Original Research Article

Effect of headgear on physiological, physical response of male farm worker under heat stress condition

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ABSTRACT

India has a vast geographical area with variations in climate and temperature from region to region. Summers are very harsh in many parts of the country where temperature exceeds 45°C. Most of the agricultural operations in the country are performed by manual labour in such a warm climate where it becomes difficult for the body to maintain its heat balance with the environment. In leads to heat stress many a time. Heat stress causes many heat disorders like systemic disorder, heat syncope, heat odema, heat cramp, heat exhaustion and heat stroke. To minimize heat stress in warm climate many techniques are used. One of them is the use of headgear which protects the head. Farmers are using towel, pagadi, caps etc. as headgear from the last many years. The independent parameters of the study were WBGT (28, 30 and 32ºC), headgears (Bamboo hat, felt hat with 90 mm brim width, white pagdi and solar hat) and subject (10 male farm workers). The dependent parameters of study were heart rate, oxygen consumption rate and overall discomfort rating. The results of the research showed that use of headgear reduced the effect of heat stress significantly on physiological parameters and physical discomfort parameters.

Keywords: *Heart rate, oxygen consumption rate, headgear, etc*

INTRODUCTION

India has a vast geographical area. It has a large variation in climate from region to region. There are four major climatic zones in India. These zones are further subdivided into seven climatic zones. India has strong variations in temperature. The mean temperature in winter season is about 10°C while it is about 32°C in summer season. The temperature starts increasing all over the country in March and by April central India becomes very hot having daytime maximum temperatures about 40°C at many locations. Many stations in Gujarat, Maharashtra, Rajasthan and Madhya Pradesh have high day-time temperature during this season. The difference in day and night time temperature in these states was found more than 25 °C at many places. Maximum temperatures exceed 45°C by the end of May and early June. It results in harsh summers in the north and north-west regions of the country. Maximum temperature was recorded up to 51°C was at Phalodi in Jodhpur district of Rajasthan state in 2017(Anonymous, 2017; Pal & Patel, 2021).

Most of the agricultural operations in the country are performed by manual labour. Ploughing, sowing, intercultural and harvesting are the main agricultural operations which are being performed in hot sunny days (Anusha et al., 2023). Many of these operations are performed by manual tools. The hardships involved in these operations combined with hot and adverse climatic conditions increases the drudgery of the farm workers too much (Boonruksa et al., 2020).

Heat stress is a condition that is caused by worker's over-exposure to the high temperature work environments often found in outdoor agriculture operations. The best protection against heat stress is to educate and train the workers on the best practices for heat stress prevention (Lumingu & Dessureault, 2009). Heat stress is a build-up of heat in the body generated by muscle use and surrounding conditions. It is the result of a combination of environmental conditions, work demands, and clothing requirements that are likely to increase body temperature when the body cannot adequately cool itself, injury, illness, or even death can occur. The more intense the work, the hotter the conditions, and the higher the humidity, the faster heat will be generated and the body will struggle to get rid of excess heat.

Workers should be informed of the nature of heat stress and its adverse effects as well as the protective measures provided in the workplace. They should be taught that heat tolerance depends to a large extent upon drinking enough water and eating a balanced diet. In addition, workers should be taught the signs and symptoms of heat disorders, which include dizziness, faintness, breathlessness, palpitations and extreme thirst. They should also learn the basics of first aid and where to call for help when they recognize these signs in themselves or others.

MATERIAL AND METHOD

Harvesting of wheat crop was selected as the operation for study. Traditionally this operation is performed by manually operated sickle. when the study was conducted average dry bulb temperature was above 32°C. This temperature combined with high humidity in the field causes heat stress. The independent parameters of the study were WBGT (28, 30 and 32ºC) and headgears (Bamboo hat, felt hat with 90 mm brim width, white pagdi and solar hat). The dependent parameters were physiological parameters (resting HR, working HR, delta HR, resting OCR, working OCR, delta OCR) and physical parameter (ODR). The HR and OCR were measured with the help of Computerized Ambulatory Metabolic Measurement System (K4b^2) which records the oxygen consumed in every breath. Overall discomfort rate (ODR) was calculated using the 10-point psycho-physical rating scale.

RESULT AND DISCUSSION

Effect of headgear on physiological responses in heat stress conditions

Effect of headgear on heart rate in heat stress conditions

Working Heart Rate of ten subjects at different WBGT under different headgear conditions were measured during this experiment. Mean value table of working heart rate with WBGT and different headgear is given below in Table 1.

Table 1: Mean Values of working heart rate with WBGT using different headgear

Headgear condition	**WBGT 28ºC**	**WBGT 30ºC**	**WBGT 32ºC**	**Increase in HR Beats/min**	**WBGT CD**
No headgear	117.03	122.04	129.05	12.02	2.03
Felt hat 90 mm brim	114.10	118.80	125.66	11.56	
White pagdi	115.11	119.99	127.02	11.91	
Solar hat	110.62	115.11	121.10	10.48	
Bamboo hat	113.99	118.62	125.43	11.44	
Mean	114.17	118.91	125.65	11.48	
CD at 1 per cent level of significance	2.62				

CV	3.25	3.25

It can be seen that working HR varied from 5.38 beats/min to 6.92 beats/min at different headgear and WBGT. Working heart rate significantly increases with increase in WBGT at 1 per cent level of significance. Headgear reduces this increase in working heart rate with increase in WBGT. Increase in working heart rate is highest in case of no headgear condition condition and lowest in case of solar hat with air circulation. Combined effect of headgear and WBGT on working heart rate is significant at 5 per sent level of significance.

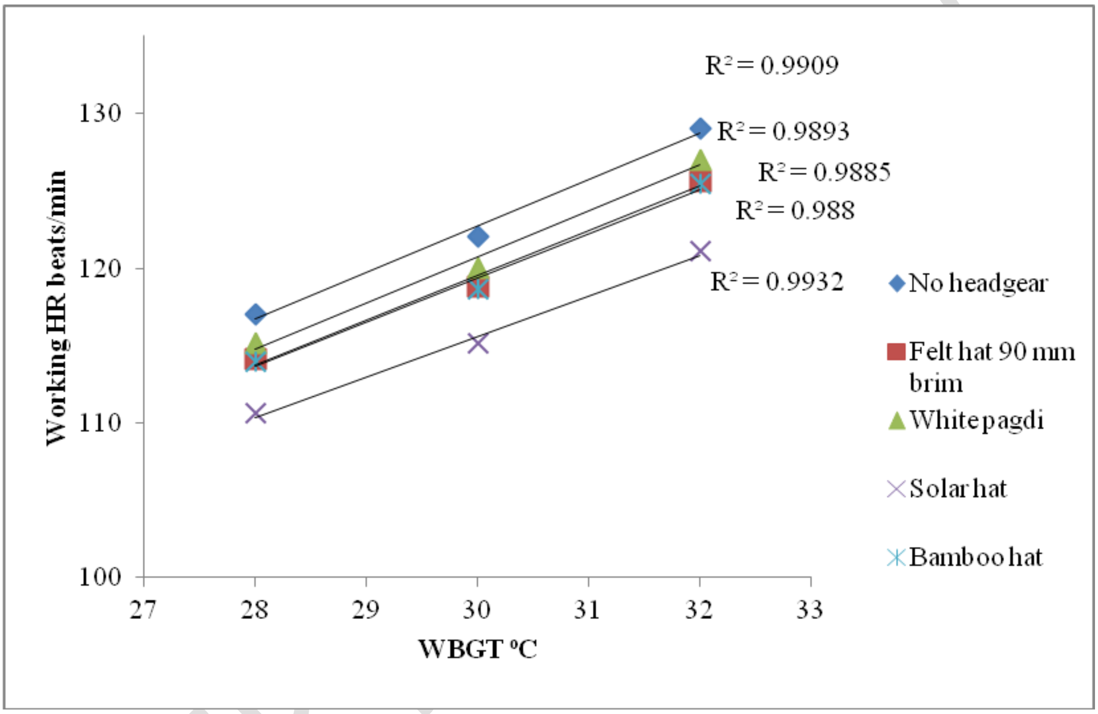

Fig 1 Effect of different headgear on working HR

In Fig. 1, working heart rate was observed to increase with an increase in WBGT. This happened due to increase in body core temperature due to which more blood for pumping was required for compensating the temperature rise. This increase in working HR was lowest in case of solar hat with air circulation and highest in case of no headgear condition. There was a linear relationship between WBGT and working heart rate and R^2 values were higher than 0.9932 in all cases of headgear with WBGT showing high degree of correlation. Working HR showed positive linear trend with increase in WBGT. Suggs and Splinter (1961), Hori et al (1978) and Majid & Mansour (2006), Singh (2013) and Dharaiya (2015) also reported similar increase in heart rate with increase in environmental temperature**.**

Mean value table of resting heart rate with WBGT and different headgear is given below in Table 2. It can be seen that resting HR varied from 76.51 beats/min at WBGT of 28°C to 79.44 beats/min at WBGT of 32 °C. Headgear reduces this increase in resting heart rate with increase in WBGT. Increase in resting heart rate is highest in case of no headgear condition and lowest in case of solar hat with air circulation. Combined effect of headgear and WBGT on resting heart rate is non significant.

Table 2: Mean Values of resting heart rate with WBGT using different headgear

Headgear condition	**WBGT 28ºC**	**WBGT 30ºC**	**WBGT 32ºC**	**WBGT CD**	**WBGT CV**
No headgear	77.86	78.96	80.91	2.03	4.99
Felt hat 90 mm brim	76.14	77.17	79.21		
White pagdi	76.94	77.97	79.95		
Solar hat	75.51	76.54	78.01		
Bamboo hat	76.09	77.10	79.12		
Mean	76.51	77.55	79.44		

In Fig. 2, resting heart rate was observed to increase with an increase in WBGT. The increase in resting HR was found less in comparison to increasing in working HR with increase in WBGT. It reflects that there was more heat load during the work at higher WBGT. There was a linear relationship between WBGT and resting heart rate and R^2 values were higher than 0.9898 in all cases of headgear with WBGT showing high degree of correlation. Resting HR showed positive linear trend with increase in WBGT. Singh (2013) and Dharaiya (2015) also reported similar increase in resting heart rate with increase in environmental temperature.

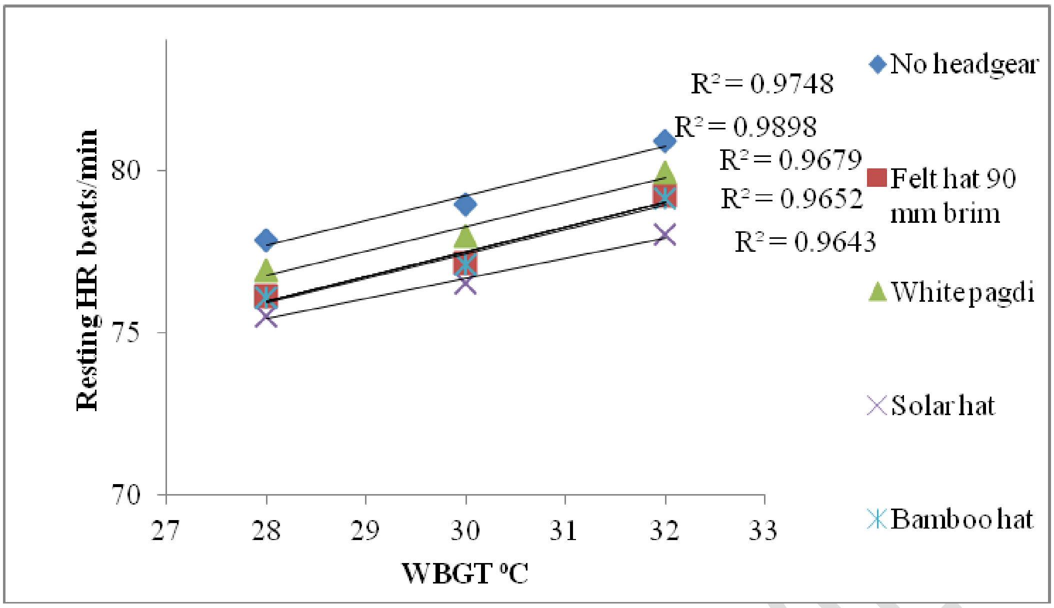

Fig. 2 Effect of different headgear on resting HR

Mean value table of delta heart rate with WBGT and different headgear is given below in Table 3. It can be seen that delta HR varied from 37.66 beats/min at WBGT of 28 °C to 41.11 beats/min at WBGT of 32 °C. Headgear reduces this increase in delta heart rate with increase in WBGT. Increase in delta heart rate is highest in case of no headgear condition and lowest in case of solar hat with air circulation. Combined effect of headgear and WBGT on delta heart rate is non significant.

Table 3: Mean Values of delta heart rate with WBGT using different headgear

Headgear condition	**WBGT 28°C**	**WBGT 30°C**	**WBGT 32°C**	**WBGT CD**	**WBGT CV**
No headgear	39.17	43.08	48.14	2.03	2.85
Felt hat 90 mm brim	37.96	41.63	46.45		
White pagdi	38.17	42.02	47.07		
Solar hat	35.11	38.57	43.09		
Bamboo hat	37.9	41.31	46.31		
Mean	37.66	41.32	46.21		

In Fig. 3, delta heart rate was observed to increase with an increase in WBGT. There was a linear relationship between WBGT and delta heart rate and R^2 values were higher than 1 in all cases of headgear with WBGT showing high degree of correlation. Delta HR showed positive linear trend with increase in WBGT.

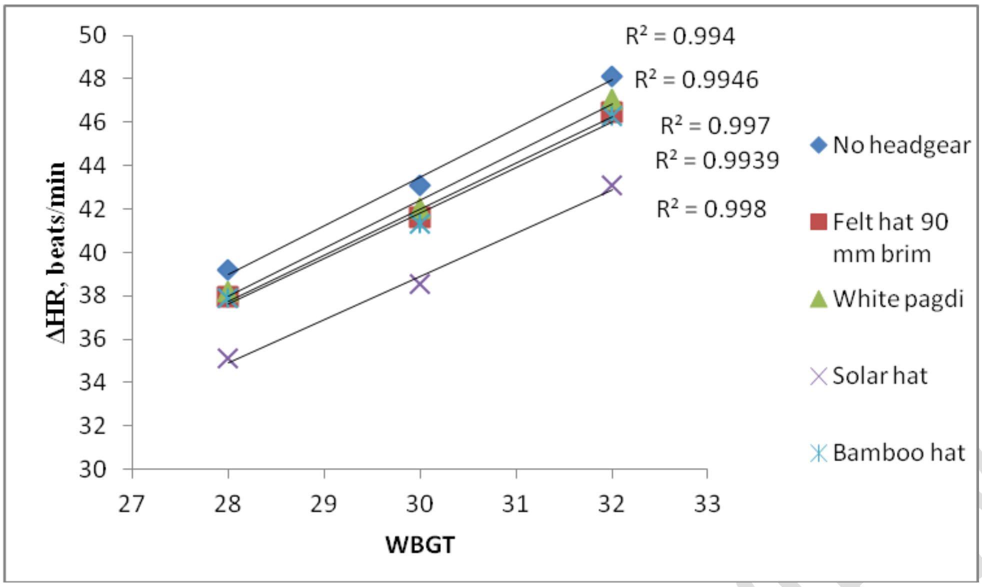

Fig 3 Effect of different headgear on delta HR

Effect of headgear on OCR in heat stress conditions

Working oxygen consumption rate of ten subjects at different WBGT under different headgear conditions were measured during this experiment. Mean values of working oxygen consumption rate with WBGT and different headgear is given in Table 4.

Table 4: Mean values of working oxygen consumption rate with WBGT using different headgear

Headgear condition	**WBGT 28°C**	**WBGT 30°C**	**WBGT 32°C**	**Increase in OCR ml/min**	**WBGT CD**
No headgear	724.43	778.44	837.65	113.22	81.57
Felt hat 90 mm brim	708.57	763.65	821.42	112.85	
White pagdi	722.65	777.95	832.53	109.88	
Solar hat	643.35	693.78	747.89	104.54	
Bamboo hat	697.61	772.48	810.46	112.85	
Mean	699.32	757.26	809.99	110.67	
CD at 1 per cent level of significance	105.31				
CV	20.70				20.70

It can be seen that variation in difference of working oxygen consumption rate Increase in $OCR_{working}$ was found maximum in no headgear conditions and lowest for solar hat with air circulation. Working OCR varied from 113.22 ml/min in no headgear condition to 104.54 ml/min in solar hat with air circulation.

Working oxygen consumption rate significantly increases with increase in WBGT at 1 per cent level of significance. Headgear reduces this increase in working oxygen consumption rate with WBGT. Increase in working oxygen consumption rate is highest in case of no headgear condition and lowest in case of solar hat with air circulation. The increase in working OCR was more than the resting OCR with increase in WBGT condition. It also signifies the effect of heat load on working condition is higher. Combined effect of headgear and WBGT on working oxygen consumption rate is non significant.

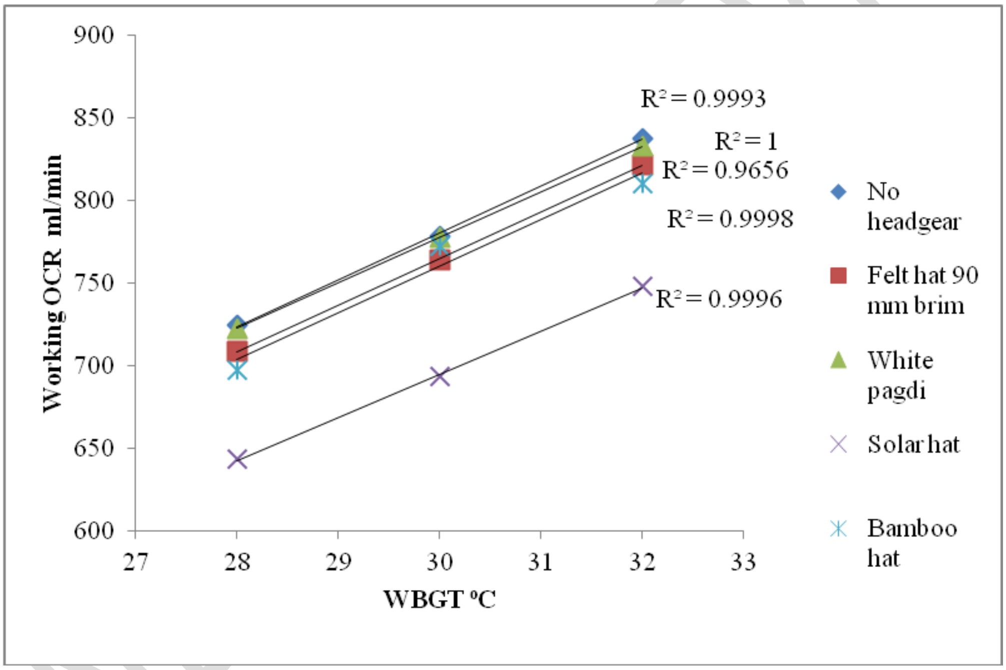

Fig 4 Effect of different headgear on working OCR

In Fig. 4, working oxygen consumption rate was observed to increase with an increase in WBGT. This increase in working OCR was highest in no headgear condition and lowest in solar hat with air circulation condition. There was a positive linear correlation between them and R^2 values were higher in all cases of headgear with WBGT showing very high degree of correlation between them. Working OCR exhibited a positive linear trend with increase in WBGT. Singh (2013) also reported similar increase in working OCR with increase in environmental temperature.

Mean values of resting oxygen consumption rate with WBGT using different headgear in table 5. Resting OCR increased from 181.16 ml/min at WBGT of 28 ºC to 204.83 ml/min at WBGT of 32 ºC. The resting oxygen consumption rate significantly increases with increase in WBGT at 1 per cent level of significance. Headgear reduces this increase in resting oxygen consumption rate with WBGT. Combined effect of headgear and WBGT on resting oxygen consumption rate is non significant.

Table 5: Mean values of resting oxygen consumption rate with WBGT using different headgear

Headgear condition	**WBGT 28ºC**	**WBGT 30ºC**	**WBGT 32ºC**	**WBGT CD**	**WBGT CV**
No headgear	191.29	204.89	217.69	26.32	25.84
Felt hat 90 mm brim	179.46	194.51	208.16		
White pagdi	188.49	203.53	215.12		
Solar hat	170.15	183.43	194.39		
Bamboo hat	176.41	191.29	204.83		
Mean	181.16	195.53	208.04		

In Fig. 5, resting oxygen consumption rate was observed to increase with an increase in WBGT. There was a positive linear correlation between them and R^2 values were higher in all cases of headgear with WBGT showing very high degree of correlation between them. Resting OCR exhibited a positive linear trend with increase in WBGT. Singh (2013) also reported similar increase in resting OCR with increase in environmental temperature.

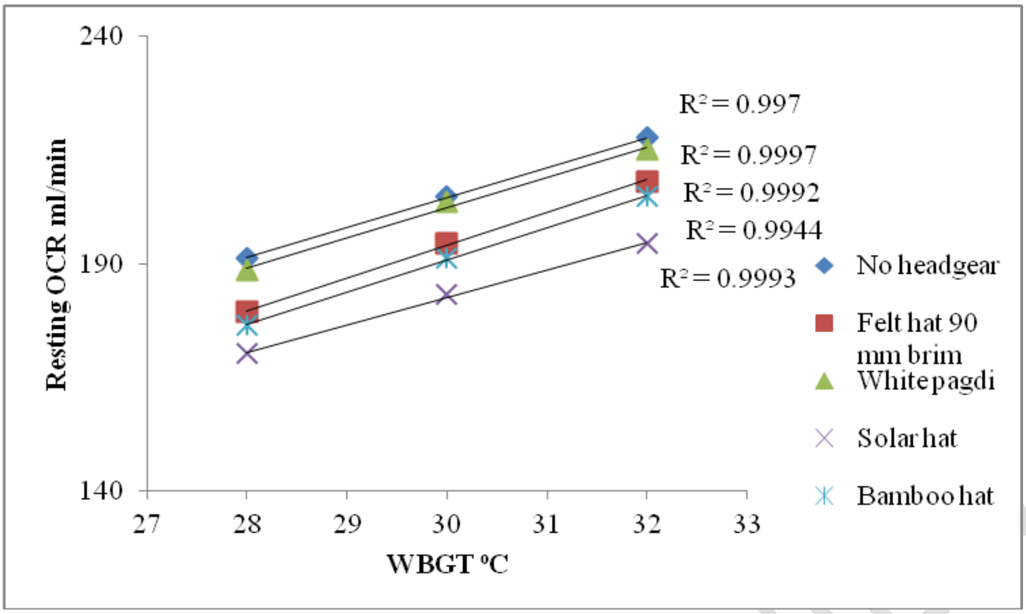

Fig. 5 Effect of different headgear on resting OCR

Mean values of delta oxygen consumption rate with WBGT using different headgear in table 6. Delta OCR increased from 518.16 ml/min at WBGT of 28 ºC to 542.95 ml/min at WBGT of 32 ºC. The delta oxygen consumption rate significantly increases with increase in WBGT at 1 per cent level of significance. Headgear reduces this increase in delta oxygen consumption rate with WBGT. Combined effect of headgear and WBGT on delta oxygen consumption rate is non significant.

Table 6: Mean values of delta oxygen consumption rate with WBGT using different headgear

Headgear condition	WBGT 28ºC	WBGT 30ºC	WBGT 32ºC	WBGT CD	WBGT CV
No headgear	533.14	573.55	619.96	81.92	28.03
Felt hat 90 mm brim	529.11	569.14	613.26		
White pagdi	534.16	574.42	617.41		
Solar hat	473.2	510.35	553.5		
Bamboo hat	521.2	561.19	605.63		
Mean	518.16	557.73	601.95		

In Fig. 6, delta oxygen consumption rate was observed to increase with an increase in WBGT. There was a positive linear correlation between them and R^2 values were higher in all cases of headgear with WBGT showing very high degree of correlation between them.

Delta OCR exhibited a positive linear trend with increase in WBGT. Singh (2013) also reported similar increase in delta OCR with increase in environmental temperature.

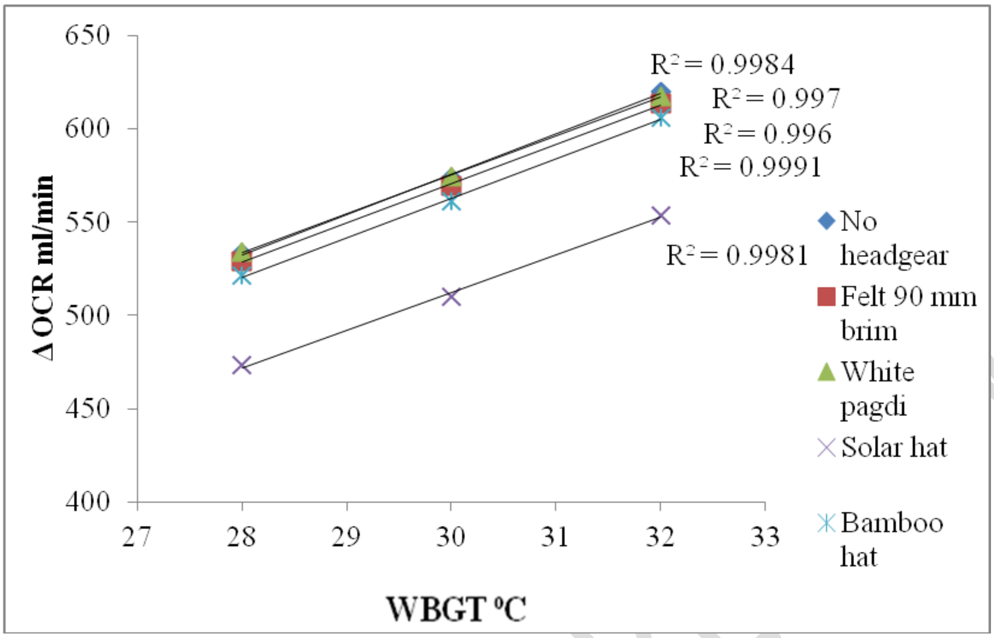

Fig. 6 Effect of different headgear on Delta OCR

Effect of headgear on physical discomfort in heat stress conditions

Overall discomfort rate of ten subjects at different WBGT under different headgear conditions were measured during this experiment. Mean Values of Overall Discomfort Rate with WBGT and Different Headgear is given below in Table 7.

Table 7: Mean Values of Overall Discomfort Rate with WBGT using different headgear

Headgear condition	**WBGT 28°C**	**WBGT 30°C**	**WBGT 32°C**	**Increase in ODR**	**WBGT CD**
No headgear	5.25	7.25	8	2.75	0.25
Felt hat 90 mm brim	4.6	5.5	6	1.4	
White pagdi	4.8	6.6	7.3	2.5	
Solar hat	4.2	4.7	5.3	1.1	
Bamboo hat	5	7	7.7	2.7	
Mean	4.77	6.21	6.86	2.09	
CD at 1 per cent level of significance	0.32				
CV	7.86				7.86

It can be seen that ODR varied from 4.77 at WBGT of 28 °C to 6.68 at WBGT of 32°C. ODR varied from 2.75 in no headgear condition to 1.1 in solar hat with air circulation. Overall Discomfort Rate significantly increases with increase in WBGT at 1% level. Headgear reduces this increase in Overall Discomfort Rate with WBGT. Increase in Overall Discomfort Rate is highest in case of no headgera and lowest in case of solar hat with air circulation. Combined effect of Head Cover and WBGT on Overall Discomfort Rate is non significant. Fig. 7 shows the variation of ODR with WBGT for different headgear. Singh (2013) and Dharaiya (2015) also reported similar increase in ODR with increase in environmental temperature.

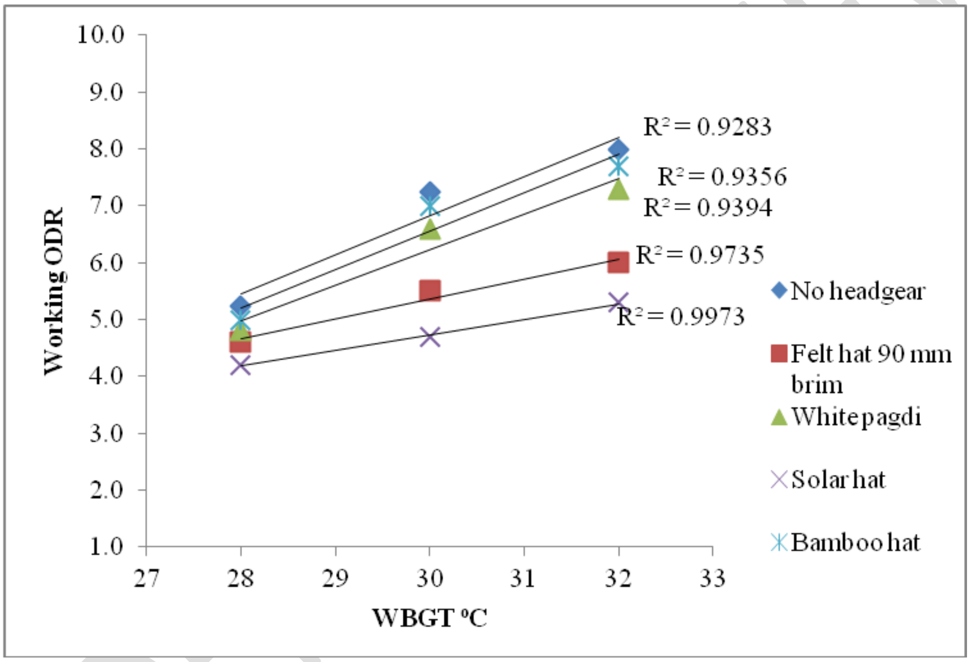

Fig. 7 Effect of different headgear on ODR

CONCLUSION

Physiological parameters like resting and working heart rate as well as resting and working oxygen consumption rate increased with increase in WBGT. Overall Discomfort Rate (ODR) increased with increase in WBGT due to heat stress. Use of headgear reduced the effect of heat stress significantly on physiological parameters (working heart rate and working oxygen consumption rate) and on physical discomfort parameters (overall discomfort rate). Solar hat with air circulation mechanism was found better than felt hat 90 mm brim, white pagdi and bamboo hat as headgear in reducing the ill effects of heat stress.

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