PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS ON HEAT ACCLIMATIZATION IN EXTREME HOT ENVIRONMENT

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Abstract- A cross sectional study of physiological and psychological effects on heat acclimatization in hot environment was conducted among construction workers in Pahang, Malaysia. The goals of this study are to assess the physiological (blood pressure, heart rate and oral temperature) and psychological (fatigue feeling) effects of workers in hot environment. A correlation between fatigue feeling and physiological effects is determined. An increment of physiological parameters toward exposure of heat environment proves that the workers are affected by heat acclimatization. The finding of this study reveals that there are significant differences between before and after session of oral temperature ($p = 0.0001$), heart rate ($p = 0.0001$), systolic blood pressure ($p = 0.0001$), diastolic blood pressure ($p = 0.0001$) and sweating rate ($p = 0.004$) among the workers who are working in hot environment. The relationship between fatigue and physiological effects reveals with spearman test that the correlation is weak ($p < 0.05$). The results show that the physiological changes happen during workers conducted their jobs under hot environment. Only physiological of workers were shifted to achieve the heat acclimatization in extreme hot environment.

Keywords- Hot Environment, Heat Acclimatization, Physiological, Psychological, Fatigue

I. INTRODUCTION

A gigantic number of industries operate under the direct sunlight such as coke oven, iron, steel, and glass manufacturing, mining, and some military and construction. The construction industry allows the workers have a high tendency to expose to the extreme hot environments which temperatures is above 35ºC for living and above 32ºC for working (Tian et al., 2011). According to Japan International Center of Occupational Safety and Health Association the construction industry is found to be more susceptible to heat stress than other industries. Lu and Zhu (2007) mentioned that physical work in a hot and humid environment imposes considerable physical strain of workers, with significant associated health risks; reduce productivity and certain safety problem.

Malaysia, as a tropical country experiences constantly high temperature (24ºC to 38ºC) and relative humidity, light and variable wind condition, long hours of sunshine with heavy rainfall and overcast cloud cover throughout the year. This circumstance shows that the outdoor workers in Malaysia also have high probabilities to the exposure of extreme heat environment. They have enormous risks of a variety of heat related disorder, such as heat rash, heat cramps, heat syncope, heat exhaustion and heat stroke.

When, the workers expose to direct sunlight for longer period, their body start to tolerate via acclimatization process which alters the physiological and physiological effects. Heat acclimatization occurs very rapidly with significant adaptation apparent after only 2 hours heat exposure per day for 8 consecutive days. The Table 1 below show the re-acclimation period after routine absences and illnesses. However, the lack of acclimatization tends the workers to the heat fatigue. The victim is not adapting with the hot environment surrounding and contributes to heat fatigue to the body. There is no treatment for heat fatigue except to remove the heat stress before more serious heat related condition developed. Tian et al., (2011) studied the score of the fatigue feeling increased as the increase of the exposure time in the extreme hot environment. They revealed that people was easier to feel fatigue before heat acclimatization training, thus heat acclimatization can be reduced the feeling of fatigue in extreme hot environments.

TABLE 1
RE–ACCLIMATION PERIOD AFTER ROUTINE ABSENCES AND ILLNESSES

Day	Activity Level (% of full work)	
	Experienced	New
Day 1	50	20
Day 2	60	40
Day 3	80	60
Day 4	100	80
Day 5	-	100

The body system of workers can be acclimatized by enhancing the blood pressure, sweating rate and heart rate. The previous study which conducted by Tian and co-workers (2011) stated that before the training and after the manual working the heart rate of the subjects significantly increased above the normal rate which was average range 40-8-beats/min. Besides, they also proved that the significant difference between the sweating rates before and after the training. It indicates that the heat acclimatization training stimulated a greater sweating rate, thus the ability for adjusting body temperature in the extreme hot environment enhanced. According to Moriola et al., (2006) although the changes in the blood pressure were not remarkable in the research, monitoring the blood pressure is useful to evaluate the effects of work in hot environment on the health. By considering the acclimatization of workers who are directly exposed to extreme hot environment, this study assesses the physiological and physiological alteration among them. This study was conducted at construction site in Pahang, Malaysia. The finding of this study can be used for developing and providing guidance and reference of heat acclimatization among the workers in Malaysia.

II. METHODOLOHGY

This study was carried at three construction sites which located in Pahang. The numbers of respondents are about 41 construction workers. The demographic data (the gender, and the age and education level) and physiological indices (oral temperature, heart rate, blood pressure and mass body weight) were recorded The psychological study of construction workers were determined by interviewing them the thermal sensation and fatigue feeling.

A.Questionnaire

The age, weight, and height of the subjects were taken during the respondents answered the questionnaire. The subjects were dressed up in fully clothing with the safety shoes and safety helmet. The subjects were asked to respond the questionnaires of fatigue feeling before and after do their work. The subjective assessments are based on the subjects' vote on the fatigue feeling. The fatigue feeling was a command psychological – physiological phenomenon. In order to evaluate the fatigue feeling in the extreme hot environment, the questionnaire of "Evaluation of Subjective Symptoms of Fatigue" was adapted. It was developed by the working group for occupational fatigue of the Japan Society for Occupational Health, as given in the Table 2. Based on the score, the fatigue level can be determined as shown in Table 3.

TABLE 2
THE QUESTIONNAIRE OF FATIGUE FEELING.

Drowsiness and dullness	Difficulties in concentration	Projection of physical disintegration
Heavy head	Unorganized thought	Headaches
Languid body	Don't want to speak	Stiff shoulder
Stiff legs	Irritated	Lower back pain
Yawns	Cannot concentrate	Chest distress
Dull head	Not interested on the matter	Thirsty
Drowsy	Minor details cannot be thought up	Hoarse
Tired eyes	Lack of confident	Dizzy
Unnatural movements	Anxious	Twitch in the eyelids and muscles
Standing firm	Easy to get angry	Tetany
Want to lie down	No patience	Feel unwell

TABLE 3
FATIGUE LEVEL

Scores	Fatigue level
< 6	Un fatigue
6 -12	Feel fatigue but can proceed to work
12 – 18	Fatigue, physical decline and inattentive
18 – 24	Physical and psychic fatigue, and hard to endure
> 24	Extreme fatigue and immediate rest

B. Statistical Analysis

Statistical Package for the Social Science (SPSS) software was used to analyze the statistical analysis and the correlation of relationship between the psychological and physiological effects of heat acclimatization in extreme hot environment. The effects of heat acclimatization on the physiological and the psychological indexes were analyzed by using paired sample t-tests. An alpha level of 0.05 was adopted in all tests to identify significant differences by using the SPSS software.

III. RESULT

A.Environmental Parameters

In order to study the physiological and psychological effects of construction workers on heat

acclimatization in hot environment, the environmental parameters were measured. Table 4 summarizes the environmental parameters started from 1st day till 3rd day assessment. On the 1st day assessment, the respondents were conducted the heavy work under the extreme hot environment between 35ºC until 42ºC. The minimum value of the dry bulb temperature was 28.92ºC, meanwhile the maximum value was 34.18ºC. Hence, the average value of the temperature of the day was 31.76ºC. The minimum value for relative humidity of the day was 47% and the maximum value was 95%. The average value of the relative humidity for the day was 53.28%. Besides that, the minimum of air velocity was 2.10m/s and the maximum value was 3.94m/s, as the average value of the day was 3.07m/s.

The last parameter is WBGT value, as the minimum value was 27.92ºC and the maximum value was 33.23ºC. The average value of the WBGT of the day was 30.59 ºC. The maximum temperature for that day was 34.18ºC as stated by dry bulb temperature.

TABLE 4
A SUMMARY OF ENVIRONMENTAL PARAMETERS FOR THREE DAYS ASSESSMENT.

Environmental parameters	Minimum	Maximum	Average
1st day assessment			
Dry bulb temperature (ºC)	28.93	34.18	31.76
Relative humidity (%)	47	95	53.28
Airflow velocity (m/s)	2.10	3.94	3.07
WBGT (ºC)	27.92	33.23	30.59
2nd day assessment			
Dry bulb temperature (ºC)	30.33	37.48	34.23
Relative humidity (%)	33	89	50.57
Airflow velocity (m/s)	0.01	1.19	0.37
WBGT (ºC)	27.26	35.77	31.66
3rd day assessment			
Dry bulb temperature (ºC)	29.59	37.07	33.38
Relative humidity (%)	28	78	47.83
Airflow velocity (m/s)	0.01	1.48	0.55
WBGT (ºC)	29.38	35.72	32.03

The 2nd day assessment indicates that the minimum value of the dry bulb temperature was 30.33ºC; meanwhile the maximum value was 37.48ºC. Hence, the average value of the temperature of the day was 34.23ºC. The minimum and maximum value for relative humidity of the day was 33% and 89%, respectively. The average value of the relative humidity for the day was 50.57%. Besides that, the minimum of airflow velocity was 0.01m/s and the maximum value was 1.19m/s, as the average value of the day was 0.37m/s. The WBGT minimum, maximum and average values were 27.26ºC, 35.37ºC and 31.66 ºC, respectively. The maximum temperature for that day was 37.48ºC as showed by dry bulb temperature.

The 3rd day assessment, the minimum, maximum and average value of the dry bulb temperature was 29.59ºC, 37.07ºC and 33.38ºC respectively. The minimum, maximum and average value for relative humidity of the day was 28%, 78% and 47.83%, respectively. Besides, the minimum of airflow velocity was 0.01m/s and the maximum value was 1.48m/s, as the average value of the day was 0.55m/s. The WBGT minimum value was 29.38ºC and the maximum value was 35.72ºC. The average value of the WBGT of the day was 32.03ºC. The maximum temperature for that day was 37.07ºC as stated by dry bulb temperature.

B. Statistical Analysis of Physiological and Psychological Effects

Effects of the heat acclimatization on the physiological and the psychological indexes were analyzed by using the paired sample t-test. An alpha level of 0.05 ($\alpha = 0.05$) was adopted in all tests to identify significant differences by using the SPSS software. The statistical results (Mean ± Standard Deviation) of the oral temperature, heart rate, blood pressure, sweating rate and fatigue feeling along the heat acclimatization during the work day are expressed in Mean ± Standard Deviation (SD) is presented in the Table 5. The Paired sample t-test was conducted to test the significant differences of

the physiological and psychological indexes before and after work day in the hot environment. The results of the paired sample t-test are shown in Tables 6 and 7.

TABLE 5
THE PHYSIOLOGICAL INDEXES OF CONSTRUCTION WORKERS BEFORE AND AFTER IN EXTREME HOT ENVIRONMENT

Parameters	Mean ±SD Before (morning)	After (morning)	Before (noon)	After (noon)
Oral temperature	36.098± 0.609	37.256± 1.347	37.220± 1.124	37.566± 1.221
Heart rate	77.683± 7.181	85.659± 9.630	82.829± 7.148	88.561± 7.025
Systolic blood pressure	101.927± 13.233	123.659± 11.761	116.854± 8.737	124.683± 7.132
Diastolic blood pressure	70.976± 5.002	78.976± 9.259	75.366± 6.851	80.829± 6.906
Sweating rate	Morning 0.26%± 0.14%	Noon 0.23%± 0.56%		

N=41,*significant at $p < 0.05$

TABLE 6
PAIRED SAMPLE T-TEST RESULTS AT THE MORNING SESSION

Morning	Difference Mean	Standard Deviation	Standard Error Mean	Sig. (2-Tailed) p-value
Oral Temperature	-1.159	1.126	0.176	*0.0001
Heart Rate	-7.976	6.502	1.015	*0.0001
Systolic Blood Pressure	-21.732	13.282	2.074	*0.0001
Diastolic Blood Pressure	-8.000	8.106	1.266	*0.0001

N=41,*significant at $p < 0.05$

TABLE 7
PAIRED SAMPLE T-TEST RESULTS AT THE NOON SESSION

Noon	Difference Mean	Standard Deviation	Standard Error Mean	Sig. (2-Tailed) p-value
Oral Temperature	-0.3463	0.3225	0.0503	*0.000
Heart Rate	-5.7317	6.3443	0.9908	*0.000
Systolic Blood Pressure	-7.8292	6.4416	1.0060	*0.000
Diastolic Blood Pressure	-5.4634	5.6925	0.8890	*0.000

N=41,*significant at $p < 0.05$

C. Oral Temperature

Oral temperature is an index of core temperature which is usually adequate to every respondent. Figure 1 illustrates the oral temperature of the respondent before and after session. This figure 1 shows that the oral temperatures of the respondents were increased when exposed to hot environment. A comparison of the mean values of respondents' oral temperature before and after heat acclimatization during working hour is tabulated in Table 5. Before the working hour in the morning session (mean ± SD =36.0975± 0.6092) and after (mean ± SD = 37.2561± 1.3472) during the working hours, there are small differences between the values. Then, before (mean ± SD = 37.2195± 1.1241) and after (mean ± SD = 37.5658± 1.2214) working hours during noon session also has small differences mean ± standard deviation (SD) values.

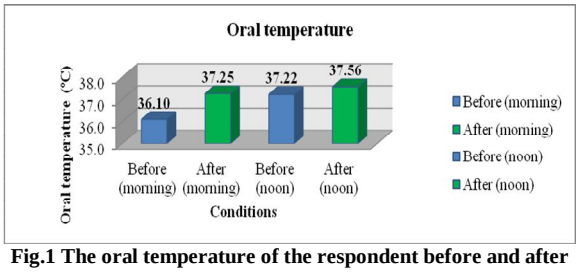

Fig.1 The oral temperature of the respondent before and after assessment session.

The paired sample t – test results with the significance value is smaller than 0.05 (p = 0.0001) proves the finding of this study as tabulated in Tables 6 and 7. It indicates that there was a significant difference between the oral temperature before and after work hours. The American Conference of Governmental Industrial Hygiene (ACGIH) stated that workers should not be permitted to work when their deep body temperature exceeds 38ºC (100ºF). Pertaining this study, the oral temperature of the respondents were not achieved the recommended standard by ACGIH. There are significant differences between the oral temperature before and after session. It proves that the effects of physiological changes among the respondents in extreme hot environment.

D.Heart Rate

Figure 2 illustrates the heart rate of respondents before and after assessment session. It can be seen that the trends of the Mean values of the respondents before and after working hour between morning and noon session was changed. The comparison of the Mean ± standard deviation (SD) of heart rate before and after heat acclimatization during working hour can also be observed in Table 5. Before the working hour at the morning (mean ± SD =77.6829± 7.1813) and after (mean ± SD =85.6585± 9.6296) during the working hours, there was significant difference before and after the working hour in the morning. Besides that, before (mean ± SD =82.8292± 7.1481) and after (mean ± SD =88.5609± 7.0251) the respondents working hours during noon there was also significant difference mean ± standard deviation (SD) values. It can be deduced according to the paired sample t-test result as tabulated in Tables 6 and 7, thus significance value is smaller than 0.05 (p = 0.0001). It depicts that there was a significant difference between the oral temperature before and after work hours. The heart rates of respondents are in the range between the 40 to 180 beats/min. This finding is a good agreement with Zhang and Zhao (2009) which stated that before training and after the manual working the heart rate of the subjects significantly increased above the normal rate (average range 40 to 180beats/min). It assumes that the heart rate surprisingly reacted to the ambient temperature and more or less oscillated synchronously with the temperature surrounding the subjects.

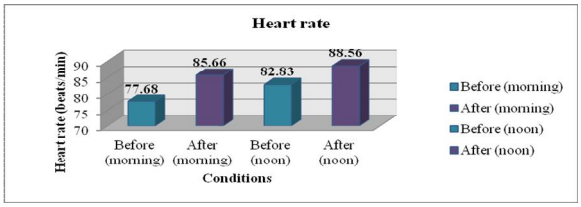

Fig.2 The heart rate of the respondent before and after session

E. Systolic Blood Pressure

Figure 3 shows the systolic blood pressure before and after heat acclimatization during working hours in hot environment. As tabulated in Table 6 and 7, there is a significant different before and after the working hour at the morning. It is due to before the working hour at the morning (mean ± SD =101.9268± 13.2332) and after (mean ± SD =123.6585± 11.7614) during the work hours. In addition, before (mean ± SD =116.8536± 8.7365) and after (mean ± SD =124.6829± 7.1324) the respondents working hours during noon there is also significant difference mean ± standard deviation (SD) values. It can be proved via the paired sample t-test result as tabulated in Tables 6 and 7 with the significance value is smaller than 0.05 (p = 0.0001). It points out that there is a significant difference between the systolic blood pressure before and after work hours. It deduces after heat acclimatization training, the body response to the extreme hot environment become more rapid, and blood vessels dilated to increase the heat loss of the body.

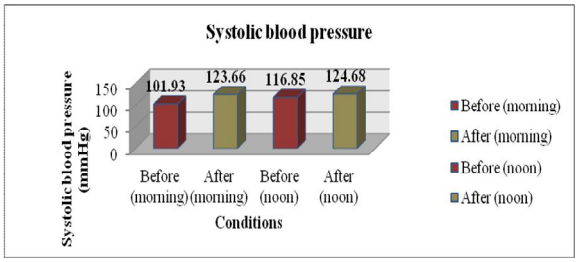

Fig. 3 The systolic blood pressure of the respondents before and after session.

F. Diastolic Blood Pressure

Figure 4 depicts the Mean values of the respondents before and after working hour between morning and noon session. As tabulated in Table 4, we can see that the comparison of the Mean ± standard deviation (SD) of diastolic blood pressure before and after heat acclimatization during working hour. The diastolic blood pressure of respondent before the working hour at the morning (mean ± SD =70.9756± 5.0024) and after (mean ± SD =78.9756± 9.2587) during the working hours. It shows that there is a significant difference before and after the working hour at the morning. Then, before (mean ± SD =75.3658± 6.8511) and after (mean ± SD =80.8292± 6.9061) the respondents working hours during noon there is also significant difference Mean ± standard deviation (SD) values.

The paired sample t-test result as tabulated in Table 6 and Table 7, a significance value is smaller than 0.05 (p = 0.0001). It explains that there is a significant difference between the diastolic blood pressure before and after work hours. The variation of the diastolic blood pressure was fluctuated before and after the session. However, the previous study

which conducted by Zhang and Zhao (2009) the variation of the diastolic blood pressure was different from the systolic blood pressure. There are no transient increased as the diastolic blood pressure remained relatively constant when the subject working in extreme hot environment. The reason is that the diastolic blood pressure depends on the elasticity of the artery wall and the effects of small artery resistance and there is little relationship between the diastolic blood pressure and the stroke volume (the amount of blood pump out from the heart with each contraction. Therefore, the variation of the diastolic blood pressure is different from the systolic blood pressure or heart rate.

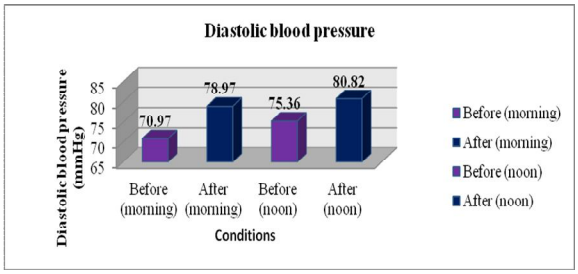

Fig. 4 The diastolic blood pressure before and after session

G.Sweating Rate

The changes of body weight and the mean percentages of sweating rate at the morning and noon are illustrated in Figures 5 and 6, respectively. By using the Wilcoxon test, it can be determined the significance differences between the non parametric data of the sweating rate. Table 8 shows the significant difference between sweating rate before and after working hours at the morning and noon as the sig (2-tailed) value is smaller than 0.05 (p = 0.004). It means that the decreasing of sweating rate among the workers during noon session indicates most of the workers were already lost of sweat during working in the extreme hot environment at the end of the day. The respondents were advised to drink enough water to make up for about 80% of the working sweat loss (100% replacement is virtually unattainable in hard-working labors (Coyle, 2004). Workers chronically exposed to hot environments should have their body weight monitored. As Occupational Safety and Health Guidance Manual for Hazardous Waste Site activities suggested that body weight loss and sweating rate of workers in a workday should not exceed 1.5%. (Lu and Zhu, 2006).

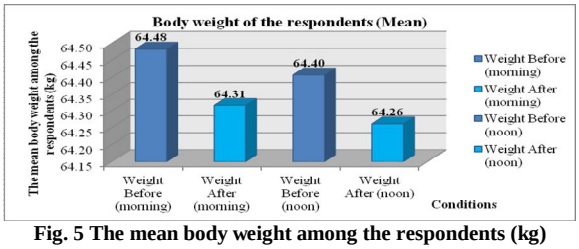

Fig. 5 The mean body weight among the respondents (kg)

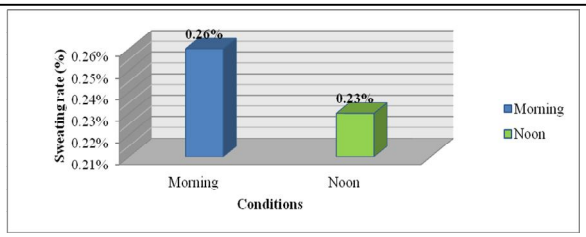

Fig. 6 The sweating rate among the workers during morning and noon

TABLE 8
WILCOXON TEST STATISTICS OF SWEATING RATE

	Sweating rate (noon) – Sweating rate (morning)
Z	-2.85
Asymp. Sig (2-tailed)	0.004*

N = 41; *Significant at p < 0.05

H.Fatigue

As shown in Table 6 and 7, the values of fatigue feeling were determined by using t-test. It mentioned that a significant difference is smaller than 0.005 (p = 0.00). It indicates that the respondents are getting feeling fatigue during the work hours. Thus, heat acclimatization training reduced the feeling of fatigue in extreme hot environment. Most of the respondents were feeling fatigue as the score of the level fatigue between 6 to 12 values which means they felt fatigue but still can be proceeded their work. It believes that the respondents were already acclimatizing during working hours as they worked past 30 days. Heat acclimatization occurs very rapidly, with substantial adaptation after only 2 hour of heat exposure per day for 8 consequences days. The result score of the each respondent can be observed in Tables 9 and 10 which points out the level of the fatigue feeling.

I. Correlation between fatigue feelings and physiological effects

The Pearson test shows there were weak relationships of the physiological conditions of the respondents towards fatigue feeling during working hour in hot environment as illustrated in Table 11. The result indicates that the oral temperature (R = -0.180, p = 0.260) and fatigue feeling were also in a very weak relationship as the p value is not significance. The heart rate (R = -0.071, p = 0.660) also depicts the weak relationship between fatigue feeling of the respondents during working hour in hot environment as the p value also is not significance. As for the blood pressure, systolic blood pressure (R= 0.037, p= 0.820) and diastolic blood pressure (R= -0.0057, p= 0.723) were determined as weak relationship between the fatigue feeling of the respondents as the p value also not significance when

p > 0.05. The relationship between fatigue feeling towards sweating rate also can be determined with the (R= -0.035, p= 0.829) which means the relationship between the variables were weak and not significance to each other.

TABLE 9
THE FREQUENCIES RESULTS OF FATIGUE FEELING AMONG THE RESPONDENT

Score		Frequency	Percent (%)
Valid	2.00	1	2.4
	4.00	7	17.1
	5.00	6	14.6
	6.00	4	9.8
	7.00	4	9.8
	8.00	5	12.2
	9.00	7	17.1
	10.00	1	2.4
	11.00	2	4.9
	12.00	1	2.4
	13.00	1	2.4
	15.00	1	2.4
	22.00	1	2.4
	Total	41	100.0

N = 41

TABLE 10
THE T-TEST RESULT OF FATIGUE FEELING AMONG THE RESPONDENTS (JAPAN SOCIETY FOR OCCUPATIONAL HEALTH, 2005)

Scores	Fatigue level
< 6	Unfatigue
6-12	Feel fatigue but can proceed to work
12-18	Fatigue, physical decline and in attentive
18-24	Physical and psychic fatigue, and hard to endure
>24	Extreme fatigue, and need immediately rest

TABLE 11
THE CORRELATION BETWEEN PHYSIOLOGICAL EFFECTS TOWARDS FATIGUE FEELING AMONG THE RESPONDENTS.

Variables	R	p-value
Oral Temperature	-0.180	0.260
Heart Rate	-0.071	0.660
Systolic Blood Pressure	0.037	0.820
Diastolic Blood Pressure	-.0057	0.723
Sweating rate	-0.035	0.829

N = 41; *Significant at p <0.05

J. Heat Acclimatization

The human body can adapt to heat stress to some extent. This physiological adaptation is called acclimatization. The reaction of the automatic nerves to prevent the increase of the body temperature is quick 4 to 5 day after beginning the work in hot environments. The hormonal regulation starts after 3 to 4 weeks later (Zhang and Zhao, 2009). The finding of this study seems the workers to be acclimatized to hot environment, because they had been working there more than 5 days Therefore, the heat acclimatization training can be improving adaptability of human body to extreme hot environment. The permissible heat exposure threshold limit values established by ACGIH can be applied to nearly all acclimatization workers.

IV. DISCUSSION

A. Physiological

The physiological effects towards the extreme hot environment were obtain from the study as the physiological parameters showed that the significant result between before and after working in hot environment. The changes of physiological of the workers in extreme hot environment were determined as the effects of the heat acclimatization of the workers. From this study, the results were showed that the physiological changes happen during their work hour in hot environment. It means that the workers physiological were effects toward the heat acclimatization. According to the study result, the changes of heat acclimatization in high temperature workplace can be obtained, and the heat acclimatization training is beneficial for enhancing workplace safety. When people working in hot environment, the oral temperature increased, the heart rate speeded up and the blood pressure fluctuates. Heat acclimatization in humans biological adaptation that controls physiological activities. By exposure of working hours in hot environment, the heat acclimatization can induce biological adaptations, reduce oral temperature, improve thermal sensation, working capabilities, and obtain perfuse sweating.

B. Psychological

The psychological effects toward the extreme hot environment were obtained from the fatigue questionnaire. From the questionnaire the result studies obtain that most of the construction workers were feeling fatigue but can proceed to work. Moreover, the fatigue feeling by subjective methods adopted in this study was used to evaluate the level of fatigue in the work environments. However the subjective evaluation in the related studies is still lacking. As the Z. Tian [2] said, the application of fatigue feeling in the heat acclimatization is

meaningful. Brown I.D.[12] also said that fatigue also has psychological meaning, which was not having the energy to do anything, and subjectively experienced reluctant to continue with a task.

CONCLUSION

The physiological effects towards the extreme hot environment were studied as the physiological parameters showed that the significant results between before and after working in hot environment. The results were also showed that the physiological changes happen during their work hour in hot environment. Besides, the questionnaire result points out that most of the construction workers were feeling fatigue but can be proceeded to work. As a conclusion, the physiological and psychological changes of workers in extreme hot environment were determined as the effects of the heat acclimatization of the workers. The changes of heat acclimatization in high temperature workplace can be obtained. Therefore, heat acclimatization training is beneficial for enhancing workplace safety.

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