INVESTIGATION OF HEAD COVERING AND THERMAL COMFORT IN RADIANT COOLING MALAYSIAN OFFICES

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ABSTRACT

This study investigated the head covering in a radiant cooling Malaysian office building. We studied the Energy Commission's Diamond Building in Putrajaya, which is equipped with radiant slab cooling. The objective was to determine the effectiveness of head covering on thermal comfort. We adopted the assessment procedure from the ASHRAE 55 and the ISO 7730 standards and applied to the building's second and sixth floors and analysed the data through cross tabulation. We collected 132 data sets completed by 49 participants continuously for four days (two days for each floor) during working hours. The survey was the results of two online questionnaires (a background survey and a daily survey). In the dissatisfaction with overall thermal environment and actual mean vote, the analysis showed a strong correlation between head covering and discomfort (warmer feel) (V = .5, p< .01). We correlated the head covering with all of the independent variables in the background and daily surveys. Females outnumbered male in wearing a head covering (V = .8, p<.001). Wearing a head covering was not affected by age(V = .3, p > .05). Wearing a head covering does not affect subjects' dissatisfaction with floor temperature (V = .3, p> .5). Person who wore a head covering preferred increased air speed (V = .4, p< .05). Wearing a head covering increased the sweating (V = .3, p< .05).In conclusion, wearing a head covering affects thermal comfort in radiant cooling office building.

Keywords: *head covering, scarf, radiant cooling, thermal comfort, office building, Malaysia*

1 INTRODUCTION

This study investigated the effect of head covering on thermal comfort in a radiantly cooled Malaysian office building. It is essential to evaluate the impact of head covering on thermal comfort in existing radiantly cooled building, whereby thermal comfort is a key indicator of the head covering affect.

Clothing is a critical factor when calculating PMV. However, head covering is not included in the summer clothing of thermal comfort standards such as ISO 7730 and ASHRAE 55. Moreover, although wearing a head covering is common in Malaysia (Figure 1 shows the types of head covering used by the female workers in the case building), no previous studies investigated the head covering in office building. The available international studies

investigated head covering affect in different environment (chambers, hospitals, and farms) and subjects (infants, patients, and harvesters).

Figure 1: Types of head covering in females in the building (at the right, the two-piece scarf covered the nick, at the middle, the one-piece scarf used to cover the head, and upper part of the chest, at the left, the two-piece scarf covers the head and the upper part of the chest)

Al-ajmi *et al.* (2008) studied the thermal insulation and the clothing area factors of typical Arabian Gulf clothing ensembles for males and females using thermal manikins. The researcher examined ensembles and garments worn in the summer and winter. Clothing insulation (clo) was measured for males and females using thermal manikins in accordance with ISO 9920. These same researchers found that the most widely used regression calculation fclis not valid for non-Western clothing. ASHRAE (Invitation 1504 RP, 2012) invited clothing researchers to participate in a project to establish a database for non-Western clothing. Therefore, non-Western head covering was considered in the present study.

Kamitani *et al.* (1999) determined the effect of covering the patients head and face on the prevention of intra-operative hypothermia (35.5 °C). The subjects were 44 adults undergoing elective abdominal surgery of which 22 were their face and head fully covered. Ambient temperature maintained near 25 °C. The same researcher found that Covering the patient's head and face maintains intra-operative core temperature.

In contradict with Kamitani *et al.* (1999), Chop *et al.* (2008) used head covering (cooling hat) in hot environment to maintain the core temperature from rising. They concluded that the combination of the cooling vest, a scarf, and a brimmed hat eliminated the heat strain of farm workers. Piumelli and Nassi (2008) postulated that the thermal stress represents the relationship between head covering and the increased risk, because the infants who died because of sudden infant death syndrome were found drenched in sweat.

2 RESAERCH METHODOLOGY

The method used in the present study was online questionnaire and included the head covering in the questionnaire. The objective was to investigate the effects of head covering on thermal comfort in radiant cooling environment and the relationship with the personal variables, expectations, preferences, and sweating. The subjects themselves choose their garment from the online clothing list. The data then analysed using SPSS program.

Figure 2: Diamond Building in Putrajaya, Malaysia

Figure 2 shows the Energy Commission Building (the Diamond Building) in Putrajaya, Malaysia. The structure is a seven-floor office building that was completed 15 March 2010 and has a total area 11473 m^2. Radiant cooling in the building is designed for office work. The building is cooled by a radiant cooling system through slab cooling and conventional air-cooling.

The target sample size for the survey was a minimum of 40 of the 170 building occupants. However, larger numbers were sought to sharpen the statistical inferences. Therefore, all subjects available at the time the survey was conducted were targeted. The subjects were limited to the occupants of the second and sixth floors.

Two questionnaires were put online for participants to complete, namely background survey and daily survey. The questionnaires were structured in accordance to thermal comfort survey administrated by latest update of ASHRAE 55.

The background survey questionnaire comprised the personal variables (the gender, age, and using air condition at home).The expectation in the form of dissatisfaction questions (dissatisfaction with the floor temperature, variation of day temperature, air condition difference temperature, and air speed),the preferences variable (increased air speed, fans, fresh air, workplace air conditioners, open window, and manual control of air temperature),the sweating (by time, activity, and location). To disallow any biases, a question of assess overall thermal environment (OTE) was asked at the end of the questionnaire. The daily survey constructed to a minimum number of questions required. The daily survey comprised the actual mean vote (AMV), the clothing, and activity.

The data were collected in four days (two days for each floor). The time of the survey was divided into three periods: morning (8:00 - 10:59 a.m.), midday (11:00 - 1:59 p.m.), and afternoon (2:00 - 5:00 p.m.). Finally, statistical analysis of the data was performed using the SPSS program. The head covering in the data sets of daily survey was merged with data of the background survey. The merging was performed according to the research objectives, i.e., by subject name.

3 DESCRIPTION OF THE SURVEY PARTICIPANTS

The sample size was 49 out of 170 workers in the building. Females outnumbered males (61%). Subjects were 51% under 30, 42% under 50 years of age,77% had worked for more than one year in the building, and 55% did not use an air-conditioner at home.

4 DESCRIPTIVE OF QUESTIONNAIRES DATA

In the background survey, 70 data sets were collected, of which 49 data sets were valid. These data were collected on the second and sixth floors. The participants were asked to complete the background questionnaire online a single time. Some participants completed the questionnaire many times, and these additional questionnaires were considered invalid. The participants were selected according to their availability during the survey. However, most of the participants were occupied or otherwise unavailable. In the daily survey, 132 data sets of 138 were valid. The valid participants were 49 out of 59 who were asked to complete the questionnaire at the three periods (morning, midday, and afternoon). Some participants completed the questionnaire more than one time during one period; these additional questionnaires were not counted.

Participants' head covering in the daily survey was merged with the same participant in the background survey. The 39 participants in the daily survey were also completed the background survey. Only 10 participants, who completed background survey, did not complete daily survey and thus their clothing was not recorded. Only 39 participants completed the personal variables, expectations, preferences and sweating.

5 THE RESULTS AND ANALYSIS

Head covering in summer is not included in the standard. Therefore, the only way to understand its impact on thermal comfort is the comparison with the dependent and independent variables such as thermal comfort

variables (OTE and AMV), personal variables, expectation, preferences, and sweating.

5.1 Head covering and thermal comfort

The two thermal comfort variables were OTE and AMV. The OTE analysis shows that those who wore a head covering dissatisfied with the thermal environment (V = .5, p< .01) (Table 1), which contradict Al-ajmi *et al.* (2008). This result confirms the warmer feel of subjects who wore a head covering in the AMV (Table 2) (Figure 3). This agreed with Chop *et al.* (2008), Kamitani *et al.* (1999), and Newsham and Tiller (1995).

The purpose in which head covering is used in Chop *et al.* (2008) study contradict with the purpose of wearing a head covering by the subjects in the present study. The head covering did not manage to maintain the head temperature. Therefore, head covering caused discomfort because it prevents the body from releasing the excessive heat from the head.

Table 1: Cross Tabulation of Head Covering and OTE

		Overall thermal comfort		
		No	Yes	Total
Head covering	Cap (for male)	2	0	2
	Light scarf (for female)	4	11	15
	No any	1	19	20
	Thick scarf (for female)	0	2	2

5.2 Head covering and personal variables

In table 3, the cross tabulation analysis showed a perfectly positive association between gender and head covering (V = .8, p<.001). Female participants were wearing a head covering more than male participants do. In addition, head covering has a small, insignificant association with age of participants (V = .3, p > .05). Furthermore, those who wore a head covering were using air-conditioner at home (V = .4, p< .01).

Table 2: Cross Tabulation of Head Covering and AMV

		AMV						
		Hot	Warm	Slightly Warm	Neutral	Slightly Cool	Cold	Total
Head covering	Cap (for Male)	1	0	0	2	0	0	3
	Light scarf (for Female)	0	1	18	23	11	2	55
	No Any	1	1	10	35	19	1	67
	Thick Scarf (for Female)	0	0	0	4	1	2	7

Table 3: Cross Tabulation of Head Covering With Age and Home A/C

		Head covering			
		Cap (for male)	Light scarf (for female)	No any	Thick scarf (for female)
Gender	Female	0	15	4	2
	Male	2	0	16	0
Home A/C*	No	2	8	7	2
	Yes	0	7	13	0

*Home air-conditioner

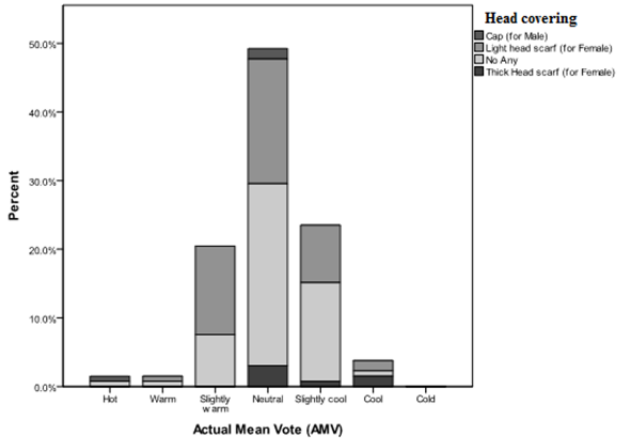

Figure 3: AMV and Head Covering

5.3 Head covering and expectations

The cross tabulation in Table 4 shows that although a small association was found between wearing a head covering and subjects' dissatisfaction with floor temperature, the relationship is insignificant (V = .3,p> .5). Those who wore a head covering dissatisfied with the variation in the outdoor air temperature during the working hours and dissatisfied with the variation in the indoor air temperature, V = .4, P< .01 and V = .5, P< .01, respectively. Finally, some subjects who wore a head covering reported insignificant dissatisfaction with unpleasing air speed (V = .5, p > .05). This dissatisfaction occurs in certain places where the subjects seated in front of the duct outlet (Figure 4).

Table 4: Cross Tabulation of Head Covering and Expectation

		Head covering			
		Cap (for male)	Light scarf (for female)	No any	Thick scarf (for female)
Dissatisfaction with floor temperature	Not sure	0	1	1	0
	No	1	12	16	2
	Yes	1	2	3	0
Dissatisfaction with the variation in the outdoor air temperature	No	2	7	17	1
	Yes	0	8	3	1
Dissatisfaction with the variation in the indoor air temperature	Not sure	0	1	1	1
	No	2	7	16	0
	Yes	0	7	3	1
Dissatisfaction with unpleasing air speed	Not sure	0	2	0	0
	No	1	7	15	0
	Yes	1	6	5	2

5.4 Head covering and preferences

The only variable in preferences that correlated with head covering was air speed. Subjects with head covering significantly, moderately preferred increased air speed (V = .4, p< .05). The other preferences variable were not correlated with head covering, which were adding fan, fresh air, workplace air-conditioner, and open window (Table 5).

Figure 4: In the enclosed office, the duct outlet provides non-uniform air distribution

Table 5: Cross Tabulation of Head Covering and Air Speed

		Preference for more air speed			
		No	No Change	Yes	Total
Head covering	Cap (for male)	0	0	2	2
	Light scarf (for female)	6	2	7	15
	No any	8	6	6	20
	Thick scarf (for female)	1	0	1	2
Total		15	8	16	39

5.5 Head covering and sweating

It was found, in the present study, that wearing a head covering caused sweating ($V = .3$, $p < .05$) (Table 6). This agreed with Piumelli and Nassi (2008). However, this sweating during wear head covering does not relate to the time, location, and activity when sweating occurs.

Table 6: Cross Tabulation of Head Covering and Sweating

		Sweating			
		No	SOMTIMES	Yes	Total
Head covering	Cap (for male)	1	0	1	2
	Light scarf (for female)	6	6	3	15
	No any	15	4	1	20
	Thick scarf (for female)	1	1	0	2
Total		23	11	5	39

6 CONCLUSION

The analysis showed a strong relationship between head covering and dissatisfaction (warmer feel) with OTE and AMV ($p < .01$). We correlated the head covering with all of the independent variables in the background and daily surveys. Females outnumbered male in wearing a head covering. Wearing a head covering was not affected by age. Wearing a head covering does not affect subjects' dissatisfaction with floor temperature. Person who wore a head covering preferred increased air speed ($p < .05$). Head covering increased the sweating rate ($p < .05$). In conclusion, wearing a head covering affects thermal comfort in radiant cooling office building.

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