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Activity Patterns and Spatial Distribution of Older Adults in Community Parks: A SOPARC-Based Case Study in Changsha, China

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Abstract

Drawing on 964 field observations from typical community parks in Changsha, this study utilizes the System for Observing Play and Recreation in Communities (SOPARC) alongside Kernel Density Estimation (KDE) to quantitatively dissect the intrinsic associations between older adults' outdoor activity patterns and micro-spatial characteristics. The findings reveal a pronounced demographic differentiation in spatial utilization. Specifically, female-dominated collective activities, such as square dancing, exhibit a profound reliance on central plazas with unobstructed sightlines to cultivate a sense of social security. Conversely, male users demonstrate a distinct preference for static social interactions, including playing chess or cards, within semi-enclosed and shaded spaces beneath a tree canopy. Beyond gender distinctions, age-related spatial anchoring is also evident. Intergenerational caregiving activities among the younger old cohort (aged 55 to 74) are exclusively concentrated around children's playgrounds, whereas older old individuals and those with impaired mobility rely heavily on densely distributed micro-scale resting amenities. Driven by these empirical insights, this research contends that age-friendly park design must transcend generic accessibility standards, advocating instead for a "categorized spatial provision" strategy. By meticulously balancing open exhibition plazas, semi-private shaded units, and composite caregiving zones within a single park ecosystem, this approach can effectively accommodate the multifaceted health and social requirements of various older adult subgroups.

Keywords: healthy aging; SOPARC; older adults; urban parks

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1. Introduction

Green spaces such as parks hold significant potential for promoting healthy aging [1,2]. With advancing age, the physiological functions of human organs and tissues, including the respiratory, circulatory, immune, and digestive systems, gradually decline, making older adults more susceptible to various diseases [3,4]. A large body of empirical research indicates that park-based activities play a crucial role in promoting physical activity, walking exercise, social interaction, interpersonal relationships, quality of life, and the physical and mental health of older adults [5–8]. For instance, park-based activities can effectively

promote physical activity among older adults, reducing the incidence and mortality of cardiovascular diseases [9]; they help control blood glucose levels and reduce the incidence of diabetes [10]; and through moderate exercise, they can alleviate joint burden and relieve arthritis symptoms [11]. Furthermore, park-based activities can enhance the social and cognitive abilities of older adults, contributing to the prevention of dementia onset [12]. Therefore, greater exposure to green spaces is associated with better overall health-related quality of life [13]. In the pursuit of healthy aging, China has promulgated policies such as the "Healthy China 2030" Planning Outline, emphasizing the development of age-friendly environments [14]. Distinct from the Western concept of "neighborhood," a "community" in the Chinese context typically refers to an area with defined administrative boundaries and serves as a fundamental component of urban structure. While current guidelines, including the "Standard for Planning and Design of Urban Residential Areas," offer macro-level direction, practical insights into the micro-scale construction of age-appropriate community parks remain scarce [15]. Despite the significant health benefits associated with community parks, existing research consistently indicates that older adults constitute a disproportionately low percentage of park users [16,17]. This low level of participation suggests a potential misalignment between contemporary park design and the actual requirements and preferences of the elderly [18]. Identifying and comprehending the spatial behavior logic of this specific demographic has therefore become a critical issue in park planning and age-friendly design. To address this gap, the present study aims to explore the correlations between the outdoor activities of older adults and the spatial characteristics of community parks through empirical data and analysis, particularly within the context of densely populated and highly built-up Chinese cities, thereby providing evidence-based support for age-friendly park construction.

1.1. Older Adults' Park Activities

Research examining the outdoor activities of older adults conventionally categorizes them into two distinct typologies: static and dynamic activities. Characterized by autonomous selection and intrinsic motivation, static activities are guided by psychological principles and often involve a rich degree of imagination [19,20]. This activity type serves not merely as physical rest but rather acts as a vital process for psychological energy restoration. Building upon this foundational classification, several studies further subdivide the static behaviors of older adults into restorative activities (such as sightseeing or quiet contemplation), cognitive social activities (including playing chess or cards), and perceptual activities (such as observing others perform or practice) [21–23]. Being highly sensitive to the quality of the micro-environment, participants in these activities consistently gravitate toward specific spatial nodes, such as shaded areas or benches, that offer elevated levels of comfort and security. Conversely, dynamic activities are generally defined as behaviors driven by explicit physiological health objectives or functional purposes, encompassing exercises like brisk walking, jogging, and the use of fitness equipment [24]. Within the Chinese urban context, these dynamic activities concurrently exhibit pronounced cultural and commercial attributes. Older adults frequently engage with commercial services or temporary stalls surrounding parks. Classified as commercial and dining activities, these engagements indirectly prolong outdoor dwell times by incentivizing older populations to leave their residences [25]. Furthermore, domestic research highlights a unique phenomenon associated with intergenerational dynamics, identifying grandparents as the primary companions for children's outdoor play [26].

1.2. SOPARC and Other Observation Tools

Past research evaluating physical activity among older adults has predominantly relied on two categories of assessment tools: subjective evaluations, such as self-reported questionnaires like the Physical Activity Scale for the Elderly (PASE), and objective measurements, including accelerometers, heart rate monitors, and GPS tracking [27–29]. While questionnaire surveys are capable of capturing activity frequencies across large-scale samples, they are frequently susceptible to recall bias [30–32]. Conversely, wearable devices such as accelerometers provide precise records of activity intensity but struggle to capture the specific environmental contexts and social interaction dynamics in which these activities take place [33,34].

Direct observation tools are widely applied in the assessment of physical activity within public spaces such as parks. Among various observational frameworks, the System for Observing Play and Recreation in Communities (SOPARC) is widely recognized as a highly representative instrument. Its primary advantage lies in its specialized design for monitoring physical activities and recreational behaviors within outdoor community environments, including parks, playgrounds, and leisure areas, enabling the simultaneous recording of physical activity levels, environmental characteristics, and the sociodemographic attributes of users [16].

Seeking to comprehensively explore the park utilization patterns of older adults within the Chinese urban context, the current study adopts a localized SOPARC observational protocol. Beyond retaining standard records of physical activity intensity, this adapted protocol systematically incorporates the capture of older adults' mobility status, group size, and precise location data, ultimately aiming to construct a multidimensional behavioral database.

1.3. The Geographic Imbalance in Research on Older Adults' Park Utilization and Spatial Characteristics

A review of the literature concerning the environmental behaviors of older adults reveals that geographic evidence supporting the global "Age-Friendly Cities" movement is disproportionately concentrated in developed Western nations. Although these studies broadly substantiate the central role of parks in promoting individual physical activity, their conclusions are predominantly grounded in low-density urban morphologies, rendering them difficult to extrapolate directly to the highly dense urban environments of China. Within the Chinese context, while previous research has identified path width, vegetation coverage, and facility adequacy as critical factors influencing the intensity of older adults' participation, a significant bottleneck remains [35,36]. Current explorations frequently emphasize macro-level accessibility assessments or single-dimension functional quantification, thereby neglecting the internal heterogeneity of older adults' activity systems and their interactive logic with micro-spatial morphologies. Specifically, empirical studies presently lack a refined analysis of the spatiotemporal distribution patterns among older cohorts with varying physical capabilities and social attributes. Additionally, few investigations have successfully translated complex behavioral logic into intuitive spatial morphological language through quantitative methodologies. Furthermore, for inland hub cities experiencing rapid demographic aging, such as Changsha, a systematic and evidence-based interpretation of the environment–behavior interaction mechanisms within high-density community settings is still notably absent.

1.4. Research Aim and Questions

To bridge this identified gap, the current study employs large-scale field observations alongside spatial analysis to uncover the profound connections between the multifaceted

activity requirements of older adults and the spatial morphological systems of parks. Undertaking this approach yields robust empirical evidence to inform precise age-friendly design interventions. By systematically analyzing the spatiotemporal distribution patterns of this demographic, the research further investigates the critical spatial characteristics of parks that dictate their outdoor engagements. These efforts ultimately serve to enrich the international literature with urgently needed evidence derived from the Chinese urban context. Consequently, this investigation seeks to address the following two research questions:

(1) What are the intrinsic associations between the activity typologies of older adults and diverse community park spaces?
(2) How can suitable and age-appropriate activity zones be effectively provisioned for the elderly across varying types of community parks?

2. Method

2.1. Study Area

As a core city in central China, Changsha has actively responded to national strategic plans for the development of aging programs in recent years, committing to the construction of an age-friendly city. By the end of 2022, the resident population of Changsha reached 10.42 million, marked by a significantly accelerated aging process. Initially, this study conducted a comprehensive retrieval within the main urban area of Changsha using "community park" as the keyword on the Baidu Maps open platform, yielding a total of 119 relevant points of interest (POIs). Subsequently, the research team subjected these retrieval results to two rigorous rounds of screening:

(1) Preliminary filtering (reducing the count from 119 to 62): By examining detail pages and conducting street-view cross-references, locations that did not align with the research objectives were excluded. These exclusions comprised: (a) private green spaces within residential areas managed by property companies; (b) protective street greenbelts or traffic islands lacking activity facilities (devoid of social functions); and (c) excessively large comprehensive urban parks (inconsistent with the spatial characteristics of community-level parks).
(2) In-depth screening (reducing the count from 62 to 13): To ensure the external validity of the data, the sample was further narrowed based on the following criteria: (a) exclusion of parks situated in areas undergoing administrative boundary changes or large-scale peripheral construction; (b) exclusion of sites with singular functionality, such as those possessing only greening functions without hard-surfaced plazas; and (c) ensuring that the selected parks were located at the core of high-density residential areas, maintaining a stable 15 min walking service radius.

Following the completion of the aforementioned screening process, the research team conducted sequential on-site visits to the remaining 13 candidate community parks. Ultimately, based on the typicality of their spatial layouts and their functional complementarity, Hongxing, Hepan, and Yuedao Community Parks were selected as the case studies for this research (Table 1). Notably, constrained by land planning regulations and administrative allocations, Hepan Community Park and Yuedao Community Park are registered as two independent units in statutory planning, yet they present a highly integrated state in their physical space. In practical utilization, these two parks collectively fulfill the age-friendly activity demands of the area through functional complementarity, with the Hepan side tending toward dynamic exercise, while the Yuedao side caters more to static leisure and performance. This composite model, characterized by administrative independence, spatial

amalgamation, and functional complementarity, holds profound typical significance within the context of high-density urban renewal in Changsha.

Table 1. Environmental Attributes of Parks.

		Changsha Hongxing Community Park	HePan Community Park	YueDao Community Park
Size (ha)		3.2	4.24	4.83
Facilities	Seats	√	√	√
	Lighting		√	√
	Children's play facilities		√	√
	Shade facilities	√	√	√
	Sports fields	√	√	√
	Fitness		√	√
	Trash Bins	√	√	√
	Restrooms	√	√	√
Landscape Design	Landscape ornaments		√	√
	Rain gardens			
	Flower beds	√	√	√
	Fountains/water features		√	√
Path System	Main Path (vehicle)		√	√
	Secondary Path (walking/bicycles)	√	√	√
	Trail (only walking)	√	√	√
Nature	Lawns	√	√	√
	Lakes/ponds	√	√	√
	Shady trees	√		
	Shrubs	√	√	√

The SOPARC method is based on the momentary time sampling technique, which involves the systematic and periodic scanning of individuals and their associated factors within predefined target areas. Although this method provides only a snapshot of users at a specific moment and may repeatedly count individuals who remain for extended periods, its validity has been widely demonstrated; therefore, the results should be interpreted as spatial-temporal occupancy intensity rather than the number of unique park visitors. Previous research has indicated that conducting 12 to 16 observations per week, ensuring the inclusion of at least one weekend day, can yield sufficiently robust estimates of park use and physical activity levels, with results that are highly consistent with up to 96 h of continuous measurement [37]. This finding provides strong theoretical support for the sampling protocol of this study. We assessed these outdoor spaces by observing the physical evidence of residents' park use.

2.2. Variables

The use of community parks by older adults is not an isolated phenomenon but is instead a complex process influenced by the interplay of multi-level factors [38,39]. This study establishes the age threshold for observation subjects at 55 years and older. Driven by China's statutory retirement age (50 or 55 years for women and 60 years for men), individuals aged 55 and above constitute the predominant demographic engaging in daytime activities within community parks. Seeking a more comprehensive understanding of the behavioral and spatial characteristics inherent to this population, the research employs a stratified classification system, categorizing participants into "younger old" (aged 55 to 74)

and "older old" (aged 75 and above) cohorts [40]. Gender is often associated with specific activity types (e.g., men preferring board games and women preferring dancing) and social patterns [41]. Furthermore, an individual's mobility directly determines their accessible range within the park and the breadth of their activity participation, making it a key indicator of the inclusivity of park design [42,43]. Therefore, to integrate these theoretical insights with objective behavioral data, this SOPARC (System for Observing Play and Recreation in Communities) observational study focused on capturing the core variables related to these key dimensions. This was achieved through the systematic recording and analysis of the age group, gender, mobility, activity type, group size, and spatiotemporal distribution of older adult users (Table 2).

Table 2. Variables and Their Analytical Roles in the SOPARC Observational Study.

Attribute Category	Observed Variable	Role in Analysis	Categories/Codes
Individual Attributes	Age Group	Serves as a core comparative variable for analyzing behavioral differences among older adults at various life stages and for assessing the extent to which park design meets the needs of different age groups.	Young old group (55–74); Oldest old group (75+)
	Gender	Used as a demographic comparative variable to explore potential differences in gender-based behavioral patterns.	Male; Female
	Mobility Status	A key variable for evaluating the inclusivity and accessibility of park design, used to analyze the activity range and behavioral constraints of individuals with limited mobility.	Mobile; Mobility-impaired; Wheelchair user
Social Attributes	Group Composition	A core metric for measuring the park's social function, used to analyze the social attributes of different activities (whether they are individually or group-oriented).	Individual; Small group (2–4 people); Large group (5+ people)
Behavioral & Spatiotemporal Attributes	Activity Type	One of the primary outcome/dependent variables, directly reflecting "what" older adults do in the park and serving as a primary target for design interventions.	
	Geographic Location	One of the primary outcome/dependent variables, used for all spatial analyses (heatmaps, clustering) to reveal "where" activities take place.	GPS coordinates of point features
	Time & Day	Serves as a contextual variable, used to analyze the "temporal patterns" of park use and to identify peak and off-peak periods.	Morning/Afternoon, etc.; Weekday/Weekend

Furthermore, to systematically capture the behavioral characteristics of older adults within high-density urban parks, this study established a pre-defined activity classification framework. Prior to the formal investigation, this framework was initially delineated through a comprehensive review of classic environmental behavior theories, including

Gehl's classification of public space activities, and integrated with a pilot study conducted in Changsha's community parks. The underlying logic of this classification aims to distinguish the diverse socio-functional demands that older adults place on spatial utilization. Complex behaviors were subsequently synthesized into four dominant forms: Performance Form, Exercise Form, Static Activities, and Interactive activities. To eliminate subjectivity, stringent coding rules were formulated. As illustrated in Table 3, each category possesses explicit physical manifestation characteristics and determination criteria.

Table 3. Classification and Coding Rules for Older Adults' Activities in Community Parks.

Type	Coding Rules & Physical Traits	Examples	Theoretical Basis
Performance	Highly organized and rhythmic activities, often accompanied by music or specific props; typically occupying large, open areas.	Square dancing, ballroom dancing, playing musical instruments, traditional opera.	Social performative activities
Exercise	Continuous physical movements with clear fitness objectives; primarily occurring in pathways or specialized equipment zones.	Brisk walking, jogging, Tai Chi, use of outdoor fitness equipment.	Necessary physical activities
Sedentary/Static	Minimal physical displacement; characterized by sitting, standing, or resting without active engagement in other tasks.	Sightseeing, napping, reading, sunbathing, people-watching.	Restorative activities
Interactive	Involving two or more individuals in verbal exchange or joint tasks; often requiring seating or specialized social infrastructure.	Chess/card playing, deep conversation, intergenerational care (childcare).	Social/Optional activities

During the framework testing phase, two observers were assigned to conduct independent double-blind coding of the pilot data. Through deliberations on disputed codes, the Dominant Behavior Rule was established to address activities with blurred boundaries. For instance, when older adults converse while briskly walking, the behavior is uniformly coded as the "Exercise Form" because its primary spatial occupation characteristic involves movement. In contrast, if two individuals converse while seated on a bench, the behavior is coded as "Interactive".

2.3. SOPARC Procedure

The data collection process strictly adhered to the SOPARC protocol to ensure data accuracy. Prior to the formal data collection, the researchers undertook a rigorous process of self-training and a pilot study to achieve a high level of intra-rater reliability. First, the researchers gained a comprehensive understanding of the tool's theoretical foundations, coding protocols, and operational procedures by systematically studying the original SOPARC training materials provided on the official Active Living Research website. Subsequently, they engaged in repeated coding exercises using official instructional videos and image samples, self-calibrating through comparisons with standard examples until their judgment of each variable reached a high degree of stability. Finally, on-site pilot observations were conducted in two of the case study parks. It should be noted that the individual attributes of the older adults in this study, such as age, gender, and mobility, were

assessed on-site by trained observers based on their physical appearance and behavioral characteristics. To maximize the consistency of these assessments, all observers underwent collaborative calibration training before the study commenced, standardizing the evaluation criteria through cross-checking and discussion. During the actual observations, in cases that were difficult to judge, observers would verify the information through brief conversations (Figure 1).



Figure 1. On-site observation photos of community parks.

Subsequently, to systematically capture the temporal rhythms of older adults' activities, this study established a rigorous time-sampling schedule. Field observations were conducted from April to May 2024. This period was selected because the climate in Changsha City during these months is mild and pleasant, encouraging a high frequency of outdoor activities, and the relatively low rainfall is conducive to consistent and repeatable observations. The observation schedule was designed to cover weekdays, weekends, and a public holiday (International Workers' Day on 1 May) to facilitate a comprehensive comparison of park usage patterns and intensity across different day types. To capture

diurnal variations, each day was divided into five observation periods, each lasting approximately three hours: early morning (6:00–8:00), morning (8:00–11:00), midday (11:00–14:00), afternoon (14:00–17:00), and evening (18:00–21:30).

2.3.1. Observation Schedule and Sampling

Field observations were conducted during the period from April to May 2024. To effectively capture behavioral patterns across varying timeframes, four full observation days were scheduled for each case study park, encompassing two weekdays, one weekend day, and one statutory holiday. Daily monitoring was divided into five standard temporal segments: early morning (06:00–08:00), mid-morning (08:00–11:00), midday (11:00–14:00), afternoon (14:00–17:00), and evening (18:00–21:30). This finding provides strong theoretical support for the sampling protocol of this study. Based on the environmental characteristics of Hongxing Community Park, Yuedao Community Park, and Hepan Community Park, we divided them into 22 distinct areas or sites (Figures 2 and 3). Within each designated time slot, two observers executed a systematic clockwise scan across 22 pre-defined target zones within the park, thereby ensuring the consistency of the observational sequence. Lasting approximately 3 to 5 min per zone, each individual scan was carefully timed to guarantee the accurate recording of the instantaneous state of all older adults present. In the event of extreme weather conditions, such as heavy precipitation or sudden temperature drops, data collection was systematically postponed to the subsequent corresponding date featuring similar weather, thus maintaining the stability of the environmental variables.

2.3.2. Standardized Modifications and Validation

Building upon the foundational SOPARC coding framework, the present study introduced three standardized extensions specifically tailored to the behavioral characteristics of older adults navigating high-density urban environments:

Attribute inference and validation: Observers categorized age brackets (ranging from 55 to 74 years or 75 years and older) alongside mobility status by relying on visual cues, including skin condition, posture, and attire. To substantiate the accuracy of these deductions without interrupting ongoing activities, observers conducted brief, randomized conversational verifications with approximately 10% of the sample (Figure 1), yielding an accuracy rate that exceeded 90%.

Precise spatial mapping: Through the integration of GPS devices, documented activity points were instantaneously anchored to high-resolution satellite basemaps. This methodological enhancement effectively elevated conventional zonal statistics to a more rigorous, coordinate-based spatial distribution analysis.

Mobility classification: The parameter of "mobility" was systematically expanded to encompass unassisted movement, assisted movement relying on aids such as canes, and wheelchair utilization. Implementing this nuanced categorization facilitated a thorough assessment of how environmental affordances accommodate older adults with varying physical capabilities.

2.3.3. Observer Training and Inter-Rater Reliability

To mitigate potential biases arising from subjective judgment, the research team underwent a rigorous one-week intensive training program prior to the formal investigation. This preparatory phase encompassed the comprehensive study of official SOPARC instructional videos alongside on-site pilot calibration exercises. During the subsequent pilot phase, two observers independently coded 50 randomized samples, allowing for the calculation of Cohen's Kappa (κ) coefficients to accurately evaluate inter-rater reliability. The analytical results demonstrated exceptionally high reliability across all assessed variables, including gender ($\kappa = 0.96$), age group ($\kappa = 0.84$), activity type ($\kappa = 0.88$), and mobility status

(κ = 0.82). These values substantially exceeded the universally recognized excellence threshold of 0.75.



Figure 2. The 22 observation sites in Hongxing Community Park, Changsha, China. (H1–H8 represent the SOPARC observation points in Hongxing Community Park.)

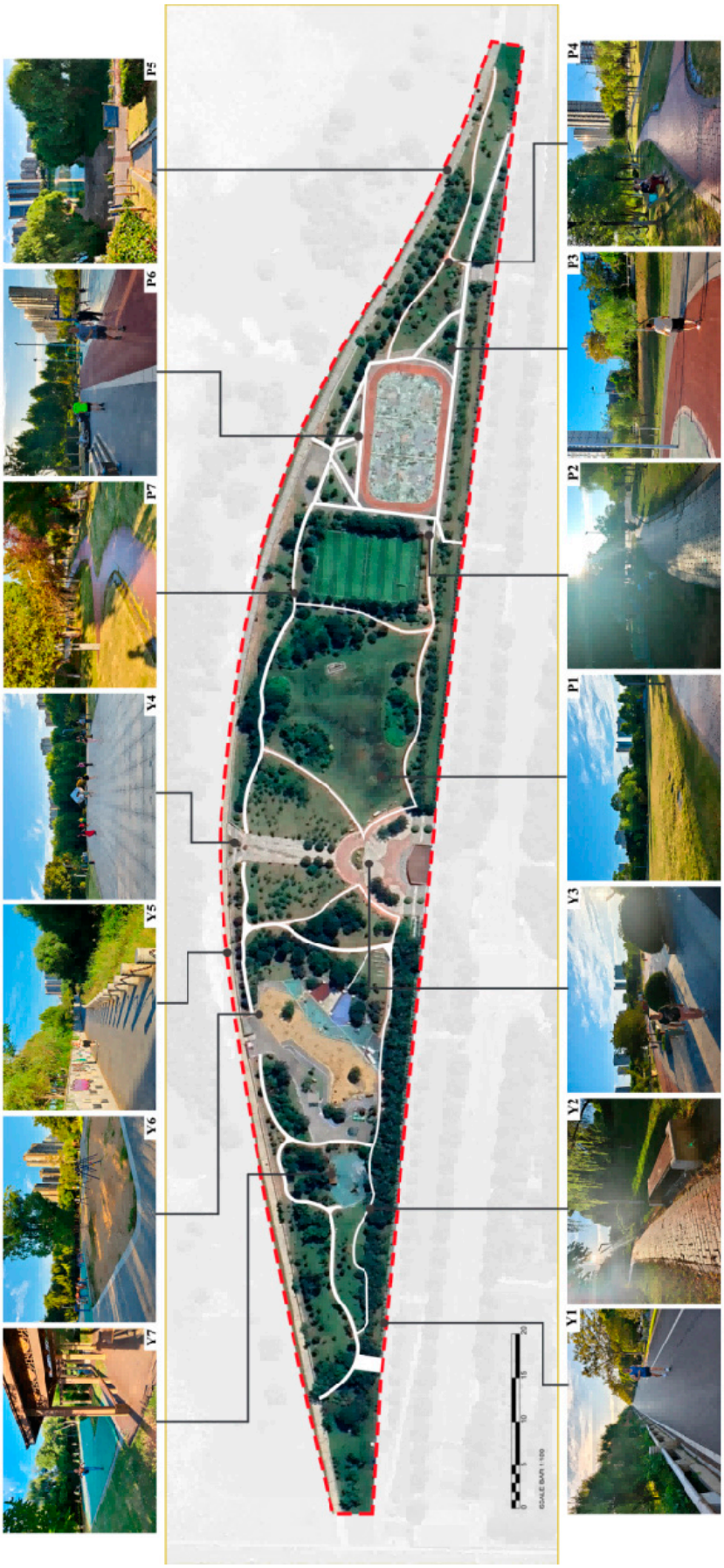


Figure 3. The 22 observation sites in He Pan & Yue Dao Community Park, Changsha, China. (Y1–Y7, P1–P7 represent the SOPARC observation points in He Pan & Yue Dao Community Park.)

2.3.4. Ethical Considerations and Privacy

This study rigorously adhered to academic ethical guidelines and obtained ethical review approval from the relevant academic institutions. Given that the research primarily employed non-participant observation methodologies conducted within public open spaces, it imposed no physiological or psychological interventions on the subjects. During the data validation process, the occasional brief conversations undertaken were exclusively for verifying demographic background information, such as age; they involved no personal privacy or sensitive data, and the duration of each interaction was strictly limited to 30 s to guarantee their non-intrusive nature. To safeguard participant privacy effectively, all photographs captured on-site (Figure 1) and geospatial data are utilized solely for the purpose of academic analysis. Furthermore, at the investigation sites, all observers wore conspicuous identification badges, proactively explained the research intent, and secured the verbal consent of the older adults prior to initiating any brief dialogue.

2.4. Data Analysis

The data analysis in this study was a multi-stage, integrated process aimed at extracting meaningful behavioral patterns and spatial insights from the collected SOPARC observation points. The analysis was conducted primarily using Microsoft Excel 2021 (Microsoft Corporation, Redmond, WA, USA) for data management, SPSS 26.0 for statistical analysis, and QGIS 3.40 for spatial analysis. The entire analytical strategy can be divided into three interconnected steps. Prior to the analysis, all SOPARC observation data, which were manually recorded in the field, were first systematically entered into Microsoft Excel spreadsheets. Subsequently, the organized attribute data table (containing information such as age group, gender, and activity type) was matched with the geographical coordinates recorded via GPS. This process culminated in the generation of a complete spatial point data layer (Shapefile) in QGIS, containing all attribute information.

Chi-square tests were employed to examine the associations between elderly individuals' physical activity types and their demographic characteristics (gender and age group). For 2×2 or 2×3 contingency tables where more than 20% of the cells had expected counts less than 5, Fisher's exact test or Yate's continuity correction was applied to ensure the accuracy of the p-values. Furthermore, to address the practical significance of the findings, effect sizes for all significant chi-square associations were calculated using Cramér's V. The strength of the association was interpreted according to Cohen's established statistical guidelines: V values between 0.10 and 0.29 indicate a small effect, values between 0.30 and 0.49 indicate a medium effect, and values of 0.50 or greater represent a large effect [44].

Kernel Density Estimation (KDE), a non-parametric statistical method, is widely used to transform discrete point data into a smooth, continuous density surface, thereby intuitively revealing the spatial clustering intensity and distributional variations in events within a study area [45]. The application of this method is well-established in the fields of geography and urban planning [46,47] and is increasingly being used to analyze the relationship between the neighborhood built environment and residents' physical activity [48]. Particularly in research focusing on older adults, KDE has been demonstrated to be an effective tool that provides reliable and stable estimation results across different spatial scales [49]. By efficiently identifying "hotspots" in spatial distributions, KDE can clearly quantify and visualize the usage density of specific populations (e.g., older adults in this study) in different spaces. Its computational principle is based on the following formula:

$$\hat{f}_h(x) = \frac{1}{n \cdot h} \sum_{i-1}^{n} K\left(\frac{x - x_i}{h}\right)$$

where X_1, X_2, . . ., X_i are the n observation points, K (•) is the kernel function with a bandwidth of h, and its input is the distance between x and one of the observation points [50]. In this study, the KDE was performed using QGIS 3.40 software. Procedural details:

(1) Bandwidth Selection: The search radius (bandwidth) was determined based on Silverman's Rule of Thumb to automatically optimize the smoothing effect according to the spatial distribution of activity points, preventing arbitrary bias in hotspot identification.
(2) Kernel Function: A Quartic kernel function was selected to ensure a smooth transition of density values across the park space.
(3) Spatial Resolution: The output cell size was set to 5 m, ensuring a high-resolution representation of micro-scale activity hotspots within the community parks.
(4) Coordinate System: All spatial data were projected into the WGS 1984 UTM Zone 49N system to ensure accurate Euclidean distance calculations in meters.
(5) Edge Effects: To mitigate edge effects, a spatial buffer was applied around the park boundaries during calculation, and the final results were clipped to the precise administrative limits of each park.

3. Results

3.1. Descriptive Statistics

This section presents a descriptive statistical analysis of the 964 data points on the valid observation samples, which were systematically collected using the SOPARC observation method. The analysis aims to systematically reveal the demographic composition, key behavioral patterns, spatial usage characteristics, and social interaction modes of the study sample through quantitative methods, thereby establishing a comprehensive empirical baseline for an in-depth understanding of the activity landscape of older adults within the case study parks in Changsha.

Of the total sample (N = 964), 389 observations (40.4%) were recorded in Hongxing Community Park, while 575 (59.6%) were recorded in Yuedao and Hepan Community Parks. In terms of gender composition, male older adults constituted 62.4% of the sample (n = 602), while female older adults accounted for 37.6% (n = 362). With respect to the age structure, the young old group (55–74 years) was the predominant user group, accounting for 86.1% of the observations (n = 830). The oldest old group (≥75 years) comprised the remaining 13.9% (n = 134). Furthermore, data on mobility indicated that the vast majority of older adults (94.9%, n = 915) moved without assistance, while 4.9% (n = 49) of the sample exhibited some form of mobility limitation.

3.1.1. Activity Composition and Variations Among Older Adult Park Users

The socio-ecological model framework posits that the park-based activities of older adults are influenced by multi-level factors [51]. The SOPARC observational data provide objective behavioral evidence for understanding these influences at the individual and socio-cultural levels. Table 4 reveals the overall landscape of the activity composition among older adults. The data indicate that among the more than 30 types of activities observed, three dominant patterns emerged, each corresponding to a distinct core need in the lives of older adults. Walking, as the most prevalent activity (accounting for 23.3% of total observations). This was followed by playing cards (11.5%) and accompanying children (9.1%).

Table 4. Statistics of the number of people participating Activity frequency.

No. of Older Adults Involved in Activity per Day	Hongxing Community Park				Yuedao & Hepan Community Park			
	Male	Female	All	%	Male	Female	All	%
Accompany kids	5	8	13	3.34%	29	30	59	10.26%
Aerobics	0	0	0	0%	0	8	8	1.39%
Ballroom Dancing	4	4	8	2.06%	0	0	0	0%
Basketball	6	0	6	1.54%	6	1	7	1.22%
Camping	0	0	0	0%	8	7	15	2.61%
Chess	10	0	10	2.57%	4	0	4	0.70%
Choir	0	0	0	0%	10	8	18	3.13%
Dog walking	7	3	10	2.57%	7	3	10	1.74%
Fast walking	0	0	0	0%	11	9	20	3.48%
Fishing	1	0	1	0.26%	4	0	4	0.70%
Flexibility exercises/stretching	1	3	4	1.03%	3	1	4	0.70%
Flute	1	0	1	0.26%	0	0	0	0%
Flying kite	0	0	0	0%	2	2	4	0.70%
Jogging	2	1	3	0.77%	24	7	31	5.39%
Machine exercise	10	1	11	2.83%	0	0	0	0%
Musical Instruments	4	0	4	1.03%	8	5	13	2.26%
Peking Opera	0	0	0	0%	3	3	6	1.04%
Play cards	78	33	111	28.53%	18	6	24	4.17%
Qi gong	8	2	10	2.57%	11	4	15	2.61%
Rolling hoop	0	0	0	0%	3	0	3	0.52%
Singing	4	2	6	1.54%	1	0	1	0.17%
Sitting	6	4	10	2.57%	35	6	41	7.13%
Softball	0	0	0	0%	10	17	27	4.70%
Square dance	4	25	29	7.46%	3	21	24	4.17%
Standing	13	13	26	6.68%	20	14	34	5.91%
Tai Chi	15	13	28	7.20%	8	6	14	2.43%
Talking	4	12	16	4.11%	20	17	37	6.43%
Traditional game	0	0	0	0%	6	0	6	1.04%
Walking	58	24	82	21.08%	98	36	134	23.30%
Watching	0	0	0	0%	2	0	2	0.35%
Wu shu	0	0	0	0%	7	3	10	1.74%
Total	241	148	389	100%	361	214	575	100%

In addition to these dominant activities, a series of low-frequency yet distinct niche activities also warrant attention, as they collectively constitute the rich ecosystem of park activities. For example, unstructured sedentary activities such as sitting (7.1%), standing (5.9%), and talking (6.4%), while not as goal-oriented as playing cards or dancing, collectively account for nearly 20% of observations. Furthermore, activities such as machine exercise (2.8%), Tai Chi (2.4%), and Qigong (2.6%), while individually accounting for small percentages, collectively form an activity cluster centered on traditional Chinese wellness culture.

The findings reveal that gender constitutes one of the prominent determinants shaping physical activity choices, with effect size analysis (Cramér's V) uncovering a distinct hierarchy of behavioral divergence. Specifically, female participants display an exceptional propensity to aggregate in square dancing, which exhibits the most robust gender association in the dataset ($V = 0.245$, $p < 0.001$). Other dynamic activities, such as aerobics ($V = 0.118$) and walking ($V = 0.108$), also demonstrate significant but weaker gender effects. By contrast, male individuals command a majority in traditional competitive and sedentary social pursuits. However, while activities like playing cards ($p = 0.025$) and playing chess

(p = 0.003) are male-dominated, their effect sizes remain relatively small (V = 0.072 and V = 0.094, respectively). This indicates that while male static socialization is prevalent, it does not dictate the overall gendered spatial distribution of the park as powerfully as female-driven performative activities. Meanwhile, behaviors including standing and practicing Tai Chi exhibit no statistically significant differences across the gender dimension (p > 0.05), thereby demonstrating a substantial degree of gender inclusivity (Table 5).

Table 5. Distribution of older adults' physical activity types by gender and age group.

	All	Gender						Age					
		Male		Female		*p*-Value	V	55–74		75+		*p*-Value	V
		N	(%)	N	(%)			N	(%)	N	(%)		
Traditional game	9	9	100.0%	0	0.0%	0.019 *	0.075	9	100.0%	0	0.0%	0.226	0.039
Square dance	53	7	13.2%	46	86.8%	<0.001 ***	0.245	50	94.3%	3	5.7%	0.074	0.057
Singing	7	5	71.4%	2	28.6%	0.622	0.016	6	85.7%	1	14.3%	0.976	0.001
Musical Instruments	18	13	72.2%	5	27.8%	0.387	0.028	11	61.1%	7	38.9%	0.002 **	0.010
Peking Opera	6	3	50.0%	3	50.0%	0.528	0.020	6	100.0%	0	0.0%	0.324	0.032
Choir	18	10	55.6%	8	44.4%	0.542	0.020	12	66.7%	6	33.3%	0.016 *	0.077
Tai Chi	42	23	54.8%	19	45.2%	0.293	0.034	30	71.4%	12	28.6%	0.005 **	0.091
Qi Gong	25	19	76.0%	6	24.0%	0.156	0.046	21	84.0%	4	16.0%	0.758	0.010
Wu shu	10	7	70.0%	3	30.0%	0.620	0.016	8	80.0%	2	20.0%	0.575	0.018
Walking	216	156	72.2%	60	27.8%	<0.001 ***	0.108	187	86.6%	29	13.4%	0.819	0.007
Fast walking	20	11	55.0%	9	45.0%	0.487	0.022	18	90.0%	2	10.0%	0.610	0.016
Jogging	34	26	76.5%	8	23.5%	0.086	0.055	33	97.1%	1	2.9%	0.060	0.061
Machine exercise	11	10	90.9%	1	9.1%	0.050 *	0.063	10	90.9%	1	9.1%	0.643	0.015
Flexibility stretching	8	4	50.0%	4	50.0%	0.465	0.024	8	100.0%	0	0.0%	0.254	0.037
Ballroom Dancing	8	4	50.0%	4	50.0%	0.465	0.024	8	100.0%	0	0.0%	0.254	0.037
Softball	27	10	37.0%	17	63.0%	0.006 **	0.089	22	81.5%	5	18.5%	0.482	0.023
Aerobics	8	0	0.0%	8	100%	<0.001 ***	0.118	8	100.0%	0	0.0%	0.254	0.037
Basketball	13	12	92.3%	1	7.7%	0.025 *	0.072	13	100.0%	0	0.0%	0.145	0.047
Play Cards	135	96	71.1%	39	28.9%	0.025 *	0.072	123	91.1%	12	8.9%	0.070	0.058
Chess	14	14	100.0%	0	0.0%	0.003 **	0.094	6	42.9%	8	57.1%	<0.001 ***	0.152
Talking	53	24	45.3%	29	54.7%	0.008 **	0.085	49	92.5%	4	7.5%	0.169	0.044
Sitting	51	41	80.4%	10	19.6%	0.007 **	0.088	37	72.5%	14	27.5%	0.004 **	0.093
Standing	60	33	55.0%	27	45.0%	0.219	0.040	53	88.3%	7	11.7%	0.606	0.017
Watching	2	2	100.0%	0	0.0%	0.272	0.035	2	100.0%	0	0.0%	0.569	0.018
Fishing	5	5	100.0%	0	0.0%	0.082	0.056	5	100.0%	0	0.0%	0.368	0.029
Accompany kids	72	34	47.2%	38	52.8%	0.006 **	0.089	71	98.6%	1	1.4%	0.001 **	0.103
Dog walking	20	14	70.0%	6	30.0%	0.481	0.023	14	70.0%	6	30.0%	0.035 *	0.068
Flying kite	4	2	50.0%	2	50.0%	0.606	0.017	4	100.0%	0	0.0%	0.421	0.026
Camping	15	8	53.3%	7	46.7%	0.463	0.024	6	40.0%	9	60.0%	<0.001 ***	0.168

* p < 0.05; ** p < 0.01; *** p < 0.001. p-values were calculated using Pearson's chi-square test; Fisher's exact test was applied when the expected cell count was less than 5. n is the number of participants, and (%) represents the proportion within each activity group. Cramér's V (V) values indicate the effect size or the strength of association (V < 0.10 = very small effect; 0.10 ≤ V < 0.30 = small to moderate effect; 0.30 ≤ V < 0.50 = moderate to large effect).

The transition from the younger old (aged 55–74) to the older old (aged 75+) cohort is accompanied by shifting spatial requirements, corroborated by distinct effect sizes. The pronounced age-related divergences are observed in camping/gathering (V = 0.168, p < 0.001) and playing chess (V = 0.152, p < 0.001), highlighting the older old cohort's heightened reliance on static, community-oriented nodes. Conversely, childcare engagements are almost exclusively concentrated within the younger-old demographic (98.6%). Although the overall effect size for childcare is modest (V = 0.103, p = 0.001) due to the specific subgroup size, this extreme compositional asymmetry exposes a profound functional lock-in, powerfully reflecting their central role in providing intergenerational family support. Beyond these age-specific trends, fundamental activities like walking do not exhibit significant variance

between the two cohorts (p = 0.819), a consistency that highlights the universal appeal of basic mobility exercises across all stages of later life.

Of the 389 activity observations recorded in this park, "playing cards" accounted for an overwhelming 28.5%, far exceeding all other activities. A time series analysis further reinforces this finding (see Table 6): the activity of playing cards was not only frequent but also demonstrated strong daily stability, occurring at a high frequency on all observation days (Mean daily frequency M = 23.8, SD = 8.7) without significant cyclical fluctuations.

Table 6. Number of people observed to be active daily.

	Hongxing Community Park					**Yuedao & Hepan Community Park**				
	4/9	**4/11**	**4/14**	**4/17**	**4/18**	**4/23**	**4/25**	**4/27**	**4/28**	**5/1**
Accompany kids	0	2	5	2	4	12	11	14	8	14
Aerobics	0	0	0	0	0	8	0	0	0	0
Ballroom Dancing	0	0	0	8	0	0	0	0	0	0
Basketball	2	0	1	0	3	0	7	0	0	0
Camping	0	0	0	0	0	6	0	2	0	7
Chess	2	0	0	4	4	0	2	0	2	0
Choir	0	0	0	0	0	0	0	0	0	18
Dog walking	1	2	2	2	3	4	0	0	3	3
Fast walking	0	0	0	0	0	0	11	3	3	3
Fishing	0	0	1	0	0	0	0	4	0	0
Flexibility exercises/stretching	2	0	0	1	1	2	0	0	1	1
Flute	0	1	0	0	0	0	0	0	0	0
Flying kite	0	0	0	0	0	2	0	0	0	2
Jogging	3	0	0	0	0	6	13	7	2	3
Machine exercise	2	0	2	2	5	0	0	0	0	0
Musical Instruments	0	0	2	2	0	0	0	10	3	0
Peking Opera	0	0	0	0	0	0	0	6	0	0
Play cards	36	29	20	14	12	4	0	12	8	0
Qi gong	2	1	1	6	0	0	3	9	3	0
Rolling hoop	0	0	0	0	0	0	3	0	0	0
Singing	0	3	2	0	1	0	0	1	0	0
Sitting	0	2	2	4	2	6	2	15	8	10
Softball	0	0	0	0	0	18	0	0	9	0
Square dance	6	6	6	0	11	12	12	0	0	0
Standing	7	2	2	10	5	4	8	13	5	4
Tai Chi	7	12	0	0	9	0	6	0	0	8
Talking	0	3	4	7	2	2	8	15	7	5
Traditional game	0	0	0	0	0	3	0	3	0	0
Walking	5	14	27	12	24	37	33	29	18	17
Watching	0	0	0	0	0	2	0	0	0	0
Wu shu	0	0	0	0	0	0	5	5	0	0
Total	75	77	77	74	86	128	124	148	80	95

In stark contrast, Yuedao and Hepan Community Parks exhibit functional generalization, with a polycentric activity structure. Among the 575 activity observations in these parks, no single activity was absolutely dominant; the most prevalent activity, "walking" (23.3%), along with several others such as "accompanying children" (10.3%) and "sitting" (7.1%), collectively formed a diverse and balanced activity ecosystem. In terms of temporal dynamics, these parks displayed a heterogeneous pattern characterized by both foundational stability and cyclical fluctuations. Foundational activities (e.g., "walking") maintained a stable, high frequency across all observation days. However, certain group activities (e.g., "choir," "soft gymnastics") demonstrated strong episodic characteris-

tics, with participation numbers showing a pulse-like surge primarily on weekends and public holidays.

3.1.2. Temporal Dynamics and Gendered Analysis of Social Interaction Modes

An in-depth examination of social interaction modes not only reveals the diurnal rhythms of the parks' social functions but also elucidates how individual attributes (such as gender) and the socio-cultural environment jointly regulate the use of public space. Figure 4 quantitatively illustrates the significant temporal differentiation among three social modes, individual, small group, and large group, and their distinct socially gendered characteristics. First, the individual activity mode (Single) exhibits a significant bimodal distribution, with peaks in frequency occurring in the early morning (06:00–08:00) and evening (17:00–21:30) periods. The data show that during these two activity windows, which are primarily composed of individualized physical exercise, the participation frequency of males was statistically higher than that of females. The small group activity mode dominated the non-peak daytime hours, forming two other frequency peaks in the morning (08:00–11:00) and afternoon (14:00–17:00). In terms of gender composition, male participation remained higher than that of females during most of these periods. This finding is consistent with the male-dominated characteristic of card-playing activities identified in the preceding activity type analysis, further corroborating the importance of specific interest-oriented activities in the construction of male peer social networks. The large group activity mode presented markedly different temporal and gender distribution characteristics compared to the other modes. Its activity frequency was highly concentrated in the evening period, during which the gender composition of participants underwent a significant reversal, with female participation frequency far exceeding that of males.

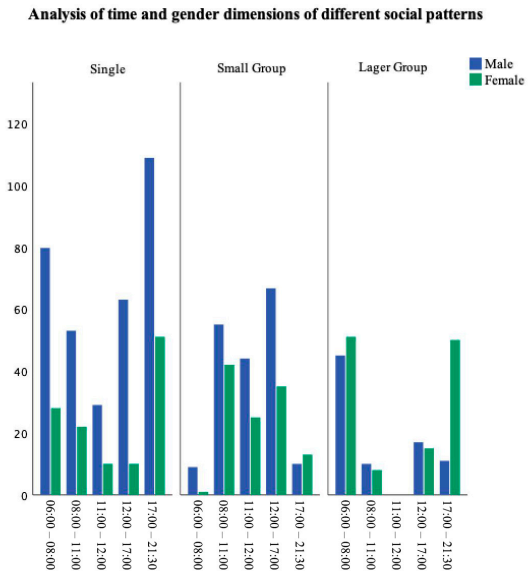


Figure 4. Analysis of time and gender dimensions of different social patterns.

3.2. Spatial Analysis of Older Adults' Activity Types

This study employed Kernel Density Estimation (KDE) to spatialize 964 valid observation samples, aiming to identify the spatial clustering characteristics of varying activity typologies within the context of high-density cities. Grounded in the classification framework delineated in Section 2.2, this research categorized the activity systems of older adults into four dominant forms. The specific activity contents, spatial preferences, and social characteristics inherent to each type are detailed in Table 7. The results of the KDE analysis indicate that the spatial behaviors of older adults within community parks manifest a

pronounced non-randomness, exhibiting distinct clustering patterns that are contingent upon their functional requirements (Figures 5 and 6).

Table 7. Types of activities for the older adults.

Activity Type	Activity Content	Space Location	Activity Intensity	Social Form	Activity Entity	Numbers
Performance Form	Traditional game	Entrance Plaza	High	Group/Individual	Male	1–3
	Square dance	Small Plaza/Entrance Plaza	High	Group	Female	10+
	Singing	Plaza/Shade/Riverside	Light	Group/Individual	Male and Female	1–3
	Musical Instruments	Shade/Riverside	Light	Group/Individual	Male and Female	1–5
	Peking Opera	Lawn	Moderate	Group	Male and Female	Not fixed
	Choir	Entrance Plaza	Moderate	Group	Male and Female	10+
Exercise Form	Tai Chi/Qi Gong/Wu shu	Small Plaza/Entrance Plaza	High	Group	Male and Female	5–20
	Walking/Fast walking/Jogging	Riverside/Lakeside/Path/Sports Field	Activity Intensity	Individual	Male and Female	1–2
	Machine exercise	Fitness Area	High	Individual	Male	Not fixed
	Flexibility exercises/Stretching	Shade/Riverside	Moderate	Group/Individual	Female	Not fixed
	Ballroom Dancing/Softball/Aerobics	Small Plaza/Entrance Plaza	High	Group	Female	Not fixed
	Basketball	Basketball Court	High	Group/Individual	Male	Not fixed
Static Activities	Play Cards/Chess	Shade/Riverside	Light	Group	Male and Female	3–6
	Flower viewing	Riverside/Lakeside/Garden	Very Light	Group/Individual	Male and Female	1–2
	Participate in community gardening (such as watching fish, camping, etc.)	Pavilion/Shade/Seating	Light	Group/Individual	Female and Children	Not fixed
	Talking/Rest	Shade/Seating	Very Light	Group/Individual	Male and Female	1–5
Interactive	Accompany kids	Children's Playground/Sports Field/Lawn	Vigorous	Group	Diverse combinations	2–4
	Dog walking/Flying kite	Lawn/Path	Vigorous	Individual	Male and Female	1–2
	Health Lectures	Small Plaza/Entrance Plaza	Light	Group	Male and Female	10+

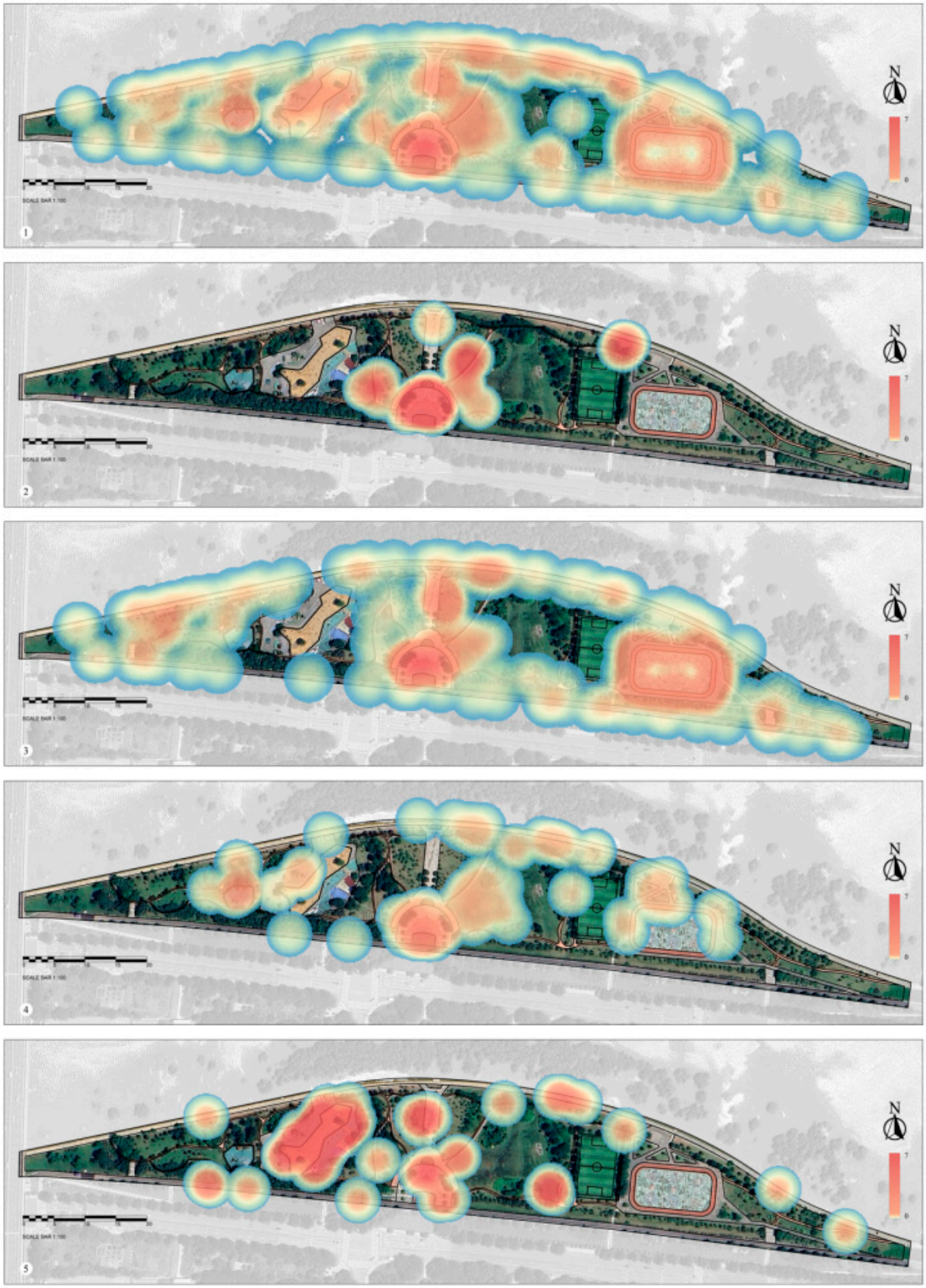


Figure 5. Spatial distribution of outdoor activities for older adults in Yuedao & Hepan community parks. (1. Overall activities; 2. Performance activities; 3. Exercise activities; 4. Sedentary activities; 5. Interactive activities.)

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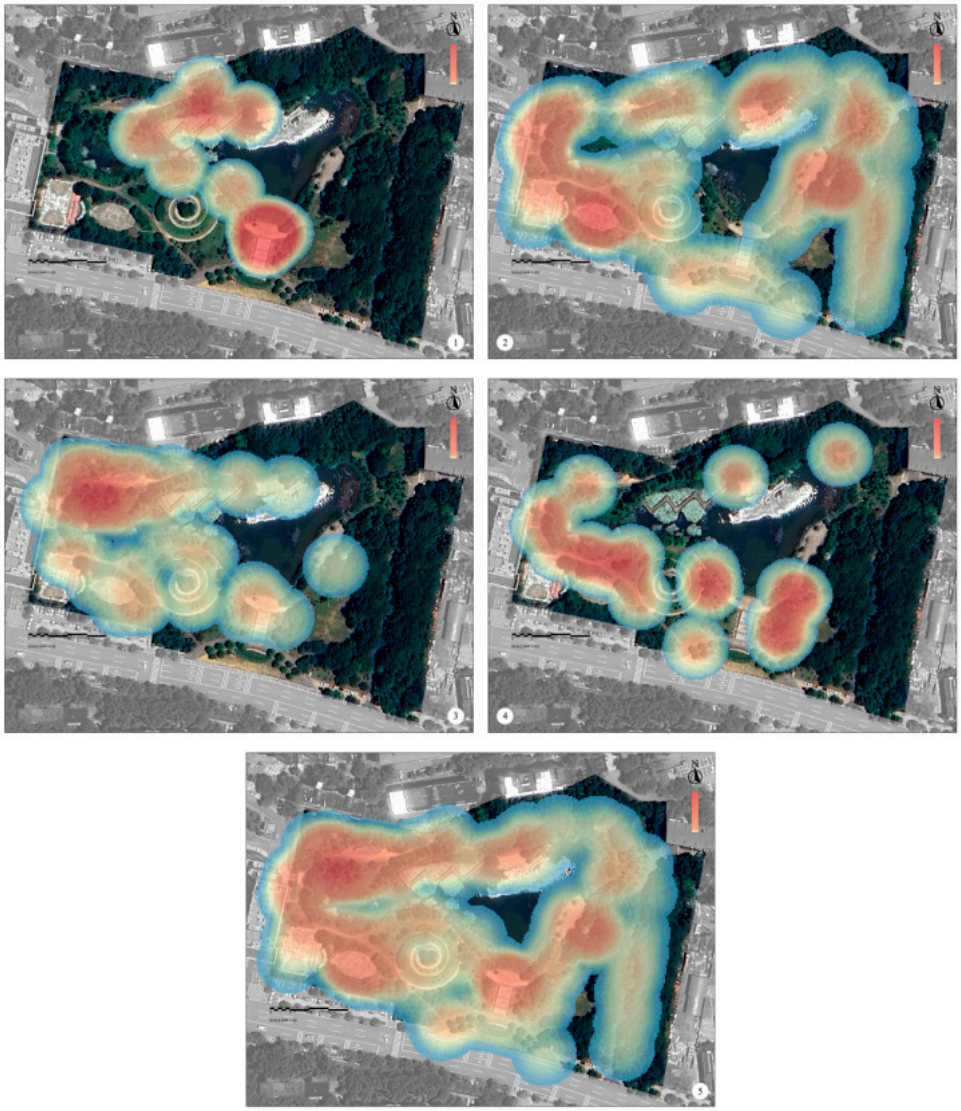


Figure 6. Spatial distribution of outdoor activities for older adults in Hongxing community parks in Changsha, China. (1. Performance activities; 2. Exercise activities; 3. Sedentary activities; 4. Interactive activities; 5. Overall activities.)

3.2.1. Functional Clustering in Hepan & Yuedao Park

As illustrated in the KDE mapping (Figure 5), the observational data for older adults' activities within Hepan and Yuedao Community Parks demonstrate highly pronounced functional clustering. For performance-based activities, observation frequencies are intensely concentrated in the eastern entrance plaza and the central activity area (Figure 5, Boxes 1 and 2), thereby verifying the profound reliance of such collective activities on expansive, hard-surfaced planar spaces. Exercise-oriented engagements reveal a distinctively linear pattern of spatial occupation. These activity hotspots are predominantly distributed along the main park roads and lakeside trails, while forming localized secondary peaks within the dedicated fitness equipment zones (Figure 5, Box 3), a distribution that clearly highlights the guiding role of pathway connectivity. Static activities present a dispersed, point-like distribution. Their high-intensity occupation zones are densely clustered around shaded areas along the river, benches, and pavilions (Figure 5, Box 4), reflecting a heightened sensitivity to micro-environmental comfort. Interactive activities manifest an extreme phenomenon of functional lock-in, with activity hotspots being almost entirely drawn to the children's play facilities on the western side (Figure 5, Box 5). This concentration

vividly illustrates the profound dependence of intergenerational caregiving behaviors on specific amenities.

3.2.2. Morphological Logic in Hongxing Park

Diverging from the linear structure of the former, the loop-based layout of Hongxing Community Park demonstrates an alternative and highly efficient model of spatial organization. An examination of the KDE analysis (Figure 6) clearly identifies a behavioral distribution logic grounded in surface, line, and point geometric typologies. Serving as a highly integrated physical center, the northwestern entrance plaza acts as the principal host for performance-based activities (Figure 6, Box 1), thereby providing the requisite spatial conditions to function as a large-scale social stage. Exercise-oriented activities align seamlessly with the lakeside loop trail (Figure 6, Box 2), where the core natural landscape, specifically the lake view, significantly amplifies the motivational capacity of the pathway as a conduit for physical exertion. Observational frequencies for static activities are densely concentrated at resting nodes along this loop, including waterfront pavilions and shaded benches (Figure 6, Box 3), effectively cultivating a micro-spatial network that sustains spontaneous social interaction and recuperation. Regarding the phenomenon of functional lock-in, consistent with previous case studies, interactive engagements once again demonstrate a profound spatial binding to specific amenities, such as caregiving vantage points situated adjacent to fitness equipment zones (Figure 6, Box 4).

4. Discussion

4.1. Contributions to and Reflections on Existing Knowledge

Taking typical community parks in Changsha as case studies, this research comprehensively employs multiple quantitative analytical methods, including SOPARC, KDE, and Chi-square tests, to conduct field investigations. This methodological approach aims to systematically collect and analyze the physical activity data of older adults alongside their spatial distribution characteristics. Diverging from previous literature that predominantly focuses on the qualitative description of activity preferences among the elderly, the current investigation identifies the significant impacts of gender and age on their activity selections. Guided by these demographic influences, complex physical behaviors are scientifically categorized into four core patterns. By integrating quantitative analysis with this systematic classification, the study enables a more precise identification of the differentiated environmental demands exhibited by various subgroups of older adults. Such distinct spatial requirements encompass the carrying capacity of central plaza spaces for collective dynamic activities, the appeal of enclosed under-canopy spaces for static socialization patterns, and the crucial spatial supporting role of auxiliary facility sites in intergenerational caregiving and functional rehabilitation engagements.

While older adults have specific requirements for physical environments that support outdoor activities, their internal expectations for social participation and needs for spatial security may frequently act as deeper factors influencing their activity choices [52]. Our observational findings indicate that older adults' outdoor activity trajectories are not randomly distributed but exhibit significant spatial clustering, which might reflect selective preferences for specific environmental features to some extent. The high-intensity activity hotspots identified through KDE analysis (as detailed in Table 7) correspond well with the socio-demographic statistical associations found in this study. For instance, square dancing groups exhibit a significant gender association ($V = 0.245$, $p < 0.001$) and are concentrated in central plaza areas with open sightlines (Box 1 in Figure 5). This phenomenon could potentially be explained by the fact that open spatial forms provide the necessary visual permeability for collective activities, thereby better supporting interaction and observation

among members. Although existing literature frequently mentions the social benefits of informal spaces, older adults in this study still showed a tendency to gather in central areas with higher pedestrian density and clear visibility; combined with previous research, this might partially stem from their potential concerns regarding fall risks or social isolation [53]. Similarly, the age-related binding observed in childcare activities (V = 0.103, p = 0.001) aligns with the hotspot distribution around children's play facilities, reflecting a potential functional spatial lock-in. Based on these observed associations between behavior and spatial characteristics, we suggest that future park design could benefit from a more nuanced consideration of older adults' internal needs for mutual assistance and passive observation. To attempt to balance the psychological demands for spatial security with the desire for social participation in public spaces, planning practices might consider providing appropriate open hardscape nodes supplemented by well-designed visual corridors.

In addition, regarding the impact of enclosed spaces beneath the tree canopy on the physical activities of older adults, the existing literature presents contradictory conclusions. Some studies contend that open spaces with high visibility are more conducive to promoting social participation among the elderly, whereas heavily enclosed areas beneath tree canopies are frequently perceived as negative spaces due to potential safety hazards [54]. Conversely, other investigations have failed to identify a significant negative correlation between spatial enclosure and the activity levels of older adults [55]. The findings of this study contribute a quantitative perspective to this debate, suggesting that the physical characteristics of enclosed spaces beneath tree canopies may act as critical environmental affordances that attract specific subgroups to engage in static socialization patterns. As demonstrated by the data analysis, the activity of playing chess exhibits a significant age-related dependency (V = 0.152, $p < 0.001$) and consistently clusters spatially within semi-enclosed micro-environments equipped with seating and natural shading. This spatial mapping appears to align with previous research, indicating that semi-enclosed spaces—by providing natural shade and a distinct sense of boundary, might significantly enhance the willingness of older adults to partake in prolonged, territorial social interactions [56].

Similar research within Chinese communities has identified a unique "informality" in how older adults utilize public spaces. Even in the absence of standardized sports facilities, shaded areas beneath trees and corners with a defined sense of boundary remain the "preferred sites" for high-density social activities, including playing cards and performing traditional opera [57]. The KDE spatial mapping in this study appears to align with this observed phenomenon of informal spatial appropriation. From a socio-ecological perspective, this pattern might be associated with the specific Chinese cultural context, where socialization among older adults often demonstrates strong collective and group-oriented attributes. Semi-enclosed spaces under the tree canopy not only provide physiological comfort by offering protection from sun and wind but also potentially provide essential environmental affordances. These spatial characteristics may help foster a perceived sense of territoriality that minimizes external distractions, which could potentially facilitate higher-quality social interactions [58,59]. Furthermore, our observations suggest that the placement and density of resting amenities (e.g., benches) within these shaded nodes could serve as critical environmental affordances influencing the duration of outdoor stays. This observation aligns with Chen et al. (2023) [60], who proposed that a high density of resting facilities can significantly foster opportunities for spontaneous socialization. Given the varying physical capacities of older adults—particularly the oldest-old and mobility-impaired cohorts observed in our study—future seating configurations might need to be more abundant and ergonomically diverse to inclusively accommodate users of all functional levels [61].

Utilizing fitness equipment is regarded as one of the most common physical activities for older adults within parks, as they frequently engage in functional exercise in zones

equipped with stationary facilities [62]. In Malaysia, well-planned open-air fitness areas and linear trails within community parks are identified as significant factors in attracting older adults and extending their outdoor stay [63]. A similar trend is observed in China, where auxiliary facility spaces indirectly increase the total duration of outdoor activity by drawing older adults into daily exercise and childcare routines [64]. These findings align with the conclusions of our study, which indicate that the accessibility and functional diversity of auxiliary facility spaces significantly influence spatial utilization rates among the elderly. Consequently, establishing integrated fitness and recreational hubs within the core areas of parks has the potential to elevate physical activity levels, addressing the dual challenges of social isolation and physical inactivity that scholars have identified as critical issues in contemporary aging societies [65–67].

4.2. Implications for Future Community Park Design Practice and Research

Our findings suggest that as older adults age, their activity patterns demonstrate a noticeable shift toward "sedentarization" and spatial withdrawal, characterized by a heightened reliance on micro-spaces equipped with supportive affordances such as seating and shade. Statistical evidence corroborates this trend, showing that the older-old cohort (aged 75+) has significantly higher participation in static social activities, including playing chess ($V = 0.152$, $p < 0.001$) and camping/gathering ($V = 0.168$, $p < 0.001$). This behavioral preference is precisely mapped onto the KDE hotspots identified at resting nodes, such as waterfront pavilions and shaded benches (Box 4 in Figure 5; Box 3 in Figure 6). These correlations imply that future age-friendly park design might benefit from prioritizing the high-density integration of fragmented rest nodes within path systems, such as ergonomic seating every 50 m, rather than focusing exclusively on large assembly plazas or long-distance fitness trails. Such micro-spatial provisions could potentially better accommodate individuals using wheelchairs or walking aids, thereby supporting observed low-consumption activities like sitting, watching, and playing cards. While previous studies emphasized the role of continuous barrier-free trails in promoting dynamic exercise [68], the extreme reliance on localized micro-environments observed in this study suggests that large-scale connected spaces without adequate rest intervals might potentially present accessibility challenges for functionally limited seniors. Consequently, future research could further examine how seasonal micro-climatic factors influence the spatial choices and duration of stay for these site-dependent, sedentary groups across diverse urban green spaces.

Encouraging older adults to spontaneously extend their outdoor stays is a vital precursor to fostering active physical engagement and informal social interaction. Our findings suggest that key environmental indicators, such as spatial visual accessibility and the sense of enclosure in under-canopy spaces, may exert differentiating influences on the outdoor behavioral preferences of various gender groups. While existing frameworks, such as the Law on the Construction of a Barrier-Free Environment, provide macro-level guidance, this study further proposes that community parks could benefit from the concept of spatial folding to establish a multi-layered, categorized provision of activity venues. Specifically, for female-dominated collective activities (e.g., square dancing), which exhibited a robust gender association ($V = 0.245$, $p < 0.001$) and clustered heavily in open plazas (Box 1 in Figure 5), design interventions might focus on providing unobstructed, level, and highly visible performative spaces. Conversely, to accommodate the selective preference of male participants for static socialization like cards and chess ($V = 0.072$ to 0.094, Table 5), planners might consider provisioning semi-enclosed units equipped with weather-protective canopies at the high-density shaded nodes identified by KDE analysis (Box 4 in Figure 5). Integrating age-friendly fitness equipment within these functional zones could potentially

encourage more diversified physical engagements. Furthermore, while introducing sensory landscapes around these areas holds potential for psychological restoration, future research is needed to more precisely investigate micro-preferences, such as specific equipment types and seating arrangements, to provide a more rigorous evidence-based foundation for precision design interventions.

Our quantitative analysis, alongside KDE spatial mapping, highlights a robust association between children's play facilities and the outdoor trajectories of the younger-old cohort (aged 55–74). As descriptive data indicates, this demographic accounts for nearly all intergenerational caregiving observations (98.6%, $p = 0.001$, V = 0.103), representing a functional lock-in that physically manifests as extreme spatial clustering around children's activity zones (Box 5 in Figure 5). Based on these observations, children's play areas could be reconceptualized as implicit intergenerational composite spaces. Consequently, design practices might benefit from addressing caregivers' spatial affordance needs for visual supervision and intermittent physical recovery, rather than solely focusing on children's play equipment. Instead of isolating age-specific zones, planners might consider strategically integrating ergonomic seating, shaded pavilions, and low-intensity flexibility equipment, such as Tai Chi wheels, within the safe visual catchment of play structures. Such a composite spatial provision could potentially ensure comprehensive sightlines for caregiving while simultaneously affording opportunities for fragmented, light physical activity and peer socialization during caregiving intervals. While previous literature suggests that the prevalent Chinese "intergenerational caregiving" model and concerns for grandchildren's safety frequently coincide with reduced moderate-to-vigorous physical activity among older adults [69,70], the exact mechanisms by which micro-environmental improvements (e.g., optimizing visual corridors and seating orientations) might mitigate this functional conflict require further investigation. Future research exploring these targeted spatial interventions could be instrumental in achieving a synergistic effect between children's free play and active health maintenance for the elderly.

Current Chinese policy frameworks, such as the "Healthy China 2030" Planning Outline and various urban renewal policies, explicitly advocate for the creation of health-supportive natural ecological environments for older adults. The Kernel Density Estimation (KDE) results of this study indicate that areas performing well in terms of natural ecological shading and micro-environmental richness exert a significant attraction for static socialization and prolonged stays among older adults, particularly the male demographic. This aligns with previous Chinese research on age-friendly landscapes, which suggests that seniors prefer engaging in informal social interaction and daily rest within green spaces characterized by high vegetation coverage, favorable microclimates, and abundant natural elements [71]. Beyond meeting the demand for hard-surfaced activity areas, community park planning should incorporate diverse and psychologically soothing natural environmental elements to provide older adults with increased opportunities for nature contact and mental restoration. Furthermore, aromatic plants, seasonally changing tree species, shallow water features, and resting facilities made of natural wood should be introduced around social spaces frequently used by the elderly to enhance the greening quality of community parks and create a more therapeutic wellness environment. These natural elements not only effectively improve local thermal comfort but also help alleviate loneliness, reduce mental stress, and maintain cognitive health through multi-sensory natural stimulation [72–74]. Future quantitative empirical research is needed to deeply explore the micro-preferences of different age groups and functional limitation levels among the elderly toward specific natural sensory elements (such as visual color, olfactory scent, and material texture), in order to formulate more detailed practical guidance for the design of therapeutic age-friendly community parks.

5. Limitations and Future Research

This study collected 964 SOPARC observation samples within typical community parks in Changsha, aiming to quantitatively reveal the correlations between the physical activity patterns of older adults and micro-spatial characteristics. In practice, through systematic instantaneous scan mapping and descriptive spatial analysis (such as KDE), we successfully constructed behavioral hotspot maps of existing users within a specific season. However, constrained by the inherent attributes of cross-sectional field observations, this methodology fundamentally relies on observer-based visual judgments to categorize critical demographic variables such as age groups and mobility status. Although rigorous measures, including a one-week intensive observer training program and on-site brief verifications for ambiguous cases, were implemented alongside a 10% conversational validation to mitigate gross misclassifications, we critically acknowledge that these measures cannot ensure absolute accuracy. The inherent subjective bias of visual estimation cannot be completely resolved; factors such as individual variations in physiological aging, seasonal clothing choices, or concealed mobility constraints could inevitably lead to categorization errors, particularly at the boundary threshold between the younger old (55–74) and older old (75+) cohorts. Consequently, the findings regarding age-specific and mobility-specific spatial preferences in this study should be interpreted with caution, serving as observational correlational trends rather than definitive demographic facts; meanwhile, the practice of merging data from multiple parks to extract common regularities may obscure local spatial heterogeneity, and purely objective observation cannot reach the internal behavioral motivations of users or the demand barriers of non-user groups. Consequently, future research urgently needs to integrate questionnaire surveys or in-depth interviews to obtain direct subjective driving force data, and attempt to conduct cross-regional comparative tracking analyses, thereby providing more comprehensive and profound theoretical support for design interventions in all-age/age-friendly public spaces.

6. Conclusions

This study employs research methodologies such as SOPARC and KDE to explore the associations between physical activity patterns of older adults and micro-spatial environmental characteristics within typical community parks in Changsha, China. Grounded in field behavior observations within a specific climatic and regional cultural context, this research highlights potential physical environmental elements that may influence the outdoor activities of different elderly sub-populations. The findings suggest that high-frequency space utilization appears to be closely associated with the demographic characteristics of the users. First, the visual accessibility and openness of central plazas emerge as important factors associated with hosting female-dominated collective activities (such as square dancing), whereas the semi-enclosure and natural shading of under-canopy spaces are significant characteristics linked to male seniors engaging in static socialization (such as playing cards and chess). Second, the data indicates that areas surrounding children's play facilities are closely linked to high-frequency intergenerational caregiving activities among the younger old (aged 55–74). Furthermore, high-density configurations of micro-supportive spaces, such as resting benches, are suggested to be important correlates for the activity boundaries and duration of stay for the older old (aged 75 and above) and those with functional limitations.

Based on these observational findings, this study provides an empirical foundation for the refined planning and spatial optimization of future age-friendly community parks. By considering the "classified spatial provision" strategies discussed in this study, urban planners and landscape architects may more effectively balance the allocation of barrier-free open display plazas, semi-private under-canopy social units, and composite intergenera-

tional caregiving spaces within park systems. Such spatial intervention strategies, grounded in observed behavioral patterns, can potentially respond to and support the diversified outdoor activity needs of various elderly groups, contributing to the construction of more inclusive and vibrant healthy-aging communities.

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