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RESEARCH ARTICLE

A REVIEW ON CLOTHING INSULATION IN A HOT AND HUMID COUNTRY

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ABSTRACT

Clothing level (clo) is one of the essential criteria used to regulate the 'occupants' satisfaction, along with the operative temperature, airspeed, relative humidity, and metabolic rate in the ASHRAE-55 CBE Thermal Comfort Tool.More often than not, thermal discomfort is due to inappropriately high clothing levels of indoor occupants. This study highlighted the influence of clothing insulation in achieving optimal thermal comfort. The influence of clothing insulation included posture, physical activity, climate, clothing fit, bedding system, season, gender, age level, building type, and indoor and outdoor temperature variations. Therefore, the clothing level per human individual was widely different and should be considered carefully in the design and operation of the built environment.

INTRODUCTION

One of the most significant indicators used in thermal comfort is clothing insulation(I_{cl}),which is adopted by the International Standards Organization (ISO-1995) and by ASHRAE-2005 (Al-ajmi*et al.,* 2006). According to ISO 9920:1995, clothing insulation can be interpreted as thermal insulation (resistance to dry heat loss from the body) of a clothing ensemble and expressed in square meter degrees Celsius per watt (m^2.°C/W), which is the insulation from the skin to the clothing surface. The dry heat loss from the body through convection, radiation and conduction then takes place from the skin surface through the clothing to the clothing surface (1 clo = 0.155 m^2.°C/W). Besides that, Choi (2021) interpreted clothing insulation as the thermal resistance of the clothing worn by an individual. In other words, it protects the body from the sun, cold, wind, rain, and other environmental hazards (such as chemical and mechanical).The clothing insulation values were essential to determine and improve occupants' comfort prediction (Rupp *et al.,* 2021; Tang *et al.,* 2022).Human comfort and health needto subtract or add clothing (Parsons, 2002) as the heat transfer between the human body and the external environment is through the barrier of clothing (Talukdar *et al.,* 2016). According to Oğulata (2007), people must wear appropriate garments in the summer or winter to maintain the body's heat balance. Moreover, Choi *et al.* (2022) found that the electrical energy consumption was high when the clothing insulation increased.

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The average power consumption in the summer and winter would be reduced by 16 % and 13.7 %, respectively, with a reduction of 0.1 clo (Choi *et al.,* 2023). Estimating clothing insulation levels was essential to control the indoor inhabitants' comfort. Fukawa*et al.* (2021) also reported that more than 30 % of occupants were affected with symptoms related to coldness (*i.e.,* overcooling problem) in Thailand, Indonesia, and Singapore. The comfort for occupants with lighter clothing (0.30–0.59 clo) is achievable when the indoor temperature exceeds 24.5 °C; thus,it can contribute to reducing power consumption.

FACTORS OF CLOTHING INSULATION: Many factors influenced the clothing insulation based on the occupant's clothing behaviour, as shown in Table 1. Those factors included posture, physical activity (*i.e.,* movement), climate (*i.e.,* wind, hot & humid), clothing fit, bedding system, season (*i.e.,* summer& monsoon), gender (*i.e.,* male & female), age level (*i.e.,* adult & children), building type, indoor and outdoor temperature variations.

CLOTHING INSULATION IN MALAYSIA: Table 2 shows the results of clothing ensembles based on the factors of clothing insulation in naturally (*i.e.*, AC switched off) and mechanically (*i.e.*, AC switched off) ventilated buildings in Malaysia. The types of buildings, gender, and types of clothing fit influenced the variations' statistics of clothing insulation. Meanwhile, Table 3 shows the six daily wear clothing types estimated per ISO 7730 (Dahlan, 2008). The most frequently worn clothing was type 1, while type 1 and type 6 were the most comfortable clothing during rainy days (Dahlan, 2008).

Table 1. Factors influencing the clothing insulation based on the occupant's clothing behavior

No.	Factors of Clothing Insulation (occupant clothing behaviour)	Authors
1.	Posture, movement, wind and clothing fit	Havenith*et al.* (1990)
2.	Climate, building type	Feriadi& Wong (2004)
3.	Clothing, climate, and physical activity.	Oğulata (2007)
4.	Bedding systems (*i.e.*, bed and mattress, the type of sleepwear, and percentage coverage of body surface area by bedding and bed.	Lin & Deng, (2008)
5.	Season, gender, age level (*i.e.,* adult and children)	Nam *et al.* (2015)
6.	Climate, season, building type (such as office, school, or residential), and indoor and outdoor temperature variations	Wang *et al.* (2019)

Table 2. The results of clothing ensembles based on the factors of clothing insulation in naturally (*i.e.*, AC switched off) and mechanically (*i.e.*, AC switched off) ventilated buildings in Malaysia

No.	Types of Building	Results	Factors of Clothing Insulation	Authors
1.	In non-air-conditioned residences in Kota Kinabalu city, in Malaysia	The statistic of clothing ensembles: Mean: 0.27 clo; Std dev: 0.09 clo Range: 0.09 clo to 0.56 clo	Type of buildings	Djamila*et al*., (2013)
2.	The naturally and mechanically ventilated classroom is on a 3-storey building at a local school in Bandar BaruBangi, Selangor, Malaysia.	The thermal environmental condition of the class is warm to hot in 7-point ASHRAE standard 55scale.	Type of buildings	Kamaruzzaman & Tazilan, (2013)
3.	In the classrooms of two universities,*i.e*., (UniversitiTeknologi Malaysia (UTM) and UniversitiTeknologi MARA(UiTM)) with the setting of two conditions: mechanical cooling (CL) mode (*i.e*., AC was switched on and switched off) alternately.	The statistic of clothing ensembles: 1)UTM Male: 0.51 clo, Std dev: 0.16 clo Female: 0.56 clo, Std dev: 0.18 clo 2)UiTM Male: 0.62 clo; Std dev:0.20 Female: 0.59 clo; Std dev: 0.17	Gender	Zaki*et al.* (2017)
4.	It is in the Universiti Tun Hussein Onn Malaysia (UTHM) library building, approximately 20 km from BatuPahat.	Average Clothing insulation: (Types of clothing) 1) Flexible: 0.47-0.77 clo (complies with ASHRAE 55–2020 standard) 2) Strict Uniform: 0.74- 1.32 clo (not comply withASHRAE 55–2020 standard)	Types of clothing fit	Allah *et al*., 2023

Figure 1 shows the example standard of school uniform in Malaysia with the white sleeve shirts and straight, long dark blue trousers for males, and dark blue pinafore or 'baju kurung' (light blouse) and dark blue a-line skirts and hijab for females with the estimated value based on ASHRAE was 0.6 clo (Kamaruzzaman & Tazilan, 2013). Besides, Allah *et al.* (2023) also reported that the employees who work in the office environment with flexible clothing insulation had high thermal satisfaction compared to those with strict uniform policies.

Figure 1. The example of a standard school uniform in Malaysia (Kamaruzzaman & Tazilan, 2013)

Table 3. The six daily wear clothing types estimated following ISO 7730 (Dahlan, 2008)

Daily wear clothing	Clo value
Type 1: Short sleeves t-shirt; track suit/jeans; underwear	0.5
Type 2: Long sleeves t-shirt; track suit/jeans; underwear	0.6
Type 3: Sleeveless t-shirt; sarong/shorts; underwear	0.3
Type 4: Short sleeves t-shirt; sarong/shorts; underwear	0.4
Type 5: Just sarong; underwear	0.2
Type 6: Sweater; cotton long sleeves shirt; track suit/jeans; underwear	1.0

CONCLUSION

Clothing insulation is a significant indicator used in thermal comfort. This study found that posture, physical activity, climate, clothing fit, bedding system, season, gender, age, building type, and indoor and outdoor temperature variations can influence clothing insulation levels. It is crucial to know about clothing insulation because it reduces energy use from air conditioning. Therefore, clothing insulation was one of the vital indicators that needed to be considered, as it is helpful for the occupants 'comfort. The use of unnecessary air conditioning for thermal comfort would result in energy used unsustainably.

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REFERENCES

Allah, Mohammad Zaraa, et al. 2023. "Investigating adaptive thermal comfort in office settings: A case study in Johor Bahru, Malaysia." *Case Studies in Chemical and Environmental Engineering* 8 (2023): 100466.

Choi, E. J., Choi, Y. J., Kim, N. H., & Moon, J. W. 2023. Seasonal effects of thermal comfort control considering real-time clothing insulation with a vision-based model. *Building and Environment*, 235, 110255.

Choi, E. J., Park, B. R., Kim, N. H., & Moon, J. W. 2022. Effects of thermal comfort-driven control based on real-time clothing insulation estimated using an image-processing model. *Building and Environment*, 223, 109438.

Choi, H., Na, H., Kim, T., & Kim, T. 2021. Vision-based estimation of clothing insulation for building control: A case study of residential buildings. *Building and Environment*, *202*, 108036.

Dahlan, N. D., Jones, P. J., Alexander, D. K., Salleh, E., & Dixon, D. 2008. Field measurement and subjects' votes assessment on thermal comfort in high-rise hostels in Malaysia. *Indoor and Built Environment*, *17*(4), 334-345.

Djamila, H., Chu, C. M., &Kumaresan, S. 2013. Field study of thermal comfort in residential buildings in the equatorial hot-humid climate of Malaysia.*Building and Environment*, 62, 133-142.

Feriadi, H., & Wong, N. H. 2004. Thermal comfort for naturally ventilated houses in Indonesia. *Energy and buildings*, *36*(7), 614-626.

Fukawa, Y., Murakami, R., & Ichinose, M. 2021. Field study on occupants' subjective symptoms attributed to overcooled environments in air-conditioned offices in hot and humid climates of Asia. *Building and Environment*, *195*, 107741.

Havenith, G., Heus, R., & Lotens, W. A. 1990. Resultant clothing insulation: a function of body movement, posture, wind, clothing fit and ensemble thickness. *Ergonomics*, *33*(1), 67-84.

Kamaruzzaman, K., & Tazilan, A. S. M. 2013. Thermal comfort assessment of a classroom in tropical climate conditions. *Recent Advances in Energy, Environment and Development*, 88-91.

Lin, Z., & Deng, S. 2008. A study on the thermal comfort in sleeping environments in the subtropics—Measuring the total insulation values for the bedding systems commonly used. *Building and Environment*, *43*(5), 905-916.

Nam, I., Yang, J., Lee, D., Park, E., & Sohn, J. R. 2015. A study on the thermal comfort and clothing insulation characteristics of preschool children in Korea. *Building and Environment*, 92, 724-733.

Oğulata, R. T. 2007. The effect of thermal insulation of clothing on human thermal comfort. *Fibres& Textiles in Eastern Europe*, 15(2), 61.

Parsons, K. C. 2002. The effects of gender, acclimation state, the opportunity to adjust clothing and physical disability on requirements for thermal comfort. *Energy and Buildings*, *34*(6), 593-599.

Rupp, R. F., Kazanci, O. B., & Toftum, J. 2021. Investigating current trends in clothing insulation using a global thermal comfort database.*Energy and Buildings*, 252, 111431.

Talukdar, P., Das, A., & Alagirusamy, R. 2016. Heat and mass transfer through thermal protective clothing–A review. *International Journal of Thermal Sciences*, *106*, 32-56.

Tang, Y., Su, Z., Yu, H., Zhang, K., Li, C., & Ye, H. 2022. A database of clothing overall and local insulation and prediction models for estimating ensembles' insulation. *Building and Environment*, *207*, 108418.

Tartarini, F., Schiavon, S., Cheung, T., Hoyt, T., 2020. CBE Thermal Comfort Tool is an online tool for calculatingand visualizing thermal comfort. Software X 12, 100563. https://doi.org/10.1016/j.softx.2020.100563.

Wang, L., Kim, J., Xiong, J., & Yin, H. 2019. Optimal clothing insulation in naturally ventilated buildings. *Building and Environment*, *154*, 200-210.

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