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Physiological and Physical Responses of Heat Stress: A Study on Women Farm Workers during Wheat Harvesting

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Authors' contributions

This work was carried out in collaboration of all the authors. All the authors read and approved the final manuscript.

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ABSTRACT

Heart rate and mean skin temperature (MST) are the physiological workload and overall discomfort rate (ODR), Rating of Perceived Exertion (RPE) is the physical workload due to heat stress. The whole study was conducted during the manual harvesting of wheat crop by using local sickle at instructional Farm, CTAE, Udaipur. The study was conducted on ten female farm workers identified from the population of workers in the age bracket of 18 to 45 years. The chosen workers were wearing their usual outfits during the whole operation. Mean skin temperature measurement is necessary to assess the thermal comfort of the farm workers. Experiments were conducted to evaluate the mean skin temperature of Indian farm women. Therefore, the experiment was designed for five WBGT conditions i.e. 28, 29, 30, 31 and 32°C which falls under the category of

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heat stress given in norms of ACGIH. A variation of ± 0.5°C was assumed in the open field conditions, as it is very difficult to achieve exact thermal conditions i.e., WBGT conditions in the open field.

Keywords: Agricultural activities; heat stress; women farm workers; wheat; harvesting.

1. INTRODUCTION

India has a vast geographical area. It has a large variation in climate from region to region. India has strong variations in temperature too. The hot weather season in India starts from March and ends in May. Maximum temperatures exceed 45°C by the end of May and early June in the north-western parts of the country. Udaipur city has a hot semi-arid climate. Because the Udaipur city is located within the desert areas of Rajasthan, the climate and weather of the city is usually hot sometimes. The summer season in Rajasthan runs from March to June and touches temperature ranging from 31 °C to 44 °C in the months of March to June. It has an average temperature of 37°C , Anonymous [1]. The variation in temperature means the changes in skin temperature. According to ACGIH norms, the indication of the WBGT heat stress is identified between the temperatures 28°C to 32°C.

Heat stress is a condition that occurs when the body is unable to regulate its internal temperature in response to high environmental temperatures, Liu et al. [2]. It can have significant physiological and physical effects on individuals, particularly those engaged in physically demanding activities such as wheat harvesting. This study aims to investigate the physiological and physical responses of heat stress in women farm workers during wheat harvesting.

Physiological responses to heat stress include increased heart rate, elevated body temperature, and excessive sweating, Dhariaya et al. [3]. These responses are the body's attempt to cool itself down and maintain a stable internal temperature. However, prolonged exposure to high temperatures can overwhelm the body's cooling mechanisms, leading to heat exhaustion or even heat stroke.

Physical responses to heat stress can also be observed in women farm workers during wheat harvesting, Singh et al. [4], Dhariaya et al. [11]. These may include fatigue, muscle cramps, dizziness, and decreased physical performance. The combination of physical exertion and high temperatures can put a significant strain on the body, leading to reduced productivity and increased risk of accidents [5,6].

The study involved monitoring the physiological responses of women farm workers during wheat harvesting. This will be done by measuring heart rate, body temperature, and sweat rate using wearable sensors. Additionally, physical performance measures such as work output and fatigue levels was assessed [7-11] Understanding the physiological and physical responses of women farm workers to heat stress during wheat harvesting is crucial for developing appropriate preventive measures and interventions. This study aimed to contribute to the existing body of knowledge on heat stress in occupational settings, particularly among women workers [12-14]. By identifying the specific challenges faced by women farm workers during wheat harvesting, it will be possible to implement targeted strategies to protect their health and enhance their productivity [15-16] Therefore, the study was undertaken to assess the thermal workload on female human body along with physiological and physical workloads during harvesting of wheat crop by using local sickle.

2. JUSTIFICATION OF THE RESEARCH STUDY

The research study on the physiological and physical responses of heat stress in women farm workers during wheat harvesting is justified for several reasons:

2.1 Occupational Health and Safety

Heat stress is a significant occupational hazard, particularly in agriculture that involve physically demanding work in hot environments. By studying the specific responses of women farm workers during wheat harvesting, the study can contribute to improving their health and safety conditions. It can help to identify the specific risks and challenges they face, leading to the development of targeted interventions and preventive measures.

2.2 Gender-specific Considerations

Women may have unique physiological responses to heat stress compared to men. Factors such as hormonal differences, body composition, and clothing choices can influence their heat tolerance and susceptibility to heat-related illnesses. This study focuses specifically on women farm workers, providing valuable insights into their experiences and enabling the development of gender-specific guidelines and policies.

2.3 Agricultural Industry Impact

The agricultural sector plays a crucial role in food production, and farm workers are essential for maintaining productivity. Understanding the physiological and physical responses of women farm workers during wheat harvesting can help optimize their performance and reduce the risk of heat-related accidents or illnesses. This research can contribute to enhancing the efficiency and sustainability of the agricultural industry.

2.4 Knowledge Gap

While there is existing research on heat stress and its impact on various occupational groups, there is a limited understanding of the specific experiences of women farm workers during wheat harvesting. This study aims to fill this knowledge gap by providing empirical data and insights into their physiological and physical responses to heat stress. This information can inform future research and contribute to the development of evidence-based guidelines and interventions.

2.5 Policy and Intervention Development

The findings of this research study can serve as a basis for developing policies, guidelines, and interventions aimed at protecting the health and well-being of women farm workers. By understanding their specific challenges and needs, appropriate measures can be implemented, such as improved access to shade, hydration strategies, training programs, and work scheduling adjustments. This research can contribute to ensuring better working conditions and reducing the impact of heat stress on women farm workers.

Overall, this research study is justified due to its potential to enhance occupational health and safety, address gender-specific considerations, impact the agricultural industry, fill knowledge gaps, and inform policy and intervention development. In terms of research, very few studies pertaining to physiological and physical workload while performing agriculture activity i.e., harvesting operation of wheat crop by using the local sickle have been carried out in India, in particular, Udaipur district. The objectives of the study were:

i. Assessment of physiological workload i.e., heart rate, mean skin temperature during harvesting of wheat crop.
ii. Assessment of physical workload i.e., overall discomfort rating (ODR) before and after the operation, Rating of Perceived Exertion (RPE)

3. MATERIALS AND METHODS

3.1Subjects

A study was conducted on a group of 10 female farm workers. These workers were selected based on certain criteria such as age, stature, and weight, and they were representative of the overall population of farm workers. All the tasks and operations during the study were carried out exclusively by these ten female farm workers. The selected subjects primarily relied on agriculture for their livelihood. It is worth noting that none of the subjects had the habit of chewing tobacco or consuming alcohol. The subjects were between the ages of 18 and 45, and they were in good physical health, without any chronic diseases or disorders. Each subject provided both verbal and written consent to participate in the study.

3.2 Experimental Design

The experimental analysis consists of physiological workload i.e., mean skin temperature, heart rate (HR) and sweat rate and physical workload i.e., ODR, RPE and BDPS. In the morning, the time of operation was in between 9 AM to 1 PM and in the evening from 2 PM to 5 PM. All the female farm workers were allowed to take rest for 15 minutes before performing the task and asked to perform the harvesting operation by using local sickle continuously for 30 minutes and then allowed to take rest for 15 minutes. This procedure was followed for entire operation by following the proper work-rest cycle.

3.2.1 Physiological workload

1. The effect of environmental heat on the performance of female farm workers, five WBGT (wet bulb globe temperature) i.e. 28, 29, 30, 31, 32°C conditions during harvesting of wheat crop by using local sickle were selected. Heat stress monitor make Quest Temp 36, was used to assess the heat stress index (Wet Bulb Glob Temperature) as shown in Fig. 1. Contact type skin temperature thermometer, make EXTECH (Model- SDL200) was used to measure the skin temperature as shown in Fig. 2. A method, to evaluate calculation methods of mean skin temperature, in order to find appropriate ones for use in human thermal comfort study Liu et al. [17] Three indices were proposed to evaluate MST (Mean skin temperature) calculation methods viz; reliability, sensitivity and number of measurement sites. Liu et al. [17] also suggested that adopting the evaluation method, 26 types of mean skin temperature calculation methods were evaluated based on the experimental data. The results indicate that a calculation method of mean skin temperature with 10 sites is the most appropriate one, due to its high reliability, excellent sensitivity and fewer measuring sites. Hence, keeping the same in view, the mean skin temperature of the body was measured by using Hardy Du-Bois- 7 Point model with fewer measuring sites to achieve high reliability. Hardy Du-Bois- 7 Point model was selected for calculation of mean skin temperature of the body at seven different places namely fore head, left forearm, left hand, left foot, left anterior calf, left anterior thigh and left abdomen. The formula for measuring the mean skin temperature for the selected model is given below.

Hardy Du-Bois- 7 Point model

MT_{SK} (°C) = 0.07 T_{sk} Forehead + 0.14 T_{sk} Left forearm + 0.05 T_{sk} Left hand + 0.07 T_{sk} Left foot + 0.13 T_{sk} Left anterior calf + 0.19 T_{sk} Left anterior thigh + 0.35 T_{sk} Left abdomen

2. Heart rate (resting HR, working HR) and oxygen consumption rate were measured by using $K4b^2$ make by Cosmed (Italy) and polar heart rate monitor as shown in Fig. 3. and Fig. 4. The increase in HR was calculated by using the following formula:

Increase in Heat rate, ΔHR (beats/min) = (Average working heart rate – average resting heart rate)

3.2.2 Physical workload

3.2.2.1 Overall Discomfort Rating (ODR)

Overall discomfort rating (ODR) had been defined by using a 10-point psycho-physical rating scale developed by Borg et al. [2]. A scale of 70 cm length was fabricated having 0 to 10 digits' marks on it equidistantly as shown in Fig. 5. A movable pointer was provided to indicate the rating. The subject was asked to report her discomfort level on the scale before start of work. She was again asked to report the discomfort level at the end of work. The difference in the score of before and after the work was the real discomfort score.

Fig. 1. Contact type skin temperature thermometer

Fig. 2. Heat stress monitor

Fig. 3. K4b2

Fig. 4. Polar heart rate monitor

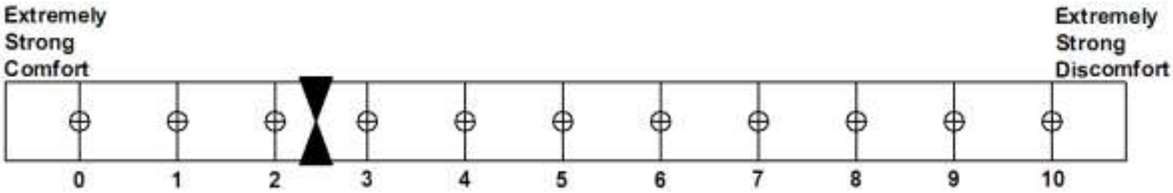


Fig. 5. ODR 10-point scale

Table. 1. 5-point scale developed by Varghese et al. (1994)

Very light	light	moderately heavy	heavy	very heavy
1	2	3	4	5

3.2.2.2 Rating of Perceived Exertion (RPE)

There is discomfort when there is pain. As a result, while performing agricultural activities, discomfort due to pain was reported. The 5-point continuum was used to assess the RPE. As shown in Table 1, Perceived Exertion was assessed using a 5-point scale developed by Varghese et al. [18] The average rating was calculated using the mean of these shoulder joint, upper arm, elbows, wrist/hands) and lower body parts (lower arm, low back, upper leg/ thigh, knees, calf muscles, ankles, feet).

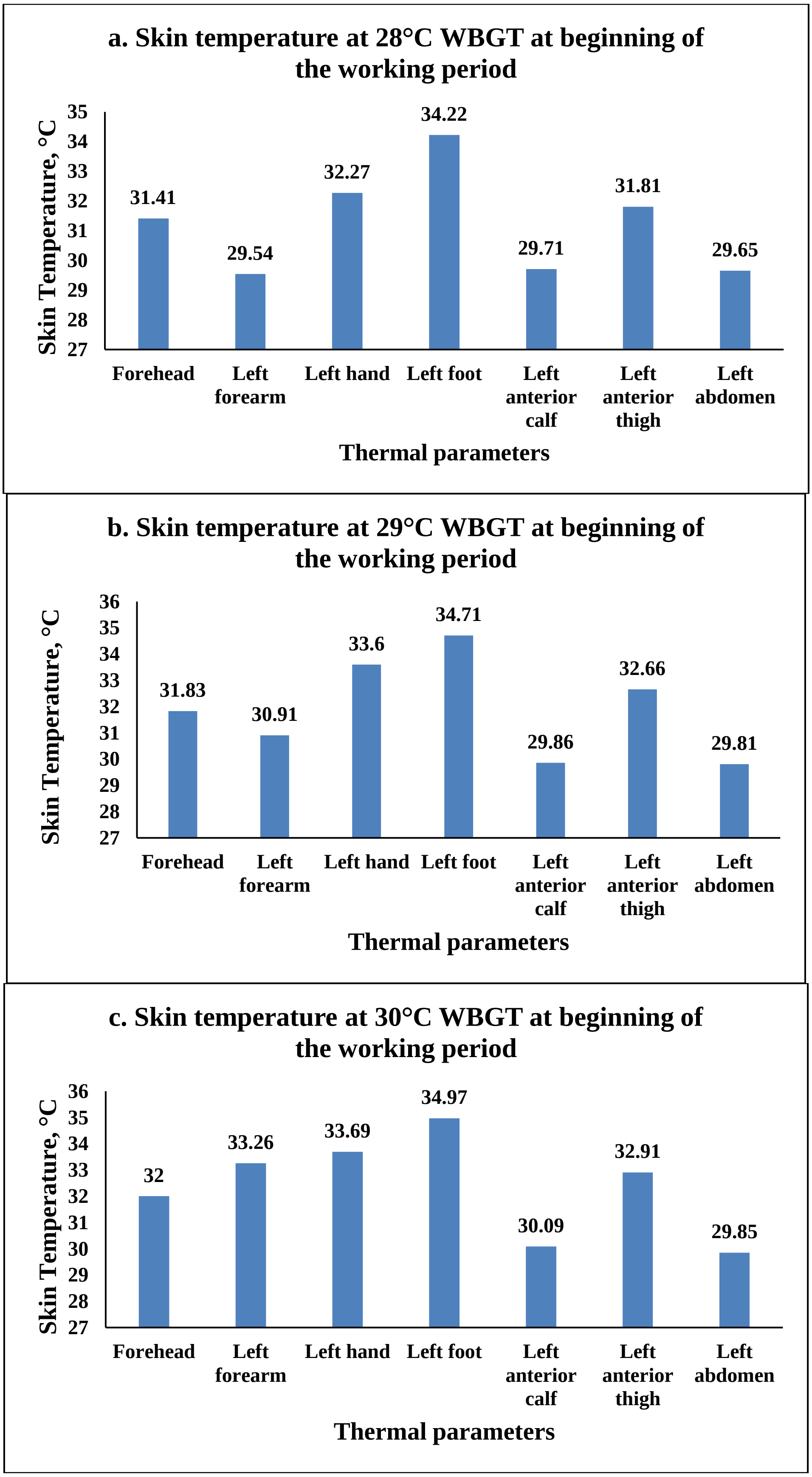
4. RESULTS AND DISCUSSION

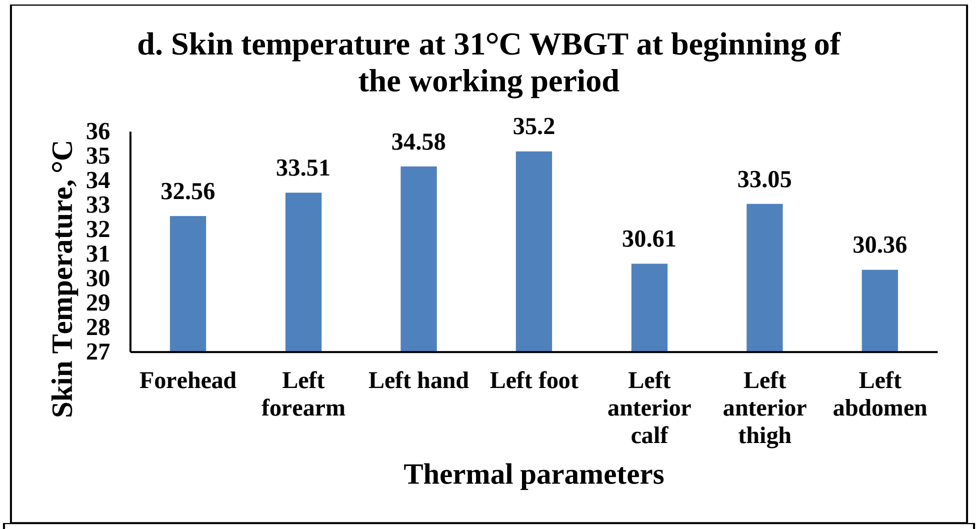
4.1 Physiological Workload

4.1.1 Effect of WBGT on selected body sites at the beginning and end of the operation

Skin temperature at different WBGT conditions, i.e., 28, 29, 30, 31, 32 °C on forehead, left forearm, left hand, left foot, left anterior calf, left anterior thigh and left abdomen as shown in Fig. 6. were taken for the calculation of mean skin temperature with contact type thermometer.

Fig. 7. indicates the mean skin temperature at different WBGT conditions at the beginning of the operation. Mean skin temperature was calculated by using Hardy du-bois 7-point model formula by measuring the skin temperature of forehead, left forearm, left hand, left foot, left anterior calf, left anterior thigh, left abdomen of ten female subjects. As shown in Fig. 7. the mean skin temperature at the beginning of the work increases with increase in WBGT. Kashyap et al. [19] and Patil et al. [20] also reported similar result that temperature of the body sites increases with increase in WBGT. It was noted that the lowest mean skin temperature was recorded as 30.67°C at WBGT 28°C and highest as 32.43°C at WBGT 32°C.


a. Skin temperature at 28°C WBGT at beginning of the working period
Skin Temperature, °C
35
34
33
32
31
30
29
28
27
31.41
29.54
32.27
34.22
29.71
31.81
29.65
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters
b. Skin temperature at 29°C WBGT at beginning of the working period
Skin Temperature, °C
36
35
34
33
32
31
30
29
28
27
31.83
30.91
33.6
34.71
29.86
32.66
29.81
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters
c. Skin temperature at 30°C WBGT at beginning of the working period
Skin Temperature, °C
36
35
34
33
32
31
30
29
28
27
32
33.26
33.69
34.97
30.09
32.91
29.85
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters



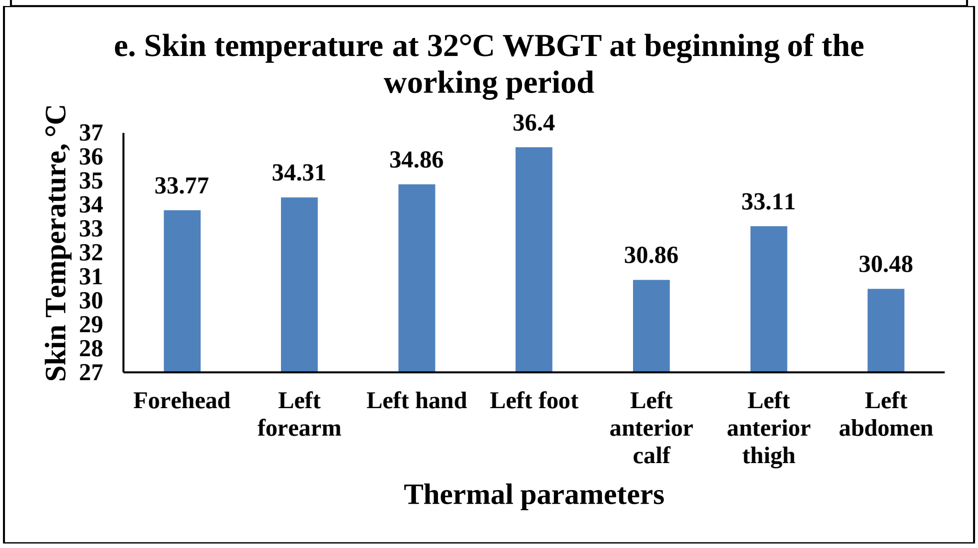


Fig. 6. Skin temperature at the beginning of working period

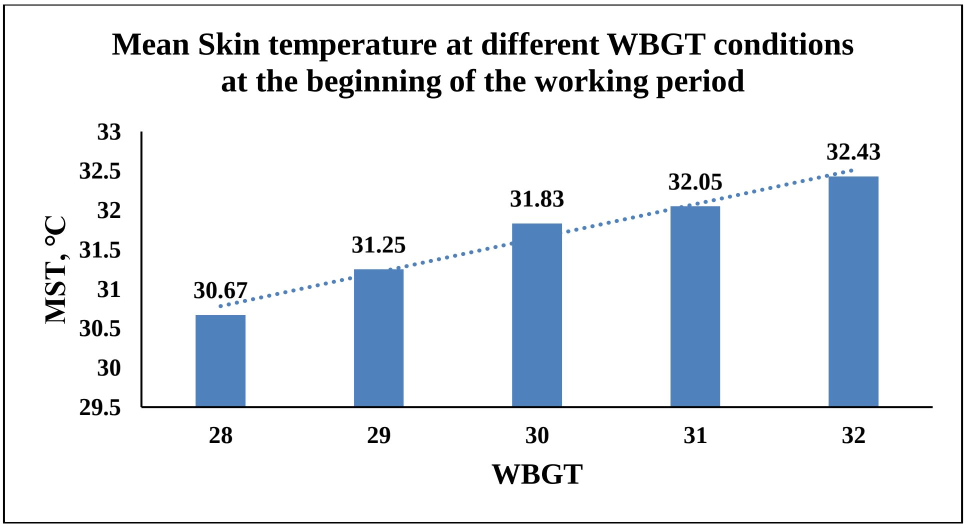


Fig. 7. Mean skin temperature at the beginning of working period using Hardy du-bois 7-point model formula

Skin temperature at different WBGT conditions, i.e., 28, 29, 30, 31, 32 °C on forehead, left forearm, left hand, left foot, left anterior calf, left anterior thigh and left abdomen as shown in Fig. 8. were taken for the calculation of mean skin temperature with contact type thermometer at the end of the working period.

Fig. 9., indicates the mean skin temperature at different WBGT conditions at the end of the operation. The value of mean skin temperature of left forearm, left hand, left foot, left anterior calf, left anterior thigh, of ten female subjects at the end of the work increases with increase in WBGT. But forehead, left abdomen temperature decreased with increase in WBGT. This is mainly due to the sweating caused with increase in WBGT. Due to the air, the sweat was evaporated and reduced the forehead temperature and left abdomen temperature. Thus, the increase in temperature due to environmental heat reduced the forehead and left abdomen temperature. Dhariya et al. [21], Patil et al. [20] also reported that the forehead temperature decreased with increase in WBGT temperature. It was noted that the lowest mean skin temperature was recorded as 34.89°C at WBGT 28°C and highest as 36.22°C at WBGT 32°C.

ANOVA table for different sites of the body at 28, 29, 30, 31 and 32 °C WBGT conditions at beginning of working period and at the end of working period is given in Table 2 and Table 3. It can be seen that there was significant effect on different sites at different WBGT conditions at 1 percent level of significance at the beginning of working period and 1 percent level of significance at the end of working period.

4.2 Effect of WBGT on Heart Rate

Experiments were conducted to assess the effect of different WBGT conditions, i.e., 28, 29, 30, 31 and 32 °C on heart rate. Effect of WBGT on heart rate (resting HR, working HR, ∆HR) of ten female farm workers in harvesting of wheat crop was studied. Fig. 10. and Fig. 11. indicates the mean values of heart rate of ten female farm works at different WBGT conditions.

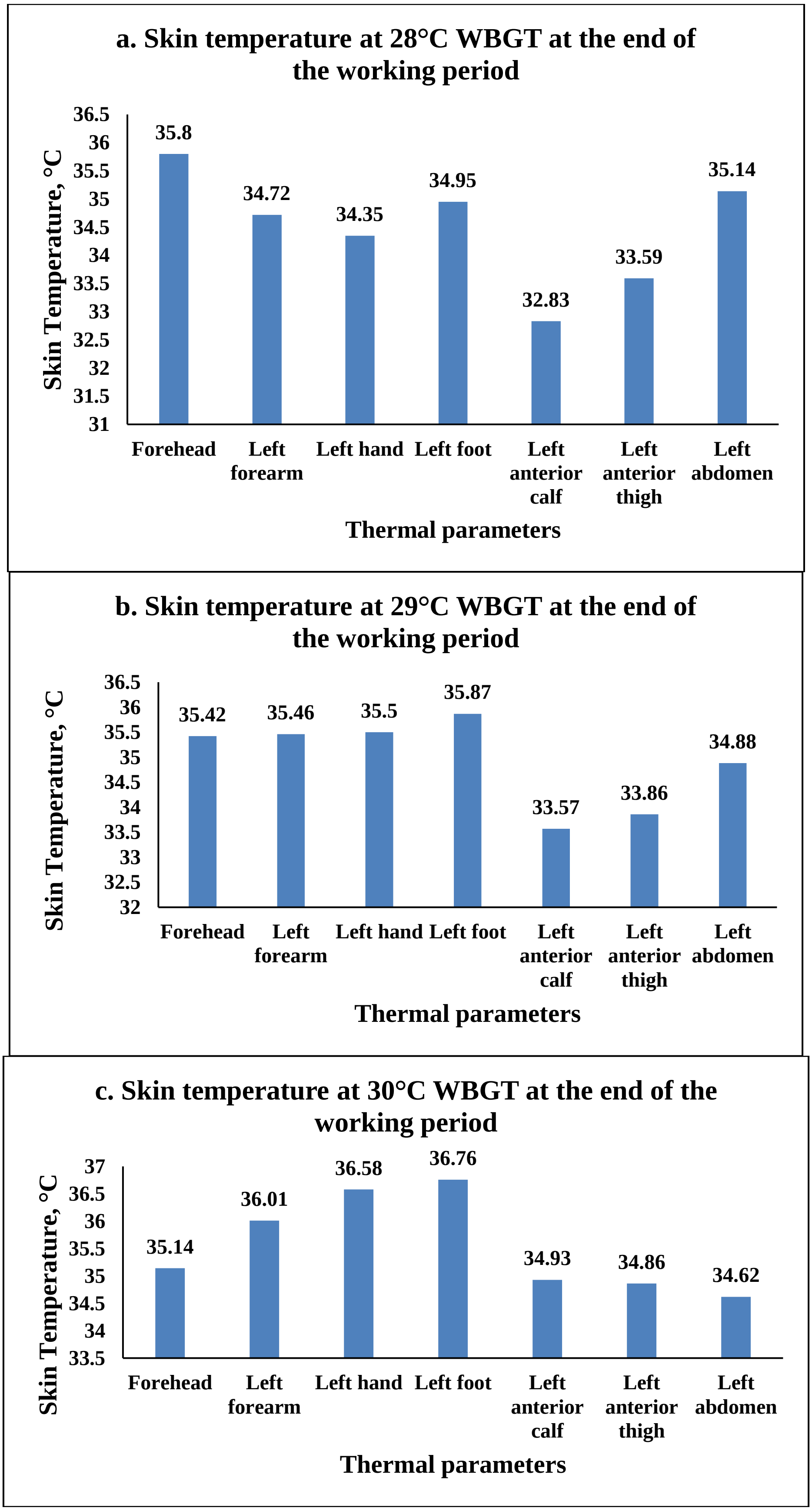
It can be seen from Fig. 10. that, mean Resting heart rate of ten female farm workers varied from 76.1 beats/min at 28°C to 83.1 beats/min at 32°C. Mean working heart rate of ten female farm workers varied from 99.5 beats/min at 28°C to 110.6 beats/min at 32°C. Increase in heart rate varied from 23.4 beats/min at 28°C to 27.5 beats/min at 32°C. It can be seen from Table 4. that there was effect of WBGT on heart rate. This effect was mainly due to the thermal workload faced by the female farm workers. Resting HR and working HR were observed to increase linearly with increase in WBGT. Huguette and Pierre et al. [22], Singh et al. [23], Dharaiya et al. [21], Kashyap et al. [19] and Patil et al. [20] also found that resting HR and working HR increases with increase in WBGT conditions.

ANOVA of mean resting heart rate (RHR) in resting period and working heart rate (WHR) in working period was conducted to detect any differences between responses measured over different WBGT conditions which is given in Table 4 and Table 5. Results of the study indicates that there was no significant difference between the heart rate measured at different WBGT conditions. There does not appear any effect of different WBGT conditions on resting heart rate (P=0.49), and working heart rate (P=0.87). Wells et al. [24] also reported that there were no significant differences in HR, VO_2, rectal temperature, or sweat loss in exercise trials. Conolly et al. [3] also concluded that there was no significant effect of WBGT on heart rate (P=0.41).

4.3 Effect of WBGT on ODR

Experiments were conducted to assess the effect of different WBGT conditions, i.e., 28, 29, 30, 31 and 32 °C on physical discomfort i.e., overall discomfort rate (ODR). Effect of WBGT on overall discomfort rate (resting ODR, working ODR) of ten female farm workers in harvesting of wheat crop was studied. Fig. 12. shows the mean values of ODR of ten female farm works at different WBGT conditions.

It can be seen from Table 6 that, mean ODR of ten female farm workers varied from 3.3 at 28°C to 5.0 at 32°C. It can be clearly seen from Table 6 that there was effect of WBGT on ODR. This effect was mainly due to the variation in thermal workload faced by the female farm workers. Resting ODR and working ODR were observed to increase linearly with increase in WBGT. Singh et al. [23], Dharaiya et al. [21], Kashyap et al. [19], Patil et al. [20] also found that ODR increases with increase in WBGT conditions.


a. Skin temperature at 28°C WBGT at the end of the working period
Skin Temperature, °C
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
35.8
34.72
34.35
34.95
32.83
33.59
35.14
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters
b. Skin temperature at 29°C WBGT at the end of the working period
Skin Temperature, °C
36.5
36
35.5
35
34.5
34
33.5
33
32.5
32
35.42
35.46
35.5
35.87
33.57
33.86
34.88
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters
c. Skin temperature at 30°C WBGT at the end of the working period
Skin Temperature, °C
37
36.5
36
35.5
35
34.5
34
33.5
35.14
36.01
36.58
36.76
34.93
34.86
34.62
Forehead
Left forearm
Left hand
Left foot
Left anterior calf
Left anterior thigh
Left abdomen
Thermal parameters

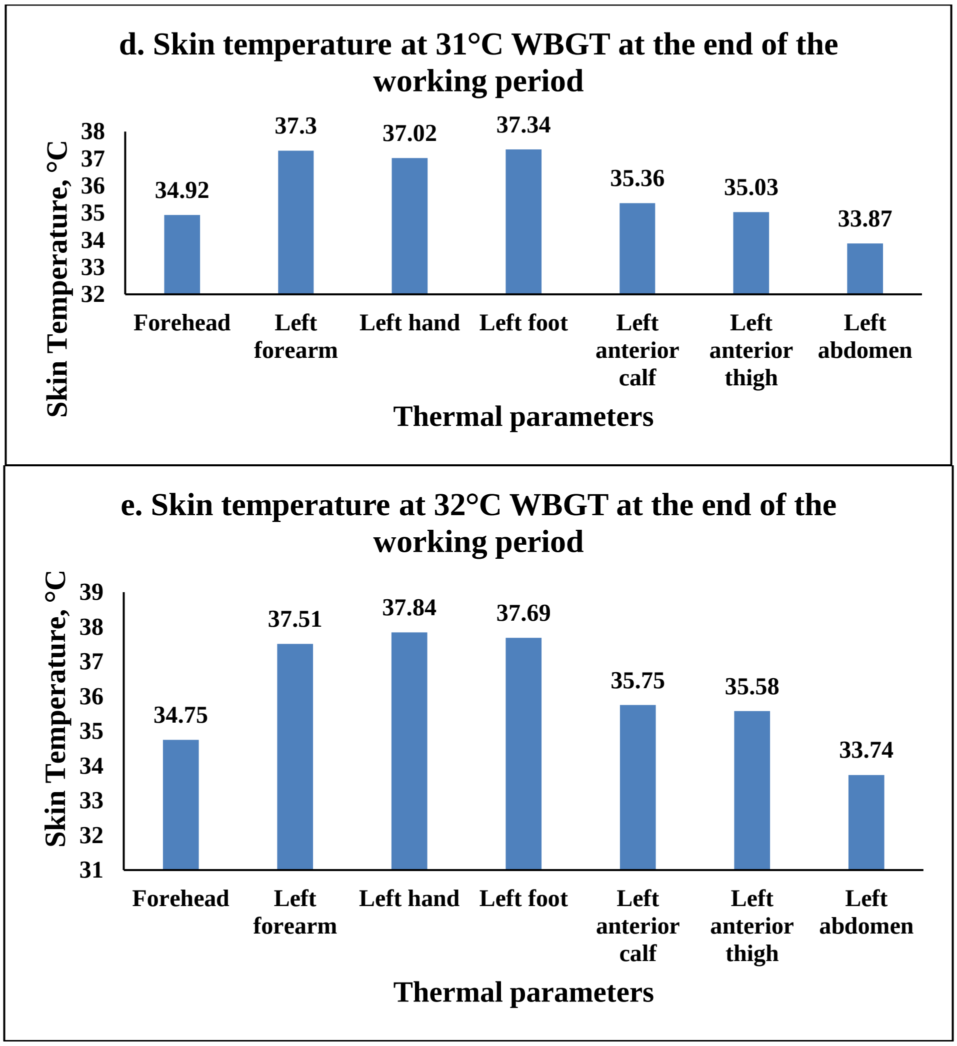


Fig. 8. Skin temperature at the end of working period

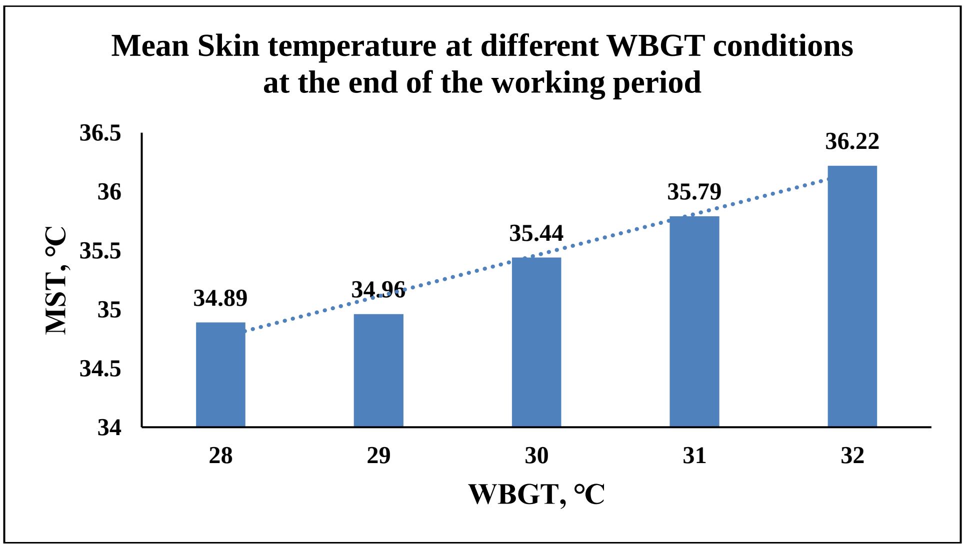


Fig. 9. Mean skin temperature at the end of working period using Hardy du-bois 7-point model formula

Table 2. ANOVA for different sites of the body at selected WBGT conditions at the beginning of working period

Source	SS	df	MS	F	P-value	F crit
Rows	3.98649333	2	1.99324667	95.4620051	2.6158E-06*	4.45897011
Columns	5.6258	4	1.40645	67.3587165	3.3771E-06*	3.83785335
Error	0.16704	8	0.02088			
Total	9.77933333	14				

**P-value significant at 0.01*

Table 3. ANOVA for different sites of the body at selected WBGT conditions at the end of working period

Source	SS	df	MS	F	P-value	F crit
Rows	1.76121333	2	0.88060667	10.4628607	0.005850*	4.45897011
Columns	5.02804	4	1.25701	14.935068	0.000880*	3.83785335
Error	0.67332	8	0.084165			
Total	7.46257333	14				

**P-value significant at 0.01*

Table 4. ANOVA for resting HR at different WBGT conditions

Source	SS	df	MS	F	P-value	F crit
Rows	95.048	4	23.762	114.607717	0.8863	3.25916673
Columns	2.172	3	0.724	3.49196141	0.4993806*	3.49029482
Error	2.488	12	0.207333			
Total	99.708	19				

**Non-significant*

Table 5. ANOVA for working HR at different WBGT conditions

Source	SS	df	MS	F	P-value	F crit
Rows	360.973	4	90.24325	225.655136	0.3304	3.25916673
Columns	6.0335	3	2.01116667	5.02896437	0.8744512*	3.49029482
Error	4.799	12	0.39991667			
Total	371.8055	19				

**Non-significant*

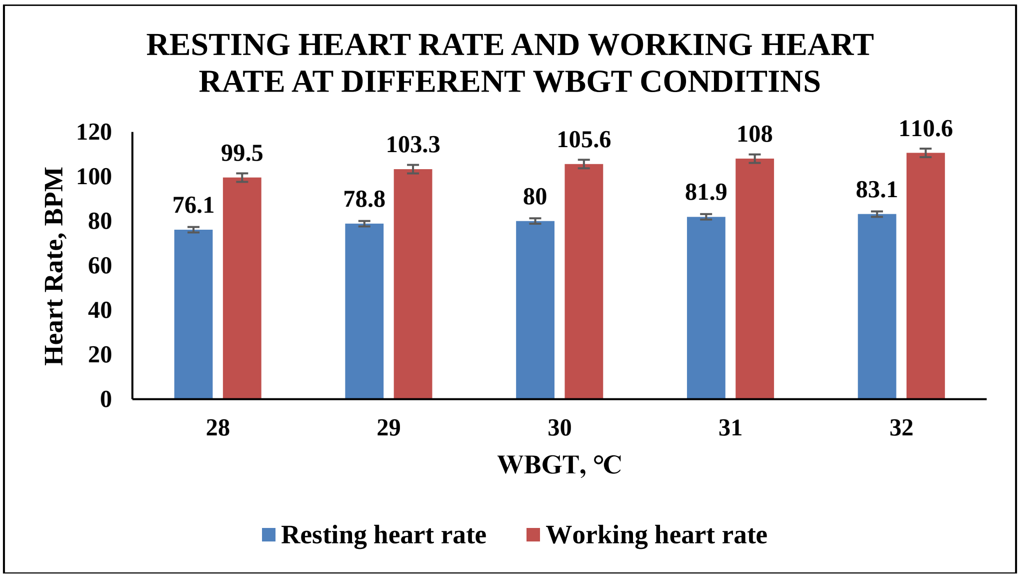


Fig. 10. Resting and Working Heart Rate at different WBGT conditions

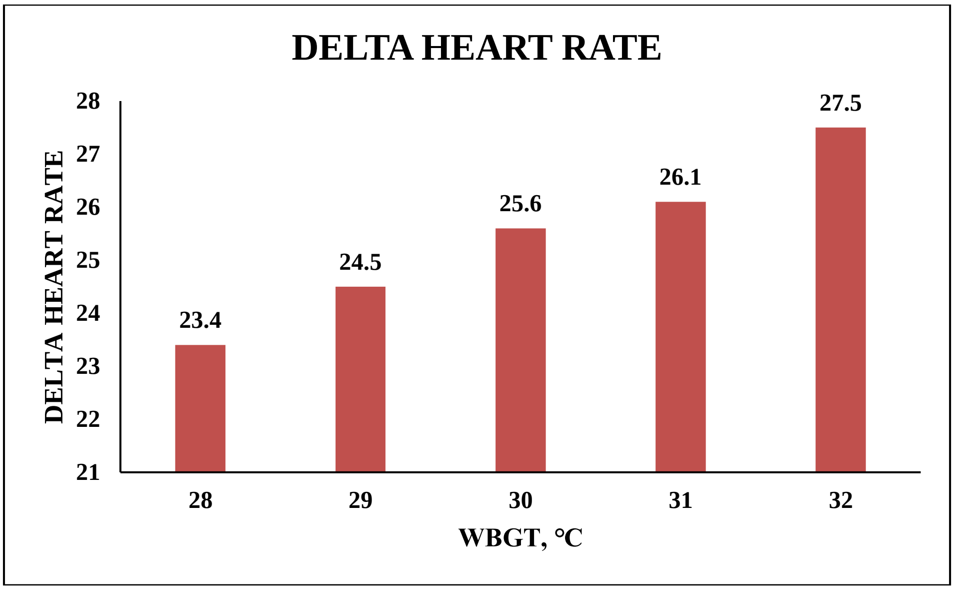


Fig. 11. Delta Heart rate at different WBGT conditions

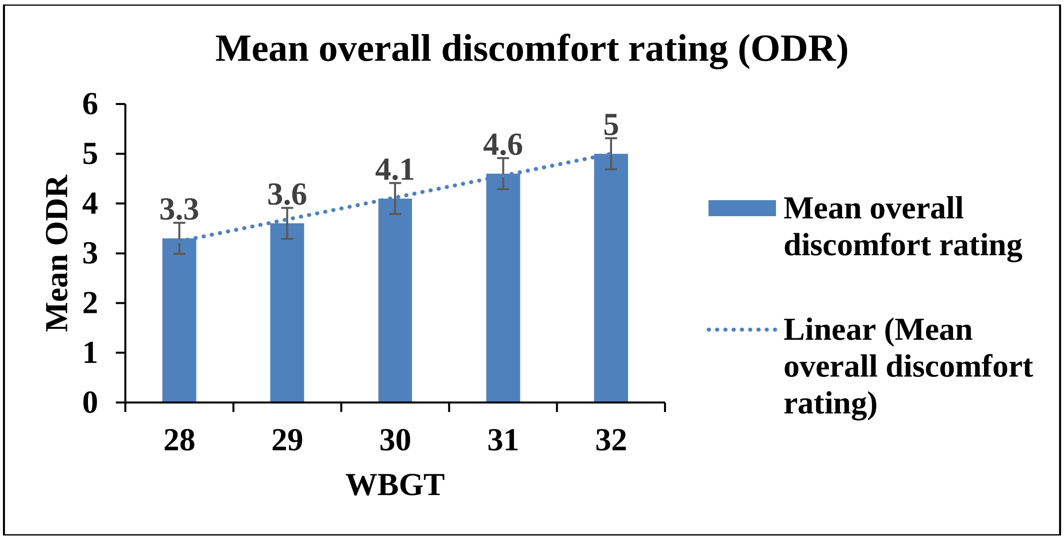


Fig. 12. Mean values of ODR at different WBGT conditions

ANOVA of overall discomfort rating (ODR) was conducted to detect any differences between responses measured over different WBGT conditions in Table 6. Results of the study indicates that there was significant difference between the ODR with different WBGT conditions. There was effect on overall discomfort rating (ODR), at different WBGT conditions at P<0.01.

4.4 Effect of WBGT on RPE

Experiments were conducted to assess the effect of different WBGT conditions, i.e., 28, 29, 30, 31 and 32 °C on physical discomfort i.e., Rating of Perceived Exertion (RPE). Effect of WBGT on RPE of ten female farm workers in harvesting of wheat crop was studied. Fig. shows the mean values of RPE of ten female farm works at different WBGT conditions. The RPE for female farm workers was high in case of WBGT 32°C. The RPE has increased from 28°C to 32°C because of increase in heat stress. The RPE was low in case of lower WBGT conditions. Fig. 13. shows the mean values of RPE of ten female farm works at different WBGT conditions.

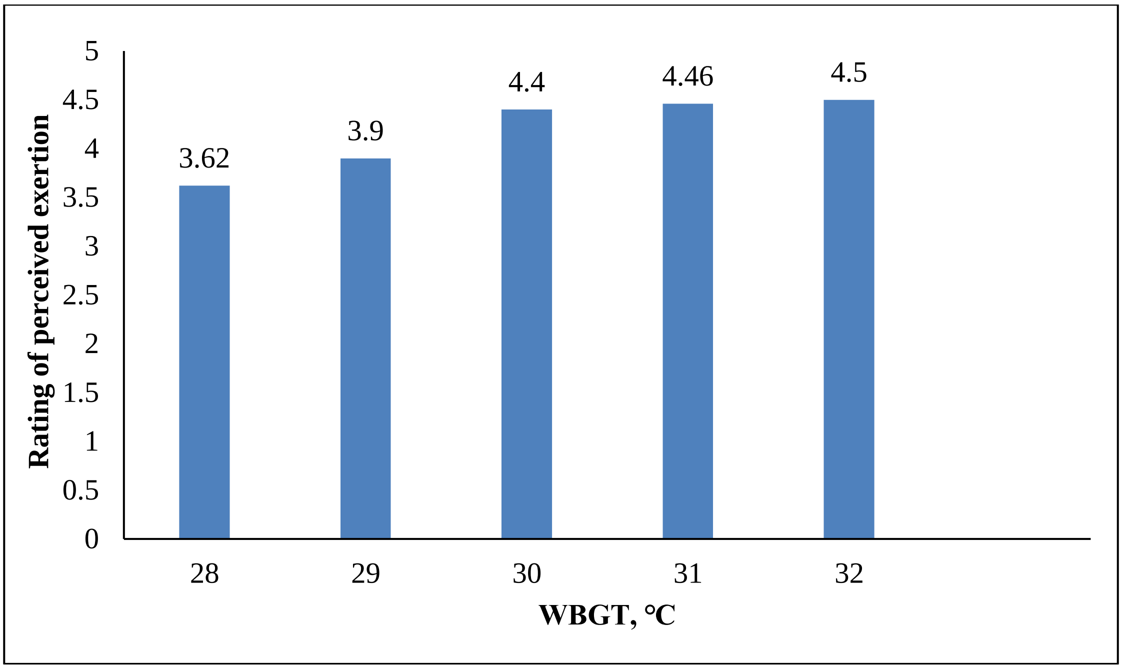


Fig. 13. Mean Rating of Perceived Exertion (RPE) in harvesting operation of wheat crop

Table 6. ANOVA for ODR at different WBGT conditions

Source	SS	df	MS	F	P-value	F crit
Rows	8.66177	4	2.1654425	8.542	0.0016772*	3.25916673
Columns	3.03004	3	1.01001333	3.984	0.001497208*	3.49029482
Error	3.04191	12	0.2534925			
Total	14.7337	19				

**P-value significant at 0.01*

Table 7. Responses on Rating of perceived exertion (RPE) of the female farm workers in harvesting operation of wheat crop at different WBGT conditions

WBGT, ℃	Rating of perceived exertion
28	Heavy
29	Heavy
30	Heavy
31	Moderately Heavy
32	Moderately Heavy

5. SUMMARY AND CONCLUSION

The results obtained here confirmed that there is effect of WBGT on physiological workload and physical workload during the harvesting operation in wheat. With increase in the WBGT, there is increase in heart rate and increase in mean skin temperature. The overall discomfort rating given by the subjects also increased with increase in WBGT. It has shown that the heart rate was the earliest response of physiological workload.

CONSENT

As per international standards or university standards, Participants' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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