW) (beats), physiological cost of work (PCW) (beats.min^{-1})[37], cardio vascular strain index (CSI)[38] and relative aerobic strain (RAS)[39] were found out. The data were collected during the period December to middle of January (During 'Aman type of paddy' threshing). The environmental and cardiac response data collected at regular intervals during morning [6-9 am], around noon [9.30-10 am to about 1pm] and afternoon hours [3-5 pm] were respectively referred to as first to third spell. Data have been presented in AM ± SD form. Obtained data were statistically analyzed. P value lower than 0.05 ($P<0.05$) was considered as significant.

Results and Discussions **:** The general characteristics of both the groups are presented in Table 1. There is no significant difference in respect of age (years), SES, working experience (year) and average working time (hr.day^{-1}).

TABLE 1: Background information of study participants

Variables	TG1	TG2
Age (years)^	26.5 ± 5.33	25.2 ± 2.86
Married individuals (%)	78	89
Ethnic background	Bengalee	Bengalee
SES^	Lower Middle	Lower Middle
Working experience (year)^	8.5 ± 1.35	7.5 ± 1.88
Working time (hr.day^{-1})^	7.0 ± 1.12	6.6 ± 0.75

AM ± SD, ^ns

The physical and physiological characteristics of the study participants are presented in (Table 2). The individuals of the two groups had no significant difference in terms of stature (cm), body weight (kg), BMI, BSA (m^2), $HR_{Pre\text{-}work}$ (beats.min^{-1}), $SBP_{Pre\text{-}work}$ (mm Hg) but had

significant difference ($P < 0.05$) in terms of DBP (mm Hg). The mean body mass index (BMI), a somatometric indicator giving a general impression about body weight status considering only the overall body weight, for TG1 and TG2 participants were 22.9 $kg.m^{-2}$and 21.7 $kg.m^{-2}$ respectively, which indicated that, all the participants were in 'normal weight' category as per the classification given by WHO (2000)[40]; the result is not surprising as the individuals participating in the study were carrying out physical activities regularly, as previous studies demonstrated that, taking part regularly even in recreational physical activity in a planned systematic manner prevents the chances of becoming overweight and hence facilitate maintaining a normal BMI[41-46]. Higher values of BMI have also been found to be associated with more chance of work related musculoskeletal disorder among sedentary workers[47-48]. Somatotype, another indicator of the morphological conformation of an individual, describes the human physique in terms of subcutaneous adipose tissue (endomorphy), musculoskeletal development (mesomorphy) and relative slenderness or linearity (ectomorpy). In the present study, the somatotyping score of the TG1 and TG2 individuals are found to belong to ectomorphic mesomorph category; similar findings have been observed in one of our earlier studies carried out human resources occupationally engaged in agricultural activity[49]. In case of estimated maximum age related heart rate ($beats.min^{-1}$), expectedly there was no significant difference between TG1and TG2 participants, as they were not differing in terms of age.

TABLE 2: Physical and physiological characteristics of the study participants

Variables	TG1	TG2
Stature (cm)^	165.0 ± 5.21	163.4 ± 7.37
BW (kg)^	59.5 ± 5.15	57.8 ± 7.11
BMI^	22.9 ± 2.34	21.7 ± 3.37
BSA (m^2)^	1.65 ± 0.05	1.62 ± 0.07
Somatotyping characteristics	Ectomorphic Mesomorph	Ectomorphic Mesomorph
$HR_{Pre\text{-}work}$($beats.min^{-1}$)^	73.9 ± 7.37	71.5 ± 8.05
$SBP_{Pre\text{-}work}$(mm Hg)^	119.5 ± 7.13	117.3 ± 9.11
$DBP_{Pre\text{-}work}$ (mm Hg)*	79.7 ± 4.59	75.4 ± 5.51

AM ± SD, ^ns, $P<0.05$

The environmental condition in terms of two indicators of thermal environmental status - WBGT and DI are presented in Table 3. In the present study the average values of calculated WBGT index in the first, second and third spell is 18.9ºC, 24.0ºC and 22.1ºC respectively. There is no restriction recommended against carrying out of the work throughout the working spell [50-51] DI, another indicator of thermal environmental status, in the present study average DI values in the first, second and third spell is 17.6º C, 23.2º C and 21.8º C respectively. The average calculated values of DI indicated that, in the first and third spell of the working hours there is no restriction against carrying out the task, whereas in the second spell the agricultural workers feel 'mild sensation of heat'[52]. However, the values of these two indices are indicating similar environmental condition. This is further affirmed by significant ($P < 0.05$) positive correlation among these two heat indices.

TABLE 3: Indicators of thermal environmental status in three different spells

Indicators of thermal environmental status	Spell 1	Spell 2	Spell 3
WBGT (^{0}C)	18.9 ± 1.15	24.0 ± 2.59	22.1 ± 3.31
DI (^{0}C)	17.6 ± 1.13	22.0 ± 2.36	21.8 ± 1.05

AM ± SD

An earlier study reported that, heart rate, the principal indicator, was not only used in evaluating circulatorystrain imposed by the workload of varying intensity[53] with minimal interference of the individual's performance ability but also provides an integrated response to energy requirement and thermal and postural demand. In the present study the $HR_{Average}$ of the TG1 individuals ranged between 142.5-160.2 $beats.min^{-1}$ while the $HR_{Average}$ of the TG2 individuals ranged between 112.2-129.5 $beats.min^{-1}$. The findings of the present study regarding the $HR_{Average}$ in agreement with the finding of an earlier study carried out among the paddy thresher in the district of Odisha[54]. In the present study, average EEE values in TG1 individuals ranged between 4.35-6.0 $kcal.min^{-1}$ whereas in case of TG2 individuals it ranged between 3.52- 4.50 $kcal.min^{-1}$, this findings was in consonance with the earlier studies [26,54-55]. Circulatory stress was also evaluated from the cardiac cost of work and cardiac cost of recovery. The total cardiac cost of work (TCCW) in TG1 individuals ranged between 1855.5-1969.3 beats and in TG2 individuals it ranged between 1550.3-1665.3 beats. The corresponding PCW value ranged between 60.5-71.5 $beats.min^{-1}$ in TG1 individuals while in TG2 individuals it ranged from 39.5 to 49.3 $beats.min^{-1}$; the findings of the present study in terms of TCCW and PCW were in consonance with the findings of the earlier studies[37]. As per the CSI, there is

cardiovascular strain of different degree in different spells. And the maximum such strain was recorded in the second spell. RAS, another indicator of cardiac response, was observed maximum in second spell. This finding in agreement with an earlier study conducted among the Bengalee male human resources occupationally engaged in manual paddy threshing task[56].

The indicators of physiological strain of human resources engaged in threshing task were assessed in terms of HR_{Peak} (beats.min^{-1}), NCC (beats.min^{-1}), EEE (kcal.min^{-1}), CSI and RAS (%). In the present study the TG1 individuals, the average values of HR_{Peak}, was found to be falling into respectively 'very heavy' in the first and third spell and 'extremely heavy' category in second spell,

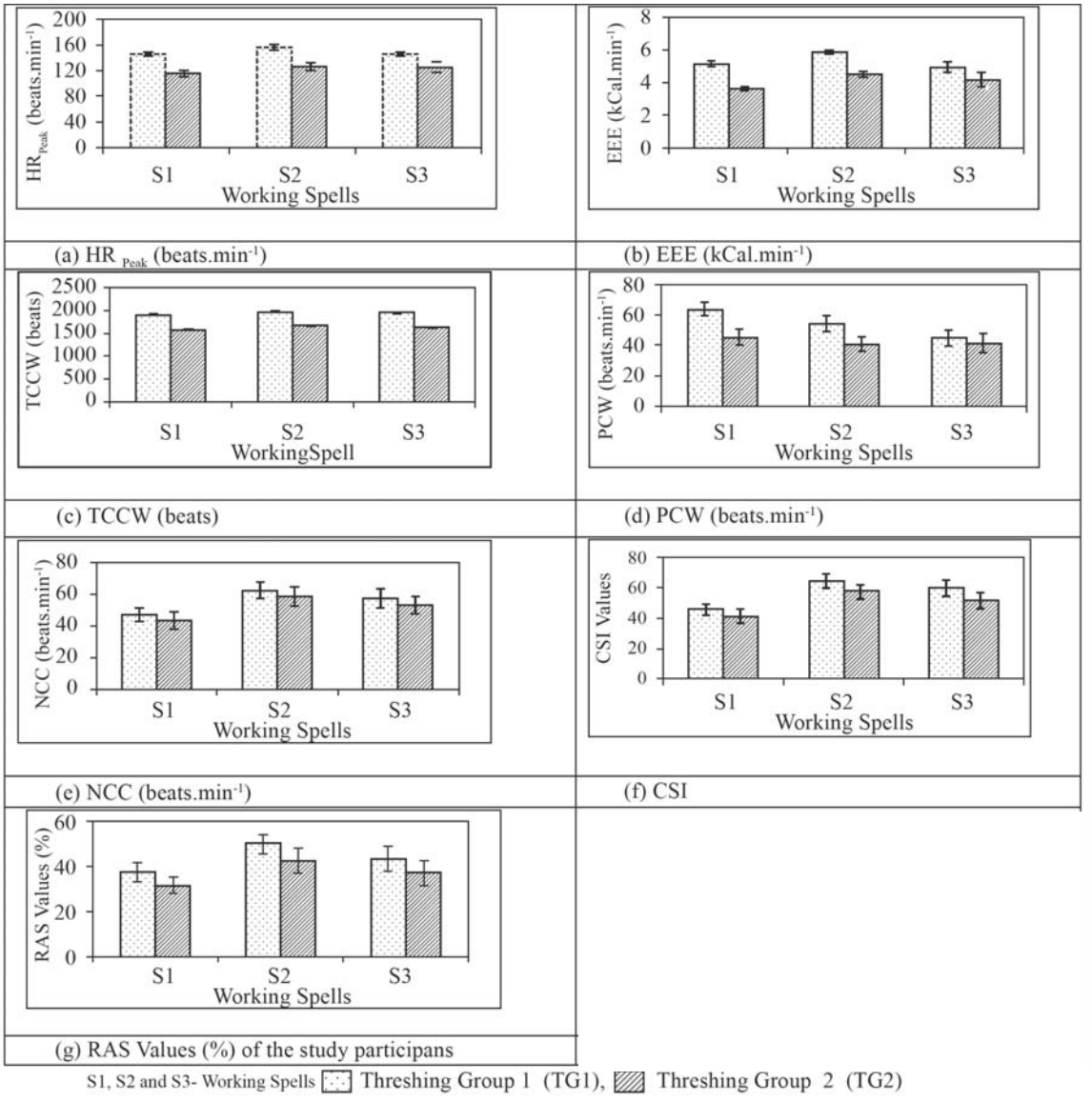

Figure 1: Comparison between TG1 and TG2 individuals in respect of HR_{peak} (beats.min^{-1}) (a), estimated energy expenditure (kcal.min^{-1}) (b), TCCW (beats) (c) and PCW (beats.min^{-1}) (d), NCC (beats.min^{-1}) (e), CSI (f), and RAS (%) (g)

In figure 1, the indicators of physiological strain in terms of HR_{peak} (beats.min^{-1}), estimated energy expenditure (kcal.min^{-1}) (b), TCCW (beats) (c), PCW (beats.min^{-1}) (d), NCC (beats.min^{-1}) (e), CSI (f), and RAS (%) (g) are presented.

Workload categorizations in terms of indicators of Physiological Strain [57] are presented in Table 4.

whereas the human resources belonging to TG2 group experience 'heavy' category workload throughout the working spell. Assessment of physiological, with NCC, it is found that, the workload is falling in to 'very heavy' category throughout the working spell for the human resources belonging to TG1 group, whereas TG2 individuals, experience 'moderate' category of workload in

TABLE 4: Category of workload in terms of indicators of Physiological Strain

Indicators of Physiological Strain	TG1			TG2		
	Working Spell					
	S1	S2	S3	S1	S2	S3
HR $_{peak}$ (beats. min^{-1})*	VH	EH	VH	H	H	H
NCC (beats. min^{-1})**	VH	VH	VH	M	H	H
EEE (kcal.min^{-1})***	H	H	H	M	H	H
CSI****	-	S	S	-	S	S
RAS*****	S	S	S	S	S	S

M- Moderate, H- Heavy, VH- Very Heavy, EH- Extremely Heavy, S- Strain

*Astrand 1986, **Chamouxet al, 1985, ***Ramanathan, 1967, ****Trites, 1993, *****Saha et al, 1979

the first spell and 'heavy' category in both the second and third spell respectively. Assessing the physiological strain, in terms of EEE (kcal.min^{-1}), it is found that, the human resources belonging to TG1 group experience 'heavy' category of workload in the first, second and third spell, but the workload for the human resources belonging to TG2 group fall in 'moderate' category in the first spell and 'heavy' category in both the second and third spell. Similar trend of result has been observed in an earlier study, that categorize paddy threshing is a 'heavy' type of task, experienced by the agricultural workers. In the present study it was observed that, the agricultural workers were suffering from high cardiovascular strain in terms of CSI. From the comparative study of CSI of agricultural workers with that of other industrial workers, it is noted that the impact was much higher in agricultural workers than that on the car assembly and steel plant human resources; 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[58]. The relative aerobic strain is one of the ways to ascertain the demand of task on the capacity of a worker. In the present study the maximum RAS value was observed in second spell of the working hours. There are recommended that RAS should not exceed 50% for an eight hour work day job but 25-55% for construction workers. And there are recommendations that it should be within 30-35% for all day job[59]. There is also report, on the basis of work on threshing task, that heart rate during work may be considered as an indicator of drudgery[33]; as the latter has detrimental impact on work performance, it may be mentioned that work performance of human resources are getting affected in adverse thermal environmental condition particularly in view of the fact that the work is carried out in the open sky directly under the sun rays.

It is also observed from the result of the present study that, individuals of both TG1 and TG2 group experience physiological strain. But the extent of strain in terms of HR_{Peak} (beats.min^{-1}), NCC (beats.min^{-1}), EEE (kcal.min^{-1}), TCCW (beats), PCW (beats.min^{-1}), CSI and RAS (%) was significantly higher ($P<0.05$) in TG1 individuals compared to their TG2 counterparts. Furthermore, agricultural being an open air avocation, human resources occupationally engaged in this sector experienced different degree of physiological strain not only during the manual threshing task but also during-manual ploughing[24-25,60-61], manual transplanting[23,56], manual reaping[56] tasks. From the result of the present study, it may be observed that human resources engaged in manual threshing task experience 'heavy' to 'extremely 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[62-65]. And if compelled by financial (these human resources hardly earn about Rs 250 per person per day with a short break in every hour), or other constraints to continue the work, the cognitive performance of the human resources may suffer in the long run[66-67]. 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}), TCCW (beats), PCW (beats.min^{-1}), CSI and RAS (%), and 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 TG1 individuals, compared to the TG 2 counterparts; this may be attributed to continuous pedal operation during threshing task, in which the individual operating the equipment is virtually forced to stand in one leg and press the pedal applying force continuously with the other leg, standing in a not so balanced position.[26,37, and 55].

Conclusion : It may be mentioned that the physiological strain as adjudged by several indices is more, (with obvious adverse repercussion in work performance), in threshing task in paddy cultivation, in individuals when carried out involving 'mechanical' type of paddy thresher

dependent on human effort and compared to done in an electrically driven paddy thresher, possibly because of the nature of the work demand including adoption of some particular postures. With climate change due to global warming becoming a reality, agriculture being an open sky occupation, there is need to simultaneously attempt to use more human factor designed devices than absolutely being dependent on manual effort in one hand and on the other make provision for work rest cycles, protective devices, water intake and like to go for both mitigation and adaptation.

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