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Addressing 'difficulty in dining' among older adults: optimizing community senior dining halls from external and internal built environments

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Many developed and developing countries, including China, are facing the challenges of the aging population. One such challenge is the difficulty for some older adults to access nutritious hot meals to maintain their health and well-being. Community-based senior dining halls (CSDHs) providing low-cost meals for older adults are a widespread model across China and neighboring countries, which aim to cater to the dining needs of older adults within local communities. However, most CSDHs face financial difficulties due to low dining volume. Hence, understanding how built environment characteristics are associated with the dining volume can potentially increase the dining volume and financial sustainability of CSDHs in the long run. This study analyzed the association between the dining volume and both the external and internal built environment of 50 CSDHs in Guangzhou, China. By using multiple linear regression models with three different buffer sizes (400 m, 600 m, and 800 m), we found that 1) among the external built environment characteristics, floor area ratio (FAR) and distance to the nearest subway station are negatively linked to the dining volume; 2) among the internal built environment characteristics, floor level is negatively associated with dining volume, whereas availability of dine-in seating and water dispenser, and number of seats are positively associated with it. Hence, a well-designed external and internal built environment of CSDHs may increase dining volume, enhance social interaction among older adults, and support community-based senior care.

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Introduction

With the increased life expectancy and low birth rate, many global societies are rapidly aging. World Health Organization estimates the proportion of older people will rise from 12% in 2015 to 22% in 2050 globally (WHO 2022). In some countries, the situation is much severe. For example, in China, the proportion of older adults is projected to reach 33.9% by 2050, making China the country with the largest older population size. However, it is difficult for Chinese society to address the aging problem, due to the fewer children in the family, shortage of caregivers, limitation of nursing beds, and insufficient social security system (Jiang et al. 2016), which results in approximate 90% of older adults in China rely on community-based home care (Xiaomin 2024). This highlights the significance of community-based senior care (Zhou & Walker 2015). Many studies have placed community-based senior care a crucial role in addressing the aging problem, from the perspectives of improving well-being and social interaction (Aseyedali & Norouzi Tabrizi 2019; Hanley et al. 2010; Valtorta et al. 2018).

Community dining hall is an important part of community-based senior care because dining issue is an important issue in the daily life of older adults. Addressing older adults' dining issues holds great significance (Xiaomin 2024). Hence, the Chinese government is placing increasing importance on addressing the issue of "difficulty in dining" among older adults (Qin 2019). Community-based senior dining halls (CSDHs), which are defined as non-profit dining halls catering to older adults within the communities, play a crucial role in community-based home care because they offer nutritious, affordable, and accessible meals. There is compelling evidence that these CSDHs can improve the quality of life of older adults. For example, a study conducted in Japan has revealed that older adults also tend to have better social interaction and well-being when using government-subsidized senior cafeterias (JIJI 2024). In the Chinese context, using a cross-sectional experiment comparing seven villages with canteen services and seven villages without canteen services, a group of scholars confirmed that the canteen services provided by the government can improve older adults' life satisfaction and diet, and mental health status and also enrich their social connection (Wang et al. 2020). However, the operation of most CSDHs in China faces financial difficulties. For example, older adults have high expectations regarding the freshness and nutrition of food ingredients (Santos 2015), and fresh meals typically come at a higher cost. The non-profit nature of CSDHs results in lower meal prices, and they often rely on government subsidies (Qin 2019). Hence, how to attract more older adults to the CSDHs, thereby increasing the dining volume is a priority for addressing the financial sustainability of CSDHs and improving the older adults' well-being.

Previous studies have identified several factors influencing dining volume. For example, food quality and diversity are proven to have a direct impact on dining volume (Tanford & Suh 2013). Besides, Kim et al., suggested that family income has an impact on the choice of food service facilities (Kim & Geistfeld 2003). In addition to food quality and socioeconomic factors, the built environment is proven to be closely linked to dining volume. There are two types of built environment-related factors that may be linked to the propensity of an older adult to choose CSDHs or not. The first type of factors are the external built environment characteristics, which are related to the overall travel willingness of older adults, though direct evidence linking to the willingness to use CSDHs is scarce (Biernacka et al. 2020). A 3Ds framework, including Density, Diversity, and Design, has been identified as a major association between built environmental factors and the travel willingness of older adults (C. Yang et al. 2022). Density is considered to be the most crucial factor. The most commonly used density factor is building density (Maisel 2016). A study conducted by Chen and colleagues (Chen et al. 2013), shows a correlation between building density and the travel and activities of older adults. Nevertheless, in a study delving into the factors that affect individual visits to a park, the floor area ratio (FAR) around the park area was observed to have no discernible impact (Liu et al. 2017). Design, such as street density, public transit design, and greenery design, also affect the travel and visit willingness of older adults. It was also found that walking for leisure was associated with street density among older adults (Weber Corseiul Giehl et al. 2016). Moreover, older adults exhibit a high level of awareness regarding public transportation (Y. Yang et al. 2022). Evidence from Xiamen, China indicated that the number of bus stations had a positive association with active travel (Zhang et al. 2022). Furthermore, greenery design had a significant effect on travel and activity willingness among older adults (Zhang et al. 2022). Diversity of point of interest (POI) also shapes travel willingness. It has been confirmed that there was a positive association between POI diversity and active travel among older women in Japan (Inoue et al. 2011). Whereas, another study carried out by Van and colleagues, showed that perceptions of POI diversity were not found to act as moderators in the relationship between functioning and transport walking (Van Holle et al. 2016).

The second type of factors are the internal built environment characteristics. An attractive internal dining environment is a crucial factor in frequent visits among older adults (Tsai et al. 2018). Some research suggests that restaurants are an important venue for older adults to interact with others, hence providing social spaces in restaurants or canteens may attract more older adults (Cheang 2002) (Maluf et al. 2020). It was found that a community center near a canteen had a key influence on the renovation of the dining environment (Hung et al. 2016). Restaurants with dine-in seating are reported to have more frequent use than those do not have dine-in seating (Peng et al. 2020). Li conducted a field survey to investigate the functional rooms and fine design within CSDHs, including dining area, kitchen, barrier-free handrails, wash basin, water dispenser, wall clock, TV, and so on, which could provide older adults safety, convenience, and comfort during meals (LI 2018). It is worth noting that the studies mentioned above are all based on self-reported data from questionnaires to older adults.

Even though many studies have found that the external and internal built environment characteristics could impact the travel and usage willingness among older adults, there are two major research gaps. First, there are few empirical studies directly focusing on the link between built environment characteristics and usage of CSDHs. There is a possible link between built environment characteristics and usage of CSDHs among older adults, given the peripheral evidence showing that their usage of other destinations such as restaurants (Tsai et al. 2018), community centers (Walker et al. 2004), and parks (Liu et al. 2017) is strongly affected by built environment characteristics. However, direct evidence is still needed to demonstrate the impact of built environment factors on the dining volume in CSDHs. Second, in previous studies, the destination-visiting behavior of older adults was often assessed subjectively via self-report questionnaires (Zang et al. 2022), which are prone to recall biases and social desirability biases. Hence, using objective measures to assess destination-visiting behavior, e.g., dining volume records, may reduce such bias and increase the reliability of the studies. To fill the gaps, we explored the association between official records of dining volume data and built environment factors collected by the Geographic Information System (GIS) and on-site audit of 50 CSDHs in Guangzhou, China. Here, we propose two hypotheses

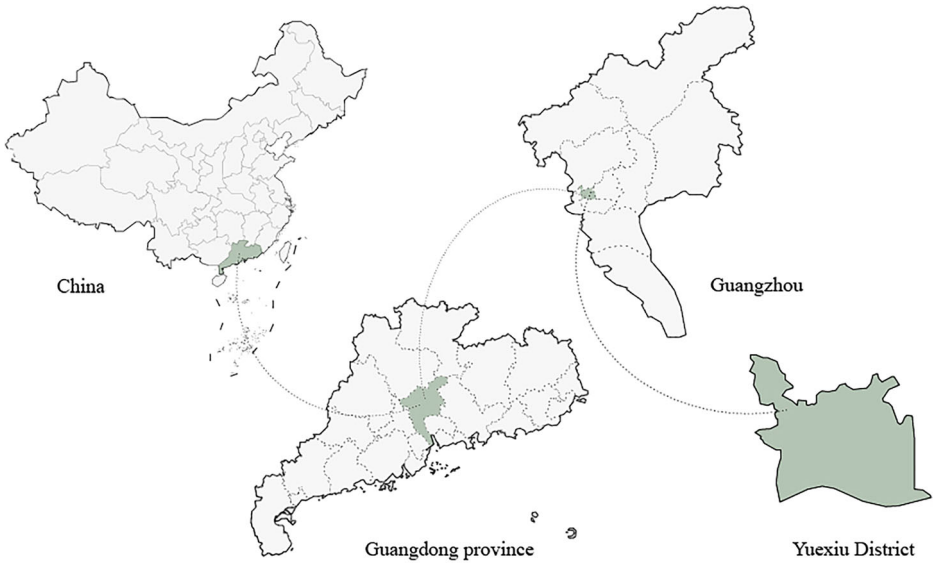

Fig. 1 The Maps of Yuexiu, Guangzhou, China.

regarding associations between built environments and dining volumes in CSDHs: first, a comfortable and convenient external built environment could increase the likelihood of traveling to CSDHs among older adults; second, an attractive, safe, and comfortable indoor environment, especially with social-interaction spaces, may encourage the willingness of older adults to use CSDHs. This is among the first attempt to investigate the association between external and internal built environment factors and the dining volume at CSDHs in a high-density Asian city, informing the government to improve the development of community senior care.

Method

Study area. The research area is located in Yuexiu District, Guangzhou City, the capital city of Guangdong Province in China. By the end of 2022, the registered population of Guangzhou City was 10.3491 million, of which 1.4231 million, or 13.75%, are aged 65 and above. Yuexiu District is in the central urban core of Guangzhou, with the smallest land area and the densest population in Guangzhou (Fig. 1). Furthermore, Yuexiu District also has the highest aging level (28.41%) among all districts in Guangzhou, with 333,600 people (Commission 2023).

Since 2016, Guangzhou has established many CSDHs to address the practical issues faced by older adults and provide them with affordable and healthy meals, promoting community-based senior care (Daily 2019). In 2023, there are a total of 50 CSDHs in operation in Yuexiu District, which gives us a sufficient sample size and variation in built environment characteristics.

Data on dining volume. We obtained the dining volume data of the CSDHs in Yuexiu District, Guangzhou City for the first half of 2023 from the Civil Affairs Bureau of Yuexiu District. This data was collected and compiled by the district government. The dataset includes the names and detailed addresses of the CSDHs, as well as the total dining volume for the first and second quarters of 2023. Considering the possible impact of the COVID-19 pandemic on the dining volume of the CSDHs during the first quarter of 2023, this study chose the dining volume data for the second quarter of 2023 for analysis (Fig. 2). Each CSDH in Yuexiu District has at least one meal delivery person assigned, and all CSDHs offer take-out services. The dining volume data also encompasses these two scenarios. Compared to previous studies that relied on questionnaire surveys among the older population (Zang et al. 2022), this dataset is more comprehensive and objective.

External built environment factors. The 3Ds framework has been confirmed to be applicable for evaluating the relationship between behavior and environmental factors (Chen et al. 2022), including density, diversity, and design (Wei et al. 2023). Each CSDH's address was geocoded using the Geographic Information System (GIS). Three Euclidean buffers (400 m, 600 m, and 800 m) were created taking center on the CSDHs, which are typically employed in considering older population's walking distance (Kolbe-Alexander et al. 2015). A distance of 400 meters typically takes a 5–7 min walk for older adults; a 600-meter distance takes 7–10 minutes; an 800-meter distance takes 10–14 min (Panizzolo et al. 2013). All external built environment factors data were computed in GIS (Table 1).

Density. Floor area ratio (FAR) is a key metric used extensively in architecture and urban planning, which is defined as the ratio of the building's total floor area to the total land area. Building coverage ratio (BCR) is calculated as the ratio of the built-up area to the total land area (Fig. 3). Previous research commonly employed BCR (Pan et al. 2008). However, BCR is a two-dimensional measure and is insufficient to describe the characteristics of building density in Chinese cities. In Chinese older urban areas, regions with high BCR are usually characterized by older residential areas dominated by low-rise buildings. For instance, the BCR of the buffer zone of Baiyun Street CSDH is lower than that of Guangta Street CSDH, but the FAR of Baiyun Street CSDH is higher than that of Guangta Street CSDH (Fig. 4). FAR reflects the building's total floor area within the buffer zone from a three-dimensional perspective. Thus, FAR was utilized to evaluate the building density in this study.

Design. There are four variables in this section. Street density is considered one of the potential factors that influence the dining volume of CSDHs. Also, the accessibility of public transportation is employed to assess the accessibility of CSDHs within buffers, it is assessed by two variables: the number of bus stops and the distance to the nearest subway station. Besides, the normalized difference vegetation index (NDVI) is a remote sensing index

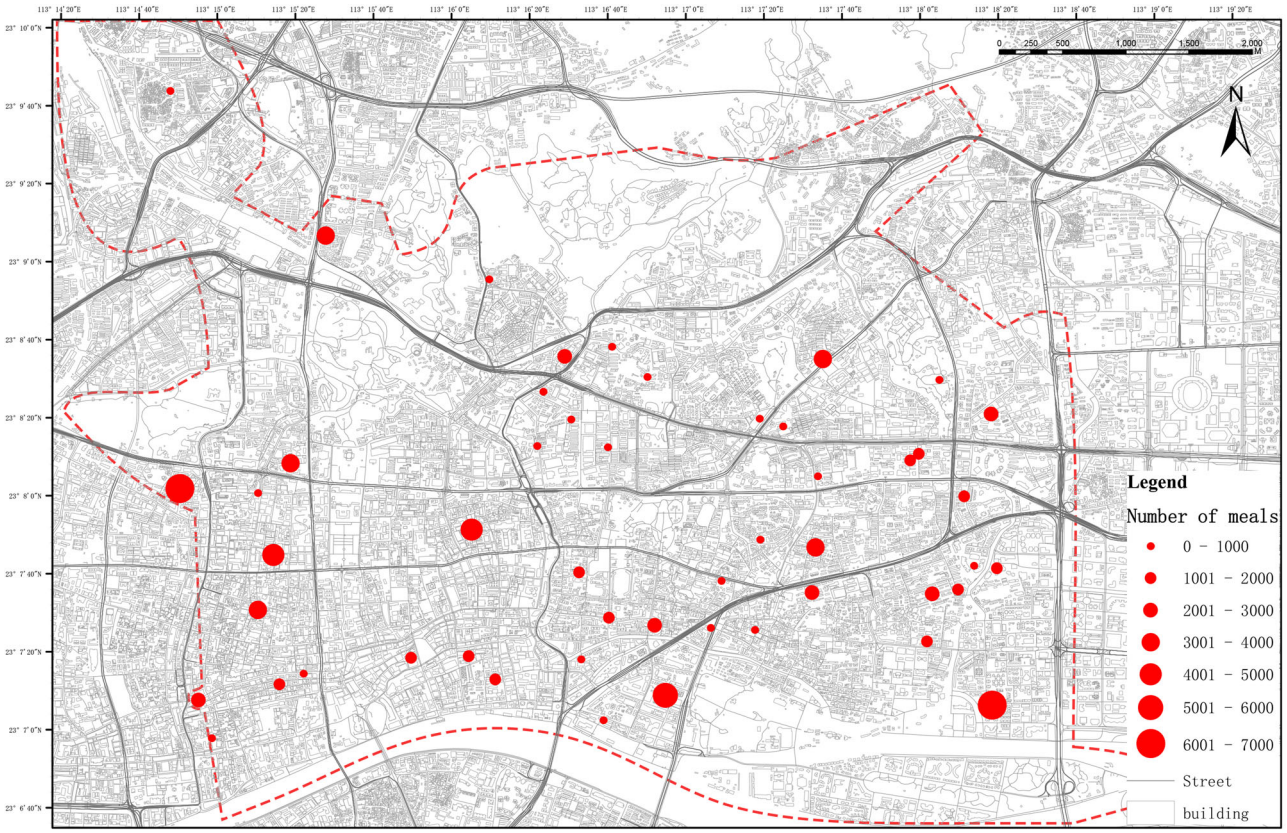

Fig. 2 The Dining Volume of CSDHs in Yuexiu District for the Second Quarter of 2023.

used to assess the presence and condition of green vegetation on a site.

Diversity. The factor of catering POI diversity was assessed, as the surrounding restaurants and food stores may have an impact on the dining volume of the CSDHs. The category, quantity, and percentage statistics are presented in Table 2. Shannon diversity (Shannon 1948) is applied to calculate catering POI diversity.

Internal built environment factors. Three categories of internal built environment factors are investigated, including facilities, architectural design, and interior design. All internal built environment factors are listed in Table 1.

Facilities. Availability of kitchen, dine-in seating, and health center are considered in facility factors. Firstly, some CSDHs have full-scale kitchens for food preparation, while others have no full-scale kitchens, and the food is prepared in centralized kitchens somewhere else. Secondly, some CSDHs provide dine-in seating, while others only serve as takeaway points without dine-in seating. Thirdly, some CSDHs are located within a senior care center providing other facilities, such as a free activity room, reading room, rehabilitation room, or therapy room, specifically designed for older adults.

Architectural design. Architectural design factors include the number of entrances, building floor level, and whether the entrances are accessible. More entrances can improve the accessibility of CSDH, allowing older adults to enter from different directions. Similarly, a lower floor can also improve accessibility. Moreover, an accessible entrance is friendly to older adults with mobility difficulties.

Interior design. Barrier-free handrails, number of tables, number of seats, availability of wash basins, water dispensers, clocks, TVs, air condition, menus, bulletin boards, spice racks, and sterilization lamps are taken as design factors for interior design (Fig. 5). Number of seats is divided into 4 groups (≤10, 11–20, 21–30, >30), and the group with less than 10 seating is used as a reference group. These indicators were selected based on previous research experience (LI 2018) and were adjusted according to the circumstances of the study.

Covariates. In addition to the influence of the external and internal built environment, the older population density in the area and the taste of the food served in the CSDHs may also have an impact on the dining volume (Bakar et al. 2020). The older population density was calculated based on the data from the seventh national census released by the Chinese government. The food taste was assessed by the voting results from the senior dining hall competition in August 2023. A total of 566,353 votes were collected to rate the food taste of each CSDH. Food price is not considered in the study as these CSDHs have the same dining price standards (15 Yuan per serving).

Statistical analysis. A multiple linear regression model was employed to investigate the impact of built environment factors on the dining volume in community CSDHs in R v4.3.1. Before running the model, we examined all independent variables. Firstly, air condition, menus, and bulletin boards were removed from the analysis, since it was found that all CSDHs have the same value for these three variables. The correlation matrix for all independent variables within three different buffer zones was presented in Supplementary Figure S1. Secondly, the variance inflation factor (VIF) was used to test for potential multicollinearity among the variables. Variables with a VIF value

Table 1 Definition and Data Source of Dependent Variables of the Dining Volume and Independent Variables of the Built Environment. ($N = 50$).

Variables		Data source
Outcome		
	Dining volume (N)	Statistics on the dining volume of CSDHs in Yuexiu District in the second quarter of 2023 from Yuexiu District Civil Affairs Bureau
External built environment		
Density	FAR	The building footprint data of Guangzhou in 2023 from Open Street Map (geographic vector data)
Design	Street density (m/m^2)	The road data of Guangzhou in 2023 from Open Street Map (geographic vector data)
	Number of bus stops (N)	The bus stop data of Guangzhou in 2023 from Open Street Map (geographic vector data)
	Distance to the nearest subway station (m)	The subway station data of Guangzhou in 2023 from Open Street Map (geographic vector data)
	NDVI	Landsat-5 satellite images from April 1 to June 31, 2021 (30 × 30 m)
Diversity	Catering POI diversity (0 or 1)	The catering POI data of Guangzhou in 2023 from Gaode Maps (geographic vector data)
Internal built environment		
Facilities	Availability of kitchen (0 or 1)	Field research
	Availability of Health center (0 or 1)	
	Availability of dine-in seating (0 or 1)	
Architectural design	Number of entrances (N)	
	Building floor (N)	
	Accessible entrances (N)	
Interior design	Barrier-free handrail (0 or 1)	
	Number of tables (N)	
	Number of seats (N)	
	Availability of wash basin (0 or 1)	
	Water dispenser (0 or 1)	
	Clock (0 or 1)	
	TV (0 or 1)	
	Air condition (0 or 1)	
	Menu (0 or 1)	
	Bulletin board (0 or 1)	
	Spice rack (0 or 1)	
	Sterilization lamp (0 or 1)	
Covariates		
	Older population density (N/km2)	The 7th National Population Census Bulletin of Yuexiu District, Population Situation and Population Age Composition of Each Street
	Food taste (votes) (*N*)	The online voting results for the taste evaluation of the CSDHs in Yuexiu District from the Yuexiu District Civil Affairs Bureau

FAR Floor area ratio, *NDVI* Normalized difference vegetation index.

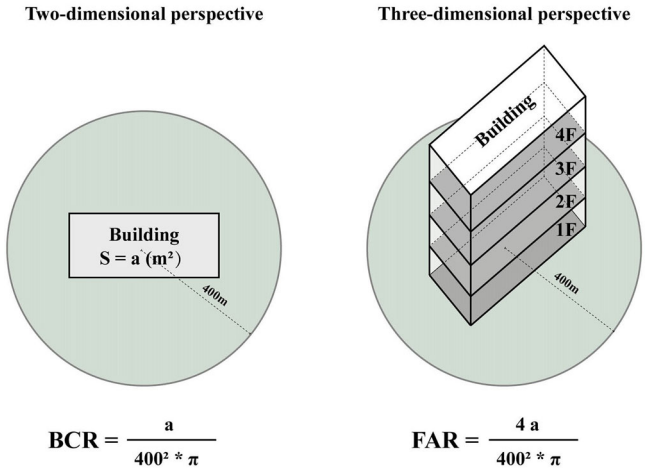

Fig. 3 The calculation distinction between building coverage ratio (BCR) and floor area ratio (FAR), using a 400 m buffer zone as an example.

exceeding 4 were eliminated (including the spice rack, sterilization lamp, NDVI, and the number of tables). The dependent variable, dining volume, was logarithmically transformed to achieve a better approximation of a normal distribution. All remaining independent variables were standardized. Multiple linear regression models were separately computed for each buffer zone, and the regression coefficients, p-values, and VIF values for each variable were reported. Additionally, the adjusted R-squared and Akaike info criterion (AIC) were reported for each model.

Results

Descriptive results. Table 3 describes the summary statistics of dependent variables for the dining volume of CSDHs in the second quarter of 2023 and independent variables for the built environment of Yuexiu District. Minimum (Min) maximum (Max), mean, and standard deviation (SD) of variables are reported. For example, the minimum and the maximum dining volume of CSDHs are 130 and 6390 meals respectively in the second quarter of 2023. For the external built environment, fluctuations in FAR, ranging from 2.51 to 9.31, reflect the dynamic attributes of urban development within the context of limited land resources in old urban districts. Besides, the street density is 0.04 m per square meter (SD = 0.00). The average distance to the subway station is 386.03 m (SD = 20.64). The catering POI diversity within the three buffer zones is similar, with an average value of 0.32 in the 400 m buffer (SD = 0.00),

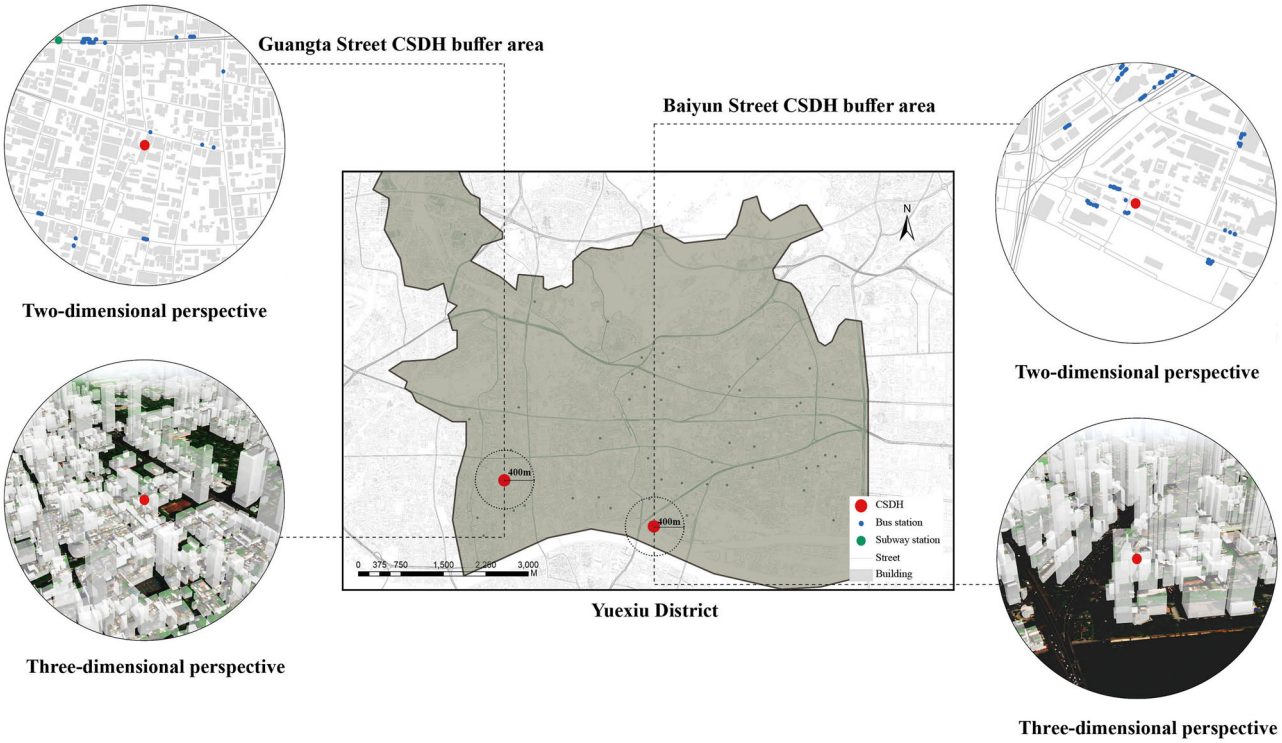

Fig. 4 The two-dimensional and three-dimensional urban built environment around Baiyun Street CSDH and Guangta Street CSDH, using a 400 m buffer zone as an example.

Table 2 Count and Percentage of Catering POI in Three Buffer Zones.

	Micro-level categories in Gaode Map	400-m buffer		600-m buffer		800-m buffer	
		Count	Percentage	Count	Percentage	Count	Percentage
Catering	Chinese Cuisine, Foreign Cuisine, Snacks and Fast Food, Coffee, Cake and Dessert Shops, Tea Houses, Others	6372	22.0%	14396	22.0%	24214	21.9%

Fig. 5 The CSDHs in Yuexiu district.

0.33 in the 600 m (SD = 0.00), and 800 m (SD = 0.00) buffers. For the internal built environment, the average number of entrances for CSDHs is 1.24 (SD = 0.05), and the average number of seats in each CSDH is 16.68 (SD = 1.44).

Regression results. Table 4 shows the associations between dining volume and built environment factors. The adjusted R^2 is 0.478 for the 400 m buffer zone, 0.476 for the 600 m buffer zone, and 0.494 for the 800 m buffer zone, respectively. For the external built environment, FAR and distance to the nearest subway station are statistically significant. The CSDH buffer zone with lower FAR tends to have higher dining volume (coefficient = −0.271, $p < 0.05$) in both the 400 m and 600 m buffers. Besides, closer proximity of CSDHs to subway stations is associated with higher dining volume, with correlation coefficients of −0.214 in the 400 m buffer, −0.232 in the 600 m buffer, and −0.241 in the 800 m buffer. To compare the dining volume in CSDHs with different conditions of external built environments, we further divided the CSDHs into different groups according to the value of FAR (≤ 5.00, 5.01–6.00, 6.01–7.00, and å 7.00) and distance to nearest subway station (≤ 300, 301–500, and å 500). The results reveal that the dining volume has a sudden increase when the FAR is lower than 6.00, while the CSDHs located beyond a 500-meter radius from the subway station had approximately 500 fewer dining volumes compared to CSDHs within a 500-meter radius of the subway station (Figs. 6, 7).

Table 3 Summary Statistics of Dependent Variables of the Dining Volume and Independent Variables of the Built Environment. (N = 50).

Variables		Min			Max			Mean (SD)		
		400 m buffer	600 m buffer	800 m buffer	400 m buffer	600 m buffer	800 m buffer	400 m buffer	600 m buffer	800 m buffer
Outcome										
	Dining volume	130			6390			1764.42 (222.27)		
External built environment										
Density	FAR	2.51	2.11	2.08	9.31	5.30	5.06	5.96 (0.20)	3.94 (0.10)	3.84 (0.10)
Design	Street density	0.01	0.01	0.02	0.08	0.06	0.06	0.04 (0.00)	0.04 (0.00)	0.04 (0.00)
	Number of bus stops	0	29	90	148	261	462	71.38 (5.29)	163.20 (8.18)	275.72 (10.85)
	Distance to the nearest subway station	21.64	21.64	21.64	454.04	454.04	454.04	386.03 (20.64)	386.03 (20.64)	386.03 (20.64)
	NDVI	0.14	0.11	0.13	0.41	0.42	0.40	0.23 (0.01)	0.25 (0.01)	0.24 (0.01)
Diversity	Catering POI diversity	0.23	0.23	0.26	0.37	0.37	0.37	0.32 (0.01)	0.33 (0.00)	0.33 (0.00)
Internal built environment										
Facilities	Availability of kitchen	0			1			0.12 (0.05)		
	Availability of Health center	0			1			0.28 (0.06)		
	Availability of dine-in seating	0			1			0.98 (0.02)		
Architectural design	Number of entrances	1			2			1.24 (0.06)		
	Building floor	1			2			1.04 (0.03)		
	Accessible entrances	0			1			0.88 (0.05)		
Interior design	Barrier-free handrail	0			1			0.96 (0.03)		
	Number of tables	0			13			3.76 (0.38)		
	Number of seating	0			50			16.68 (1.44)		
	Availability of wash basins	0			1			0.94 (0.03)		
	Water dispenser	0			1			0.78 (0.06)		
	Clock	0			1			0.94 (0.03)		
	TV	0			1			0.86 (0.05)		
	Air condition	1			1			1.00 (0.00)		
	Menu	1			1			1.00 (0.00)		
	Bulletin board	1			1			1.00 (0.00)		
	Spice rack	0			1			0.88 (0.05)		
	Sterilization lamp	0			1			0.88 (0.05)		
Covariates										
	Older population density	1140	1140	1140	14985	14985	14985	7371 (3861)	7371 (3861)	7371 (3861)
	Food taste (votes)	6183			75476			27704.74 (3035.13)		

FAR Floor area ratio, *NDVI* Normalized difference vegetation index.

Table 4 Regression Models of the Association between Dining Volume and Built Environment. ($N = 50$).

Variables		400 m buffer		600 m buffer		800 m buffer	
		Coef. (SE)	*P*-value	Coef. (SE)	*P*-value	Coef. (SE)	*P*-value
External built environment							
Density	**FAR**	**−0.271 (0.127)**	**0.042****	**−0.271 (0.139)**	**0.038****	**−0.224 (0.132)**	**0.101**
Design	Street density	−0.166 (0.151)	0.282	−0.166 (0.170)	0.352	−0.262 (0.147)	0.085*
	Number of bus stops	0.072 (0.135)	0.597	0.072 (0.171)	0.249	−0.188 (0.140)	0.192
	Distance to the nearest subway station	**−0.235 (0.129)**	**0.080***	**−0.235 (0.124)**	**0.046****	**−0.285 (0.124)**	**0.029****
Diversity	Catering POI diversity	−0.107 (0.145)	0.466	−0.107 (0.156)	0.125	−0.187 (0.145)	0.206
Internal built environment							
Facilities	Availability of kitchen	0.046 (0.157)	0.774	0.046 (0.158)	0.526	0.090 (0.154)	0.565
	Availability of healthcare center	0.173 (0.167)	0.311	0.173 (0.172)	0.544	0.117 (0.165)	0.487
Architectural	**Availability of dine-in seating**	**0.392 (0.170)**	**0.029****	**0.392 (0.166)**	**0.038****	**0.333 (0.169)**	**0.060***
	Number of entrances	−0.022 (0.146)	0.880	−0.022 (0.146)	0.996	−0.022 (0.139)	0.875
design	**Building floor**	**−0.255 (0.153)**	**0.107**	**−0.255 (0.153)**	**0.080***	**−0.262 (0.148)**	**0.087***
	Accessible entrances	−0.015 (0.142)	0.918	−0.015 (0.157)	0.970	0.079 (0.155)	0.615
Interior design	**Number of seats (ref. < = 10)**						
	11–20	0.137 (0.158)	0.392	0.137 (0.157)	0.232	0.166 (0.153)	0.287
	21–30	**0.317 (0.136)**	**0.027****	**0.317 (0.141)**	**0.009*****	**0.345 (0.136)**	**0.017****
	> 30	**0.319 (0.134)**	**0.025****	**0.319 (0.135)**	**0.031****	**0.309 (0.132)**	**0.026****
	Barrier-free handrail	0.245 (0.136)	0.083*	0.245 (0.136)	0.201	0.207 (0.134)	0.135
	Availability of wash basins	0.030 (0.170)	0.863	0.030 (0.182)	0.710	−0.032 (0.172)	0.852
	Water dispenser	**0.305 (0.154)**	**0.057***	**0.305 (0.153)**	**0.028****	**0.393 (0.154)**	**0.016****
	Clock	0.172 (0.167)	0.312	0.172 (0.166)	0.325	0.154 (0.165)	0.358
	TV	0.069 (0.135)	0.614	0.069 (0.145)	0.353	0.080 (0.131)	0.546
Covariates							
	Older population density	0.135 (0.145)	0.359	0.135 (0.149)	0.161	0.261 (0.157)	0.107
	Food taste (votes)	0.266 (0.142)	0.071*	0.266 (0.146)	0.152	0.198 (0.148)	0.190
Adjusted R^2		0.478		0.476		0.494	
AIC		127.52		127.65		125.95	

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$, *FAR* Floor area ratio, bold values indicate significant regression coefficient.

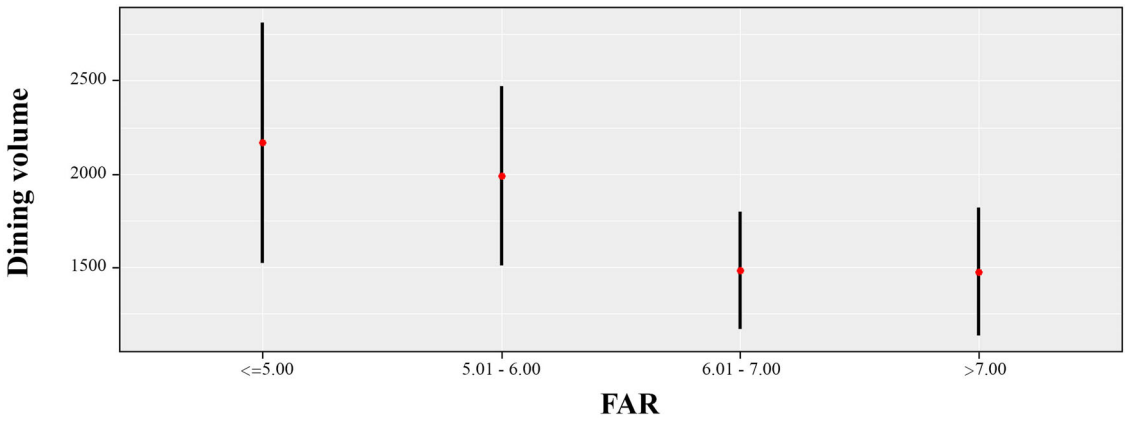

Fig. 6 The Dining Volume under Different FAR Groups in the 400 m Buffer zone.

For the internal built environment, availability of dine-in seating, floor level, number of seats, and water dispenser have a significant impact on the dining volume of CSDHs. Availability of dine-in seating has a positive effect on the dining volume, with correlation coefficients of 0.392 in the 400 m and 600 m buffer model, and 0.333 in the 800 m buffer model. Moreover, the lower the floor level of the building, the higher the dining volume of the CSDHs, with a coefficient of −0.255 in the 600 m buffer and −0.262 in the 800 m buffer. Furthermore, Compared to the group with less than 10 seating, there is a significant increase in dining volume for groups with 20 to 30 seating and the group with more than 30 seating. Similar to the external built environment, we further divided CSDHs into several groups with different seating capacities (≤ 10, 11–20, 21–30, and å 30). We found that when the number of seats exceeds 30, there is a significant increase in the dining volume at CSDHs, reaching an average of over 4000 meals (Fig. 8). Lastly, the presence of a water dispenser in the CSDH can also contribute to the promotion of dining volume. The correlation coefficient for the 400 m and 600 m buffer is 0.305 and for the 800 m buffer is 0.393.

Discussion

This study explores the association between dining volume of CSDHs and built environment factors, which could provide urban planning implications for promoting community-based senior care, in the context of an aging population in China. Data on objective dining volume is used to assess the usage of the

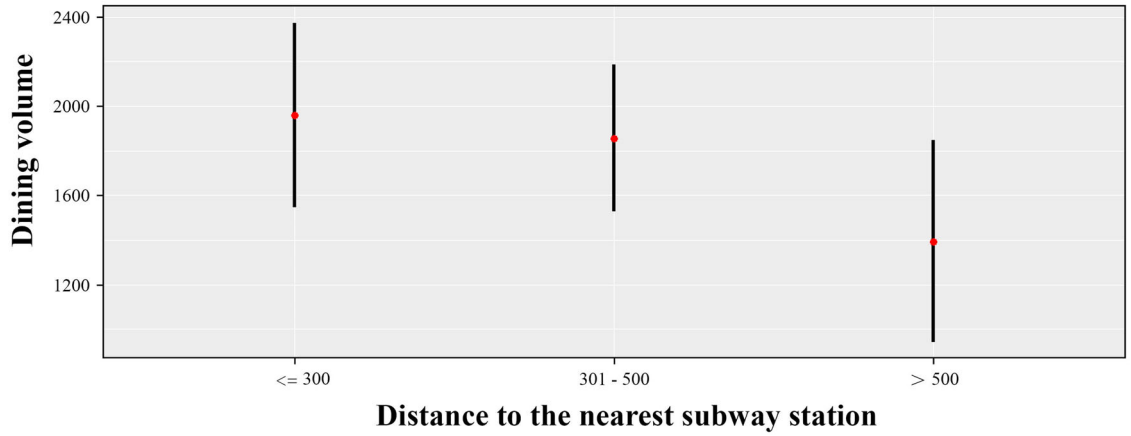

Fig. 7 The Dining Volume under Different Distances to the Nearest Subway Station Groups.

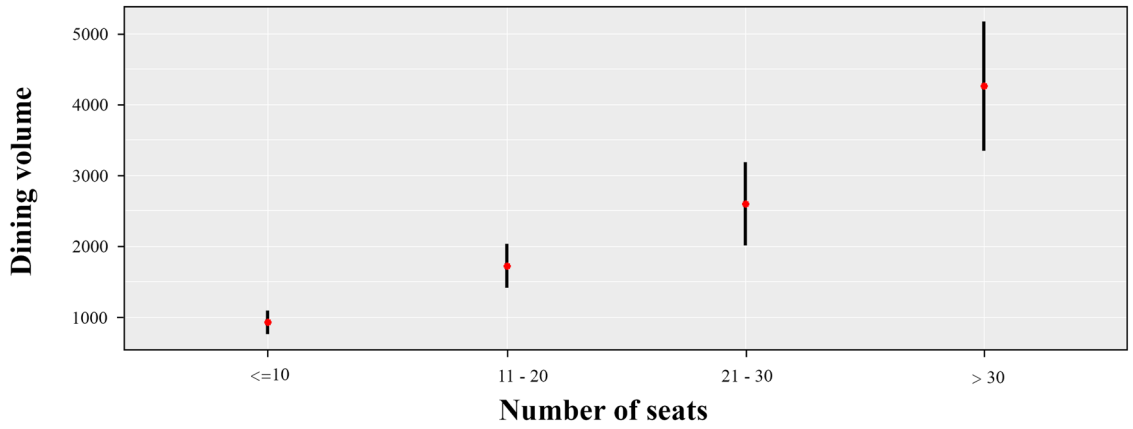

Fig. 8 The Dining Volume under Different Numbers of Seat Groups.

CSDHs. Both external built environment factors and internal built environment factors are considered simultaneously. Separate multiple linear regression models are used to calculate such associations in three different buffer zones to increase the reliability of the results.

External built environment

Lower building density. The research findings demonstrate that FAR has a negative impact on the dining volume at CSDHs. A lower FAR in the vicinity of CSDH is associated with higher dining volume. There are three possible reasons. Firstly, areas with lower FAR tend to have more older residents and a higher demand for dining. Because areas with lower FAR are generally older residential districts with buildings of four or five floors in Guangzhou (Pan et al. 2008), and the aging population has become prominent in these older residential areas(Teng et al. 2023). Secondly, it is evidenced that low FAR area may contribute to walking, since there may be an inverted U-shaped relationship between building density and the travel behavior of older adults(Lu et al. 2019). Thirdly, low FAR neighborhood is often associated with better cognitive health of older adults, who are more likely to use CSDHs. One recent study from Shanghai, China, provides evidence that both cognitive health and social engagement of older adults in low FAR communities are better than those in high FAR communities (Zhang et al. 2023). Enhanced social cognition can assist older adults in better integrating into society, and participating in community interactions, such as dining in CSDHs. Thus, CSDHs in less crowded, older residential areas see more diners because these areas are home to many older people, offer a more comfortable environment for walking, and may support better cognitive health, encouraging more frequent visits to CSDHs.

Near subway station. CSDHs in closer proximity to subway stations are more popular among older adults. This finding is consistent with previous research findings, which indicate that older adults are highly sensitive to the availability of public transit facilities (Y. Yang et al. 2022). There is a significant drop in dining volume at CSDHs when the distance to the nearest subway station exceeds 500 meters. Previous research has found that the average walking fatigue limit for healthy older adults is 10 min, corresponding to a walking distance of approximately 450–500 meters (LI 2018). Therefore, the location selection of future CSDHs should consider the distance to the nearby subway stations.

These two external built environment factors, lower FAR and shorter distance to the nearest subway station, were both associated with increased travel willingness to CSDHs among older adults, supporting the first hypothesis. However, we found that other external built environment factors, such as street density, number of bus stops, and catering POI diversity, were not related to older adults' travel willingness to CSDHs.

Internal built environment

Dine-in options. The provision of dine-in seating, which served as an attractive facility in a CSDH, has a positive impact on the

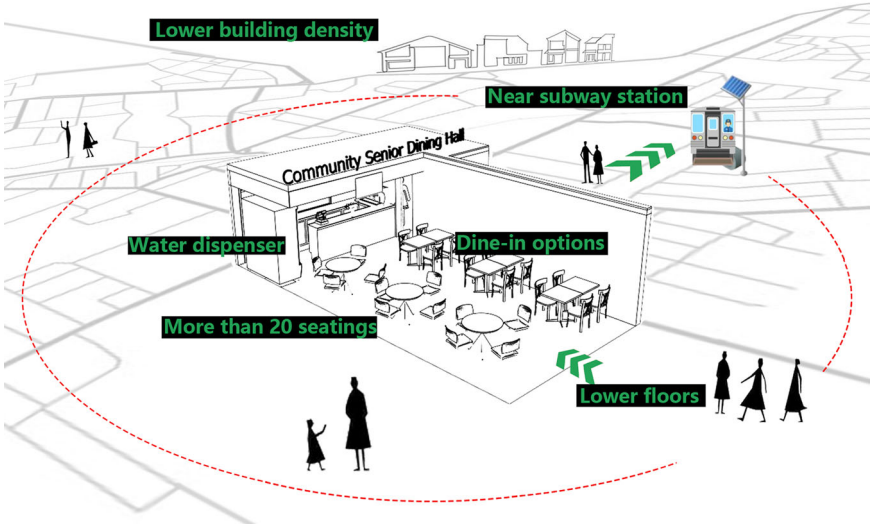

Fig. 9 The optimal CSDH features.

dining volume. The findings align with previous research (Peng et al., 2020), indicating that dining in a restaurant serves as an important social setting for older adults (Maluf et al. 2020). Thus, a welcoming and comfortable dining environment plays a vital role in encouraging frequent visits among older adults (Tsai et al. 2018).

Lower floors. For older adults, CSDHs located on lower floors are associated with higher convenience, resulting in a higher dining volume. The floor level significantly impacts the ease of travel and accessibility of destinations for older adults. A study from the United States found that older adults residing in multi-story buildings tend to have relatively lower health conditions (Lyu et al. (2021)).

Increased seating. CSDHs with a larger number of seats typically exhibit higher dining volume. There is a noticeable increase in dining volume for groups with seating capacities ranging from 20 to 30 and groups with seating capacities exceeding 30, as compared to groups with less than 10 seating. This result is similar to the previous study, which estimated that the ideal number of seats is approximately 25 (LI 2018). During the field research, we found that CSDHs which have less than 10 seatings, are often shared between staff members for office work and older adults for dining. This arrangement does not provide a conducive environment for socializing among older adults. Hence, a sufficient number of tables and seats are needed to offer a favorable social environment, attracting more older adults to patronize. Besides, CSDHs with higher dining volume often have larger dining tables, where older adults gather and engage in conversations before meals. This reflects how CSDHs can enhance social interactions among older adults (Hung et al. 2016). Furthermore, the presence of a water dispenser is also crucial for the dining frequency at the CSDHs. A possible reason is that older adults are more sensitive to drinking water availability, allowing them to get hot water and make tea. The same finding was revealed in a previous study (LI 2018).

The availability of dine-in seating, lower building floors, more seats, and the presence of water dispensers were all positively associated with increased dining volumes at CSDHs, providing support for the second hypothesis. This suggests that an attractive, safe, and comfortable internal environment, especially with ample social interaction spaces, can encourage older adults' willingness to utilize CSDHs. However, other internal built environment factors, such as the availability of on-site kitchens, healthcare centers, and the number of building entrances, were not significantly related to older adults' dining volumes at the CSDHs.

Implication. The findings of this research have meaningful implications both for CSDHs' planning and built environment design (Fig. 9). Firstly, for existing CSDHs, the region between 400 m and 800 m from the CSDHs should be emphasized, as several built environment factors were found to be significant within this range. Secondly, we found that CSDHs in areas with lower FAR and closer to the subway station tend to have higher dining volume. Such results can guide the location selection of CSDHs in Guangzhou and other cities in China, i.e., CSDHs should be selected in areas where the FAR is less than 6 and within 500 meters of a subway station. Thirdly, the dine-in seating and the number of seats are positively associated with dining volume. It is suggested that a newly constructed CSDHs should have sufficient dine-in seating or more than 20 dining seats, which can promote social interaction among older adults, as a key factor in attracting their patronage. Also, CSDHs located on lower floors tend to have higher dining volume. Priority is given to ground floor space when selecting CSDHs' location, by making CSDHs more convenient and accessible for older adults. Lastly, facilities within the CSDHs, such as water dispensers, should also be considered for older adults. Hence, it is advisable to install water dispensers in CSDHs. Such suggestions may help the government in planning and designing CSDHs, improving CSDH's operational efficiency, and optimizing the allocation of public resources.

Limitation. This study has several limitations. First, the individual factors of older adults, such as socioeconomic status, social needs, or health conditions, were not taken into account, which may introduce confounding impacts. However, due to data unavailability, we cannot consider these individual factors in this study. Our study concentrated on objective built environmental metrics, to offer clear and direct information for informing policy and practice, free from the complexities of individual perceptions (Smith et al. (2017)). Second, this study did not consider ambient environment factors, such as lighting conditions and noise levels. Acoustics and lighting may affect the comfort level of a restaurant (Luzzi et al. (2021)). However, the research primarily focused on

factors related to the built environment that could influence the dining volume of CSDHs. Therefore, these ambient environment factors fell outside the scope of the study. Furthermore, obtaining statistics on these physical environment factors was challenging due to time and equipment constraints. Future studies should measure such factors in CSDHs. Third, this study did not encompass specific factors of individual CSDHs, such as whether service quality (including cleanliness and staff friendliness) would increase dining volume (Tanford & Suh, 2013), and the impact of advertising/marketing strategies. These factors could potentially have implications on the research findings and conclusions, warranting consideration in future studies. Finally, research should incorporate the subjective perceptions of older adults. Conducting questionnaire surveys would validate whether these built environment factors indeed have an impact on the dining frequency at CSDHs.

Conclusion

This study analyzed the association between the dining volume and both the external and internal built environment of 50 CSDHs in Yuexiu District, Guangzhou. Overall, these findings indicate that specific features of both the external and internal built environments play an important role in shaping older adults' willingness to visit and utilize the services provided at CSDHs, as proposed in the two hypotheses in the introduction. The efficient operation of CSDHs can save public funding support while enhancing social interaction among older adults. The research findings are beneficial for the urban planning strategies of CSDHs.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Zou Xinyi: Drafting, data collection, research, editing; Zhou Ying: Conceptualization, data collection, Supervision; Lu Yi: Supervision, revision, editing.

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Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required as the study did not involve human participants.

Informed consent

Informed consent was not required as the study did not involve human participants.

Additional information

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