A COMPARISON OF THE THERMAL RESPONSE OF MIDDLE EASTERN AND UNITED STATES STUDENTS

by

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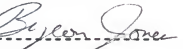

Major Professor

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Special thanks to my family for their constant support and encouragement, and to my wife, Hala, for being kind and considerate throughout this study.

Introduction

The study of thermal comfort can be approached from two different directions using two different methods. First, empirical methods, using social survey techniques such as comfort votes under defined environmental conditions. Second, analytical methods, tracing the heat flow paths from metabolic heat production to the environment and considering resistance to this flow (Szokoky, 1987).

The Institute for Environmental Research at Kansas State University (Manhattan) has conducted an extensive empirical testing on 1600 college-age students paralled by analytical work to produce the data base for ASHRAE Standard 55 "Thermal Environmental Conditions for Human Occupancy" ASHRAE (1981). The ASHRAE standard specifies two comfort zones, one for summer and one for winter. The students who participated in these testings were normally clothed and engaged in sedentary activities. They were also residents of the United States. Thus the environmental conditions of this standard are appropriate and do provide comfort for people represented by those students. However the ASHRAE standard of thermal comfort may not be applicable to people of different ethnic groups because of the great differences in diets, customs, life styles and geographic locations throughout the world. For this reason,

in this study an attempt was made to examine the thermal comfort differences between Middle Eastern people and U.S. residents under similar environmental conditions.

There are two methods for comparing thermal comfort between people of different ethnic origins. The first is to compare thermal comfort between two different groups exposed to similar environmental conditions and to have all subjects participate at the same location of the test as was done by Ellis (1953), Angus (1957), Wyon et al (1968), Deader and Aulicien (1985) and Jones et al (1988). Ellis (1953) compared the thermal response of Asian and European residents in Singapore. He found that in Singapore the comfortable levels of warmth for groups of acclimatized European men and women and Asian men and women residents are very similar, and are not markedly affected by differences in race, age or sex. Angus (1957) compared students of different ethnic origin in London. Wyon (1968) studied thermal comfort in British operating rooms. His study included people of different races. He found that age, sex and race produced minor differences in thermal comfort. Deader (1985) investigated the thermal response of different people living in six different climatic conditions in Australia. Jones (1988) compared thermal response of subjects from the Peoples Republic of China and from the United States. He found very little difference in temperature preference between the two groups. A draw-back

of the latter method is that when people are removed from their home environment, they may change their diet, cultural customs, and even their physiology may change. For example, in acclimatization to hot weather the volume of blood may increase up to 20% to maintain a constant vasodilation. Also in acclimatization to cold weather the thyroid gland is activated and the hormones produced increase the overall rate of metabolism (Szokoky, 1987). Thus when people are disturbed from their home environment, their thermal response may be affected and the result of the test may be invalid.

The second method is to conduct different comfort tests in different locations so that no disturbance my occur for the subjects away from their home environment as was done in the work of Fanger (1970). He conducted thermal tests with Danish students under thermal conditions similar to those conducted by Nevin et al (1966) with the United States students. He compared the result of the two tests and concluded that there was no difference in thermal comfort response between the Danish and U.S. students. However, these two groups have similar cultures and live under similar environmental conditions. A draw-back of the latter method is that any minor differences between the two tests, such as differences in room furniture, wall painting, and/or test protocol will always influence the thermal response of the subjects involved and hence the

result of the test. Rohles (1976) showed that using different wall treatment (wood treatment vs. painted metal) under similar thermal conditions significantly affected the thermal response of the subjects.

Yet all the above mentioned studies are still incomplete and it is not clear how much difference exists between people of different cultures and geographic locations. In this study, subjects from Kansas State University were selected to represent the U.S. and subjects from the newly arrived Middle Eastern students to represent their countries. All subjects participated at the same location, K.S.U. ASHRAE Chamber. The U.S. subjects were required to be native born U.S. citizens and to have lived in the U.S. continuously for the past two years preceeding the test. The Middle Eastern subjects were required to have come directly to the U.S. and not to have lived in the U.S. for more than 5 months at the time of the test.

Experimental Method

Nine Middle Eastern and 9 U.S. male subjects whose ages ranged between 18-30 were selected for testing. They were selected so that their mean heights and weights would be a representative of the height and weight of an average person in the Middle Eastern and/or U.S. population. Anthropometric data for all subjects are summarized in Table 1.

The subjects reported for the test in groups of 8 in the afternoon (4 Middle Eastern subjects and 4 U.S. subjects) and in groups of 10 in the evening (5 Middle Eastern and 5 U.S. subjects). If their oral temperature didn't exceed 98.6°F (37.0° C) by 1°F (0.62°C) they were accepted for the test. The subjects were provided cotton/polyester sweat suits to wear during each test. The suits were worn over the subjects own underwear. This clothing ensemble had a total thermal insulation (It) of 1.4 c/o as measured on the KSU Nordic manikin. Then, the subjects were seated inside the KSU ASHRAE chamber. Two subjects, one Middle Eastern and one U.S. were seated at each study table in the experimental chamber. Each subject had a skin temperature thermistor attached to the left pectoral region of the chest, the radial surface of the left arm and the fibular surface of the right leg.

Following this, they were oriented about the purpose of the study and asked to remain seated during the test which lasted for 150 minutes not counting the time needed for preparation. They were allowed to read and study but not to discuss their thermal sensation or their opinion about the environment.

A total of three tests were conducted on each of the subjects. The tests were run at 71°F (21.7°C), 78° F (25.5° C) and 86° F (30°) respectively. The dew point for all tests was 53° F (11.6°C) (Figure 1). The air velocity was less than 40 fpm (0.2 m/s), and the mean radiant temperature was equal to dry bulb temperature. These conditions were selected to make comparison between the Middle Eastern and U.S. subjects under "warm", "cool" and "neutral" conditions. Four measurements were taken on all subjects. These were: clothing moisture gain, skin temperature, thermal sensation and thermal quality.

It was necessary to measure clothing moisture gain because there may exist differences in the tendency to sweat between Middle Eastern and U.S. subjects. Clothing moisture gain was measured by weighing the clothes before and after each experiment and using the difference as an indication of the level of sweating. Before each test, the sweat suits were laid out in the experimental chamber to condition them with the test conditions and shortly before the subjects arrived the garments were put in a plastic bag

and weighed. At the end of each test, the subjects put the garments back into the plastic bag and sealed them immediately. Then the garments were weighed without removing them form the bag. It should be pointed out that the moisture gain was expected to be small since the activity level and environmental conditions posed no heat stress.

The skin temperatures of the forearm, chest, and calf were recorded every 5 minutes continuously throughout the experiment. A weighted mean skin temperature was calculated for each subject using Burton's formula (Burton, 1935).

Tm = .5xTc + .36xTLg + .14xTar where

Tm is the weighted mean skin temperature

Tch is the chest temperature

TLf is the leg temperature, and

Tar is the arm temperature.

Thermal sensation ballots (Figure 2) were given to every subject at the beginning of the experiment and every 30 minutes thereafter. The subjects used the ballot to report their thermal sensation by making a horizontal line on the nine-point ballot shown in Figure 2. This was later converted to a numerical score with -4 being very cold, 0 being neutral, and +4 being very hot.

Thermal quality ballots (Figure 3) were given to the subject along with the thermal sensation ballots. This

ballot was developed at the Institute of Environmental Research at Kansas State University (Manhattan). The ballot is used as a supplement for the thermal sensation ballot and can provide a simple and reliable measure of satisfaction and dissatisfaction with the thermal environment. The thermal sensation ballot if used alone can lead to misleading results. For example, two people may vote for "warm" but they may disagree on how unsatisfactory they are with the condition of the environment. The subjects recorded their votes on thermal quality by making a horizontal mark on the ballot shown in Figure 3. All votes were converted to a numerical score with -2 being intolerable, 0 being satisfactory and +2 being pleasant. The subjects were well instructed on how to fill out the ballots and care was taken to prevent any subject misunderstanding of the terms in the ballots.

Results and Discussion

The results of the weighted mean skin temperature, clothing moisture gain, thermal sensation votes and environmental quality votes are summarized in Tables 2 through 5. Statistical analysis was conducted to compare the response of the Middle Eastern and U.S. subjects. A t-statistic was calculated for the difference in means between the Middle Eastern and U.S. subjects for the 150 minute measurement period.

The mean skin temperature results in Table 2 indicate that the U.S. subjects have consistently higher temperatures on the three different tests. The differences in skin temperatures are statistically significant at the 95% condition interval for the last two tests when the air temperatures were 78 F (25.5 C) and 86 F (30 C) respectively. These results indicate that the U.S. subjects may have a higher metabolic rate than the Middle Eastern subjects. However, more physiological study would be required to prove or disprove the latter conclusion.

The clothing moisture gain as summarized in Table 3 shows that the U.S. subjects have a higher moisture gain than the Middle Eastern subjects. However, the differences in the means of clothing moisture gain for the two groups were not statistically significant. The amount of moisture

gained by the garments is an indirect measure of the level of sweating by the subjects because most of the moisture generated by the sweat is expected to evaporate to the air with little accumulation in the garments. The weight of moisture gain was negligible compared tot he weight of the garments. Several factors influence the amount of moisture gained by the garments. The moisture content of the fabric is dependent on the relative humidity of the air adjacent to the skin and to the relative humidity of the room environment. So the skin temperature of the subjects may affect the amount of moisture content in the sweat suits. Moisture content is also affected by the posture of the subjects because it is expected to be high in places unexposed to the atmosphere where evaporation is lowest such as on the back and the buttocks. In spite of all the factors mentioned above, the U.S. subjects did exhibit a consistently higher amount of sweat compared to the Middle Eastern subjects.

The results of the thermal sensation vote are shown in Table 3. All comparisons are not statistically significant except when the air temperature was 78 F (25.5 C). However, the results show that the Middle Eastern sense the 78 F (25.5 C) and 86 F (30 C) temperatures to be warmer than what was sensed by the U.S. subjects. Moreover, the Middle Eastern subjects sensed the 71 F (21.7 C) to be less cold than the U.S. subjects. The reason for the latter result

may be the mild to moderate environment in which most of the Middle Eastern subjects lived. All the subjects from the Middle East lived near the Mediterranean Sea except for one subject who was from Sudan.

The results of the environmental quality ballot are shown in Table 5. These results indicate that the Middle Eastern subjects favor a cooler condition compared to U.S. subjects and that the former are more dissatisfied with warmer conditions. However, the differences were not statistically significant except when the air temperature was 78°F. Moreover, the U.S. subjects were not as dissatisfied with warm conditions as they were in the study done by Jones et al (1988). The reason may be due to the fact that this study is conducted in a different time and season than the study of Jones et al. The following study was done at the end of the winter season when subjects are expected to favor warm conditions.

For a better interpretation of the results, additional graphs were made, and these are shown in Figures 4-6. Figures 4, 5 and 6 represent the weighted mean skin temperature, the mean sensation and the mean environmental quality respectively. All figures were made for means for all subjects as a function of time.

In Figure 4, an initial rise in the mean skin temperature for all subjects is noticed. The latter is due to the fact that the subjects were undressed when the

sensors were attached to their skin. The temperature kept rising for 30-90 minutes and then decreased continuously. However, in the thermal sensation graph a near steady state in the mean sensation was obtained after 60-90 minutes. The reason for the latter situation may be that the human body needs more than 150 minutes to reach steady state after fixing the activity level and the environmental conditions.

The figure of the mean sensation show that the beginning of the experiment all the subjects sensed the temperature to be higher than at the end of the experiment. This can be interpreted by the fact that the subjects had a greater activity level than sedentary because most of these subjects walked some distance to get to the test.

Figure 6 shows that during the 1st hour of the experiment, the subjects preferred the 71 F (21.7 C). Such a cool temperature could have been desirable because of the higher activity level experienced by most subjects before the beginning of the test. As the subjects activity declined to the sedentary level, the cool temperature 71 F (21.7 C) became less desirable. At the 78 F (25.5 C) temperature the subjects' response was the reverse of their response at the 71 F where the former temperature became more desirable after one hour of the test. The 86 F (30 C) was not preferred by the subjects throughout the test period. This graph indicates that there is not one constant environmental condition preferred by the subjects. In the

first hour the subjects preferred the 71 F temperature whereas later their temperature preference shifted to the 78 F.

When comparing U.S. and Middle Eastern subjects we found some differences that were sometimes significant. Several factors limit the validity of latter findings. First, comparisons were made between average U.S. and average Middle Eastern subjects and the present study was limited to males. However, average males are not the only inhabitants of a population. The results could have been more interesting if females were included in this study because there are greater cultural differences between U.S. and Middle Eastern females than between males. Second, there was a great degree of individual varieties within any population. To better interpret this variant, graphs 7-10 were constructed. These graphs show that the differences in the means of the two populations are much less than the differences existing within any population.

CONCLUSION

Some differences in the physiological response between the Middle Eastern and the U.S. subjects were found. The Middle Eastern subjects had a lower skin temperature and appeared to sweat less than the U.S. subjects. There were differences in the thermal sensation between the two groups. The Middle Eastern subjects sensed the temperature conditions of the experiments to be warmer than what was sensed by the U.S. subjects. They also preferred cooler room temperatures than the U.S. subjects, however, the results were not statistically significant. More importantly, the individual variations within either population were larger compared to those between the two populations.

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Table 1

Anthropometric Data for Subjects

Subject Group	Height			Weight			DuBois Area		
US Males	69.7	(1.5)	in	160.1	(12.5)	lbm	20.3	(.75)	ft
	177.1	(3.7)	cm	72.6	(5.7)	kg	1.88	(.07)	m
ME Males	67.4	(2.5)	in	151.5	(21.9)	lbm	19.5	(1.4)	ft
	171.3	(6.4)	cm	68.7	(9.9)	kg	1.81	(.15)	m

Table 2

Weighted Mean Skin Temperature[1] (150 minute measurement)

Subject Group	Air Temperature °F 71	°C 21.7	°F 78	°C 25.5	°F 86	°C 30
U.S. Males	91.7(1.2)	33.2(.7)	93.6(1.1)	34.2(.6)	94.6(.9)	34.8(.5)
M.E. Males	91.2(1.3)	32.8(.7)	92.7(1.2)	33.7(.6)	93.9(.6)	34.4(.3)
U.S. - M.E.	.5	.4	.9	.5	.7	.4
Significance	--		95%		95%	

1: Numbers in parentheses are standard deviations.

Table 3

Clothing Moisture Gain

Subject Group	°F 71	°C 21.7	°F 78	°C 25.5	°F 86	°C 30
	Air Temperature					
	Moisture Gain					
	g	lbm	g	lbm	g	lbm
U.S. Males	1.125(1.36)	.0024	2.01(1.44)	.0044	2.42(2.22)	.0053
M.E. Males	.89 (1.22)	.0018	1.8 (1.00)	.0039	2.09(1.5)	.0046
U.S. - M.E.	.235	.0006	.21	.0005	.33	.0007
Significance	--		--		--	

1: Numbers in paranthesis are standard deviations.

Table 4

Thermal Sensation Votes (150 min. Vote)

Subject Group	Air Temperature ^{o}F	^{o}C	^{o}F	^{o}C	^{o}F	^{o}C
	71	21.7	78	25.5	86	30
	Thermal Sensation[1]					
U.S. Males	-.29 (.22)		.51 (.52)		1.78 (.77)	
M.E. Males	-.15 (.59)		.96 (.51)		1.80 (.69)	
U.S. - M.E.	-.14		-.45		-.03	
Significance	----		90%		----	

1: Numbers in parenthesis are standard deviations.

Table 5

Environmental Quality Votes (150 min. Vote)

Subject Group	Air Temperature ^{o}F 71	^{o}C 21.7	^{o}F 78	^{o}C 25.5	^{o}F 86	^{o}C 30
	Environmental Quality[1]					
U.S. Males	.36 (.63)		.72 (.5)		-.24 (.47)	
M.E. Males	.43 (.66)		.34 (.63)		-.45 (.52)	
U.S. - M.E.	-.07		.38		.21	
Signifance	----		90%		----	

1: Numbers in parenthesis are standard deviations.

Figure 1

Environmental Conditions Used in Experiments

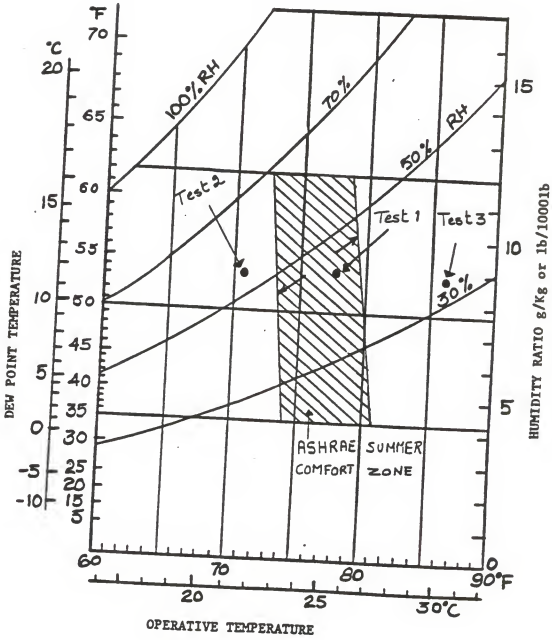


Figure 2

Thermal Sensation Ballot

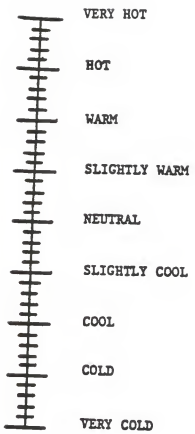


Figure 3

Thermal Environment Quality Ballot

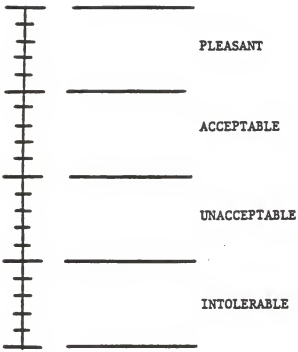


Figure 4

Thermal Sensation for all Subjects

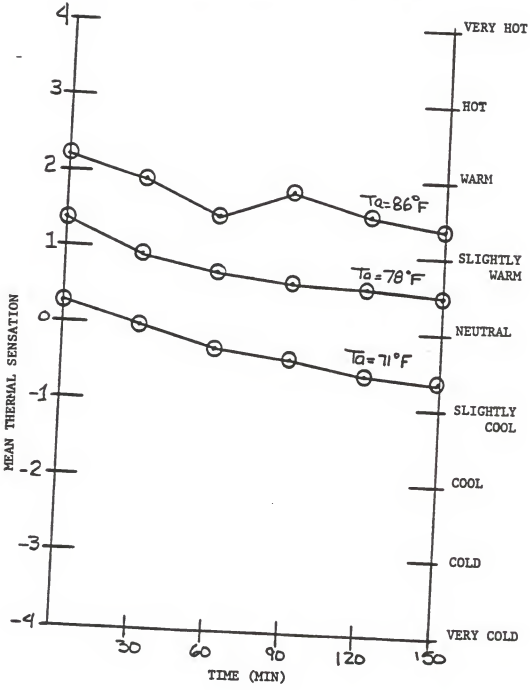


Figure 5

Skin Temperatures for all Subjects

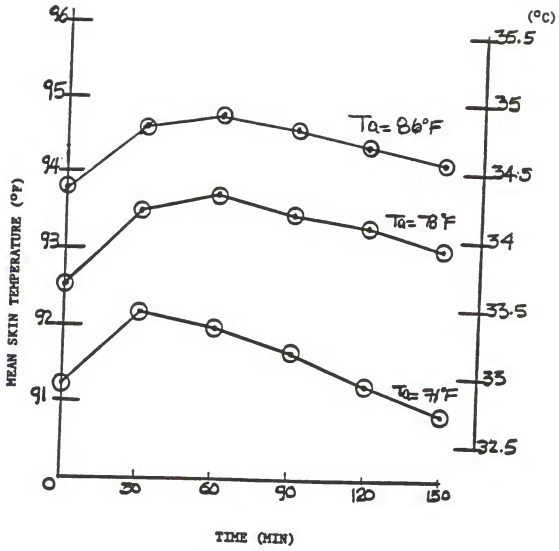


Figure 6

Environmental Quality for all Subjects

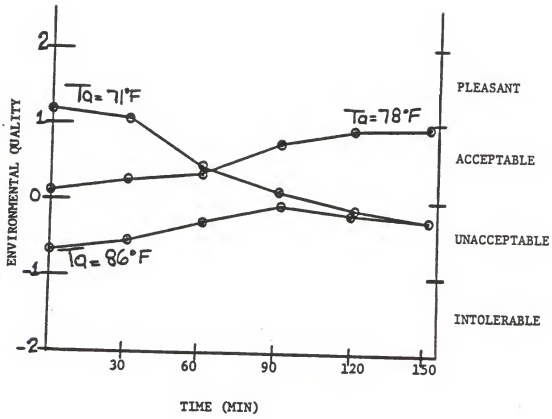


Figure 7

Individual Skin Temperatures (at 150min)

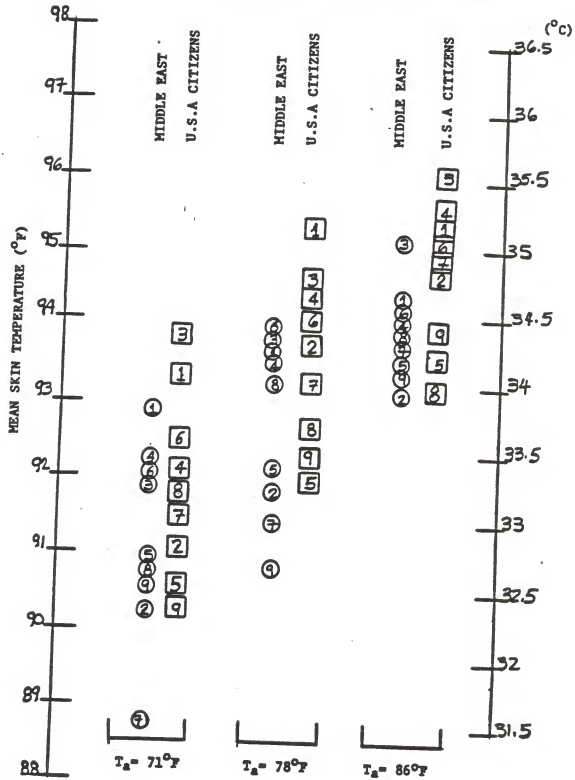


Figure 8

Individual Clothing Moisture Gains

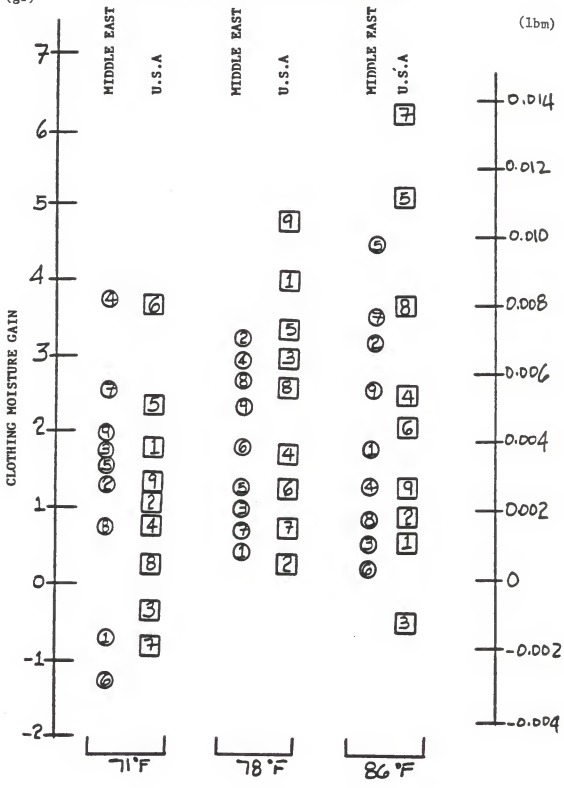


Figure 9

Individual Thermal Sensations (at 150min)

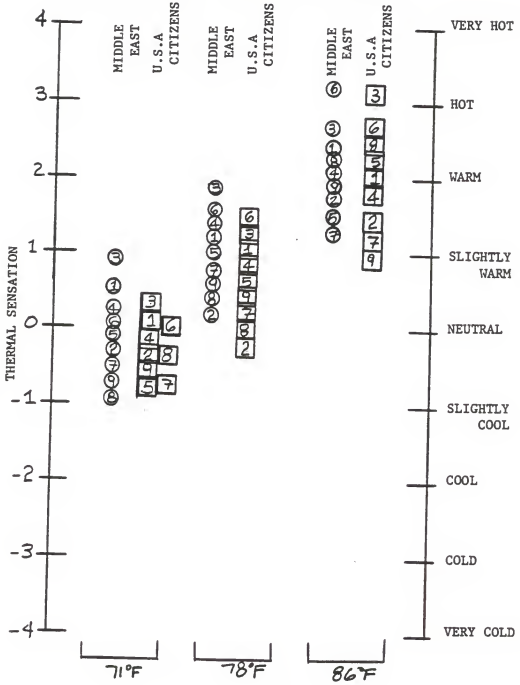


Figure 10

Individual Environmental Quality Votes (at 150min)

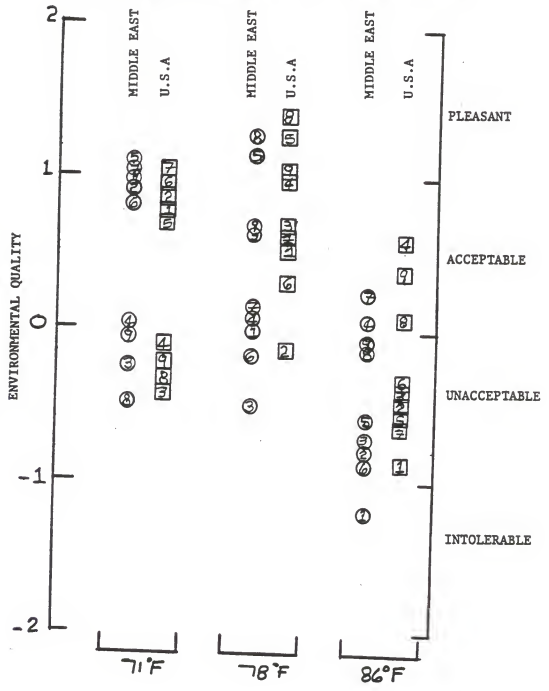


Figure 11

Comparison of U.S. and Middle Eastern Environmental Quality Votes (at 150min)

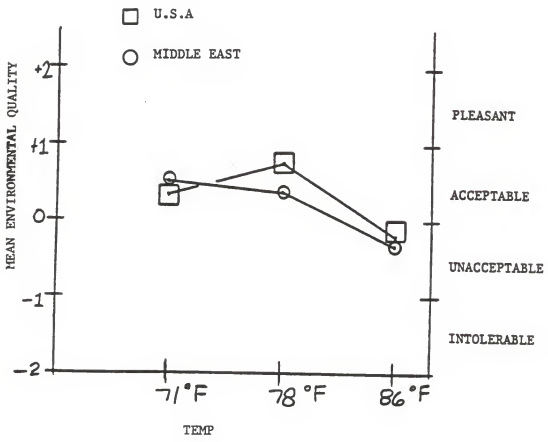


Figure 12

Comparison of U.S. and Middle Eastern Thermal Sensation (at 150min)

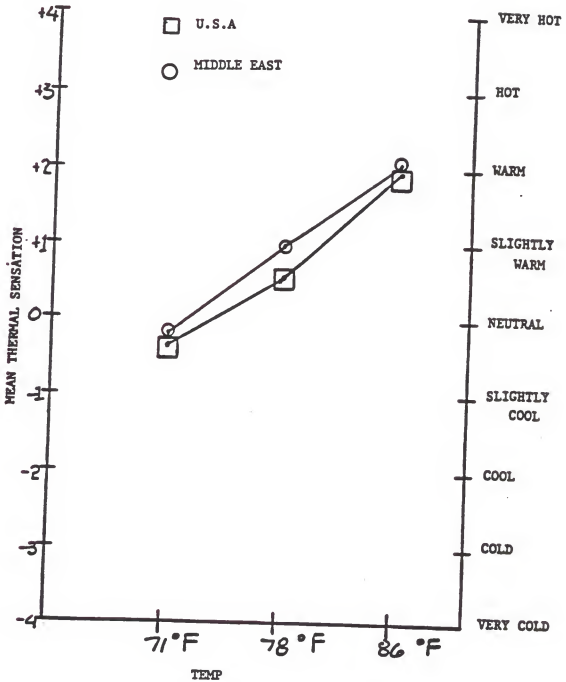


Figure 13

Comparison of U.S. and Middle Eastern Moisture Gain

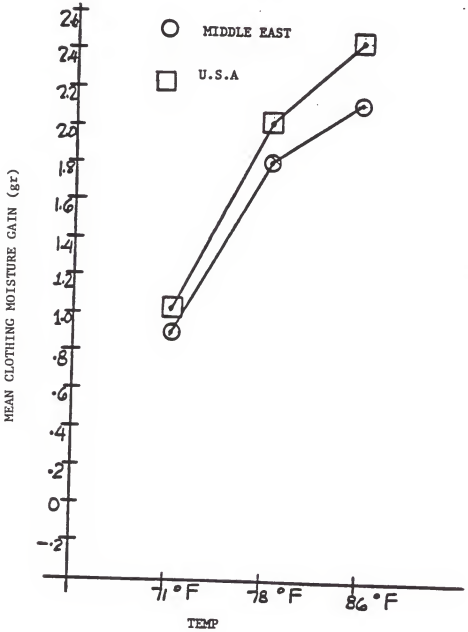
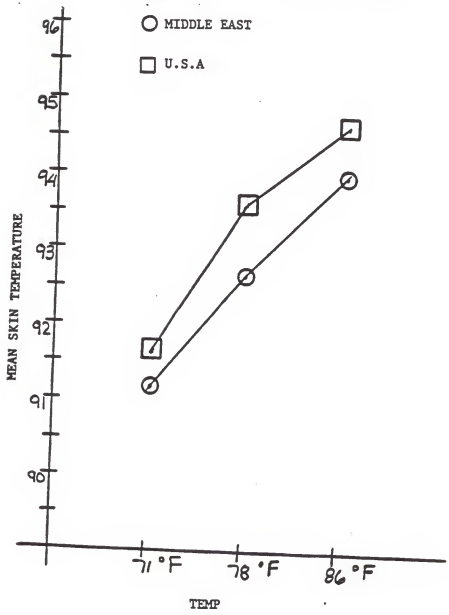


Figure 14

Comparison of U.S and Middle Eastern
Mean Skin Temperature (at 150min)



APPENDIX

ENVIRONMENTAL QUALITY FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 86 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	-1.5	-1.5	-1.75	-1.0	- .75	- .75
2	-1.5	-1.0	-1.25	- .5	- .25	- .5
3	-2	-1.75	- .25	0	.25	- .5
4	- .5	- .25	.25	0	.25	.75
5	- .5	- .75	0	-1.0	- .5	-1
6	-1.75	-1.75	-1.0	0	- .5	- .5
7	-1	- .75	0	1	1.0	1.5
8	- .25	- .25	- .25	.25	- .25	.25
9	- .25	- .25	0	0	- .5	.5

ENVIRONMENTAL QUALITY FOR U.S. SUBJECTS

(Air Temperature 86 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	-1.0	- .75	-1.5	- .75	- .75	- .75
2	-1.0	- .5	- .5	- .75	0	0
3	- .5	- .5	- .25	- .5	- .25	- .25
4	.75	.75	.75	1.25	.75	- .75
5	-1.5	-1.0	0	0	- .25	- .5
6	- .5	- .5	- .5	- .25	- .25	0
7	- .5	- .5	- .5	- .5	- .75	- .8
8	.25	.25	.25	.25	- .25	- .25
9	.25	.25	0	.25	.75	.75

ENVIRONMENTAL QUALITY FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 78 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	- .5	- .5	- .5	.5	.5	.5
2	1.25	.75	0	.75	.75	.75
3	-1.0	-1.0	-1.0	- .75	- .25	0
4	- .75	- .75	-1.25	.75	1.25	1.25
5	1	1	1	1.25	1.25	1.25
6	-1	- .5	0	0	0	0
7	- .5	- .5	- .25	0	1	1
8	.5	.3	1	1.75	1.75	1.75
9	.25	0	0	1	1.5	1.5

ENVIRONMENTAL QUALITY FOR U.S. SUBJECTS

(Air Temperature 78 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	.25	.75	.75	0	.75	.75
2	-1.25	- .25	- .5	.25	.25	.5
3	0	.25	.75	1	.75	.75
4	.75	.75	1	.75	1.5	1.5
5	.5	.75	1.25	1.5	1.75	1.75
6	- .25	0	.25	1	.25	.25
7	.5	.5	0	1	.75	.75
8	1.25	1.25	1.25	1.5	1.5	1.5
9	.75	.75	1.25	1	1.25	1.25

ENVIRONMENTAL QUALITY FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 71 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	1.75	2	1.25	.75	0	0
2	1.25	1	1	.85	.75	.5
3	.75	0	- .25	- .25	-1	-1.25
4	1	.75	.5	- .75	- .75	- .75
5	2	1.75	.75	.75	.75	.5
6	1.25	1	.75	.75	.75	.75
7	1.25	1.25	1	.75	1	.75
8	.75	.5	1	-1.5	-1.25	-1
9	1.25	.75	.5	0	-1	- .75

ENVIRONMENTAL QUALITY FOR U.S. SUBJECTS

(Air Temperature 71 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	1.75	1.5	1.25	.65	0	0
2	1.25	1.25	.5	.85	.75	.5
3	.5	0	- .25	- .25	-1.5	-1.25
4	.75	1	- .75	- .75	- .5	- .75
5	1.25	1.75	.75	0	.75	.5
6	1.25	1.25	.5	.75	1	.75
7	1.5	1.5	1.25	1	.65	.45
8	.5	.5	- .25	-1	-1	-1
9	.5	.25	- .25	0	- .75	-1

THERMAL SENSATION FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 86 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	3	2.5	2.5	2.5	1.5	1.5
2	2.5	1.5	0	1.75	1	1
3	2.5	2.5	1	3.5	2.5	2.5
4	2.5	2.5	.25	2.5	1	1
5	1.75	.75	1.5	1	1	1
6	3.25	3	3	3	3	3
7	1	1.5	.25	.75	1	1
8	2.5	2	2	2	2	2
9	2	2.5	3	.5	.75	.25

THERMAL SENSATION FOR U.S. SUBJECTS

(Air Temperature 86 F)

Time (Minute)

Subject	0	30	60	90	120	150
1	1	.5	2	2	3	2.5
2	1.25	1.25	1.25	1.25	1.25	1
3	3	3	3.25	3	3	3.25
4	2	2	2	1.5	.25	.25
5	2.5	2	2	2	2	2
6	2	2.5	2.5	3	2.5	2.5
7	1.25	1	0	1	1	1
8	3	3	2.5	2.5	2	1
9	2	2	1	0	0	0

THERMAL SENSATION FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 78 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	1.25	1.25	1.25	1	1	1
2	.5	.5	.25	0	.25	.25
3	3	2.5	2.25	1.75	.75	.25
4	2	2	1.5	1	.5	.5
5	2	2	2	.75	0	0
6	2	2	2	1	1	1
7	1.25	.25	.25	.5	.75	.75
8	1	.75	.25	.25	.25	.25
9	1.5	1.5	.5	0	0	0

THERMAL SENSATION FOR U.S. SUBJECTS

(Air Temperature 78 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	2.75	.75	.25	.75	.75	.25
2	1	.5	.25	-1	-1	-1
3	1.25	1	0	1.5	2	1
4	1	.5	.5	.5	.75	1
5	1	.5	.25	.5	.5	.5
6	1.25	1.25	1.25	1	1	1
7	1	.25	0	0	0	0
8	- .75	- .75	- .25	0	0	0
9	2	1	0	0	- .25	0

THERMAL SENSATION FOR MIDDLE EASTERN SUBJECTS

(Air Temperature 71 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	1	.25	.25	.75	0	0
2	- .25	- .5	- .5	- .5	- .5	- .5
3	.75	.25	1	1	1	1
4	.5	.5	0	1	- .25	- .25
5	.25	.25	- .25	- .25	- .25	- .5
6	1	0	- .25	0	0	- .25
7	0	- .25	-1	-1	- .75	-1
8	0	0	0	-2	-2	-2
9	.25	0	-1.5	- .75	-1	-1

THERMAL SENSATION FOR U.S. SUBJECTS

(Air Temperature 71 F)

Subject	Time (Minute) 0	30	60	90	120	150
1	- .25	- .25	1.25	2.25	- .75	- .75
2	.25	0	- .25	- .75	- .75	- .75
3	.5	0	.25	.25	0	- .25
4	.75	- .25	- .5	- .5	- .5	- .75
5	.25	- .25	-1.5	- .75	- .75	- .5
6	0	- .25	- .25	- .25	0	0
7	- .5	0	0	-2.25	-1	-1
8	.25	.25	- .75	- .5	- .75	- .5
9	- .25	- .5	-1	- .75	0	- .75

SKIN TEMPERATURE FOR THE MIDDLE EASTERN SUBJECTS

(Air Temperature 86 F)

Time (Minute) / Skin Temperature (F)

Subject	0	30	60	90	120	150
1	93.87	94.26	94.44	94.55	93.89	93.85
2	92.62	93.22	92.82	92.9	93.06	92.85
3	94.25	95.35	94.67	95.1	94.85	94.67
4	93.54	94.16	94.64	94.35	94.64	94.4
5	93.52	94.09	94.1	93.52	93.24	93.47
6	92.7	94.37	94.82	94.51	94.2	93.85
7	93.35	93.79	93.51	93.27	93.81	93.72
8	92.87	93.33	93.86	94.07	94.03	93.87
9	93.75	94.16	92.8	93.2	93.26	92.95

SKIN TEMPERATURE FOR THE U.S. SUBJECTS

(Air Temperature 86 F)

Time (Minute) / Skin Temperature (F)

Subject	0	30	60	90	120	150
1	95.32	95.43	95.75	94.85	94.75	94.67
2	94.2	94.75	94.98	94.52	94.86	94.55
3	94.5	96.59	96.86	96.02	95.84	95.94
4	95.3	95.6	95.8	95.94	95.78	95.5
5	93.94	94.2	95.2	93.86	93.19	93.42
6	94.65	95.05	95.45	94.95	95.3	94.65
7	94.21	95.12	95.83	95.05	95.1	94.95
8	92.5	94.5	93.46	92.15	93.58	93.01
9	92.54	94.72	94.75	94.58	93.09	92.63

SKIN TEMPERATURE FOR THE MIDDLE EASTERN SUBJECTS

(Air Temperature 78 F)

	Time (Minute) / Skin Temperature (F)					
Subject	0	30	60	90	120	150
1	92.92	94.41	94.23	93.97	93.92	93.87
2	91.72	91.57	92.32	91.6	91.64	92.35
3	92.32	94.2	94.57	94.36	93.94	93.84
4	91.67	93.85	93.72	93.87	94.23	93.57
5	90.82	91.8	92.48	92.74	92.31	91.84
6	93.77	94.87	94.94	93.79	93.94	93.87
7	91.34	91.74	91.87	91.29	91.27	91.45
8	92.95	93.72	93.68	93.44	93.26	93.52
9	90.26	91.52	91.63	90.32	90.27	90.65

SKIN TEMPERATURE FOR THE U.S. SUBJECTS

(Air Temperature 78 F)

	Time (Minute) / Skin Temperature (F)					
Subject	0	30	60	90	120	150
1	95.25	96.28	96.21	96.27	94.85	94.57
2	92.75	93.25	93.96	94.22	93.84	93.78
3	93.95	94.32	94.84	94.8	94.4	94.72
4	93.84	94.16	94.87	94.9	94.97	93.89
5	91.2	93.0	92.5	91.86	91.89	91.85
6	92.3	94.82	94.52	94.6	94.32	93.85
7	92.55	93.78	93.75	93.48	93.21	92.85
8	91.85	92.97	93.12	92.62	92.52	92.54
9	91.7	92.42	94.87	94.83	94.91	93.89

SKIN TEMPERATURE FOR THE MIDDLE EASTERN SUBJECTS

(Air Temperature 71 F)

Time (Minute) / Skin Temperature (F)

Subject	0	30	60	90	120	150
1	92.75	93.51	93.63	92.85	92.9	92.2
2	89.8	90.52	88.95	90.43	90.15	89.89
3	91.5	92.18	92.5	92.25	91.65	91.67
4	92.47	93.95	92.51	92.12	91.48	91.25
5	89.65	91.45	92.01	92.03	91.32	89.51
6	92.39	93.27	92.9	92.75	91.56	90.6
7	89.07	89.65	89.25	89.03	88.13	87.92
8	90.4	91.35	90.87	90.9	90.04	90.46
9	90.26	91.51	91.37	90.75	90.13	89.91

SKIN TEMPERATURE FOR THE U.S. SUBJECTS

(Air Temperature 71 F)

Time (Minute) / Skin Temperature (F)

Subject	0	30	60	90	120	150
1	92.5	93.72	94.2	93.2	92.8	92.6
2	90.43	91.55	91.6	90.8	91.2	90.9
3	93.5	94.36	93.7	93.5	92.75	92.62
4	92.2	92.54	91.92	91.45	91.04	90.87
5	91.42	91.23	90.5	90.15	89.95	89.87
6	90.9	92.75	92.65	92.49	92.25	92.23
7	91.18	92.25	91.65	90.91	90.8	90.75
8	90.04	92.45	91.95	91.9	91.6	90.93
9	90.11	90.64	91.32	90.06	89.98	89.85

ANTHROPOMETRIC DATA FOR MIDDLE EASTERN SUBJECTS

Subject	Height (in.)	Weight (lbm)	Dubois Area (ft^2)
1	64	130	17.5
2	66.5	150	19.1
3	68	133	18.5
4	71.5	121	18.3
5	67	170	20.4
6	70	176	21.2
7	68	139	18.8
8	68.5	180	21.2
9	64	165	19.3

ANTHROPOMETRIC DATA FOR U.S. SUBJECTS

Subject	Height (in.)	Weight (lbm)	Dubois Area (ft^2)
1	71	154.8	20.3
2	70.25	151	20.4
3	68	159.8	20.4
4	70	160.2	20.3
5	70.5	188.6	21.8
6	68	156	19.4
7	69.5	171	20.8
8	72.75	151.4	20.4
9	68	154	19.6

A COMPARISON OF THE THERMAL RESPONSE OF MIDDLE EASTERN AND UNITED STATES STUDENTS

by

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AN ABSTRACT OF A MASTER'S REPORT

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College of Engineering

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ABSTRACT

A study was conducted to compare the thermal response of subjects from the Middle East and from the United States. Eighteen subjects were tested, nine from each country. Each subject participated in three experiments, one at 71 F (21.7 C), one at 78 F (28.5 C), and one at 86 F (30 C). These conditions were selected to make comparisons between the two groups under "warm," "cool" and "neutral" conditions. Test results indicated that the Middle Eastern subjects had lower skin temperature, sweated less and preferred cooler conditions compared to the United States subjects. Test results also showed that the intra-population differences are much greater than the inter-population differences.