APPRAISING INDOOR THERMAL PERCEPTION OF ELDERLY IN HOT CLIMATES:
An experimental investigation of free-running residential aged care homes in Colombo

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Abstract: Rapid demographic transition with higher growth in ageing population demonstrate a major societal challenge in South Asia and Sri Lankans will age faster than other developing economies in the region. Climate shocks of people living in economically deprived countries will increase in future and elders are more vulnerable to the adverse effects of temperature extremes. The study experimentally investigated free-running residential care homes in hot climate of Colombo performing simultaneous personal monitoring and questionnaire surveys. Results explicitly prove overheated indoors with less air flow. Majority of elders confirmed thermally unacceptable interiors with warm thermal sensations and low air velocities of 0.1 to 0.29 m/s with predominant preference of more air movement proves inadequate passive airflow. A significant relationship between wind preference and presence of openings of their place of stay were evident. Staying away from a window or door instigated to practice a behavioural adaptation of moving towards transitional areas such as corridors, verandas, and outdoor spaces for more wind sensation. Since ageing is associated with physical inabilities and elders spend their life mostly in indoors, findings emphasize the importance of enhancing passive airflow and application of appropriate design strategies to ensure optimum air velocities and dispersion of airflow within interiors.

Keywords: *Thermal comfort; Elder care homes; Indoor environments; Air movement.*

1. Introduction

Global population is experiencing unprecedentedly rapid demographic transition as the populations are growing older in many of the countries in Asia and Pacific. By 2050, one third of the global population will be aged over 60 and 80% of ageing population will live in low- and middle-income countries (WHO, 2015). Population ageing in developing countries are three times higher than the developed countries and the demographic transition is a major societal challenge in future (UN, 2002). Thus, it is paramount important to prioritize needs of an ageing population in the national policies of developing countries to promote healthy ageing.

Population ageing is not an exception for Sri Lanka as the national ageing population is expected to increase dramatically over the next 30 years. This demographic transition is leading among the countries in South Asia, as the people growing older in Sri Lanka will age faster than most of the other developing economies.

At present 12.5% of the national population are over 60 years of age. This will increase to 24.8% in 2040 and represents the 3rd highest percentage of elderly citizens living in an Asian Country. In 2000, 1 in 10 Sri Lankans were over 60, by 2030 Sri Lanka is expected to have 1 in 5 people over 60 (Siddhisena, 2004). Thus, it's imperative that Sri Lanka needs to better prepare for the challenges of an increasing ageing population ensuring, enabling and supportive environments.

Moreover, the consequences of climate change will impose heavy burden on ageing global population, and this will grow over the coming decades. Tropical and subtropical countries are evident for adverse warming effects due to an increase in the highest temperatures from 1-3 °C by 2020 and by 2080 from 3-5 °C (IPCC, 2007). This increasing amplitude of temperature variability is mostly confined to

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developing countries and the vulnerabilities to weather and climate shocks of people living in economically deprived countries will increase in future (Bathiany et al., 2018; Dell et al., 2012, 2014; Jones et al., 2008).

While climate change affects everyone, older people are more vulnerable to the adverse effects of temperature extremes. Their capacity to cope with climate related stresses decrease with the physical decline or frailty, chronic health conditions and social isolation. The World Health Organization predicts an additional 38000 deaths of older people emerged from climate change aggravated heat exposure for the year 2030 (WHO, 2014).

Thus, climate change and population ageing portrait synchronized global issues increasing dramatically over next several decades which will enforce a future societal challenge on human health and well-being of developing countries of tropical Asia (UNFCCC, 2017).

1.1. WARMING TROPICS AND WELL-BEING OF ELDERS

South Asia is one of the most vulnerable regions facing to the challenges of global warming. By the end of 21st Century this region will experience a warming effect of an increasing temperature of 2 to 6°C (Sivakumar, 2011; Ravindranath, 2007). During the last decade, the hot spot locations of the region such as west of Sri Lanka, southeast of India and north of Pakistan were evident for an increasing temperature of 1 to 1.5°C and these places are being transformed towards severe hotspots due to current temperatures beyond the optimum levels (World bank, 2018). Thus, the extreme temperatures pose a serious threat on health and well-being of vulnerable populations living in tropics.

Human's vulnerability to warming climates are depended on their ability to cope and adapt to the changing environmental patterns. Older people are more susceptible to the impacts of temperature extremes and heat related morbidity and mortality arising from overloading on cardiovascular and respiratory systems (Huq et al., 2007).

Elders experience a range of deteriorating sensory changes as the biological ageing process of these organs associate with the nervous system. Decreasing trend in the ability to regulate body temperature makes an elderly person more susceptible to the impacts of extreme temperature (Havernith, 2001). As people age, they are likely to spend more of their time in indoors moving between bedrooms and living rooms (Brooks et al., 1991; Simoni et al., 2003; Almeida et. al 2014). Thus, the indoor environment of the place they age has a special significance and the residences that facilitates healthy ageing has become a priority worldwide (Severinsen, 2016).

1.2. INDOOR THERMAL PERCEPTION OF ELDERS

Indoor thermal environment is a crucial factor for comfort, health, and well-being of elderly people, as they spend considerable time of their life in interiors (Mendes, et al., 2014). Elders are less sensitive to the changes in temperature and experience declined thermal perception and associated physiological responses. Thus, an older person may perceive a health threatening thermal conditions as comfortable (Wookey et al., 2014).

Interiors with poor indoor environmental quality is evident as a major cause for physical illness and poor health in elderly (Evans et al, 2002). Other than the acceptable indoor thermal levels, the indoor environmental quality performs a role of a non-pharmacological intervention to decrease the frequency of unhealthy behaviors of elders and enhance their wellbeing (Tartarini, et al, 2017).

Studies conducted in climate chambers inform the behavioral and individual differences change the preferred indoor thermal environments for elders (Tsuzuki, K. et.al, 2002). Available few onsite investigations on indoor environments and thermal comfort of elders living in care centers of Portugal, China and Korea disclose thermal preferences and neutral temperatures of elders differ in each country. Elders in Korea prefer warm and slightly hot interiors during winter and non-conditioned interiors (Yang et.al.,2016). Similarly elders in Portugal prefer naturally ventilated living spaces and perform behavioural adaptation to minimize clothing levels (Attia S, 2020).

Studies for hot climates are limited and the only available thermal comfort studies of care home environments during warm seasons were performed in Korea (Yang et.al., 2016) and Australia (Tartarini, et.al., 2018). Moreover, less interest is evident on thermal perception of elders living in care homes of extreme hot climates (Yang et.al., 2020). Thus, its paramount important to understand thermal perception of elders in indoor environments with passive cooling in warming climates of developing Asian countries.

1.3. ELDER CARE HOMES IN SRI LANKA

Ageing is associated with physical inability and caring of elderly parents has been the cultural attributes of the Sri Lankan tradition. However, due to present shifts in socioeconomic development due to urbanization, transformations from extended to nuclear families, falling family size, women in workforce and migration have limited the capacity of families for elderly care and former cultural model of co-residence is unlikely to be sustainable. Thus, there is a burgeoning demand on care homes for elders, which will continue to grow.

There are 349 care homes located in 09 provinces authorized by the National Secretariat of Elders. They are permanent living places for 8806 elders and represents 0.2% of national population above 60 years of age in 2021. Of which 47% of the elders are living in 175 care homes of western province and 41% are in 59 care homes in Colombo district.

Research interests on elders and ageing population of Sri Lanka have prioritized the fields of demography, socio-economic, public health and geriatrics. Nevertheless, limited research focus is evident on places of ageing, its indoor environments and challenges on well-being of elders in tropical climates.

Owing to the fact that thermal perception of elders differs for varying climatic types, this study investigates the thermal perception of elders living in passively cooled residential care homes of hot climate of Colombo district.

2. Method

Method of the study is composed of an onsite experimental investigation and a simultaneous questionnaire survey. The field investigation was performed to acquire measurements of indoor environmental parameters and a questionnaire survey was conducted to assess the thermal perception. Köppen climate classification signifies a tropical monsoon climate for Colombo. Field study was performed during the peak hot season from 20th June to 8th August 2018, corresponding to daytime hours of 11.00am to 14.30pm.

This study was performed in seven randomly selected residential aged care homes located in the District of Colombo. They are authorized elders' homes of the National Secretariat of Elders. Several pilot walkthrough surveys were performed prior to experimental investigations to familiarize with the daily activity profiles of the elders and to maintain informal dialogues with the staff and elders residing in these care homes. Subsequently the experimental setup was confirmed, and the consent was obtained from the randomly selected sample of respondents. Figure 1 shows the indoor environments of the surveyed residential aged care homes.

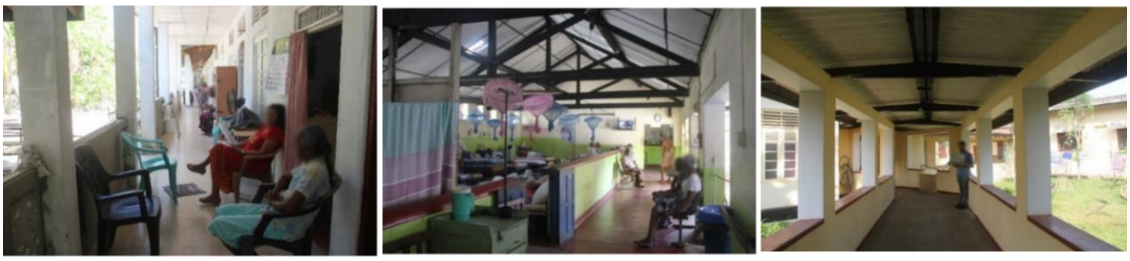


Figure 1. Indoor environments of residential aged care homes

2.1. STUDY DESIGN: ONSITE FIELD INVESTIGATION

Onsite filed investigation was performed to acquire actual measurements of the indoor environment such as air temperature (Ta), relative humidity (RH), and air velocity (v). Simultaneously a questionnaire survey was conducted among 156 randomly selected participants permanently living in the care homes. Experimental setup follows the ANSI/ASHRAE 55-2013 and ISO 9920-2004 standards. Specifications and accuracy of instruments are shown in Table 1. Measurements were recorded at a height of 0.6m from ground and within 1m distance of each respondent comfortably seated all through the interviewed questionnaire survey. Respondents

Part one of the questionnaire contains demographic and anthropometric characteristics of the respondents. Part two focuses on personal exposure assessment of participants such as thermal sensation, airflow preferences, thermal acceptability, and clothing insulation. Participants engaged in 15 mins of interviews while seated in bedrooms and living rooms and the interviewers completed the paper-based questionnaire composed of native language. A well-established thermal sensation scale, preference scale and acceptability scale were used in recording the sensations and preferences of the elders. Occupants' activities were not disturbed during the survey period, and they were allowed to adopt freely. ASHRAE 7-points thermal sensation scale (-3,-2,-1,0,+1,+2,+3 indicating cold, cool, slightly cool, neutral, slightly warm, warm and hot) was used to assess thermal sensation .Thermal acceptability was appraised as "acceptable = (+1)" or "unacceptable = (0)" and the airflow preferences of participants were obtained through 3-points scale of "Less air movement = (-1)", " No change in air movement = (0)" and "More air movement = (+1)". Participant's clothing ensembles were translated into clothing insulation values (Iclo) by referring to the ISO 9920-2004, ASHRAE standards 55- 2013. Iclo values were calculated by adding clothing insulation of the clothing they wore, footwear and materials of seated surfaces during the interview.

Parameter	Instrumentation	Accuracy	ISO7726 & ASHRAE 55,
Ta	HOBO UX-100 Temp/RH sensors & data logger	± 0.3°C	Minimum ±0.5°C; ideal ±0.2°C
RH		±3.5%	± 5%
v	VelociCalc 9545A, Hot-wire Anemometer	±0.015m/s	± 0.05m/s

Table 1, Specifications of Instruments, accuracy, and comparison with standards

3. Results and discussion

Statistical analysis of the results presents an assessment of indoor environment of care homes, participants profile and the effect of passive airflow on thermal perception, acceptance and airflow preferences of elders.

3.1. INDOOR THERMAL ENVIRONMENT

Indoor thermal environment profile of residential aged care homes represents air temperature (Ta) and relative humidity (RH) and their descriptive statistics are shown in Table 2.

Aged care home	Air temperature				Relative humidity			
	Min	Max	Mean	SD	Min	Max	Mean	SD
A	29.11	34.51	31.11	2.07	58.88	77.73	71.03	5.42
B	28.50	33.59	31.19	1.02	59.11	76.77	68.43	5.39
C	29.88	32.74	30.89	0.76	62.60	77.83	71.64	5.04
D	30.75	31.16	31.02	0.12	64.33	69.57	66.10	1.67
E	31.22	33.61	31.80	0.75	57.87	65.52	62.82	2.27
F	31.02	32.23	31.31	0.36	63.13	66.99	64.87	1.01
G	32.88	34.34	33.51	0.37	53.12	66.43	58.08	2.99

Table 2, Indoor air temperature and relative humidity profile of residential aged care homes

Maximum, minimum and mean air temperature vary in the range of 34.5 to 31.02, 28.5 to 32.88 and 33.51 to 31.31, respectively. Relative humidity profile varies in the range of 57.87 to 77.83% among all aged care homes. Standard deviation in the range of 0.12 to 2.07 for air temperature and 1.01 to 5.42 for relative humidity, confirms less diversity in indoor thermal environments of aged care homes. Thus, proves the cohort of elders are exposed to similar indoor thermal environments. Prevalence of 31 to 33.5 °C of mean Ta and mean RH of 58% to 71% characterizes overheated indoor thermal environments in the residential aged care homes.

3.2. PARTICIPANTS: BIOLOGICAL CHARACTERISTICS OF ELDERS

The cohort of participants are above 60 years of age. Table 3 describes gender, age category and physiological characteristics of the participant elders. The cohort consists of 61.54 and 38.46% female and male elders, respectively. As shown in Table 3, number of female participants in all age groups are higher than male elders. The highest number of females are over 80 years and males are within the range of 70 to 79 years of age. Mean height and weight of female and male elders are 51.53 kg and 1.53 m and 56.83 kg and 1.62 m, respectively.

Gender	Age distribution			Height				Weight			
	60-69	70-79	≥80	Min	Max	Mean	SD	Min	Max	Mean	SD
Female	25	35	36	1.22	1.78	1.53	0.09	27	72	51.53	9.44
Male	15	29	16	1.42	1.83	1.62	0.07	38	82	56.83	10.07

Table 3, Gender distribution, age categorization and physiological characteristics of the cohort

Changes in body physiology confronts with the increasing age. Thus, the weight and height are main biological characteristics to calculate body mass index (BMI) and body surface area (BSA) of the participants. Commonly used BMI classifications are WHO criteria for Asian adults (WPRO,2000) and BMI scale for elderly people over age 65 (Winters et al. in 2014). BMI scale in all-cause mortality was considered as the classification criteria; BMI over 31 kg/m^3 is an overweight and below 23 kg/m^3 is an underweight elderly person. Equation 1 corresponds to the Du Bois method used in the calculation of BSA.

BSA = Weight (kg)$^{0.4256}$ X Height (cm)$^{0.725}$ X 60.007184. (1)

Table 4 shows BMI scale and mean BSA for 03 age categories. As shown in Table 4, the cohort is predominantly under-weight with 61% and 79% of elders in the age groups of 70 to 79 and over 80 years, respectively. Moreover, the mean BSA of all age groups vary in the range of 1.48 to 1.54 and the elders over age 80 were evident for the lowest BSA. Mean BSA of the cohort is 1.51 and characterizes as lean body, which is below normal BSA of an average male and female adult.

Category	Age distribution		
	60-69	70-79	≥80
Underweight (<22.9 kg/m^2)	20 (50%)	39 (60.9%)	41 (78.8%)
Normal (23 – 30.9 kg/m^2)	20 (50%)	24 (37.5%)	11 (21.1%)
Overweight (>31 kg/m^2)	0 (0%)	1 (1.5%)	0 [0%)
Mean Body Surface Area (m^2)	1.54	1.53	1.48

Table 4, BMI categorization and BSA of the cohort of elders

Higher BSA represents a greater body surface for heat dissipation through heat transfer mechanisms and the added body mass will act as a thermal insulation (Anderson G, 1999). However, the decrease in body mass while getting older reflects adverse effects on thermal regulatory process of body (Holloszy, 2000).

3.3. INDOOR AIR VELOCITY AND CLOTHING INSULATION

Measured indoor air velocities of the residential aged care homes were binned by 0.09m/s intervals and illustrated as a histogram in Figure 2. Indoor air velocities differ in the range of 0.09 to 0.99 m/s. As shown in Figure 2, indoor air velocities are predominantly in the intervals of 0.1 to 0.19 m/s and 0.2 to 0.29, while 14.7% of air velocities are above 0.5 m/s. Higher indoor air velocities above 0.4 to 0.9 m/s will ensure thermal comfort of occupants in naturally ventilated interiors of hot climates.

Experiment carried out in a naturally ventilated Brazilian university building in warm-humid climate resulted in a minimal air velocity of 0.4 m/s to achieve thermal comfort at 26°C and air velocity of 0.9 m/s to provide comfort temperature at 30°C. In a research based on naturally ventilated classrooms in Singapore, a high air velocity in the range of 0.8 to 1.2 m/s was needed to reach thermal comfort during midday. (Liping, 2007) Thus, it is evident that the prevalent mean air velocity below 0.3 m/s confirms that the elders are experiencing low wind velocities in naturally ventilated residential aged care homes.

Additionally, the relationship of clothing insulation (I_{clo}) of elders and indoor air velocities were appraised. Clothing is necessary to protect the body against climatic influence and to assist its own thermal control functions under various combinations of environmental conditions. (Layton, 2001) An exchange of air between the clothing microenvironment and the external environment will affect the thermal insulation which in turn will affect thermal comfort of a person. (Bouskill,2002)

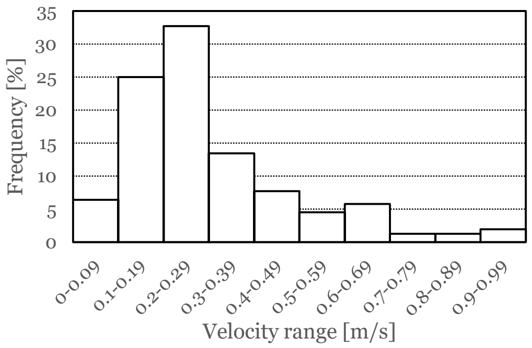


Figure 2, Histogram of binned air velocities

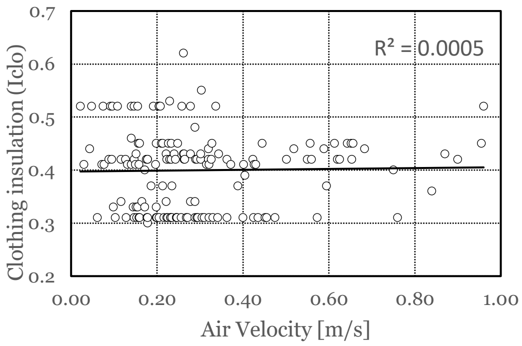


Figure 3, Variation of Iclo with Velocity

Clothing attire of elders represents tropical clothes such as long frocks, blouse with a long skirt or lungi for females and a sarong with a short-sleeved shirt or T-shirt for male elders. ASHRAE standard 55 was used in the estimation of clothing insulation (I_{clo}) of each participant. Mean I_{clo} of male and female elders are 0.37 and 0.43clo respectively. Clothing attire of females are lighter than males, thus mean I_{clo} of the cohort is 0.4. Summer clothing of ASHRAE standard 55 is 0.5 clo.

Figure 3 shows the linear regression of I_{clo} and indoor air velocity. Relationship between I*clo* and indoor air velocity is not significant ($p=0.78$; $p>.05$). Clothing variation is a predominant behavioural adaptation of people living in indoor temperatures between 18-28°C. However, clothing changes are less influential for people in tropical attires, which corresponds to least I_{clo} values and their adaptive opportunities get limited with cultural practices (Indraganti et al, 2014; Nicol and Humphreys, 2007). Thus, highlights the significance of air velocity intensity in indoors as the residential aged care homes are naturally ventilated.

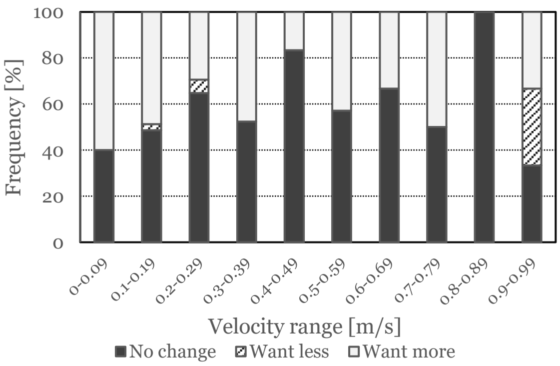
Indoor air temperature above 28°C is thermally uncomfortable and the discomfort declines with air velocities around 0.8m/s (Fanger et al., 1974; McIntyre, 1978). Thus, proves the overheated interiors of the residential aged care homes are below the acceptable level of air velocities. Furthermore, the deteriorated physical and biological systems of elders limit their adaptability as they live with less activities and bear minimum clothing level and tend to disregard any discomfort (Liang et al. 2005). This phenomenon will instigate a health risk as their ageing process is associated with indoors.

3.4. PASSIVE AIRFLOW PREFERENCES AND ASSOCIATION WITH OPENINGS

This section describes elders' preference on passive airflow and assesses their association with openings such as windows and doors. The scale represents preferences of airflow as 'no change', less and more. Figure 4 shows the airflow preference in respective to varying levels of indoor air velocities. Results indicate 58.3% and 38.5% of participants prefer no change and more air movement, respectively. Negligible number of participants (3.2%) require less air movement.

Air velocity intervals of 0.4 to 0.49 m/s and 0.8 to 0.89 m/s were evident for the highest percentage of 'no change' airflow preference of elders. Elders prefer 'more air movement' for low velocity of 0.01 to 0.19 m/s and high velocity of 0.7 to 0.79 m/s. Moreover, 33.34% prefer more air with an air velocity interval of 0.9 to 0.99 m/s. Findings inform a less influence of velocity intensities on elders' preferences for passive airflow.

Consequently, the ambience of the commonly used space of elders was assessed in respective to presence of openings such as windows. Figure 5 shows the air movement preferences and presences of openings in mostly used space. Among the cohort 41.1% stays away from an opening and the elders stay 0closer to a door or a window is 33.6% and 25.3%, respectively.



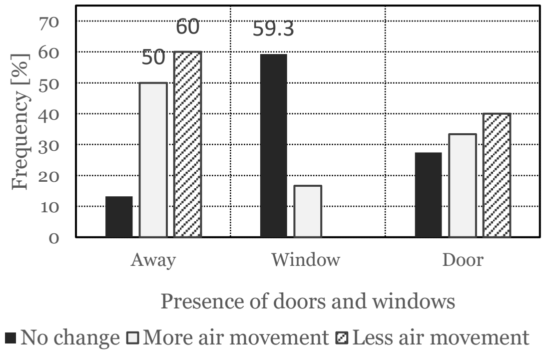


Figure 4, Air movement preferences of the elders

Figure 5, Distribution of presence of doors and windows

As shown in Figure 5 the highest frequencies of more and less air movement preferences are evident among elders stay away from openings, mainly in interior locations. In contrary the highest preference for 'no change' in airflow is apparent for elders stay closer to a window. However, elders closer to a door is apparent for similar frequencies below 40% for all three preferences.

Although adequate level of passive airflow is important for thermal comfort in hot climates, further assessment was performed for the cohort of elders prefer a change in airflow. Less and more air movement is preferred by 3.2% and 38.5% of the participants, respectively.

Majority of the participants with less air movement preferences (79.8%) are exposed to higher air velocities around 0.9 m/s. Unacceptable level of air velocities will cause wind induced discomfort such as cold sensation (Arens et al ,2009). Thus, the availability of an optimum indoor air velocity level is essential for hot climates. Remaining 21.2% of elders were suffering with illnesses of circulatory and nervous systems such as numbness, diabetes, and high cholesterol levels. As nerve densities decrease with age there is a tendency in declining thermo sensitivity. (Guergova et al., 2011; Szekely et al., 2018).

Elders with inadequate airflow inform a distinct association with openings. Of which 50%, 33.3% and 16.7% stay away, or closer to a door or window, respectively. Majority of elders with inadequate airflow stays away from openings and stay closer to a door. Optimum airflow within a building is promoted through cross ventilation strategy which is facilitated by windows and doors (Gou et al, 2018). Presence of internal openings (doors) alone is less effective in channeling passive airflow towards interiors. Thus, the integration of envelope openings (windows and doors) and behaviour of occupants in regulating the open area of these openings is an effective mechanism to promote passive cooling in hot climates.

Elders with inadequate airflow signify a constraint in achieving indoor thermal comfort in naturally ventilated residential aged care homes. Hence, the appraisal on thermal perception was performed for the cohort of elders require more passive airflow.

3.5. INDOOR THERMAL PERCEPTION: SENSATION AND ACCEPTABILITY

Indoor thermal perception of elders was determined through thermal sensation and acceptability scales. Figure 6 shows 71.7 % and 28.3% of elders confirms indoor thermal environments are unacceptable and acceptable respectively. In addition, figure 7 shows the integration of thermal sensation votes (TSV) with thermal acceptability (TA).

As shown in Figure 7, elders predominantly experience warm thermal sensation with a variation of votes from neutral to hot. Frequencies of 16.7%, 38.4%, 38.4% and 6.7% are evident for neutral, slightly warm, warm and hot TSVs, respectively. Thus informs the indoor thermal environments are overheated for 83.5% of this cohort of elders.

Moreover, the elderly with unacceptable thermal environment is evident for TSV of 1.7%, 26.7%, 36.7% and 6.7% for neutral, slightly warm, warm and hot, respectively. TSV of neutral, slightly warm and warm is experienced by 15%, 11.7% and 1.7% of the elders with acceptable indoor thermal conditions, respectively. Mean TSVs of the cohort of elders with unacceptable and acceptable thermal conditions are shown in Table 5. As shown in Table 5, MTSV of elders with acceptable and unacceptable thermal conditions are 0.6 and 1.7, respectively.

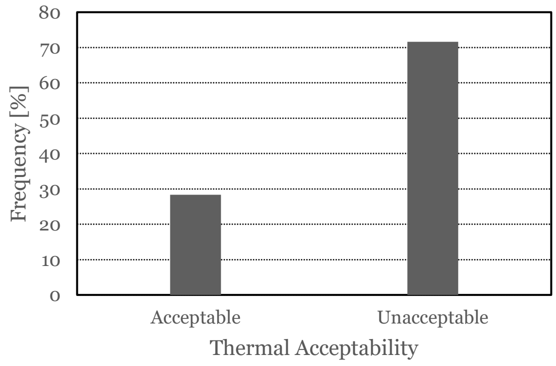


Figure 6, Thermal acceptability of the elders

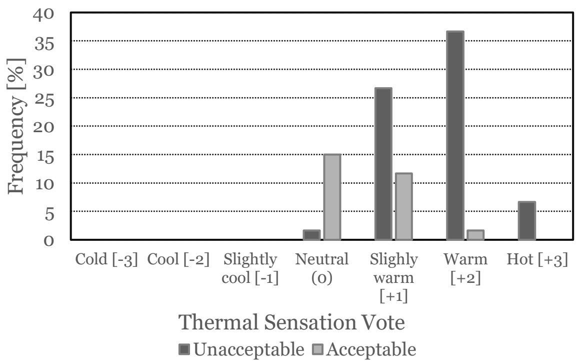


Figure 7, TSV based on thermal acceptability

Variable	Acceptable	Unacceptable
MTSV	0.6	1.7
SD	±0.61	±0.62

Table 5 - Mean TSV values of acceptable and unacceptable groups

ASHRAE standard defines TSV between -1 to 1 as the thermal comfort range which prevails an acceptable thermal condition for people (Fei H et al ,2021). Thus, the cohort of elders with acceptable thermal conditions agree with the standards. However, the majority of elders with an MTSV beyond the comfort range with unacceptable thermal conditions establish indoor environments of residential aged care homes are overheated and further confirms the passive airflow is inadequate to promote optimum thermal comfort levels. Adapting to unacceptable thermal conditions through personal behavioral adjustments such as changes in posture, clothing, or moving to a different location are commonly practiced (Thapa et al., 2016). Thus, a further analysis was performed to identify elders' choice of a preferred place in residential aged care home.

3.6. PERSONAL BEHAVIOURAL ADJUSTMENT: CHANGING PLACE OF STAY

Elders' choice of indoor places is corridor, verandah, dormitory, bedrooms and prefer to stay in outdoors. Figure 8 shows the percentage of elders and their preferred place of stay. As shown in Figure 8, 20.9%, 11.6% and 16.3% of elders prefer corridors, verandahs and outdoors, respectively. The mostly preferred indoor place is dormitory (34.9%) and lesser percentage of elders prefer their own bed (7%) and a place within bedrooms (9.3%). Results prioritize the significance of dormitory, transitional places such corridors, verandahs and immediate outdoors of residential aged care home.

Air temperature of preferred places are shown in figure 9. As shown in Figure 9, the highest temperature of 33.9°C is evident in places of beds. Preferenc of their own bed as a choice of place is limited to negligeble number of elders. Comparatively lesser temperatures in the range of 31.8 to 31°C is apparent for dormitory, corridor, verndah, bedroom and outdoors. Amid interior spaces dormitories are cooler than the places with single beds and individual bedrooms. Air temperature of transitional places such as corridors and verandahs are 31.4°C and 31.7°C, respectively. However, immediate outdoors signifies the lowest temperature of 31°C.

Preferred air temperature for indoor thermal comfort of Taiwanese and Japanese elders are in the range of 23.2 - 27.1°C and 25 – 27°C, respectively (Hwang et al. 2010; Tsuzuki et al., 2002) Although the elders demonstrate the need for personal behavioural adjustments through changing of place of stay, these places are overheated and beyond the acceptable thermal comfort range.

Thus, confirms their attraction towards transitional places and outdoors are predominanlty influenced by passive airflow. Moreover, personal behavioural adjustments on choice of place of dormitory informs the importance of sharing spaces in contrary to individual rooms. Hence, proves the free-running interiors of residential aged care homes are extensively affected by the constraints of passive airflow. This study explictly confirms the overheated residential aged care homes with inadequate passive airflows impose a greater threat on healthy ageing and initates a future societal challenge on well-being of elders.

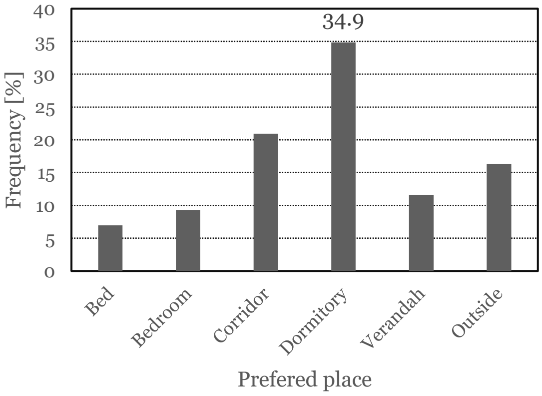


Figure 8, Preferred place distribution

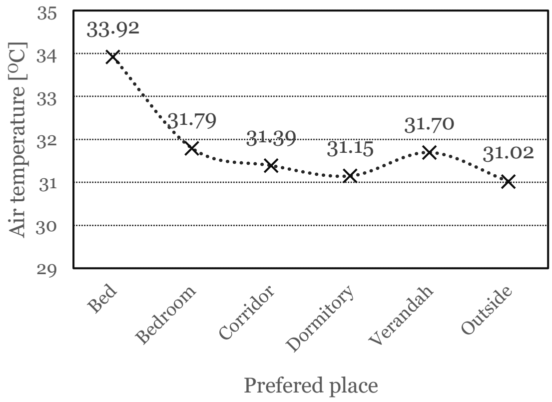


Figure 9, Air temperatures of preferred places

4. Conclusion

Extreme high temperature poses a serious threat on health and well-being of elders in tropical climates. Since, ageing is associated with physical inability, deteriorating sensory changes and decreasing body mass of elders, reflect adverse effects in thermal regulatory process. Thermal perception of elders differs for varying climatic types and as they spend majority of their life indoors, its thermal environment is a crucial factor for comfort, health, and well-being.

This paper investigates thermal perception of elderly in free-running residential aged care homes in hot climate of Colombo. Perceived thermal environments of 156 elders aged more than 60 years were recorded in a questionnaire survey along with simultaneous objective measurements of physical environments of seven authorized residential aged care homes.

Results explicitly proves the naturally ventilated indoor environments of residential aged care homes are predominantly overheated with mean air temperature and RH in the range of 31 to 33.5°C and 58 – 71% respectively. Prevalent air velocities are primarily low in the range of 0.1 to 0.29 m/s. Thus, confirms inadequate passive airflow in indoors.

Moreover, the resident elders of these care homes signify a physical characteristic of underweight and categorize as malnutrition for the age group above 60 years. Sedentary activity profile informs almost a constant metabolism and clothing insulation informs the least level of summer clothing, with a Iclo of 0.4. Thus, the adaptive behaviour of clothing modifications for thermal comfort has been limited.

Majority of resident elders (70.1%) confirmed thermally unacceptable indoor environments with warm thermal sensation and a mean TSV of 1.6. Thermally acceptable interiors were apparent for 28.3% of elders, of which 15% are with neutral thermal sensation and a mean TSV of 0.6. Prevalence of overheated interiors with low air velocities has initiated a behavioural adaptation practice of elders for thermal comfort by changing their place of stay and moving towards more open and spacious locations.

Elders' preference on air movement is primarily connected to presence of openings such as doors or windows in their place of stay. Elders staying closer to openings do not prefer changes to air movement. As majority of elders stay away from openings and of which 83.7% preferred moving towards open areas such as dormitories, corridors, verandahs and outdoors. The mean air temperature of these spaces range between 31 to 31.4^{0} C. Least preferred places are individual bedrooms with temperatures in the range of 31.8 to 33.9°C, which is well beyond the thermal comfort range of elders. Thus, the elders living in these residential care homes prefer to spend more time in common spaces than staying in overheated bedrooms.

The findings of this study prove that the aged care homes are with overheated interiors and less wind velocities with limited passive airflow. Spatial composition which controls elders' interaction with openings has resulted interior locations with stagnated air pockets of high temperatures. Thus, the planning of individual places of elder's homes with optimum connections to airflow paths will facilitate similar thermal ambience within the interiors. Variation in thermal sensation and acceptance resulted through improper design strategies will impose serious threat on elders due to an escalation of their mobility towards open areas. Moreover, increase in the frequency of mobility of elders as a behavioral adaptation for thermal comfort is unjustifiable since the process of ageing is associated with the changes in physiological and physical inabilities.

Thus, the study instigates the necessity of far-reaching design strategies to compose thermally innovative aged care homes which will ensure wellbeing of elders and also to promote user-sensitive environments for the aging population in tropics.

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