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The Influence of Transient Changes in Indoor and Outdoor Thermal Comfort on the Use of Outdoor Space by Older Adults in the Nursing Home

Hua Zong [1,*], Jiao Wang [1], Ting Zhou [1], Jiarui Sun [1] and Xuehong Chen [2]

[1] School of Architecture, Southwest Jiaotong University, Chengdu 611756, China; tianlei09@my.swjtu.edu.cn (J.W.); 18483606989@my.swjtu.edu.cn (T.Z.); sunjiarui@my.swjtu.edu.cn (J.S.)
[2] School of Life Science and Engineering, Southwest Jiaotong University, Chengdu 610031, China; chenxuehong@swjtu.edu.cn
* Correspondence: zonghua@swjtu.edu.cn; Tel.: +86-1343811516

Abstract: Recently, the requirements regarding the environment of nursing homes are high, because the elderly are a vulnerable group with limited adaptive capacity to respond to transient environmental change. This paper presents a field investigation on the influence of transient thermal comfort changes between the indoor and outdoor spaces (i.e., air temperature (T_a), solar radiation (SR), relative humidity (RH), wind speed (WS), and the thermal comfort indices of Universal Thermal Index (UTCI)) on the willingness of the elderly to use outdoor spaces of the Wanxia nursing home of Chengdu City. Results indicated that, in summer, the mean UTCI values of indoor and corridor spaces corresponded to the level of moderate heat stress, while those of road and garden corresponded to the strong heat stress level. Road and garden spaces even showed moderate heat stress in spring. Approximately 28.93% (139) of the elderly living here used outdoor spaces every day. The morning period (from 9:00 a.m. to 10:00 a.m.) was the elderly's favorited period for using outdoor spaces in seasons. The microclimatic transient differences between indoor and outdoor spaces ranged from 0.47 °C to 2.93 °C ($|\Delta T_a|$), from 86.09 W/m^2 to 206.76 W/m^2 ($|\Delta SR|$), from 5.29% to 14.76% (ΔRH), from 0.01 m/s to 0.07 m/s ($|\Delta WS|$), and from 0.25 °C to 2.25 °C (ΔUTCI). These big microclimate differences could cause enormous health risks for the elderly in the process of indoor and outdoor space conversion. The minimal transient change occurred between corridors and indoors. Pearson correlation analysis indicated ΔT_a and ΔRH between indoor and outdoor spaces were the primary meteorological factors that influenced the elderly's willing to use outdoor spaces. The elderly preferred to live in a constant Ta and RH environment. Only when the ΔT_a and ΔRH are small enough to resemble a steady-state ($\Delta UTCI \leq 0.5$ °C), ΔWS and ΔSI could affect the elderly's choice of using outdoor space. Optimal design strategies were put forward for reducing the transient differences between indoor and outdoor microclimates to inspire the elderly to use outdoor spaces safely, including improving outdoor canopy coverage and indoor mechanical ventilation.

Keywords: nursing home; indoor and outdoor spaces; microclimatic difference; elderly; thermal comfort

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1. Introduction

With increasing life expectancy and plummeting birthrates, the world population is rapidly aging [1–3]. As China's older population is the most populous in the world, there is no doubt that China will soon encounter particularly acute challenges from the aging population. The total number of elderly aged 65$^+$ in China was estimated to increase to 23.9–26.9% of the total population by 2050 [4]. Because of the shrinking family size (commonly with a 4-2-1 structure, with four grandparents, two parents, and one child), the frequent population flow, the improving social pension system, and the modernization of living patterns, an increasing number of Chinese elderly will have to trade traditional family care for institutional care.

In China, an important period of strategic opportunity for the development of nursing homes has arrived. The number of Chinese elderly who joined nursing homes grew at an unprecedented rate from 1.20 million in 2006 to 3.79 million in 2017 [4]. From 2009 to 2017, the number of beds in nursing homes increased from 2.58 million to 7.47 million [4]. However, despite the large gap in beds of nursing homes for the Chinese elderly, the vacancy rate of nursing homes was very high (e.g., 47% for Beijing and 35% for Shanghai in 2017) [5]. The reasons may be that the built environment, fees, and nursing services of nursing homes are not meeting the demands of the elderly [6]. In urban areas, the elderly are willing to wait for many years for a bed in a superior nursing home. Thus, to enhance the attractiveness of institutional care for the elderly, research has recently focused on the built environment of the nursing home.

Regarding the indoor environment of nursing homes, Mendes et al. [7] reported that most (64%) of the occupants of nursing homes of Porto City, Portugal, were dissatisfied with the indoor temperature. The Thai elderly living in nursing homes need indoor temperatures of 27.78 °C [8]. In the seven nursing homes of Utrecht City, the Netherlands, at least 65% of all common rooms had poor vertical illuminance, which remained significantly below the demand of the elderly of 750 Lux [9]. Residents in 15 aged care facilities that were both warm and moist were found to have low health risk [10]. Furthermore, keeping the door open or running air-conditioners were identified as important measures for air quality improvement in nursing home rooms [11]. The influence of outdoor climate on indoor microclimate, especially during heat stress events, has also been found [12]. Indoor temperature is mainly influenced by outdoor temperature [13]. Due to the physical characteristics of the building, indoor climate differs within the spatial and temporal differences in outdoor temperature in Berlin [14]. In addition, thermal comfort and adaptation are considered important issues in the environmental design of nursing homes, because the thermal sensation of the elderly is different from that of the young [15].

A few studies have pointed out the outdoor spaces, especially the internal gardens, of nursing homes fulfill the functions of relief from physical symptoms, improvement of bodily function [16], stress and anxiety reduction [17], communication [18], and building self-confidence [19]. However, the above benefits the elderly obtained were based on the premise that the outdoor spaces were sufficiently comfortable to attract the elderly to use and enjoy these [20]. Previous research indicated that thermal comfort was one of the main factors that determine the quality and use of outdoor spaces [21–23]. In the hot-dry Mediterranean regions, the internal gardens provide a passive cooling effect to attract people to enter them [24]. The attenuation peaks of 6.4 °C on a cold day and 5.0 °C on a hot day were found in the internal courtyard in tropical climates [25]. The thermal comforts of the internal gardens in eight nursing homes in Chengdu City partially deviated from the elderly's demands, especially in winter by thermal/humidity/radiation sensation votes [20]. However, previous efforts in thermal comfort research of nursing homes have been mostly focused on steady-state conditions [26,27].

Actually, the thermal environment is often transient and dynamic, such as moving indoors from outdoors, or moving from indoors to outdoors [28]. However, neither ASHRAE standard 55-2010 nor ISO 7730 provide a clear description of the thermal comfort in the transient environment, and the macroclimatic step-change transients of the elderly remains relatively poorly understood [28]. Older adults represent a vulnerable group as they have limited adaptive capacity to respond to the transient environment, and may consequently suffer thermal stress, cold stress, and solar stress [29,30]. Even the daily temperature fluctuation in one room may induce increased variation in the blood pressure of the elderly [31]. Moreover, their ability to respond to environmental changes is far weaker in winter and summer [15]. In China, the elderly who choose nursing homes are generally older and weaker than the average elderly, the proportion of disabled and semi-disabled elderly in nursing homes has continued to grow. The outdoor spaces of nursing homes could be the only space where the elderly may encounter nature. In search of bases for the design of more pleasant and healthy spaces in nursing homes, this study aims to (a) investigate the transient thermal comfort between indoor and outdoor spaces in nursing homes during four seasons; (b) clarify the transient microclimatic changes that may yield sufficient comfort and safety for the elderly to use outdoor spaces in all seasons, by assessing the usage patterns of these spaces; (c) adjust environmental design strategies for constructing a comfortable and balanced microclimate between indoor and outdoor spaces. These results inform the thermal comfort and energy-saving design of nursing homes.

2. Material and Methods

2.1. Sample Selection

The nursing home assessed by this study is the Wanxia Elderly Service Center (abbreviated as Wanxia nursing home) in Jinniu District of Chengdu City (30°05′ N–31°26′ N, 102°54′ E–104°53′ E), which is situated in the political and commercial center of western China [32] (Figure 1). As of the end of 2019, Chengdu City had a registered population of 15.07 million, 3.16 million of whom were aged 60 years of older, and the aging rate reached 21.07%, ranking third in China. Chengdu City has 546 nursing homes, with a total of 125,000 beds (including preparations), representing 39 beds per 1000 elderly. The coverage of elderly care facilities in urban communities has reached 97% (Chengdu Statistical Yearbook).

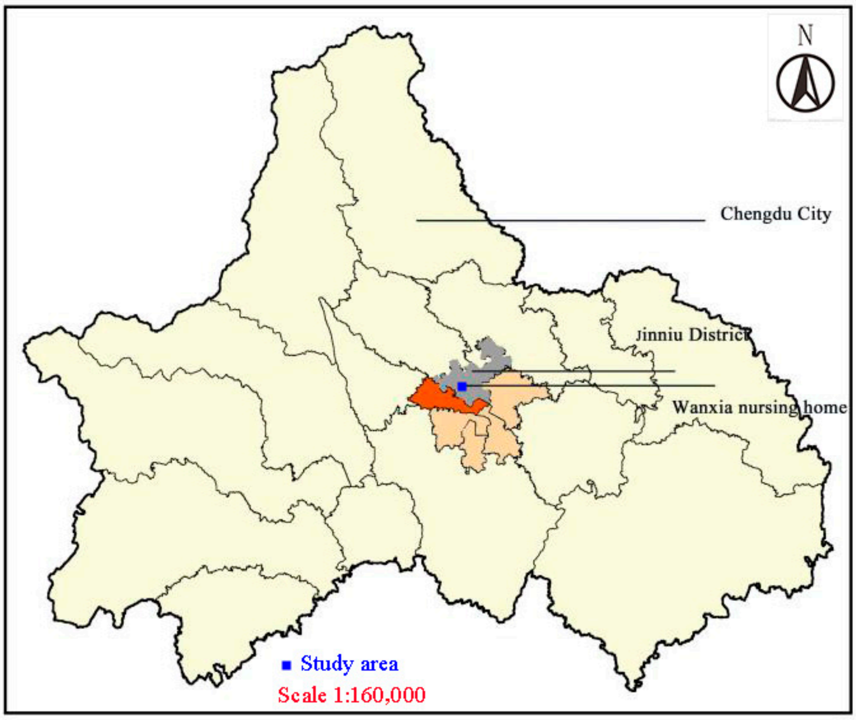


Figure 1. The location of the Wanxia nursing home, Chengdu City, China.

Chengdu City is situated in the hot summer and cold winter zone of China. The mean air temperature (T_a) of the hottest month of July is about 2 °C higher than that of other places with the same latitude across the world. The mean T_a of the coldest month of January is about 8–10 °C lower than that of other places with the same latitude across the world [33]. In 2020, the average daily T_a in summer (from June to August) was 31 °C, and the highest T_a was 39 °C. The average T_a in winter was 11 °C, and the lowest T_a was 3 °C [34]. Chengdu City belongs to a typical calm wind area. The annual mean wind speed (WS) is 0.7 m/s, and from 1980 to 2010, the frequency of calm weather in Chengdu City was approximately twice (24.06 days) that of other regions in China [35]. In addition, Chengdu

City has a high annual mean relative humidity (RH) (77.6%) and the lowest annual mean sunshine duration (of 925.7 h) in China (China meteorological administration, 2004–2015).

Wanxia nursing home is the largest privately run aged care facility in Chengdu city, with a total of 500 beds. The area of Wanxia nursing home is about 46,666.66 m^2, and the green space rate here has reached 61.78%. Northeast facing buildings in this facility are in a determinant layout. Four two-story accommodation buildings are located in the west part of the nursing home, and the other buildings are on one floor. The east of the accommodation buildings is the main road with a width of 4 m. A total of 482 old people live in this nursing home with an average age of 82 years. Of these 482 elderly people, 161 (33.40%) are men and 321 (66.60%) are women. More than 90% are over 80 years old and 2.8% are over 90 years old. More than half of the elderly are disabled, who have to rely on a caregiver to move, and moreover it did not include the elderly with dementia. Due to the civilian price, there is no standard daily care procedure for taking these disabled elderly out of their bedrooms to enjoy the outdoor sunshine.

2.2. Instruments and Measurement Methods

The nursing home was divided into indoor and outdoor spaces (Figure 2a). Outdoor spaces include covered corridor spaces (abbreviated as corridor), road spaces, and garden spaces. The indoor spaces are the bedrooms. Corridors are adjacent to the bedroom. Garden spaces provide sport and seat facilities. To evaluate the daily microclimatic variation of this nursing home throughout the seasons, five measurement sites (namely one covered corridor (Figure 2b), one main road (Figure 2c), one garden (Figure 2d), and 2 bedrooms (Figure 2e,f)), were chosen and microclimatic factors were simultaneously monitored from March 2020 to February 2021. In order to avoid walking difficulties affecting the use of outdoor spaces by older adults, two bedrooms on the first floor, facing northeast, were selected for the purpose of this study, with the total inside area of 31.9 m^2 and floor to ceiling height of 3.3 m (Figure 2e). Four elderly people lived in each bedroom, where there was a state of complete natural ventilation without any heating or fresh air system. The covered corridors, gardens and roads are all located closest to the 2 bedrooms.

Indoor and outdoor T_a, RH, and WS were measured using the Kestrel 5500 portable weather station (Nielsen-Kellerman, Boothwyn, PA, USA). The portable TES 1333R (Tes, Taipei, Taiwan, China) and AZ 8758 (AZ Instrument Corp, Taichung, Taiwan, China) instruments were used to estimate solar radiation (SR) and globe temperature (T_g). These instruments were installed horizontally in the center of outdoor spaces, 1.5 m above the ground level. Indoor fixed measurement units were placed at that side of the bedroom with sufficient distance to door and window. In order to prevent the elderly from tripping, the tripod of the instrument was removed, and these instruments were placed on a 1.5 m high cabinet. Considering that the elderly used these spaces in the daytime, at least two days in each month were randomly selected and the measurement work was carried out during spring (26 and 27 March; 27 and 28 April; 28 and 29 May), summer (15, 16 and 20 June; 19, 23, 24, and 27 July; 4, 6, 8, and 9 August), autumn (16 and 26 September; 10, 11, 14 October; 15 and 16 November), and winter (26 and 27 December; 2, 9 and 19 January; 19 and 26 February) in 2020, at 5 min intervals from 9:00 a.m. to 18:00 p.m. as these are the central hours of the daytime, as well as being the moments of the most active time for elderly. In addition, all measured spaces were not given any additional light source during 9:00 a.m. to 18:00 p.m. No data were recorded on rainy days. All indoor and outdoor measurements were carried out simultaneously. Then, to clear the effects from atmospheric and thermal comfort differences between the bedroom, corridor, road, and garden on the elderly's preference of space use, we analyzed the pairwise differences in T_a, RH, SR, WS, and UTCI values of these spaces, such as the T_a difference (abbreviation ΔT_a), $\Delta T_1 = T_{a(\text{indoor space})} - T_{a(\text{corridor space})}$, $\Delta T_2 = T_{a(\text{indoor space})} - T_{a(\text{road space})}$, and $\Delta T_3 = T_{a(\text{indoor space})} - T_{a(\text{garden space})}$.

Figure 2. The indoor and outdoor spaces of the Wanxia nursing home. (**a**) Distribution map of measuring points, (**b**) corridor space, (**c**) garden space, (**d**) road space, (**e**) and (**f**) indoor space.

2.3. Elders Observations

Direct observation was applied to identify the patterns of use and stay of the elderly in the different spaces in this nursing home. How many elders entered and stayed in these spaces more than 5 min during the measurement was recorded and then which space elders would like to choose every one hour was analyzed. Simultaneously, a series of personal factors, such as clothing and activity level, were also assessed. The total clothing insulation value (Clo) for an individual was calculated using Equation (1) [36]:

$$I_{\text{Clo}} = 0.835 \sum_{i} I_{\text{Clu},i} + 0.161 \tag{1}$$

where

- I_{Clo} is the total clothing insulation value;
- $I_{\text{Clu},i}$ is the insulation value for each piece of clothing in the unit of Clo.

The insulation value for each piece of clothing referred to ASHRAE Standard 55-2013 and GB/T 50785-2012.

2.4. Data Analysis Methods

In this study, microclimatic parameters were calculated for each measurement day, and the mean values were calculated for the whole season. Then, the mean values of microclimatic parameters were used to calculate universal thermal climate index (UTCI). UTCI is considered as one of the most complete, objective, and efficient performance indices for evaluating the outdoor thermal comfort in urban and landscape planning and design [37,38], such as the urban residential blocks in Nanjing, China [39] and the university campus in Shanghai, China [40]. Moreover, UTCI based on a multi-node dynamical model of human heat transfer and temperature regulation with a 10-level scale [41], represents the temporal variability of thermal conditions better than the other indices [42]. In recent years, UTCI has also been suggested to calculate indoor thermal comfort. Walikewitz et al. [12] found all rooms in eight buildings in Berlin, Germany, experienced heat stress according to UTCI levels, especially during summer heat waves. Grifoni et al. [43], using UTCI, revealed how cool façades help to improve indoor conditions in Italy.

The UTCI was used to describe the thermal comfort of the different spaces in this nursing home, which is a bio-meteorological index for the assessment of thermally induced stress and reflects even slight differences in the intensity of meteorological stimuli [42]. T_a, T_{mrt}, RH, and $WS_{(x=10)}$ were used to calculate the UTCI [44] (see Equation (2)). Globe thermometers combined with air temperature and wind speed sensors were used for obtaining T_{mrt} (see Equation (3)). Equation (4) below was used to convert our 1.5 m wind speed to $WS_{(10\text{ m})}$, which was required to calculate the UTCI [44].

$$\text{UTCI} = \text{f}\ (T_a;\ T_{mrt};\ WS_{(x=10)};\ \text{RH}) \tag{2}$$

$$T_{mrt} = \left[\left(T_g + 273.15\right)^4 + \frac{1.1 \times 10^8 \times {WS_{10}}^{0.6}}{\varepsilon \times D^{0.4}} \left(T_g - T_a\right) \right]^{0.25} - 273.15 \tag{3}$$

$$WS_{(x=10)} = WS_x \left(\frac{\log\left(\frac{10}{0.01}\right)}{\log\left(\frac{x}{0.01}\right)} \right) \tag{4}$$

where

- Tmrt (°C) is the mean radiant temperature, which was calculated with Equation (3);
- $WS_{(x=10)}$ is the wind speed at a height of 10 m above the ground, and was calculated using Equation (4);
- ε is the emissivity of the globe which is normally assumed as 0.95 [45];
- D is the diameter of the globe (m), and the diameter of the globe (0.075 m) used in this study.

The calculation process was performed by the UTCI website (www.utci.org (accessed on 12 August 2021)). Due to people's thermal comfort differing between different climate zones in China, the different assessed spaces can be classified according to thermal comfort levels modified for Chinese [46], as shown in Table 1. Compared with the UTCI thermal stress scale proposed by Bröde et al. [44], the lowest threshold of the cold stress rises from −40 °C to −21 °C, and the range of no thermal stress level is reduced from 9–26 °C to 12–25 °C.

Table 1. UTCI assessment scale (Adapted from Ref. [46]).

UTCI Range (°C)	Stress Category	Color	UTCI Range (°C)	Stress Category	Color
≥47	Extreme heat stress		≥−6, <12	Slight cold stress	
≥39, <47	Very strong heat stress		≥−11, <−6	Moderate cold stress	
≥33, <39	Strong heat stress		≥−16, <−11	Strong cold stress	
≥25, <33	Moderate heat stress		≥−21, <−16	Very strong cold stress	
≥12, <25	No thermal stress		<−21	Extreme cold stress	

Pearson's correlation analysis in SPSS 11.0 (SPSS Inc, Chicago, IL, USA) was used to assess the effect of the indoor and outdoor microclimatic differences on the number of the elderly who used outdoor spaces using. The results are expressed as 95% confidence intervals. Origin 8.0 was used to draw charts and for function fitting.

Based on the key microclimatic parameters affecting the choice of using outdoor spaces for the elderly, the day and the spaces with the largest differences between parameters concerning indoor and outdoor spaces were selected to carry out the simulation. This outdoor data were fed as boundary conditions to ENVI-met (version 4.1), a state-of-the-art CFD based urban microclimate modelling software. The 3D model of the outdoor space was set up in ENVI-met with a grid resolution of 7 m × 7 m (Figure 3). Even though the indoor spaces only focused on bedroom space, it was also created in the simulation as a multi-zone 3D model in Fluent Airpak software 3.0 (Fluent Inc., NYC, USA)based on the original building drawings provided by the local municipality (Table 2). Indoor Ta, RH, and WS were simulated at 0.6 m (lying position) and 1.2 m (sitting position) of the mannequin, respectively. Simulations were executed at 1 h interval from 9:00 a.m. to 18:00 p.m. Subsequently, the adjustment strategies for indoor and outdoor microclimatic differences were proposed based on the simulation at the moment of the day with the largest key parameter difference.

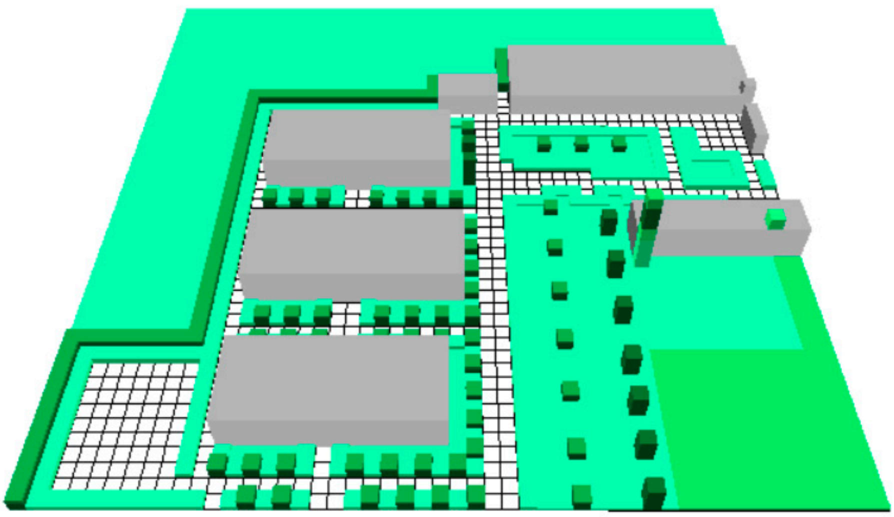


Figure 3. ENVI-met model of the study area.

Table 2. Bedroom parameters and boundary conditions.

Type	Size (m)	Number	Parameter Settings
Exterior wall	——		Constant temperature, heat transfer coefficient is 1.0 W/(K·m^2) (JGJ 134-2010)
Interior wall, ceiling, and floor	1.0 × 1.5	3	Heat insulation
Window	1.0 × 1.5	3	Heat transfer coefficient is 2.5 W/(K·m^2) (JGJ 134-2010)
Door	1.2 × 2.4	1	Heat insulation
Human	——	4	Sitting height 1.2 m, lying height 0.6 m
Size of the fresh air inlet and air-returning outlet	——	——	250 mm × 250 mm, 480 mm × 130 mm
Fresh air volume	——	——	0.033 m^3/s
Bed	2.0 × 1.2	4	——

3. Results

3.1. Seasonal Usage of Different Outdoor Spaces by the Elderly

Approximately 28.93% (139) of the elderly living in this nursing home used outdoor spaces every day throughout the whole year, including those who walked on their own or asked nursing staff to push themselves into the outdoor spaces using wheelchairs. The highest usage ratio of the elderly was observed in autumn (29.88%, 144), followed by 29.25% (141) in spring, 29.05% (140) in winter, and 27.39% (132) in summer (Figure 4). Among them, the number (105, 21.84%) of the elderly in corridors was much higher than those in road (25, 5.83%) and garden spaces (9, 1.78%). In addition, 9:00 a.m. to 10:00 a.m. was the elderly's favorited period for using outdoor spaces over four seasons. More than one half (51.79–67.62%) of the elderly preferred to sit and chat, followed by slow walking (28.78–43.16%). Only a few (4.31–5.04%) elderly performed exercises using sport instruments. Figure 5 summarizes the seasonal distribution of the thermal resistance for clothing worn by the elderly in nursing home. Furthermore, 50% of the values are concentrated in the range of 0.81—0.96 Clo in spring, 0.39–0.61 Clo in summer, 1.10–1.14 Clo in autumn, and 1.68–1.93 Clo in winter. The mean insulation values of the clothing worn by the elderly were significantly different in seasons ($p < 0.05$).

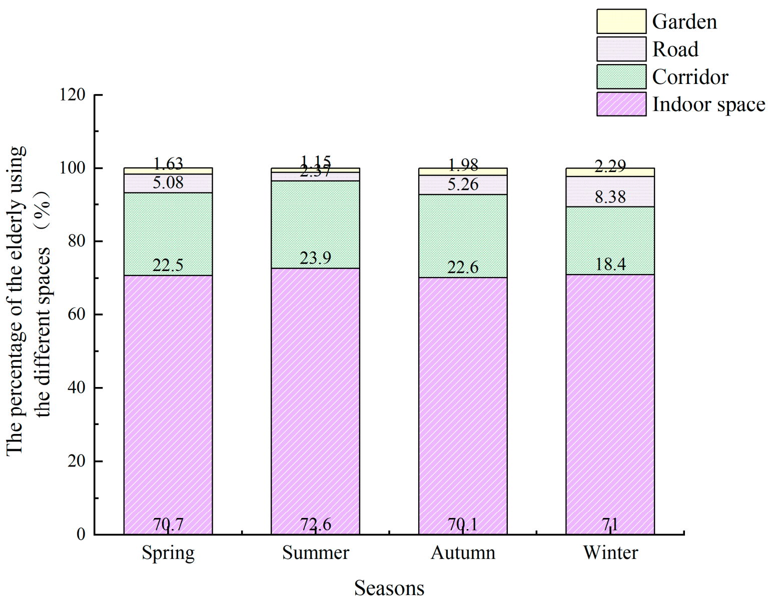


Figure 4. The seasonal usage patterns of indoor and outdoor spaces by the elderly.

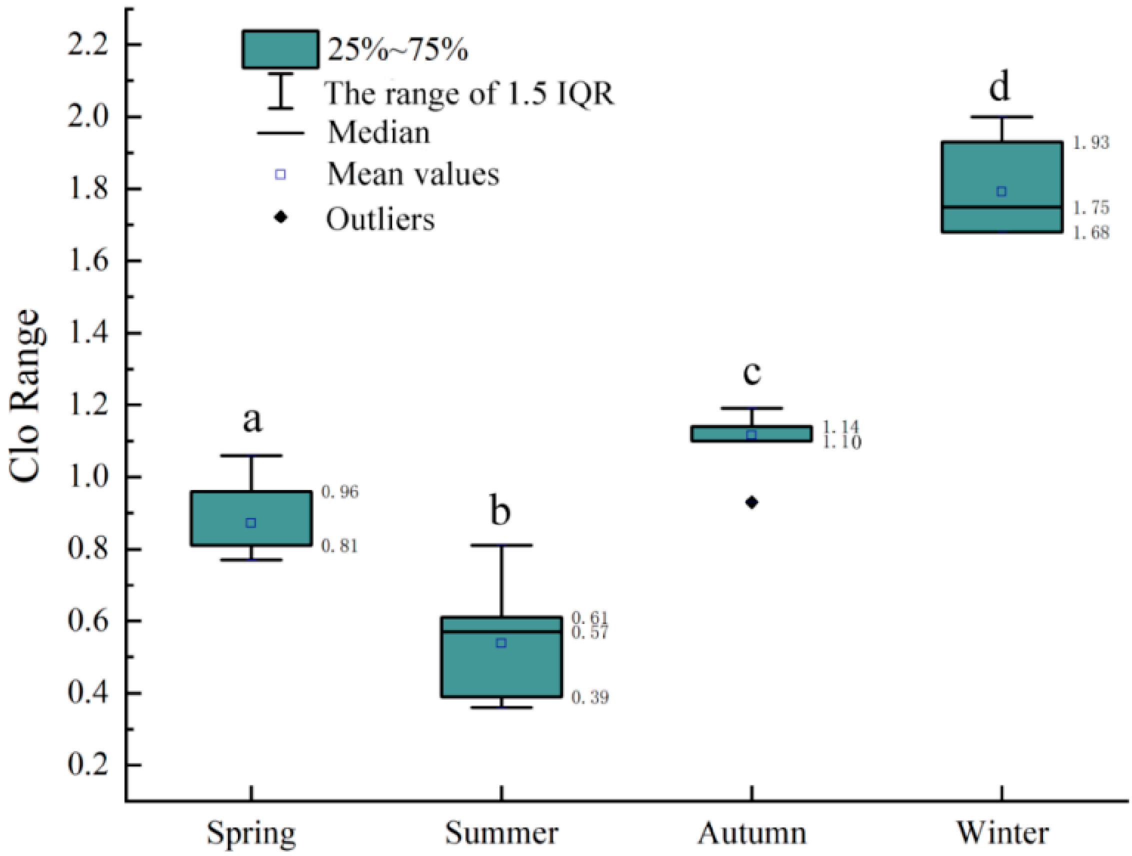


Figure 5. The seasonal Clo range of the elderly in nursing home. Note: Values followed by different letters (a, b, c, d) indicate there is statistically significant difference among the treatment groups at $p \leq 0.05$ (5%) according to the multivariate general linear model followed by a Duncan's post hoc test in SPSS. The common letters indicate there is no significant difference among groups.

3.2. The Seasonal Differences of the Microclimatic Condition between Indoor and Other Spaces

3.2.1. Seasonal Ta and Ta Difference (ΔT_a)

Table 3 shows that mean T_a fluctuated within 23.3–26.52 °C in spring, 28.58–32.29 °C in summer, 19.75–20.24 °C in autumn, and 11.81–12.59 °C in winter. The lowest and highest mean T_a was observed in corridors at winter and in road spaces during summer, respectively. In spring and summer, a decreasing trend of $T_{a\,(road)} > T_{a\,(garden)} > T_{a\,(corridor)} > T_{a\,(indoor\ space)}$ was shown. Indoor T_a was directly affected by the changes in outdoor T_a. The $|\Delta T_a|$ between indoor and outdoor spaces was highest in summer (2.93 °C), followed by spring (2.47 °C), and the smallest mean $|\Delta T_a|$ value occurred in autumn (0.25 °C). Figure 6a shows that all values of mean ΔT_2 and ΔT_3 are positive in all four seasons, which confirms the heating effect of outdoor spaces. The largest values of $|\Delta T_1|$ (1.38 °C), $|\Delta T_2|$ (3.71 °C), and $|\Delta T_3|$ (3.69 °C) were consistently observed in summer, the lowest values of $|\Delta T_1|$ (0.02 °C) were observed in winter, and the lowest $|\Delta T_2|$ (0.42 °C) and $|\Delta T_3|$ (0.39 °C) occurred in autumn (Figure 6a). In spring, summer, and autumn, a consistent trend of $|\Delta T_2| > |\Delta T_3| > |\Delta T_1|$ was found. However, a trend of $|\Delta T_3| > |\Delta T_2| > |\Delta T_1|$ was observed in winter. $|\Delta T_1|$ values in all seasons were significantly smaller than $|\Delta T_2|$ and $|\Delta T_3|$ values. Figure 7 shows that all minimum values of $|\Delta T_1|$, $|\Delta T_2|$, and $|\Delta T_3|$ during the daily survey time were observed from 9:00 a.m. to 10:00 a.m. in both spring and summer. However, in autumn and winter, these minimum values occurred from 16:00 p.m. to 18:00 p.m.

Table 3. Seasonal mean values of the microclimate parameters in four spaces.

Parameters	Spaces	Spr.	Sum.	Aut.	Win.
	Indoor space	23.30 ± 0.3	28.58 ± 1.1	19.82 ± 0.6	11.92 ± 1.1
	Corridor	24.30 ± 0.8	29.96 ± 1.6	19.75 ± 0.7	11.81 ± 1.6
T_a (°C)	Road	26.52 ± 0.8	32.29 ± 1.9	20.24 ± 0.9	12.51 ± 2.1
	Garden	26.51 ± 1.3	32.27 ± 2.3	20.21 ± 1.0	12.59 ± 2.1
	Mean	25.16 b	30.78 a	20.01 c	12.18 d
	Indoor space	2.72 ± 0.4	16.62 ± 2.0	2.08 ± 0.6	0.95 ± 0.7
	Corridor	51.83 ± 14.4	49.60 ± 13.9	36.53 ± 25.2	20.30 ± 13.3
SR (W/m^2)	Road	358.66 ± 89.9	364.86 ± 151.8	164.95 ± 80.7	147.11 ± 81.8
	Garden	217.94 ± 66.4	185.54 ± 65.6	108.23 ± 41.8	93.67 ± 56.0
	Mean	157.80 a	154.15 a	77.95 b	65.51 b
	Indoor space	69.05 ± 1.8	74.41 ± 4.8	71.15 ± 2.6	58.77 ± 10.6
	Corridor	60.30 ± 4.4	65.19 ± 6.9	68.38 ± 3.6	54.52 ± 11.6
RH (%)	Road	57.32 ± 3.6	59.40 ± 5.2	64.82 ± 4.6	52.88 ± 11.3
	Garden	51.34 ± 5.1	53.75 ± 9.6	64.38 ± 4.8	51.10 ± 11.3
	Mean	59.50 ab	63.19 ab	67.18 a	54.31 b
	Indoor space	0.00 ± 0.0	0.00 ± 0.0	0.00 ± 0.0	0.00 ± 0.0
	Corridor	0.10 ± 0.1	0.07± 0.0	0.02 ± 0.0	0.15± 0.1
WS (m/s)	Road	0.11 ± 0.1	0.12 ± 0.0	0.02 ± 0.0	0.14 ± 0.1
	Garden	0.06 ± 0.0	0.06 ± 0.0	0.00 ± 0.0	0.09± 0.1
	Mean	0.07 ab	0.06 ab	0.01 b	0.10 a

Note: Results are the seasonal mean value ± standard deviations. Values followed by different letters (a, b, c, d) indicate there is statistically significant difference among the treatment groups at $p \leq 0.05$ (5%) according to the multivariate general linear model followed by a Duncan's post hoc test in SPSS. The common letters indicate there is no significant difference among groups.

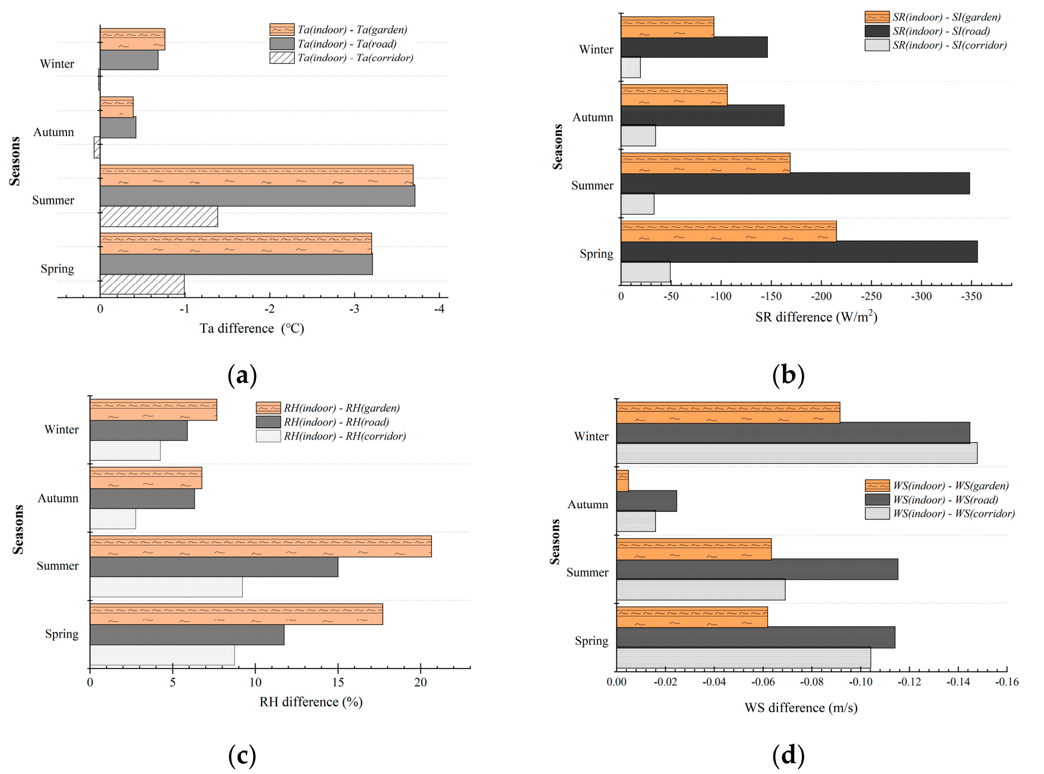


Figure 6. The seasonal microclimatic differences of indoor and outdoor spaces. (**a**) T_a; (**b**) SR; (**c**) RH; (**d**) WS.

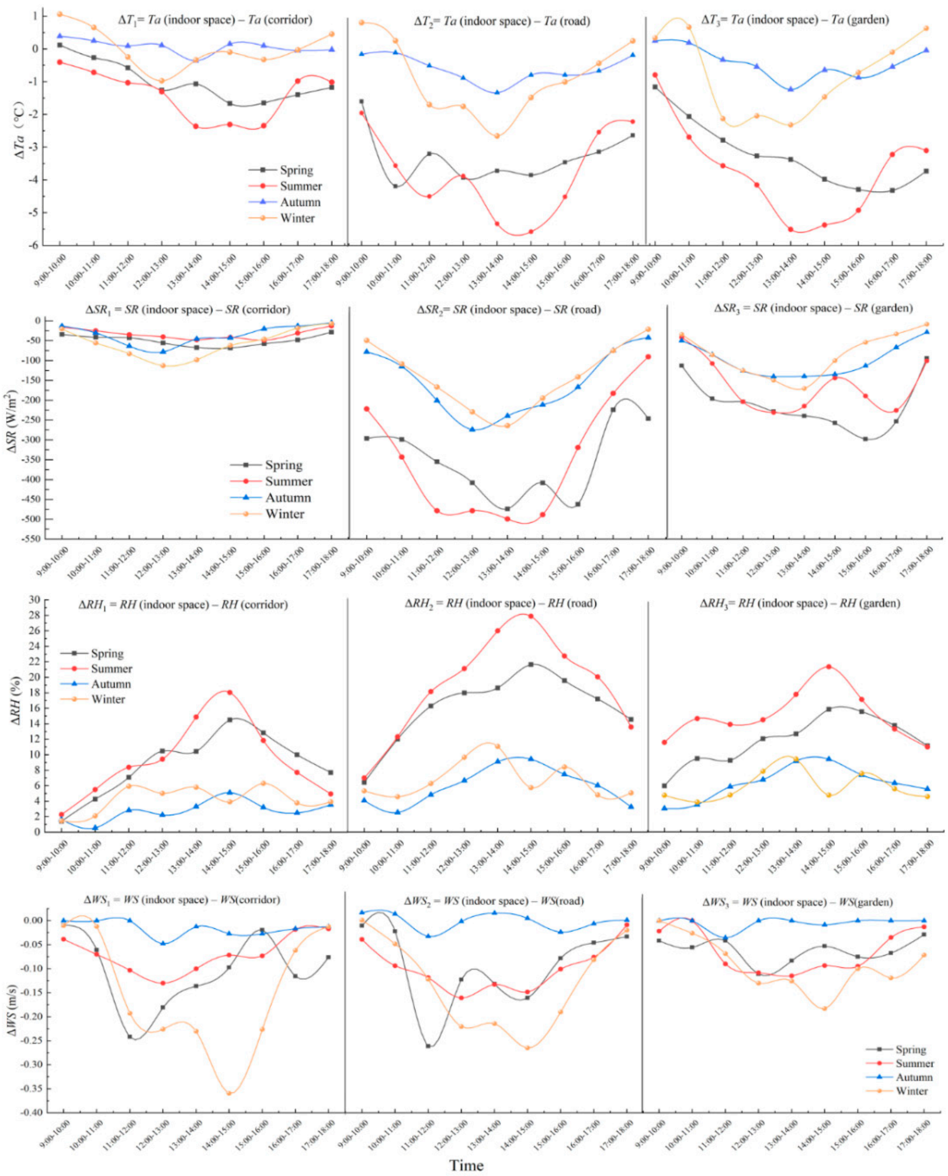


Figure 7. The daily fluctuation of the atmospheric differences between indoor and outdoor spaces.

3.2.2. Seasonal SR and SR Difference (ΔSR)

The seasonal mean SR across all four spaces fluctuated between 0.95 W/m^2 (winter) and 16.62 W/m^2 (summer) in indoor spaces, between 20.3 W/m^2 and 51.86 W/m^2 in corridors, between 147.10 W/m^2 (winter) and 367.86 W/m^2 (summer) in roads, and between 93.70 W/m^2 (winter) and 217.94 W/m^2 (spring) in gardens (Table 3). A very clear trend of $SR_{road} > SR_{garden} > SR_{corridor} > SR_{indoor}$ was found in all seasons. Figure 6b shows that all values of mean ΔSR are positive in four seasons. SR interception was not evenly distributed in outdoor spaces, and further showed the trend of $|\Delta SR_2|$ (253.30 W/m^2) > $|\Delta SR_3|$ (145.75 W/m^2) > $|\Delta SR_1|$ (33.99 W/m^2). The largest mean ΔSR ($|\Delta SR_2|$ = 355.94 W/m^2) occurred in spring, but the smallest mean ΔSR ($|\Delta SR_1|$ = 19.4 W/m^2) occurred in winter. Almost all minimum values of $|\Delta SR_1|$, $|\Delta SR_2|$, and $|\Delta SR_3|$ were observed from 17:00 p.m. to 18:00 p.m. in seasons, except for the minimum $|\Delta SR_3|$ in summer, which occurred from 09:00 a.m. to 10:00 a.m. (Figure 7). All maximum values of $|\Delta SR|$ uniformly occurred from 12:00 p.m. to 14:00 p.m., except in spring and summer, the maximum values of $|\Delta SR_1|$ were observed from 14:00 p.m. to 16:00 p.m.

3.2.3. Seasonal RH and RH Difference (ΔRH)

The mean RH values ranged from 55.14% (gardens) to 68.35% (indoor spaces) (Table 3). Moreover, the values followed the same rank (i.e., $RH_{indoor} > RH_{corridor} > RH_{road} > RH_{garden}$) in seasons. It is indicated that outdoor spaces generated less humidity than indoor spaces. In spring, summer, and autumn, RH values of both indoor and corridor spaces exceeded 60%, while all RH values of them remained below 60% in winter. The highest mean ΔRH (13.20%) was observed between indoor spaces and gardens (ΔRH_3), and the lowest value (6.25%) was observed between indoor spaces and corridors (ΔRH_1) (Figure 6c). Gardens showed optimal humidity decreasing effects. In addition, the seasonal mean ΔRH followed the ranking of ΔRH_{summer} (14.96%) > ΔRH_{spring} (12.73%) > ΔRH_{winter} (5.94%) > ΔRH_{autumn} (5.29%). During the daily survey time, ΔRH values followed a trend of increasing first and then decreasing from morning to afternoon (Figure 7). Almost all minimum values of ΔRH occurred from 09:00 a.m. to 11:00 a.m., except for ΔRH_2 in summer (which occurred from 17:00 p.m. to 18:00 p.m.). All maximum values of ΔRH_1, ΔRH_2, and ΔRH_3 were uniformly observed from 13:00 p.m. to 15:00 p.m.

3.2.4. Seasonal WS and WS Difference (ΔWS)

Because this nursing home has no mechanical ventilation facility, WS values always showed 0 m/s in the indoor spaces. Due to the generally calm conditions prevalent for Chengdu City, the seasonal mean WS of the outdoor spaces was very low (<0.2 m/s) and had a calm status in seasons (Table 3). However, WS was not uniformly distributed in these outdoor spaces. The highest mean values of |ΔWS| occurred in road spaces (0.1 m/s), followed by corridor spaces (0.08 m/s) and garden spaces (0.06 m/s) (Figure 6d). In winter, |ΔWS| was significantly higher than in other seasons. During the daily survey time, all minimum values of $|\Delta WS_1|$, $|\Delta WS_2|$, and $|\Delta WS_3|$ occurred from 09:00 a.m. to 10:00 a.m. in autumn and winter (Figure 7). The maximum |ΔWS| values between indoor and outdoor spaces were uniformly observed from 11:00 a.m. to 15:00 p.m.

3.3. The Thermal Comfort Differences between Indoor and Outdoor Spaces

Figure 8a indicates that the stress categories of indoor and corridor spaces were at the same level with no thermal stress in spring, autumn, and winter. The mean UTCI values of indoor and corridor spaces in summer corresponded to the level of moderate heat stress, while the mean UTCI values of road and garden corresponded to the level of strong heat stress (≥33 °C). Note that road and garden spaces even showed moderate heat stress (≥25 °C, <33 °C) in spring, which meant that the health of the elderly could be at thermal risk in summer and spring. That could be due to road spaces being generally uncovered, providing spaces without shade and high T_a.

In the daily survey time, a slight cold stress level (<12 °C) of all spaces has been observed between 09:00 a.m. and 10:00 a.m. at winter. The slight cold stress level lasted longer (09:00 a.m. to 11:00 a.m.) in corridors than other places. During this period, the elderly should avoid using outdoor spaces. In summer, all the UTCI values were not at the level of no thermal stress. Both roads and gardens reached the strong heat stress level after 11:00 a.m. During this period, the elderly's outdoor activities are not recommended. These spaces correspond to configurations where the sun easily penetrates in spring and summer. Therefore, these spaces need partial shading.

The highest mean ΔUTCI values (−2.25 °C) were observed between indoor spaces and road ($\Delta UTCI_2$), and the lowest mean value (−0.25 °C) was observed between indoor spaces and corridors ($\Delta UTCI_1$) (Figure 8b). During the daily survey time, ΔUTCI values followed a trend of increasing first and then decreasing from morning to afternoon. The maximum $\Delta UTCI_2$ (−3.12 °C) and $\Delta UTCI_3$ (−2.92 °C) uniformly occurred from 12:00 p.m. to 13:00 p.m. In contrast, the maximum $\Delta UTCI_1$ occurred with a time lag of two hours. The minimum $\Delta UTCI_2$ (−0.7 °C) and $\Delta UTCI_3$ (−0.4 °C) were uniformly observed from 9:00 a.m. to 10:00 a.m., while the minimum $\Delta UTCI_1$ occurred from 17:00 p.m. to 18:00 p.m.

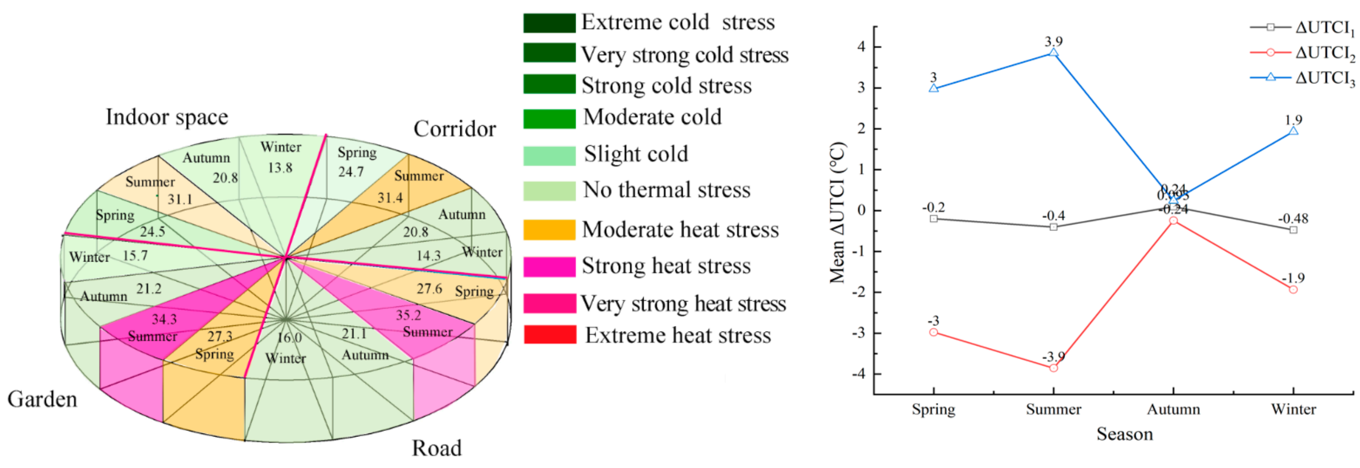


Figure 8. (**a**) The seasonal mean UTCI values of the four spaces; (**b**) The seasonal ΔUTCI values of the four spaces.

3.4. Correlation Analysis

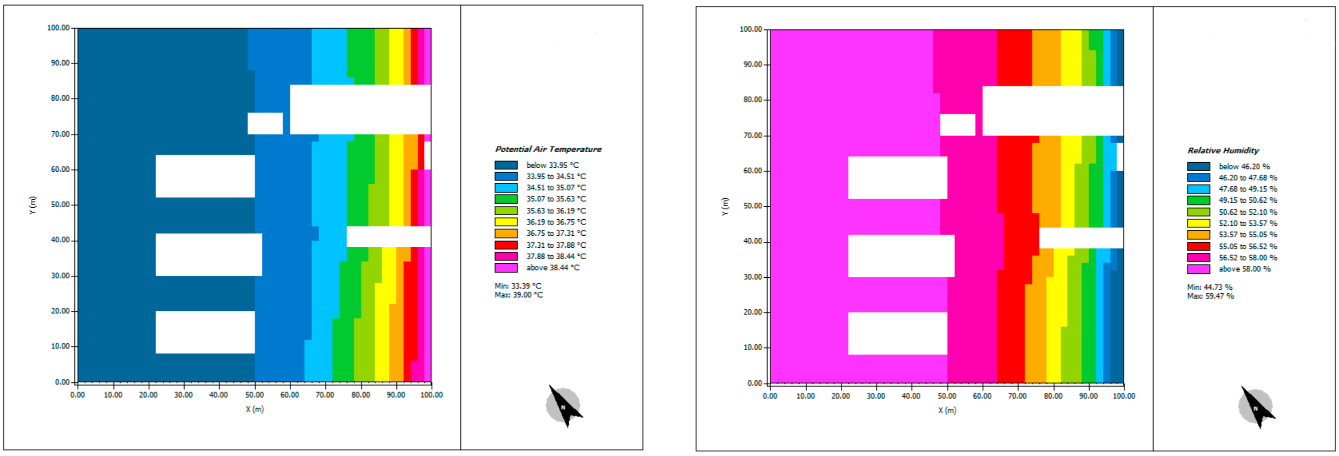
Pearson correlation (Table 4) analysis showed that the user numbers of both roads and gardens were significantly positively and negatively correlated with ΔT_a and ΔRH. This reflects that the larger the T_a difference and the smaller RH difference between indoor and outdoor spaces, the less willing the elderly are to use the outdoor space. The warmer the outdoor space is than indoors, the greater ΔRH between indoor and outdoor is; the fewer elders will use these spaces. This can explain that the corridor had an uncomfortable microclimate (e.g., the lowest mean T_a in winter, the least sunlight, and higher RH than other outdoor spaces), but it was still the favorite outdoor spaces for the elderly, because of the smallest microclimatic difference compared with indoor spaces. The elderly's favorite period (from 9:00 a.m. to 10:00 a.m.) for using outdoor spaces also happened to be the period with the smallest difference between indoor and outdoor microclimates. If ΔT_a and ΔRH values between indoors and outdoors were small enough, such as in corridors, where the T_a and RH were very close to those of indoors, the elderlies' choice of using outdoor spaces was susceptible to ΔSI, ΔWS, and ΔUTCI. The greater ΔSI_1, ΔWS_1, and $\Delta UTCI_1$ values encourage more elderly to use corridors. $\Delta UTCI_1$ was only extremely significantly correlated with ΔWS_1 (R = 0.523, $p \leq 0.01$).

Table 4. Correlation between the user numbers and the microclimate differences of outdoor spaces the in nursing home.

Parameters	**Correlation Coefficient of the Number of Corridor Users**	**Parameters**	**Correlation Coefficient of the Number of Road Users**	**Parameters**	**Correlation Coefficient of Number of Garden Users**
ΔT_1	0.014	ΔT_2 (X_1)	**0.353** *	ΔT_3 (X_1)	**0.373** *
ΔSI_1 (X_1)	**0.388** *	ΔSI_2	0.318	ΔSI_3	0.248
ΔRH_1	−0.149	ΔRH_2 (X_1)	**−0.491** **	ΔRH_3 (X_2)	**−0.433** **
ΔWS_1 (X_2)	**0.386** *	ΔWS_2	−0.242	ΔWS_3	0.021
$\Delta UTCI_1$ (X_3)	**0.330** *	$\Delta UTCI_2$	0.133	$\Delta UTCI_3$	0.196
Fit equation		**Fit equation**		**Fit equation**	
$Y_1 = 41.782 + 0.064\,X_1 + 10.67\,X_2 + 1.189\,X_3$		$Y_2 = 16.175 - 0.992\,X_1 - 0.926\,X_2$		$Y_3 = 4.797 - 0.379\,X_1 - 0.189\,X_2$	
Degree of fitting (R^2) = 0.213		R^2 = 0.266		R^2 = 0.202	

Note: Values followed by * are significantly different at $p \leq 0.05$ and by ** are extremely significantly different at $p \leq 0.01$ according to Duncan's post test.

Based on the key microclimatic parameters (T_a and RH), which affected the choice of using outdoor spaces for the elderly, 27 July 2020, when thermal comfort was at the highest level of strong heat stress, was selected to carry out the simulation. The road spaces and bedroom with the highest ΔT_a and ΔRH were simulated for T_a and RH (Figure 9a,b). R^2 is the reconciliation coefficient, indicating the degree of correlation between simulated and measured data. R^2 values of the two parameters (T_a and RH) in road space were 0.63 (T_a) and 0.71 (RH), respectively, which indicated that the simulated data were strongly in agreement with the data recorded during the measurement day (Figure 10). The models were capable of accurately reproducing the microclimatic situation of the study areas, allowing for the evaluation of possibilities for reducing the microclimatic difference of outdoor spaces by manipulating vegetal composition.



(**a**) (**b**)

Figure 9. (**a**) ENVI-met simulated T_a distribution on 27 July 2020 at 15:00 p.m.; (**b**) ENVI-met simulated RH distribution on 27 July 2020 at 15:00 p.m.

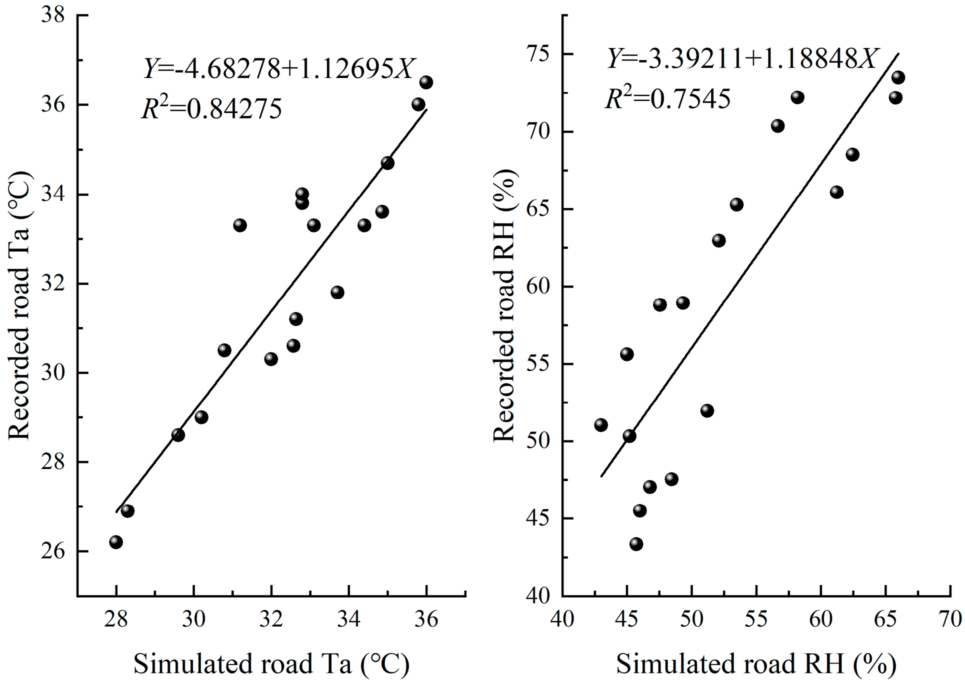


Figure 10. The correlation degree between simulated and measured data of road space.

4. Discussions

4.1. The Impact of Microclimatic Transients on the Willingness to Use the Outdoor Environment of the Elderly

Although the thermal comfort zone of the outdoor spaces obtained from previous cases located in different climate zones varied widely, such as the climate zones across Europe reporting a difference of 10 °C in thermal neutral temperature, many researchers recognized that outdoor thermal comfort is the main factor that determines the quality and use of outdoor spaces [22,23]. However, the present study showed that T_a and RH differences between indoor and outdoor spaces were the primary meteorological factors that influenced the elderly's usage of outdoor spaces. Only when the ΔT_a and ΔRH are small enough to resemble a steady-state (ΔUTCI $\leq$ 0.5 °C) could the difference in WS and SI between indoor and outdoor spaces affect the elderly's choice of using outdoor space. Therefore, as a vulnerable group, the elderly living in nursing homes need a stable and small microclimatic difference between indoor and outdoor spaces.

4.1.1. Influence of T_a and ΔT_a on the Use of Outdoor Space by the Elderly

Lin et al. [47] recommended 26 °C as the optimum T_a to achieve the lowest mortality for Chinese elderly, and people feel most comfortable when the thermal sensation is near optimum T_a. The present study showed that only in spring were the mean T_a values of all the indoor and outdoor spaces in this nursing home closest to the optimum T_a. However, in summer, the mean T_a of outdoor spaces was higher than the low-heat mortality T_a limit of 29 °C. The elderly are more sensitive to high temperatures [23]. Together with the UTCI values, it is necessary to decrease T_a of all outdoor spaces in summer, especially the garden and roads. In winter, the mean T_a of each space here was less than 13 °C, especially in corridor (11.81 °C). Collins and Exton-Smith [48] have pointed out that T_a below 15 °C negatively affects health by increasing the burden on the elderly circulatory system. They indicated that all spaces here in winter are uncomfortable spaces, and it is necessary to increase the T_a of all spaces in winter.

A previous study suggested that it is better to control the transition temperature difference (ΔT_a) within 5 °C [28]. However, sudden hot/cold exposure could cause enormous health risks for the elderly. Moreover, for a 1 °C increase of T_a in summer, the mortality levels due to cardiovascular, respiratory, and cerebrovascular failures in the elderly increased by 3.44%, 3.60%, and 1.40%, respectively [30]. In addition, every 1 °C reduction in T_a in winter also caused a 1–2% increase in mortality [30]. The reason for this may be the weak thermoregulatory responses of the elderly to sudden cold and hot environments [49]. In this research, the annual mean $|\Delta T_2|$ and $|\Delta T_3|$ values exceeded 2.00 °C. In spring and summer, $|\Delta T_2|$ and $|\Delta T_3|$ levels exceeded 3.20 °C. Undoubtedly, the high ΔT_a increases the heat-related risk of using road and garden for the elderly. Moreover, although the ΔT_1 was the smallest in winter, during 9:00 a.m. to 10:00 a.m., $T_{a\ (corridor)}$ was also more than 1° lower than $T_{a\ (indoors)}$. The elderly should postpone the time of using corridors in winter. Overall, it is necessary to decrease the T_a of road and garden to reduce $|\Delta T_2|$ and $|\Delta T_3|$ in summer and to increase the T_a of all spaces to reduce $|\Delta T_a|$ in winter.

4.1.2. Influence of SR and ΔSR on the Use of Outdoor Space by the Elderly

Moderate sunlight exposure benefits human health, e.g., by promoting the synthesis of vitamin D [50]. A lack of vitamin D can easily cause increased mortality and a functional impairment in the lower extremities, which increases the risk of falls and fractures in the elderly [51]. Previous research has indicated that vitamin D deficiency in the elderly is a common health problem across the world, and ranges from 78% to 98% in the elderly living in nursing homes [52]. The present study found that the seasonal mean SR was less than 80 W/m^2 in autumn and winter. Moreover, the seasonal indoor SR values were stable and low (0.95–16.62 W/m^2). Staying indoors for a long time is unfavorable for the health of the elderly, and it is therefore necessary to encourage them to use outdoor spaces.

In the present study, the highest mean ΔSR ($|\Delta SR_2|$ = 253.30 W/m^2) occurred between indoor space and roads, followed by $|\Delta SR_3|$ (145.75 W/m^2) between indoor spaces and gardens. The highest seasonal $|\Delta SR_2|$ exceeded 340.00 W/m^2 in spring and summer. When the elderly move from indoor spaces to outdoor spaces, the huge difference in solar exposure can cause them to experience the glare effect. The elderly are the most sensitive population for the glare effect [53]. Along with this increased susceptibility to glare, their recovery time from dazzling and disability glare also increases [54], which could produce squinting, annoyance, and an aversive mood, and also increases the risk of falls [55]. That could be the reason why the elderly prefer to stay in corridors with the relatively minimal ΔSR_1. In addition, elders should also avoid long lasting or high-intensity outdoor sunlight, as the exposure to sunlight increases the risk of skin cancer [56]. As Samefors et al. [57] pointed out, staying outdoors for 20–30 min per day is sufficient for the synthesis of vitamin D. Thus, the solar design of the outdoor environment for the elderly must reduce unobstructed sunlight exposure. Moreover, ΔSR between indoor and outdoor spaces must be decreased synchronously to balance the risks and benefits of sun exposure.

4.1.3. Influence of RH and ΔRH on the Use of Outdoor Spaces by the Elderly

In the present study, the mean RH values of indoor (68.35%) spaces and corridors (62.10%) exceeded the comfortable and healthy range (40–60%). Especially in summer and autumn, the $RH_{(indoors)}$ values far exceeded 70%, which has been associated with an increased exposure risk to fungi, mildew, and dust mites [58]. As indicated by Lin et al. [47,59], increasing RH ($\geq$60%) is more dangerous for the elderly when the temperatures are high in the summer. This may be due to the weak sunlight and poor ventilation, which cause volatilized water to remain indoors.

The seasonal mean ΔRH_2 and ΔRH_3 ranged from 9.74% to 13.20%, and the maximum value ΔRH_3 (20.66%) was measured in summer. This indicates that outdoor spaces provide a dehumidification effect. Correlation analysis confirmed that, the smaller the ΔRH of indoor and outdoor spaces is, the more attractive the outdoor space is to the elderly. As Tyrovolas et al. [60] showed, people's positive moods are correlated with a lower humidity range, and with a decreased humidity difference. In addition, a study in Tunisia suggested that for each 1% increase in RH above 57.8%, there was a 5% increase in disease [61]. Thus, to enhance the enthusiasm of the elderly for using outdoor spaces, nursing homes should provide a drier indoor space to decrease the ΔRH between indoor and outdoor spaces.

Despite its physiological importance, RH is rarely the explicit focus of health impact studies having an independent role [62]. We also found that ΔRH should be treated as a confounding variable related to ΔT_a or $\Delta UTCI$ to identify its contribution to transient thermal comfort. When $\Delta UTCI$ was less than 0.5 °C or ΔT_a was less than 1.4 °C, the instant RH drop does not have any obvious effect on the thermal comfort of the normally clothed elderly. Thus, the impact of the small RH drop (less than 25%) on the aged thermal comfort could be neglected in the steady-state environment with no heat stress or even the moderate heat stress level.

4.1.4. Influence of WS and ΔWS on the Use of Outdoor Spaces by the Elderly

Wind is one of the environmental determinants of the thermos-physiological state of the body and an important factor determining the safety of outdoor spaces for the elderly [63]. Weak WS may intensify thermal discomfort in urban spaces. However, research on optimizing the outdoor wind environment for human comfort remains relatively underdeveloped [64]. The present study found that all spaces of the Wanxia nursing home had calm wind conditions (<0.2 m/s) in all seasons. The ΔWS values between indoor and outdoor spaces were very small and showed no significant difference. This implied that ΔWS could be the least important factor influencing the use of outdoor spaces by the elderly in nursing home of Chengdu City. Moreover, because of the calm wind environment of the city, the safety of the outdoor wind environment for nursing homes in Chengdu City is not the important safety factor. This phenomenon differed from previous reports for Wellington, New Zealand [65], and Lisbon, Portugal [66], which pointed out that wind speed, is the most important factor determining the satisfaction of urban outdoor space users.

Nevertheless, calm wind easily causes the high T_a and RH environment of the nursing home to be less comfortable in summer, and even produces a stifling feeling. Moreover, it is not conducive to the diffusion of air pollutants. In Hong Kong, the thermal comfort of people in summer requires the WS to be at least 1.6 m/s [67]. Most people prefer a light breeze (1.4–3.1 m/s) in all seasons [66]. Although no report has been published about the effects of sudden wind variations on human health, when comfort level is considered, it is necessary to increase ΔWS of both indoor and outdoor spaces in nursing home.

4.2. How Can Indoor and Outdoor Microclimatic Differences of the Nursing Home Be Controlled?

In general, all the investigated spaces in nursing homes presented the risks of heat stress in summer. Moreover, both road and garden spaces were even at risk of heat stress in spring. The user numbers of both roads and gardens were significantly correlated with ΔT_a and ΔRH. Therefore, we took road and bedroom spaces as the simulated cases to study adjustment strategies. Two strategies are proposed for the reduction of ΔT_a and ΔRH at 15:00 in 27 July 2020, to encourage the use of outdoor spaces by the elderly, as follows.

Firstly, to reduce ΔT_a between indoor and outdoor spaces, the T_a and SR of outdoor spaces must be reduced. As shaded spaces will enable the avoidance of direct sunlight, reduce outdoor thermal discomfort, and even produce flowing wind, extensive shading should be added across all outdoor spaces of the nursing home to reduce outdoor T_a and SR. Shading methods include trees, pergolas, shading devices, galleries, and overhanging facades. A series of previous studies found that trees have a marginally better cooling effect than shading devices [68]. Thus, passive shade with a tree canopy was proposed to add to the road spaces of this nursing home. During the simulation, we set three tree canopy coverage gradients of 50%, 75% (Figure 11a), and 100%. Results showed that 75% canopy coverage had an optimal cooling (1.95 °C) and dehumidification (1.22%) effect on road spaces (Figure 11b,c). Moreover, this will reduce the ΔT_a of indoor and outdoor spaces by approximately 2 °C.

In addition, this strategy is also helpful for the elderly to avoid suffering from the glare effect. However, with these shading options, care must be taken to avoid over-shading in autumn and winter, because the Chengdu Plain receives the least direct solar radiation in China [69]. Therefore, deciduous trees that sprout early in spring, such as *Koelreuteria paniculata*, *Firmiana simplex*, *Erythrina corallodendron*, and *Toona sinensis*, are suggested to be popularly used in outdoor spaces.

Secondly, to reduce ΔRH, the indoor RH must be decreased. A reduction in indoor RH of less than 25% should be recommended for the nursing home. Mechanical ventilation systems should be popularly used to decrease the seasonal RH of indoor spaces to 50–60%, especially in summer, and ΔRH between indoor and outdoor spaces should be controlled within 5%. Indoor ventilation could accelerate the evaporation of indoor moisture, and have a passive indoor cooling effect.

Combined with the requirements of the "Design code for buildings of home for the age in Sichuan province" (DBJ51/ 052-2015), the ventilation rate (ACH), which means the air changes per hour of the residential houses for the elderly should be not less than 1.5 ACH [70]. Based on the minimum ACH (1.5) and RH requirements, the minimum fresh air volume was simulated. In order to minimize the impact on the elderly, the airflow organization of mechanical ventilation is designed as top air supply and top return air (Figure 12). Simulation results showed that the fresh air volumes of 120 m^3/h (30 m^3/h per capita), should be recommended for reducing indoor RH to 50%, and the ΔRH between indoor and outdoor spaces will be controlled within 5% (Figure 13a,b). At the same time, there is no obvious fluctuation of indoor T_a (Figure 13c,d), and the mean horizontal WS remains at 0.03 m/s (Figure 13e,f).

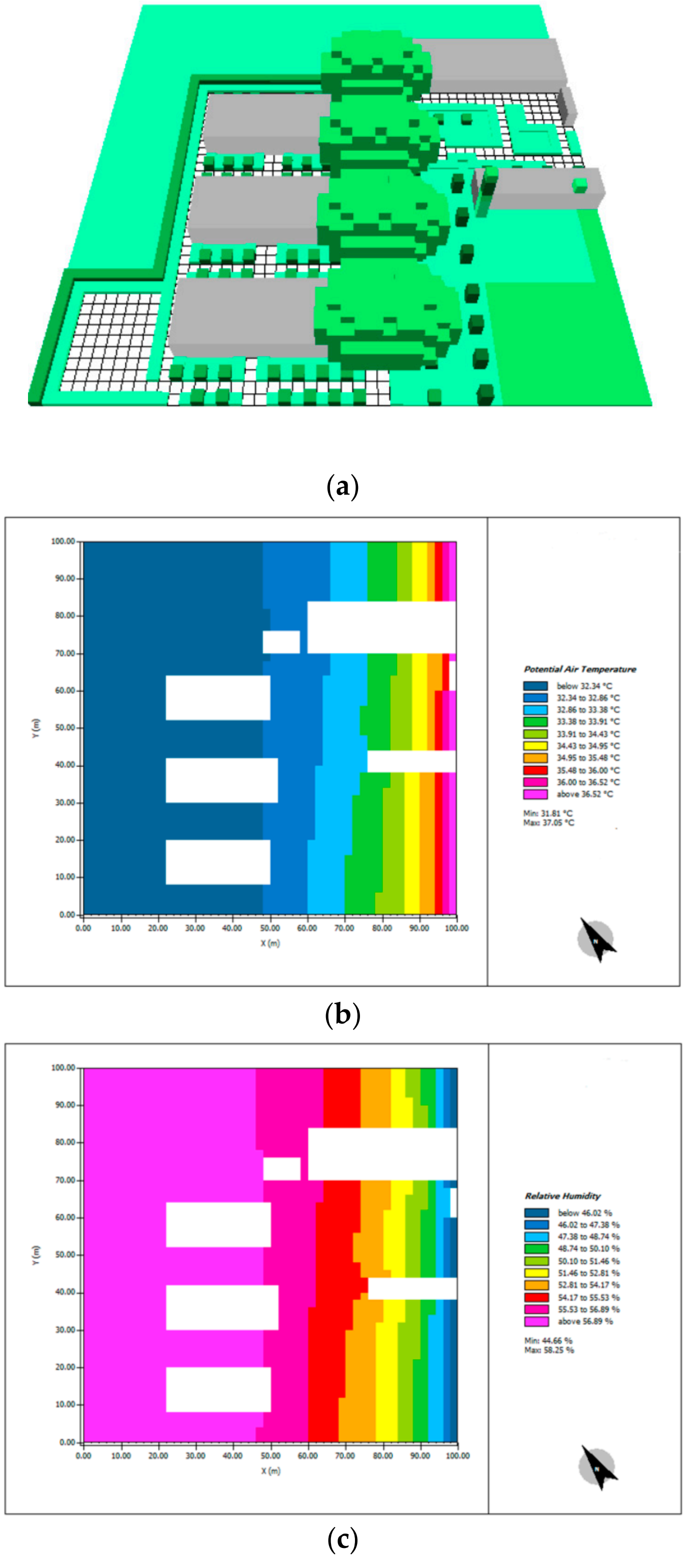


Figure 11. (**a**) ENVI-met model of the road area with 75% coverage; (**b**) ENVI-met simulated Ta distribution on 27 July 2020 at 15:00 p.m. under 75% road coverage; (**c**) ENVI-met simulated RH distribution on 27 July 2020 at 15:00 p.m. under 75% road coverage.

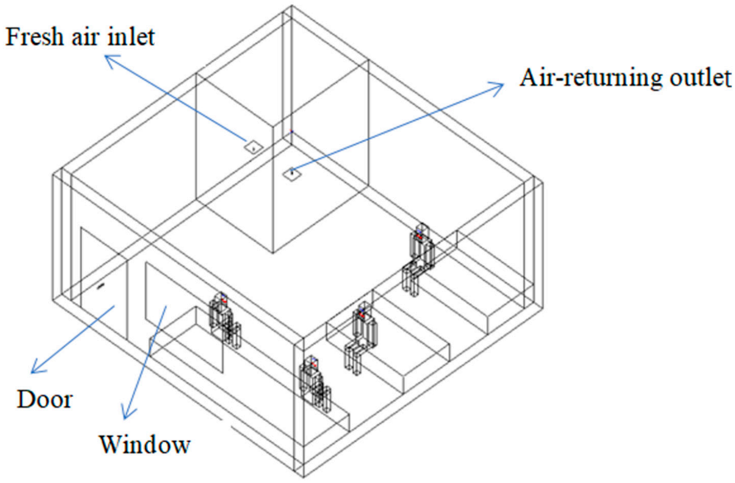


Figure 12. The arrangement of the mechanical ventilation.

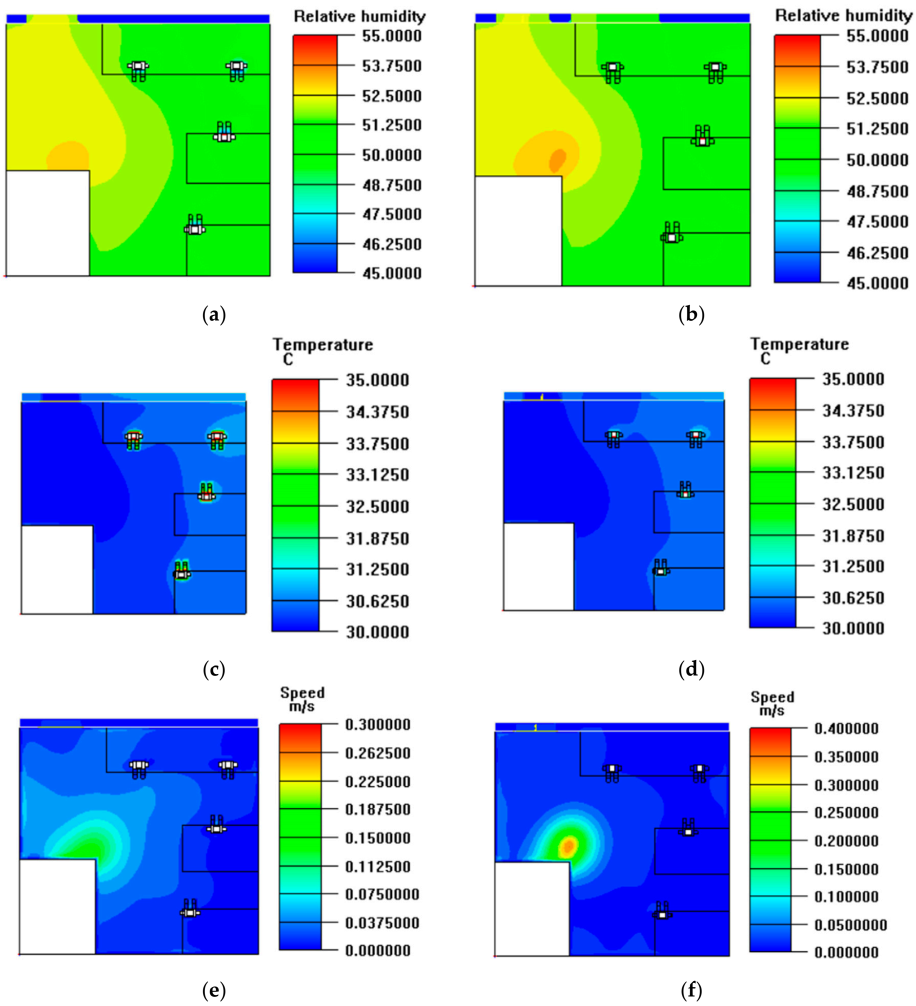


Figure 13. Indoor environment Simulation under mechanical ventilation. (**a**) indoor RH distribution cloud map of the 0.6 m height section; (**b**) indoor RH distribution cloud map of the 1.2 m height section; (**c**) indoor T_a distribution cloud map of the 0.6 m height section; (**d**) indoor T_a distribution cloud map of the 1.2 m height section; (**e**) indoor WS distribution cloud map of the 0.6 m height section; (**f**) indoor WS distribution cloud map of the 0.6 m height section.

4.3. The Limitations

In the present study, the analyses of transient thermal comfort and design strategies were based on our understanding of physical, physiological perspectives, and direct observations. In fact, several other factors could influence the elderly's thermal comfort and subsequently their usage patterns of outdoor space, such as land characteristics (e.g., surface coverage and safety), physiological parameters (e.g., age, gender, heart rate, and skin temperature), and psychological parameters (e.g., alliesthesia, thermal history, expectation, and mood) [71,72]. This study lacked an assessment of the impact of elderly psychology on their usage patterns of outdoor spaces. This was due to most of the participants here being too old to accurately describe their psychological feelings and needs. In addition, although the different age groups of old people could have a large gap in transient thermal comfort, because almost all the subjects of this study were over 80 years old, our research results mainly focused on the age of elderly.

5. Conclusions

In this study, the elderly lived in the biggest private nursing home of Chengdu, China, with the relationships of the thermal comfort under a transient state to their choice of using outdoor space examined using microclimatic measurements and observation recording the following. Large microclimatic differences between the indoor and outdoor spaces of this nursing home were found in seasons, which affected the elderly's willingness to use outdoor spaces. In general, people can adapt to microclimatic differences by removing or adding clothing. However, because the elderlies' responses to environmental change lag behind, they find it difficult to adjust in time and adapt to environmental changes. Thus, the above series of age-friendly design strategies was necessary to reduce the microclimatic differences for improving the health and well-being of the elderly. We concluded the following:

(1) The UTCI values of the different spaces in the nursing homes showed the significant differences in spring and summer. The stress categories of indoor and corridor spaces were at a level with no thermal stress in spring, autumn, and winter. In summer, the mean UTCI values of indoor and corridor spaces corresponded to the level of moderate heat stress, while those of road and garden corresponded to the level of strong heat stress ($\geq$33 °C). Road and garden spaces even showed moderate heat stress ($\geq$25 °C, <33 °C) in spring.

(2) The microclimatic differences between indoor and outdoor spaces ranged from 0.47 °C to 2.93 °C ($|\Delta T_a|$), from 86.09 W/m^2 to 206.76 W/m^2 ($|\Delta SR|$), from 5.29% to 14.76% (ΔRH), from 0.01 m/s to 0.07 m/s ($|\Delta WS|$), and from 0.25 °C to 2.25 °C (ΔUTCI). The minimal microclimatic differences occurred between corridors and indoors.

(3) T_a and RH differences between indoor and outdoor spaces were the primary meteorological factors influencing the elderly's usage of outdoor spaces. The elderly preferred a constant Ta and RH environment. Only when the ΔT_a and ΔRH are small enough to resemble a steady-state (ΔUTCI $\leq$ 0.5 °C) will the difference in WS and SI between indoor and outdoor spaces affect the elderly's choice of using outdoor space.

(4) Two optimal design strategies were put forward for creating comfortable transient environments from physical perspectives, including improving outdoor canopy coverage and indoor mechanical ventilation.

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