Behaviours of older adults in urban outdoor environments during warm days

Sandra Lujic

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Department of Earth Sciences
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Mailing address
Geovetarcentrum
S 405 30 Göteborg

Address
Geovetarcentrum
Guldhedsgatan 5A

Telephone
031-786 19 56

Geovetarcentrum
Göteborg University
S-405 30 Göteborg
SWEDEN

Abstract

As a result of climate change, heat waves are expected to increase in frequency, duration, and severity, which is particularly threatening to the urban population. Vulnerable groups, including the older population, are more likely to be affected by adverse health effects due to heat exposure. Mitigation measures to improve thermal comfort and reduce human heat stress in outdoor spaces require including various urban design strategies while also considering the needs of the population. This study aimed to investigate heat's effects on older adults' behaviour in urban outdoor environments during warm days and to identify factors that may affect their experiences. Several spatial characteristics, including urban areas, tree canopy fraction, normalized building volume, proximity to water, and individual factors of age and health status of older adults, were analyzed to discover relationships between their preferences regarding outdoor activities and the use of outdoor space. Questionnaire survey data was used to perform statistical analysis through one-way ANOVA to investigate statistical significance between the means of different groups. The findings showed that older age groups and adults with worsened health had, on average, a stronger preference for staying indoors and avoiding outdoor activities during warm days than younger age groups and older adults with very good health. In terms of spatial characteristics, older adults living in areas with high tree canopy fraction had, on average, a stronger preference to perform outdoor activities during warm days than older adults living in areas with low tree canopy fraction. Additional findings were that older adults found sunlit places in the city undesirable environments during warm days. In contrast, places with wind/good ventilation and shade from greenery were considered desirable environments. These findings highlight the importance of including the needs of older adults to understand how urban design can improve thermal comfort and encourage their use of outdoor space during warm days.

Keywords: *Older adults, urban outdoor environments, behaviour, preferences, thermal comfort*

Acknowledgments

With this master's thesis, I now finish my five-year education in geography at the University of Gothenburg. The process during this thesis has been an exciting and challenging journey, with a learning curve containing both highs and lows. Above all, the last few months have been incredibly educational, where I have had the opportunity to implement my knowledge into a larger project, which has further deepened my interest in urban planning and climate adaptation.

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Sandra Lujic

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1. Introduction

More than half of the human population lives in urban areas today, and by 2030, the global share of the urban population is expected to reach above 60 percent (United Nations, 2020). Urban population growth, global climate change, and increasing pressure from heat-related weather events are causing significant challenges for cities worldwide (IPCC, 2022). According to climate predictions, heatwaves will significantly increase in occurrence, intensity, and duration over the next century (IPCC, 2022; Park et al., 2021; Macintyre et al., 2018). Extended periods of heat waves are associated with various health consequences, including heat exhaustion, heat stress, heatstroke, and death (Macintyre et al., 2018). In Sweden, 88 % of the population lives in urban areas (SCB, 2020), which leaves them vulnerable to the present and future impacts of heat exposure due to the urban heat island (UHI) effect. Previous studies found that older adults and people with cardiovascular diseases are the most vulnerable to thermal discomfort and heat-related health impacts (Public Health Agency of Sweden, 2018; Klemm et al., 2015).

Climate effects in cities during heat waves are complex, and the magnitude of UHI effects varies depending on the spatial characteristics in the local environment, including differences in land use, building density and height, surface materials, and quantity of vegetation cover, among others (Macintyre et al., 2018; Park et al., 2021). Various climate adaptation measures can be implemented to protect the population from negative health consequences and promote thermal comfort in urban environments. These include measures such as changing the building geometry for shadowing access and increasing urban greenery and the proportion of open water surfaces to promote air and surface cooling (Oke, 2017; Park et al., 2021; Bing et al., 2021; Klemm et al., 2015).

Studies of outdoor thermal comfort are essential to understand the factors that impact human health in urban environments during warm weather and heat waves. However, researchers have demonstrated that direct factors alone, including physical and physiological factors, are inadequate for understanding the needs and preferences of urban populations in outdoor environments (Cheung & Jim, 2018; Yung, Wang & Chau, 2019). Instead, the knowledge of outdoor thermal comfort has been developed in recent years to incorporate more indirect influential aspects, such as spatial characteristics and individual aspects (Lai et al., 2020).

Until this day, only a limited amount of research has been dedicated to investigating the thermal preferences and particular needs of older adults in urban outdoor environments during warm days and heat waves (Aghamolaei & Lak, 2022; Baldwin, Matthews & Byrne, 2020; Yung, Wang & Chau, 2019). Since the population of older adults is rapidly growing, increasing knowledge about the effects of older adults' exposure to heat hazards in urban areas has become essential (Kenney, Craighead and Alexander, 2014). By considering the needs of the older population, a better understanding can be obtained of how to implement effective adaptation measures to reduce heat-related health effects and increase wellbeing (Park et al., 2021).

1.1 Aim and research questions

This study aims to investigate how heat affects the behaviour of older adults in urban outdoor environments. The main focus is to investigate the relationships between spatial characteristics and individual factors of older adults and their preferences regarding the use of outdoor space during warm days. Additionally, the environmental needs of older adults will be explored to understand how urban design can improve thermal comfort and increase the use of outdoor space during warm days. The following research questions will be explored to fulfill the aim:

- ❖ Do spatial characteristics and individual factors of older adults have an influence on their preferences regarding outdoor activities and being in various urban outdoor environments during warm days?
- ❖ What spatial characteristics are essential to older adults in the urban environment to enhance their use of outdoor space during warm days?

2. Background

2.1 Urban climate

The climate in a city depends on many factors that interact with each other. Initially, the climate depends on the climate zone of the city, prevailing regional weather conditions, altitude above sea level, topography, and the distance to water (Thorsson, 2012). In addition, rapid global urbanization trends, population increase, and significant land-use change have caused substantial climatic differences between cities and their rural surroundings, where cities generally show higher mean air temperatures than rural areas (Oke et al., 2017). The climatic differences are influenced by the combination of anthropogenic activity in urban settlements and the built urban form, which give rise to complex interactions of energy fluxes and heat partitioning and the contribution of distinctive micro- and macroclimates across the urban landscape (ibid).

The urban form refers to the difference in materials, surface cover fraction, and built structure (Baldwin, Matthews & Byrne, 2020; Oke et al., 2017). Among the material components in the urban form, construction and natural materials determine a surface's radiative, thermal, and moisture properties, which affect its ability to reflect, emit and absorb radiation. Generally, urban areas have low albedo and high emissivity paved materials, leading to increased absorption of short-wave radiation by the surface (Oke et al., 2017). Additionally, paved materials with high thermal admittance, such as concrete and asphalt, contribute to high heat storage during the daytime. During the nighttime, the heat is released, which increases the air temperature and results in urban heat islands (UHIs) (ibid; Kim & Brown, 2021). In contrast, natural materials in the urban form, such as vegetation and water bodies, can transform solar energy for evapotranspiration. As a result, moisture and cool air are released into the atmosphere (Oke et al., 2017).

Surface cover fraction corresponds to the various land cover fragments consisting of different construction and natural materials, including built-up areas, paved ground, trees, and water. Thus, the composition of different surface cover fractions is particularly relevant to partitioning heat in the urban atmosphere (Oke et al., 2017). The built structure of the urban elements, including dimensions and space between buildings and vegetation, and their spatial arrangement are significant to radiative exchange and airflow, which determines the magnitude of UHI effects within the urban canopy (ibid; Macintyre et al., 2018).

2.2 Thermal comfort and heat stress in urban outdoor environments

Populations living in urban areas may be particularly vulnerable to thermal risks and heat-related health effects during warm weather and prolonged heat waves. This is partially due to the intensified UHI effects, reduced green space, and high population density among others (Public Health Agency of Sweden, 2022; Founda & Santamouris, 2012). When exposed to high temperatures, the human body regulates its internal temperature by increasing blood flow through outer body parts to lose excess heat. As a result, increased sweating occurs, leading to water and salt loss in the body and an additional strain on the heart (Oke et al., 2017). This physical condition is called heat stress and occurs at high temperatures when the human body can no longer regulate its temperature. The consequences of these responses vary from relatively mild symptoms, such as fatigue and dehydration, to more severe effects, such as heat stroke and death (Public Health Agency of Sweden, 2022).

To reduce heat stress in outdoor environments and increase the quality of life of urban populations, an understanding of outdoor thermal comfort is essential (Charalampopoulos & Matzarakis, 2022; Lai et al., 2020). Thermal comfort is when an individual experiences no thermal stress or sign of thermal strain in relation to their surrounding environment. In terms of health, these circumstances imply a net heat gain and loss of the body that is close to zero, also defined as heat balance in the body (Oke et al., 2017). However, several studies have demonstrated that physical and physiological factors alone are inadequate to understand the complexity of outdoor thermal comfort (Cheung & Jim, 2018), partly because of various adaptation effects and thermal acceptability between populations in different climatic regions (ibid; Yung, Wang & Chau, 2019; Elnabawi, Hamza & Dudek, 2016). Due to this, many studies have been conducted to develop the current understanding of outdoor thermal comfort to include further indirect influencing factors (Lai et al., 2020). A conceptual framework proposed by Lai et al. (2020) includes physical, physiological, and psychological factors as direct influences. Personal factors, behaviour and urban site, among others, are included as indirect influences for outdoor thermal comfort, see figure 1.

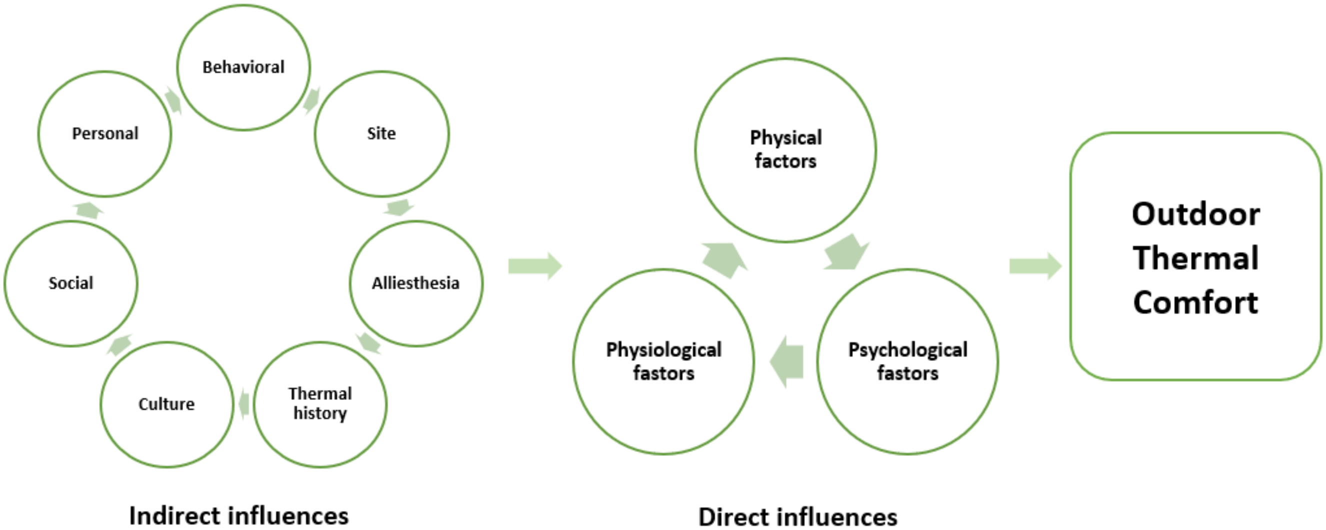

Figure 1: *Conceptual image visualizing direct and indirect influences of outdoor thermal comfort. Modified figure from Lai et al., 2020.*

2.3 Heat stress effects on older adults

The adverse effects from high temperatures affect different population groups to different extents, mainly depending on personal factors such as age and health status. Groups particularly vulnerable to heat-related risks include older adults and people with chronic illnesses such as diabetes, psychiatric illness, and cardiovascular disease (Public Health Agency of Sweden, 2018: Åström et al., 2015). Their vulnerability is mainly due to their limited capacity to regulate body temperature, reduced mobility, and ability to react to risks (Public Health Agency of Sweden, 2018). In addition, poorly built living environments and urban design in cities can aggravate the vulnerability risks of older residents and, in turn, increase morbidity and mortality (Baldwin, Matthews & Byrne, 2020).

According to previous studies, heat-related mortality risks differ between ages among the older population. Among the older population aged 80 and above, increased mortality risks are mainly related to daytime heat stress. In contrast, mortality risks among the younger groups aged 45-79 are mainly related to nighttime heat stress and heat waves continuing over an extended period of days (Thorsson et al., 2014). Due to an increasing proportion of older populations worldwide, heat-related deaths are thus expected to increase (Aghamolaei & Lak, 2022).

2.4 Older adults in urban outdoor environments during warm weather

With the increase of age, older adults have been found to be more likely to feel less thermally comfortable during warm summer months, and are thus more likely to spend shorter periods of time in urban outdoor environments (Yung, Wang & Chau, 2019). Regarding behavioural aspects during warm temperatures, studies have shown that older adults tend to change their behaviour and adapt to their outdoor thermal environment by changing their surrounding microclimate or adjusting their own thermal state (Abrahamson et al., 2009; Lai et al., 2020). For instance, performing daily routines during cooler hours of the day, traveling to the coast, seeking shade and changing the level of clothing include some of the common behaviours among older adults during periods with warm temperatures or heat waves (Yung, Wang & Chau, 2019; Abrahamson et al., 2009). Another study also found concerns from older adults about coping during prolonged periods of heat (Abrahamson et al., 2009). Due to this, it is argued that outdoor thermal comfort can have a significant impact on the use patterns of older adults in outdoor spaces and the level of outdoor activities (Yung, Wang & Chau, 2019). However, very few studies have looked explicitly at the thermal preferences of older adults concerning their outdoor environment in different spatial settings (ibid; Aghamolaei & Lak, 2022; Baldwin, Matthews & Byrne, 2020).

Since older adults are considered as an important group of outdoor space users, it has been argued that providing thermally comfortable outdoor environments is essential to help them enhance their physical and mental health and social life by encouraging activities and interaction with others (Yung, Wang & Chau, 2019). Studies have suggested that a diversity of microclimatic conditions should be provided so that older adults can adjust to various thermal conditions in different urban settings to meet their needs and preferences. Moreover, it has been found that design features which promote accessibility, walkability, and places to rest can increase the frequency of satisfaction and the number of visits of older adults in urban outdoor spaces (Baldwin, Matthews & Byrne, 2020).

2.5 Measures to improve thermal comfort in urban outdoor space

Outdoor thermal comfort varies between outdoor environments, mainly due to microclimate variations in different urban sites (Lai et al., 2020). Several adaptive planning strategies and urban design measures can help create thermally comfortable environments and microclimate conditions that reduce the adverse effects of heat stress on urban populations, and especially older adults (Aghamolaei & Lak, 2022; Yung, Wang & Chau, 2019). These include, among others, increasing the amount of urban greenery and water-covered areas, as well as changing the urban geometry to provide shade and cooling effects (Mohammad et al., 2021; Xu et al., 2010; Lindberg et al., 2016).

Increasing urban greenery has been recognized as one of the most effective methods for providing better thermal environments and mitigating heat stress in outdoor environments (Mohammad et al., 2021). The thermal benefits from vegetation are mainly due to its cooling effect from transpiration and shading. While transpiration cools down the surrounding air temperature, shade reduces the amount of direct solar radiation and heat that radiate from the ground (Oke et al., 2017). In line with this, a recent study estimated that the cooling effect from increasing the urban tree cover to 30% could potentially have prevented a significant number of premature deaths in the summer of 2015 (Iungman et al., 2023). These results indicate the importance of urban green infrastructure to increase the quality of life of urban inhabitants and promote a healthy aging for the older population. Apart from the heat mitigation effects, urban greenery also helps to improve air quality, regulate water flow, improve mental health, reduce energy consumption, and increase biodiversity (Baldwin, Matthews & Byrne, 2020; Cheung & Jim, 2018; Mohammad et al., 2021).

In addition to urban greenery, water bodies have a significant role in air temperature reduction in terms of evaporative cooling and an increase in air humidity on warm days, which can effectively improve the outdoor thermal comfort of the population (Oke et al., 2017; Xu et al., 2010). In coastal areas during summer, winds from the sea usually bring cool and humid air inland as an effect of advection. The thermal circulation can also affect areas near small lakes and rivers, but these broader climatic effects are more limited compared to coastal neighborhoods. In addition, the scope of influence depends on how neighborhoods are designed geometrically to allow advection (Oke et al., 2017).

Furthermore, the building geometry, which includes the height, direction, and space between buildings, affects the microclimatic profile due to its significant influence on the amount of incoming solar radiation that reaches the ground and wall surfaces, which in turn affects the surface temperature and, thus the surrounding air temperature (Thorsson, 2012). High and dense building structures have been considered a suitable approach to reduce outdoor heat stress in high-latitude locations and thus provide thermal comfort because of the amount of shadowing they can provide (Lindberg et al., 2016). However, it has also been found that high building densities with complex orientations could negatively affect thermal comfort due to reduced wind speed at the pedestrian level causing warm air to be trapped between buildings (Liu et al., 2018; Oke et al., 2017). Therefore, the spatial arrangement and densities of building structures should be considered an important parameter to ensure thermally comfortable outdoor environments within the built environment.

3. Methodology

3.1 Study design

This study explores the research questions through quantitative data collection, generation, and statistical analysis methods. The data is based on pre-collected questionnaire survey data conducted by the ongoing research project named *HEAT*. The choice of performing statistical analysis was based on its suitability to calculate connections and draw conclusions about a phenomenon based on a large quantity of data (Esaiasson et al., 2017). Geographical information systems (GIS) were used as a complementary tool to generate spatial variables for statistical analysis. Additionally, GIS-based methods enabled various spatial data operations to be analyzed and visualized over large geographical areas (Clifford et al., 2010). Combining different methods was advantageous in this study as they complemented each other and contributed to a broader, more profound, and strengthened explanation of the final results. Figure 2 gives an overview of the methodology workflow.

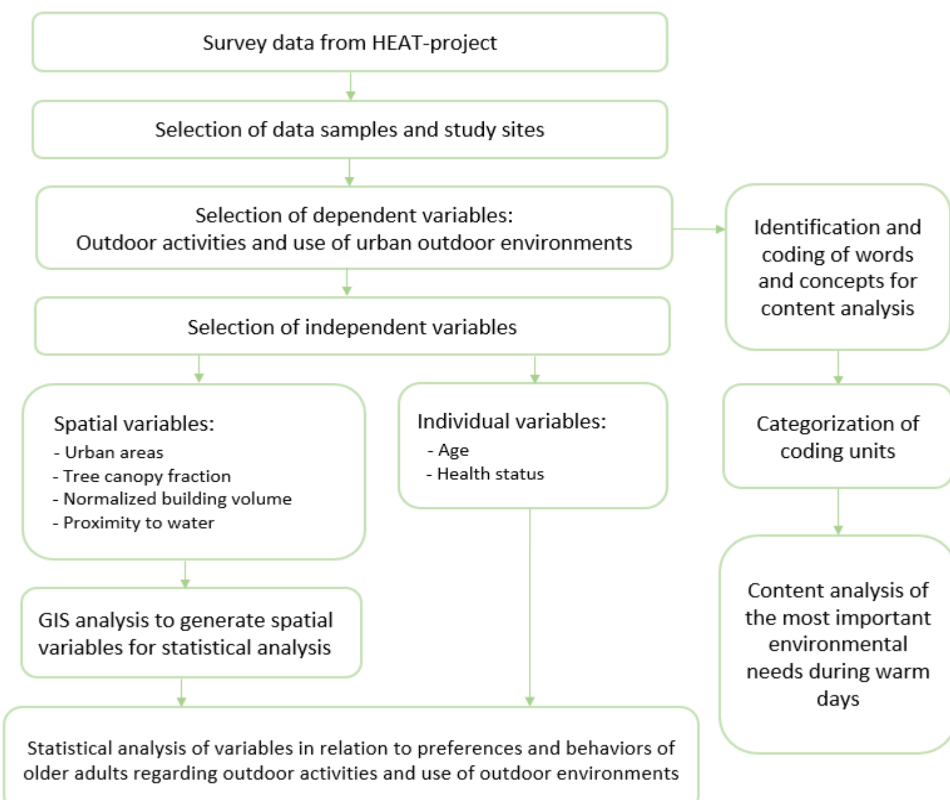

Figure 2: *Overview of the work process that enabled an understanding of how spatial characteristics of outdoor environments and individual factors of older adults relate to preferences and behaviour in regards to their use of outdoor environments during warm days and heat wave events.*

3.2 Questionnaire survey background: HEAT research project

The data used in this study was based on a secondary data source; a questionnaire survey conducted by the ongoing research project named *HEAT: Heat stress in outdoor Environments - Planning the city of the older Adults Today and in a future warmer climate.* The HEAT questionnaire survey aimed to study the experiences, behaviours, and attitudes regarding the activities of older adults in connection to warm weather and heat waves in the urban environment.

The survey was divided into five themes and included questions regarding background information about the respondents, experiences, activities during warm weather, and personal perception and knowledge about heat waves and their related health effects. The criteria for the population included participants of older adults aged 64 years and above living in southwestern Sweden. Members from local community centers, senior clubs, and organizations for older adults were recruited as participants. The selection process of respondents was based on a nonprobability sample, to reach as broad a target group as possible. The research project was approved by the Swedish Ethical Review Authority (DNR 2022-01790-01). The survey was sent out in digital and paper form and was open for responses between the 1st of July and the 30th of November 2022.

3.3 Data samples and study sites

The selection of a subsample from the HEAT questionnaire survey was an essential first step in this study since it determined the urban study sites and size of the data sample for the statistical analysis. The subsample of older adults living in urban areas was selected based on two criterias; the response rate and spatial size of each urban area which lead to Göteborg, Jönköping, and Borås being chosen as study sites. Respondents living in Partille and Mölndal municipality were included in the Göteborg respondent group since they are included in the Göteborg urban area according to SCB:s definition of "Göteborgs tätortsområde" (SCB, 2020). Geospatial information of postal codes of each respondent, provided by the survey data, was essential when selecting the urban areas. Thus, the respondents living in rural areas could be excluded from the subsample. Additionally, the respondents who did not present a postal code in the survey results had to be excluded from the analysis. Out of 704 responses from the original dataset, the subsample was reduced to 348 survey responses, divided into a sample of 163 postal codes across the three chosen study sites, see figure 3. The reason for considering the total response rate of the urban areas was because of the sample size, which can significantly impact the results. For instance, larger sample sizes increase the statistical power, accuracy, generalizability, and precision of the results obtained from the analysis (Esaiasson et al., 2017; Harris & Jarvis, 2013; Bryman & Cramer, 2011). Since there are no universal guidelines on sample size requirements, the sample size level may vary between disciplines. However, according to Harris & Jarvis (2013), a commonly held rule of thumb is that sample size (n) should be at least 30 regarding one geographical population.

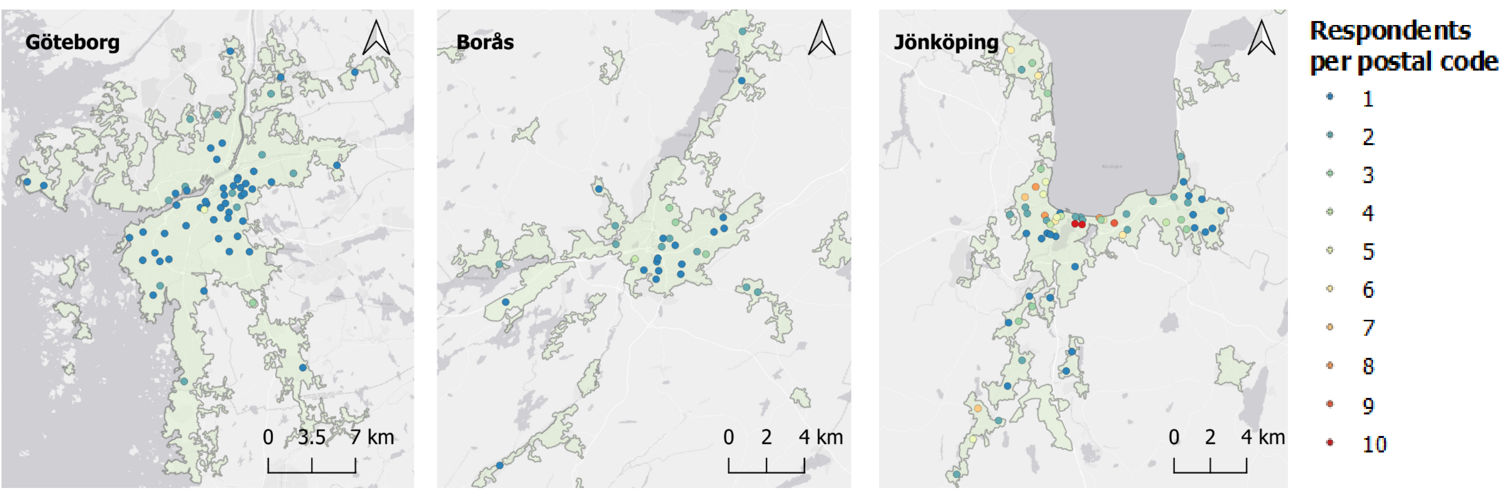

Figure 3: *Map representing the three chosen study sites; Göteborg, Borås and Jönköping. Colored points represent the number of respondents from each postal code in the data sample. Source: Google maps and Lantmäteriet.*

3.4 Dependent variables: Outdoor activities and use of urban outdoor space

Four survey questions were chosen from the HEAT questionnaire to form dependent variables in this study, see figure 4. The survey questions regarding indoor/outdoor preference, outdoor activity preference and urban outdoor space preference were analyzed through statistical analysis. To visualize and more easily compare older adults' preferences, the response options for each question were recoded into a common response scale, ranging between -2 to 2.

The survey question regarding environmental needs was analyzed through content analysis. A quantitative content analysis was beneficial in this case due to its suitability to determine the frequency of the presence of certain types of themes, concepts, or words in a dataset (Esaiasson et al., 2017). Before the content analysis, all responses in the dataset were read through repeatedly, and categorization was used to organize the data. The categories were developed based on previous research regarding thermally comfortable environments for older adults during warm weather. The selected categories were; shaded areas, greenery, water, rest areas, and wind. Words relating to a category were identified and coded to a suitable category. As a result, the coding process made it possible to analyze the frequency of concepts within a specific category.

1: Indoor/outdoor preference

"When there is a heat wave, I want to be..."

Response scale	Value
Indoors all the time	-2
Indoors most of the time	-1
Just as much indoors as outdoors	0
Outdoors most of the time	1
Outdoors all the time	2

2: Outdoor activity preference

"When there is a heat wave, I avoid outdoor activities"

Response scale	Value
All the time	-2
Almost all the time	-1
Sometimes	0
Almost never	1
Never	2

3: Urban outdoor space preference

"Indicate which places in the urban environment you avoid or seek during a heat wave"

- City streets in the sun
- City streets in the shade
- Squares in the sun
- Squares in the shade
- Green areas (park/grove) in the sun
- Green areas in the shade
- Other places, by water
- Other places, with wind/good ventilation
- Other places, in the leeward

Response scale	Value
Avoid always	-2
Avoid almost always	-1
Neither seek nor avoid	0
Seek almost always	1
Seek always	2

4: Environmental needs

"What do you think is important in your surroundings/nearby environment to be able to carry out activities during warm weather and heat waves?"

Categories
Shaded areas
Greenery
Water
Rest areas
Wind

Figure 4: *Selection of dependent variables and recoding process of dependent variables ranging from -2 to 2. Positive values indicate a stronger preference for being outdoors, not avoiding outdoor activities, and seeking specific urban outdoor environments during warm days. Negative values indicate a stronger preference for staying indoors, avoiding outdoor activities or specific urban environments during warm days. The fourth dependent variable was assigned five categories regarding environmental needs.*

3.5 Independent variables: Spatial and Individual factors

To explore possible underlying factors that influence preferences of older adults regarding the use of outdoor space, four spatial and two individual factors were selected as independent variables. The variables were developed based on previous research regarding indirect thermal comfort factors regarding the urban site and personal aspects. The spatial characteristics variables included; urban areas, tree canopy fraction, normalized building volume, proximity to water, whereas the individual variables included age and health status of older adults.

The three urban areas Gothenburg, Jönköping, and Borås were chosen as the first independent spatial variable due to their spatial, population and climatic differences. One of the primary differences is that Gothenburg and Jönköping have a more extensive land area and population size than Borås (SCB, 2020). Regarding local climate, Gothenburg is characterized by a mild maritime temperate climate due to its location by the Kattegat Sea, while a mild continental climate characterizes Jönköping and Borås. Although Jönköping and Borås have continental climates, they differ in the surrounding landscape due to Jönköping's proximity to Lake Vättern (SMHI, 2022).

In addition to studying different urban areas at a macro scale, it was also interesting to study the spatial characteristics on a local neighborhood scale within the urban environment where the respondents live. Therefore, tree canopy fraction, normalized building volume, and proximity to water were analyzed within each postal code in the sample. Three groups of tree canopy fractions volume were investigated; Low tree canopy fraction (0-5%), Medium tree canopy fraction (5-15%), and High tree canopy fraction (15-25 %). The normalized building volume was chosen to examine the influences of urban mass and building density. The normalized building volume variable refers to the share of building volume to the total area of the built-up ground surface. If the value exceeds values above 1, the building volume exceeds the ground surface area, indicating a higher built-up volume than the surface area. Three groups of normalized building volumes were investigated; Low normalized building volume (0 - 0.5 m^3/m^2), Medium normalized building volume (0.5 - 1 m^3/m^2), and High normalized building volume (1 - 2.7 m^3/m^2). The fourth spatial variable was the respondents' proximity to water, which refers to the shortest walking or cycling distance to the closest coastline or lake from where the respondents live. Three groups of distances to water were investigated; Close distance (0 - 2.5 km), Medium distance (2.5 - 5km), and Long distance (> 5 km). The grouping of variables was based on the minimum and maximum values of each variable within the subsample. The selected value-distribution between the groups was chosen to avoid a sample size below 30 respondents. The methodology and data used for generating the spatial variables in GIS are further explained in the next section.

Independent variables of age groups and health-status were examined as individual factors in this study. The age range of the respondents were divided into two groups, 64-79 and 80-92 years old. The health status variable was based on the respondents' perceived health, rated by themselves in the HEAT survey. The response options were originally divided into five groups; bad, fair, good, very good, excellent. To simplify the discovery of patterns and trends in the data (Creswell, 2014), the health status groups were recoded into three smaller subgroups; worsened (bad, fair), good, and very good (very good and excellent) health status.

3.6 Generation of independent spatial characteristic variables in GIS

Geodata presented in table 1 was used to generate spatial variables for the statistical analysis. The following section presents the methodology of generating height models and land cover data, mapping tree canopy fraction, normalized building volume, and performing a network analysis of the proximity to water.

Table 1: *Overview of the geodata used to generate height models and land cover data, mapping tree canopy fraction, normalized building volume, and performing a network analysis of the proximity to water.*

Dataset	*Description*	*Used for*	*Source*
Survey data (.csv)	Count of respondents per postal code.	Intersect survey information with postal code information to visualize spatial distribution of respondents.	Created by HEAT-research project, modified by Lujic, S., (2023)
Postal codes (.shp)	Sample of 163 postal codes across the three chosen study sites.	Analyze the spatial variables on a local neighborhood scale.	Postnummerservice Norden AB (2023)
Built-up areas (.shp)	Built-up areas within each postal code of the respondents were selected. Layer name “My_south” (Lanmäteriet, 2019) was used to create the data.	Mapping of urban tree canopy fraction, normalized building volume and network analysis of proximity to water.	Created by Lujic, S., (2023)
Urban areas, “Tätorter” (.shp)	Urban areas in Sweden. Information including county, municipality and population size.	Choosing municipality samples. Respondents living outside of urban areas were excluded from the analysis.	Statistics Sweden “SCB”, (2020)

Property map Built-up areas (.shp)	Building footprint of built-up areas. Layer names “by_13” and “by_14” were used.	Input parameter for generating DEM, DSM and Land Cover in Python.	Swedish Mapping, Cadastral and Land Registration Authority “Lantmäteriet” (2019)
Property map Land data (.shp)	Includes information about water attributes. Layer name “My_south” was used.	Input parameter for generating DEM, DSM and Land Cover in Python. Additionally, water attributes were used to generate a water polygon layer for the network analysis.	Swedish Mapping, Cadastral and Land Registration Authority “Lantmäteriet” (2019)
Railways (.shp)	Railway infrastructure.	Input parameter for generating DEM, DSM and Land Cover in Python.	OpenStreetMap (2023)
Bridges (.shp)	Bridge infrastructure.	Input parameter for generating DEM, DSM and Land Cover in Python.	Created by Lujic, S., (2023)
Swimming areas (.shp)	Swimming areas by selected lakes.	Input parameter for generating water polygons for network analysis.	OpenStreetMap (2023)
Road network (.shp)	Walking and cycling network	Input parameter for network analysis.	OpenStreetMap (2023)
LiDAR data (.laz)	Laser data containing a point cloud with a point density of 1-2 points per m^2.	Creating DEM, DSM and land cover data (2x2m resolution) for urban areas. Land cover raster consisted of classes: paved ground, buildings, deciduous trees, coniferous trees, grass, bare soil, and water. The data was then used to generate tree canopy fractions and normalized building volume for each postalcode.	Swedish Mapping, Cadastral and Land Registration Authority “Lantmäteriet” (2018)

Digital elevation model (DEM), digital surface model (DSM), and land cover data were generated as a first step in the mapping process since it was needed as input data for analyzing the urban tree canopy fraction and normalized building volume. The DEM, DSM, and land cover datasets were generated with a 2m pixel size using a predeveloped Python script (Lindberg, 2023) in Visual Studio Code. LiDAR data from Lantmäteriet (2018) was used as input data for generating the data.

The tree canopy fraction, normalized building volume, and proximity to water were analyzed using automated models in QGIS model builder. The variables were analyzed on a local neighborhood scale within the urban environment of the respondents, which refers to the built-up areas within each postal code in the sample. Thus, areas such as larger greenspaces and forests within the postal codes were excluded from the analysis. This choice was made to avoid analyzing places where no respondents live and thus risk misjudging the results.

The main tools used to calculate the tree canopy fraction were the raster calculator and zonal statistics. The raster calculator tool extracted the raster layer classes of deciduous and coniferous trees from the land cover raster, whereas the zonal statistics calculated the percentage of tree canopy fractions within each postal code. When mapping the normalized building volume, the DEM, DSM, and built-up areas within each postal code were used as input datasets. The raster calculator tool was used to extract the buildings from the digital elevation models and the zonal statistics tool was used to calculate the sum of the total building volume for all built-up areas within each postal code in the sample. Lastly, the normalized building volume was calculated by dividing the building volume to the built-up ground surface area.

The respondents' proximity to water was analyzed using the network analysis GRASS tool *v.net.distance*. Since the home address of the respondents were unknown, the distance to water was calculated from the center point of each built-up area of the postal code sample. The network consisted of roads suitable for walking or cycling. Paths with stairways were considered unsuitable for older adults and were therefore excluded from the network. The result from the network analysis was an estimation of the shortest distance between each local area of the respondents and the closest coastline or lake.

3.7 Data analysis of variables

Descriptive and inferential statistical methods were applied to analyze relationships between dependent and independent variables using SPSS Statistics. The results were presented through tables and figures. The descriptive analysis was used to compare means for different groups of independent variables. Studying the mean as a measure was suitable in this study since the data did not consist of extreme values, but only five values in each dependent variable (Harris & Jarvis). Inferential statistical analysis was applied through one-way ANOVA (Analysis of Variance) tests to study statistical significance between the means of independent groups of variables (Bryman & Cramer, 2011, p. 177). Omnibus tests were performed in ANOVA as a first step in the analysis to compare the significance between groups. If statistical significance was detected between independent groups, a post-hoc test was applied using the Bonferroni correction to compare multiple groups. The Bonferroni correction was chosen because it adjusts the significance level depending on the number of comparisons, reducing the likelihood of making an incorrect rejection of a true relationship, referred to as a Type I error (ibid). A significance level of $p \leq 0.05$ and a sample size of at least 30 respondents in each group was applied to avoid Type I errors on all statistical tests. This criterion was made based on previous research in environmental geography (Harris & Jarvis, 2013, p. 139) and social science studies (Esaiasson et al., 2017:180, Bryman & Cramer, 2011:128). Lastly, the open-ended response question regarding environmental needs was analyzed through content analysis by counting the frequency of concepts within predetermined categories, and the result was presented descriptively through figures calculated in SPSS Statistics. Apart from the results section, detailed output results from the statistical analysis in SPSS is presented in *8. Appendix*.

4. Results

4.1 General population

To broadly understand the preferences and behaviour of the population of older adults (n = 348) in relation to warm weather in urban outdoor environments, this section of the results presents an overview of the responses regarding the first three survey questions about indoor/outdoor preference, outdoor activity preference and urban outdoor space preference. After this section, the results from the statistical analysis of spatial characteristics and individual factors are presented individually. The results regarding environmental needs are presented at the end of this chapter. An overview of the frequency rate of each independent variable, including missing values, is presented in table 2.

Table 2: *Overview of the frequency rate, sample size (n), and missing values of each independent variable regards to the total population of older adults.*

Variables	Groups	Frequency	Total (n)
Urban area	Borås	48	348
	Göteborg	80	
	Jönköping	220	
Tree canopy cover	Low (0-5%)	59	341
	Medium (5-15%)	227	
	High (15-25%)	55	Missing: 7
Normalized building volume	Low (0-0.5 m3/m2)	171	340
	Medium (0.5-1 m3/m2)	63	
	High (1-2.7 m3/m2)	106	Missing: 8
Proximity to water	Close (0-2.5 km)	229	348
	Medium (2.5-5 km)	64	
	Far (>5 km)	55	
Age	64-79 years old	256	344
	80-92 years old	88	Missing: 4
Health status	Worsened	38	275
	Good	97	
	Very good	140	Missing: 73

On average, older adults prefer to stay both indoors and outdoors during warm days (-0.17) and sometimes prefer to avoid outdoor activities (-0.26), according to table 3. Regarding urban outdoor space preference, on average, older adults prefer to avoid sunlit environments during warm days, mainly squares (-1.21) and city streets (-1.14). However, desirable urban outdoor environments include places with wind/good ventilation (0.74), green areas in the shade (0.69), and places by the water (0.51).

Table 3: *Overview of the results for the total population regarding indoor/outdoor preference, outdoor activity preference and urban outdoor space preference. Negative mean (M) values represent stronger preference for staying indoors, avoiding activities, and avoiding specific outdoor environments. Positive M values represent stronger preference for staying outdoors, not avoiding activities, and seeking specific outdoor environments. Sample size (N) and standard deviation (SD) is presented for each survey question.*

General population	*M (SD)*	*N*
(1.1) When there is a heat wave, I want to be…	-0.17 (0.9)	343
(1.2) When there is a heat wave, I avoid outdoor activities.	-0.26 (0.94)	344
(2.1) Urban environments (avoid or seek) during a heat wave:		
a) City streets in the sun	-1.14 (0.74)	326
b) City streets in the shade	0.28 (1.01)	321
c) Squares in the sun	-1.21 (0.75)	324
d) Squares in the shade	0.18 (0.97)	317
e) Green areas (park/grove) in the sun	-0.37 (1.01)	321
f) Green areas in the shade	0.69 (0.80)	324
g) Other places, by water	0.51 (0.88)	324
h) Other places, with wind/good ventilation	0.74 (0.68)	327
i) Other places, in the lee (next to a house wall or similar)	-0.26 (1.05)	322

4.2 Urban areas

According to table 4, slight differences could be identified between each group regarding indoor/outdoor preference and outdoor activity preference. On average, older adults living in Jönköping have a stronger preference to stay indoors (-0.24) and avoid outdoor activities (-0.32) compared to Gothenburg (-0.09, -0.14) and Borås (-0.02, -0.19). However, no statistically significant differences were identified between the groups.

According to table 4, the groups answered similarly in most questions regarding which urban environments they chose to seek or avoid during warm days. According to the results, older adults within all groups prefer to avoid sunlit environments during warm days, mainly squares, and city streets. Regarding desirable urban environments, two environments stood out; places with wind/good ventilation and green areas in the shade. The post-hoc test regarding places in the leeward showed significant differences (p = 0.029*) between the mean values of the two groups; Borås (0.09) and Jönköping (-0.36). The results showed that people living in Borås, on average, have a stronger preference to seek places in the leeward than older adults living in Jönköping, who in contrast have a stronger preference to avoid places in the leeward.

Table 4: *Omnibus test in ANOVA for comparison of the independent groups; Borås, Goteborg, Jönköping. Level of significance (p) between groups; * p-value < 0.05.*

Urban areas	**Borås**		**Göteborg**		**Jönköping**		
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.02 (1.04)	48	-0.09 (0.92)	79	-0.24 (0.86)	216	0.212
2. When there is a heat wave, I avoid outdoor activities.	-0.19 (1.12)	48	-0.14 (0.90)	79	-0.32 (0.91)	217	0.299
3. Urban environments (avoid or seek) during a heat wave:							
a) City streets in the sun	-1.11 (0.75)	44	-1.14 (0.74)	77	-1.14 (0.74)	205	0.977
b) City streets in the shade	0.24 (0.96)	42	0.28 (1.03)	76	0.29 (1.01)	203	0.953
c) Squares in the sun	-1.09 (0.8)	44	-1.13 (0.75)	76	-1.26 (0.74)	204	0.221
d) Squares in the shade	0.26 (0.93)	43	0.18 (0.96)	77	0.16 (0.98)	197	0.849
e) Green areas (park/grove) in the sun	-0.2 (1.11)	44	-0.26 (0.97)	76	-0.44 (1.00)	201	0.216
f) Green areas in the shade	0.57 (0.76)	44	0.64 (0.86)	76	0.74 (0.79)	204	0.362
g) Other places, by water	0.51 (0.76)	45	0.60 (0.85)	77	0.48 (0.92)	202	0.61
h) Other places, with wind/good ventilation	0.57 (0.70)	44	0.68 (0.77)	77	0.80 (0.64)	206	0.076
i) Other places, in the lee (next to a house wall or similar)	0.09 (0.96)	44	-0.21 (1.02)	77	-0.36 (1.06)	201	0.029*

4.3 Tree canopy fraction of the local area

The results showed that older adults living in areas with a high tree canopy coverage (0.02), on average, have a stronger preference for being outdoors during warm days than older adults living in low and medium tree canopy coverage (-0.16, -0.22). However, no statistically significant differences were identified between the groups, see table 5. The post-hoc tests regarding outdoor activity preference showed significant differences (p = 0.025*) between the two groups; high and low canopy cover, see figure 5. On average, a stronger preference to not avoid outdoor activities was shown in areas with high tree canopy coverage (0.02) compared to areas with low tree canopy coverage (-0.46), who in contrast have a stronger preference to avoid outdoor activities during warm days.

On average, older adults within all groups avoid sunlit squares and city streets during warm weather, see table 5. In terms of places with wind/good ventilation, places by the water, and green areas in the shade were on average considered as desirable environments by all groups. However, no statistical differences were identified regarding urban outdoor space preference.

Table 5: *Omnibus test in ANOVA for comparison of the independent groups Low, Medium and High tree canopy fraction. Level of significance (p) between groups; * p-value < 0.05.*

Tree canopy fraction	**Low (0-5%)**		**Medium (5-15%)**		**High (15-25%)**		
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.16 (1.04)	58	-0.22 (0.88)	224	0.02 (0.86)	54	0.211
2. When there is a heat wave, I avoid outdoor activities.	-0.46 (0.95)	59	-0.27 (0.91)	224	0.02 (0.98)	54	0.025*
3. Urban environments (avoid or seek) during a heat wave:							
a) City streets in the sun	-1.12 (0.79)	56	-1.16 (0.73)	211	-0.98 (0.73)	52	0.292
b) City streets in the shade	0.11 (1.15)	55	0.32 (1.00)	208	0.33 (0.86)	51	0.354
c) Squares in the sun	-1.27 (0.78)	55	-1.22 (0.77)	211	-1.06 (0.65)	51	0.291
d) Squares in the shade	0.05 (1.12)	56	0.21 (0.94)	205	0.24 (0.82)	50	0.495
e) Green areas (park/grove) in the sun	-0.44 (1.04)	54	-0.38 (1.02)	211	-0.26 (0.88)	50	0.629
f) Green areas in the shade	0.61 (0.92)	54	0.70 (0.81)	214	0.76 (0.66)	50	0.637
g) Other places, by water	0.56 (0.92)	54	0.51 (0.89)	213	0.55 (0.73)	51	0.909
h) Other places, with wind/good ventilation	0.75 (0.74)	56	0.76 (0.69)	214	0.73 (0.53)	51	0.956
i) Other places, in the lee (next to a house wall or similar)	-0.24 (1.08)	54	-0.28 (1.07)	211	-0.22 (0.92)	51	0.899

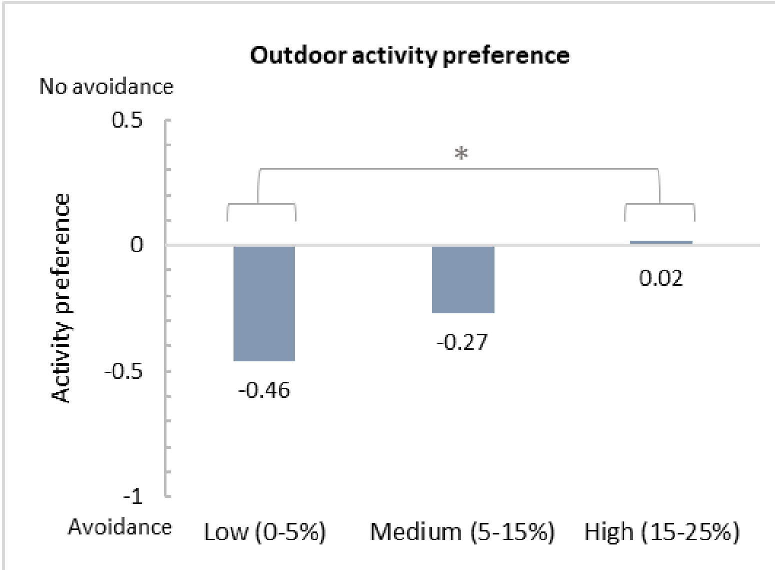

Figure 5: *Outdoor activity preference between groups living in areas with low, medium and high tree canopy fraction. Negative mean values represent stronger preference of avoiding outdoor activities, and positive values represent stronger preference of not avoiding outdoor activities during warm days. Levels of significance between groups (Post hoc-test); * p-value < 0.05.*

4.4 Normalized building volume of the local area

The results regarding indoor/outdoor preference and outdoor activity preference showed that older adults living in areas with medium building volumes have, on average, a stronger preference to stay indoors (-0.28) than older adults living in areas with low and high building volumes (-0.17, -0.12), see table 6. Regarding outdoor activity preference, the results showed that older adults living in areas with a medium and high building volume, on average, have a stronger preference to avoid outdoor activities (-0,32, -0.39) compared to those living in areas with low building volume (-0.16). However, no statistically significant differences were found between the groups in both questions.

On average, older adults within all groups avoid sunlit squares and streets during warm days, see table 6. Regarding places the older adults seek during warm weather, environments with wind/good ventilation and green areas in the shade were on average selected by all groups. However, no statistical differences were identified regarding urban outdoor space preference.

Table 6: *Omnibus test in ANOVA for comparison of the independent groups Low, Medium and High normalized building volume.*

Normalized building volume	**Low (0 - 0.5)**		**Medium (0.5 - 1)**		**High (1 - 2.7)**		
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.17 (0.91)	171	-0.28 (0.90)	60	-0.12 (0.91)	104	0.556
2. When there is a heat wave, I avoid outdoor activities.	-0.16 (0.94)	171	-0.32 (0.98)	60	-0.39 (0.87)	105	0.129
3. Urban environments (avoid or seek) during a heat wave:							
a) City streets in the sun	-1.09 (0.73)	162	-1.18 (0.72)	56	-1.16 (0.77)	100	0.623
b) City streets in the shade	0.25 (0.98)	163	0.21 (1.04)	53	0.39 (1.04)	97	0.455
c) Squares in the sun	-1.18 (0.71)	159	-1.30 (0.71)	56	-1.20 (0.85)	101	0.552
d) Squares in the shade	0.20 (0.92)	158	0.06 (1.08)	53	0.24 (0.96)	99	0.511
e) Green areas (park/grove) in the sun	-0.32 (1.00)	159	-0.35 (0.91)	55	-0.49 (1.06)	100	0.402
f) Green areas in the shade	0.69 (0.77)	163	0.70 (0.86)	54	0.69 (0.85)	100	0.991
g) Other places, by water	0.45 (0.89)	162	0.59 (0.71)	54	0.59 (0.92)	101	0.347
h) Other places, with wind/good ventilation	0.74 (0.67)	162	0.89 (0.63)	55	0.69 (0.70)	103	0.198
i) Other places, in the lee (next to a house wall or similar)	-0.30 (0.99)	159	-0.18 (1.17)	55	-0.28 (1.07)	101	0.784

4.5 Proximity to water from the local area

The results regarding indoor/outdoor preference and outdoor activity preference showed similar values between groups, according to table 7. On average, older adults in all groups have a stronger preference to stay indoors and avoid outdoor activities during warm days than to be outdoors and perform outdoor activities. As a result, the omnibus test showed no statistically significant differences between the groups.

On average, older adults with all groups avoid sunlit squares and city streets during warm weather, see table 7. The post-hoc test regarding places with wind/good ventilation showed significant differences (p = 0.011*) between the mean values of the two groups; Close distance (0.82) and Medium distance (0.54). The results showed that people living close to water, on average, have a stronger preference to seek places with wind/good ventilation than those living from a medium distance to water.

Table 7: *Omnibus test in ANOVA for comparison of the independent groups close, medium and long distance to water. Level of significance (p) between groups; * p-value < 0.05.*

Proximity to water	Close (0 - 2.5km)		Medium (2.5 - 5km)		Long (> 5km)		
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.18 (0.86)	226	-0.18 (0.98)	62	-0.13 (1.00)	55	0.923
2. When there is a heat wave, I avoid outdoor activities.	-0.29 (0.91)	227	-0.21 (0.99)	62	-0.20 (0.99)	55	0.749
3. Urban environments (avoid or seek) during a heat wave:							
a) City streets in the sun	-1.12 (0.75)	216	-1.12 (0.70)	59	-1.22 (0.76)	51	0.699
b) City streets in the shade	0.31 (0.99)	212	0.25 (0.95)	60	0.20 (1.15)	49	0.788
c) Squares in the sun	-1.25 (0.73)	213	-1.08 (0.79)	60	-1.18 (0.77)	51	0.283
d) Squares in the shade	0.21 (0.97)	208	0.13 (0.87)	60	0.12 (1.07)	49	0.79
e) Green areas (park/grove) in the sun	-0.43 (1.02)	210	-0.20 (1.01)	60	-0.29 (0.97)	51	0.246
f) Green areas in the shade	0.75 (0.78)	213	0.59 (0.80)	61	0.58 (0.88)	50	0.213
g) Other places, by water	0.54 (0.89)	211	0.41 (0.92)	61	0.52 (0.78)	52	0.593
h) Other places, with wind/good ventilation	0.82 (0.64)	215	0.54 (0.74)	61	0.65 (0.72)	51	0.011*
i) Other places, in the lee (next to a house wall or similar)	-0.25 (1.10)	210	-0.34 (0.93)	61	-0.24 (0.97)	51	0.801

4.6 Age groups

The results regarding indoor/outdoor preference showed, on average, that the older age group (-0.29) has a stronger preference to stay indoors during warmer days than the younger age group (-0.13), see table 8. However, no statistically significant difference was identified between the groups. Regarding outdoor activity preference, a statistically significant difference (p = 0.007**) was identified between the two age groups, see figure 6A. On average, the older age group (-0.49) have a stronger preference to avoid outdoor activities during warm days compared to the younger age group (-0.18).

According to table 8, the results of the post-hoc test showed statistically significant differences between the age groups in three out of nine outdoor environment types: city streets in the shade (p = 0.037*), by water (p = 0.004*), and places in the leeward (p = 0.014*), see figure 6B. On average, the younger age group has a stronger preference to seek city streets in the shade (0.34) and places near water (0.59) in comparison to the older age group (0.07, 0.26). When it comes to being in places in the leeward, the results showed, on average, that the younger age group (-0.35) has a stronger preference to avoid these environments compared to the older age group (-0.01).

Table 8: *Omnibus test in ANOVA for comparison of the independent age groups 64-79 yrs. and 80-92 yrs. old. Levels of significance (p) between groups; * p-value < 0.05; **p-value < 0.01.*

Age groups	64-79 yrs.		80-92 yrs.		
	M (SD)	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.13 (0.90)	253	-0.29 (0.92)	86	0.156
2. When there is a heat wave, I avoid outdoor activities.	-0.18 (0.89)	253	-0.49 (0.99)	87	0.007**
3. Urban environments (avoid or seek) during a heat wave:					
a) City streets in the sun	-1.12 (0.73)	243	-1.18 (0.76)	79	0.576
b) City streets in the shade	0.34 (0.97)	241	0.07 (1.06)	76	0.037*
c) Squares in the sun	-1.20 (0.75)	244	-1.25 (0.77)	76	0.619
d) Squares in the shade	0.20 (0.94)	239	0.07 (1.04)	74	0.298
e) Green areas (park/grove) in the sun	-0.39 (1.01)	242	-0.31 (1.00)	75	0.541
f) Green areas in the shade	0.69 (0.80)	243	0.68 (0.82)	77	0.879
g) Other places, by water	0.59 (0.82)	243	0.26 (1.03)	77	0.004**
h) Other places, with wind/good ventilation	0.77 (0.62)	244	0.61 (0.82)	79	0.058
i) Other places, in the lee (next to a house wall or similar)	-0.35 (1.05)	242	-0.01 (0.01)	76	0.014*

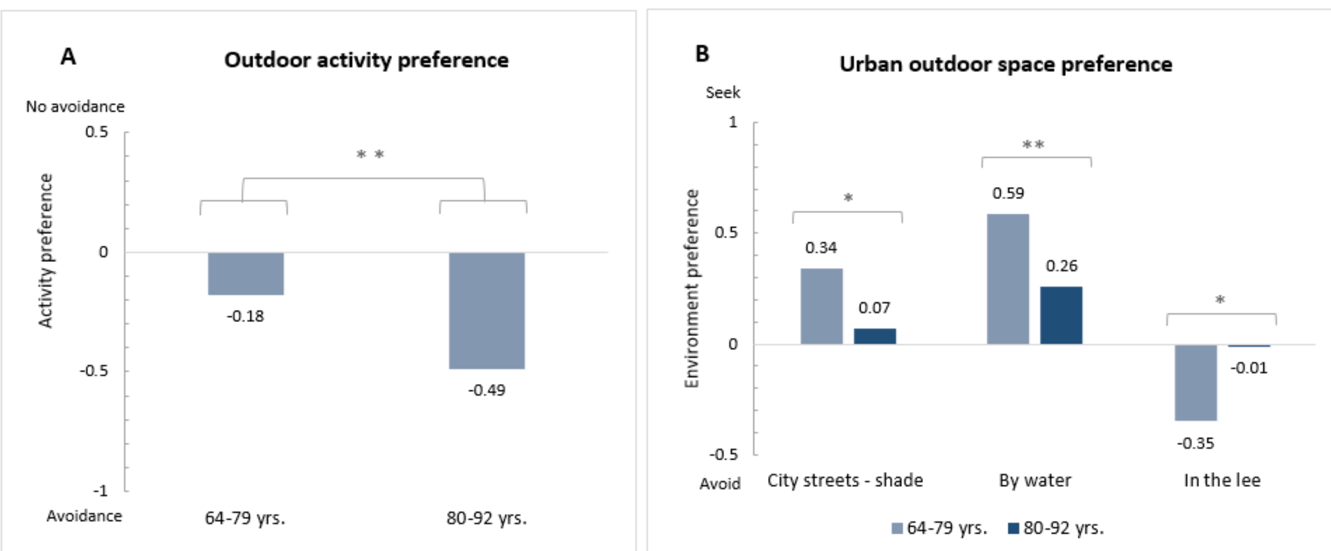

Figure 6: *Outdoor activity preference (A) and urban outdoor space preference (B) during warm days between age groups. Negative mean values represent stronger preference of avoiding outdoor activities and specific outdoor environments, and positive values represent stronger preference of not avoiding outdoor activities and seeking specific outdoor environments during warm days. Levels of significance (p) between groups; * p-value < 0.05; **p-value < 0.01.*

5.7 Health status

The post-hoc test results showed significant differences between the health groups regarding indoor/outdoor and outdoor activity preferences, see table 9. Firstly, significant differences were found between the group with worsened and very good health ($p = 0.015^*$) regarding indoor/outdoor preference. The results showed, on average, that the group with worsened health has a stronger preference to stay indoors during warm days (-0.51) compared to the group with very good health (-0.06), see figure 7A. Secondly, the results showed statistical differences between all three health groups (<0.001***) regarding outdoor activities. The results showed, on average, that preferences to avoid outdoor activities increased with worsening health status, see figure 7B. The highest level of significance (<0.001***) was found between the group with worsened health (-0.7) and very good health (-0.01). The remaining significant differences were found between the group with worsened and good health ($p = 0.068^*$) and between good and very good health ($p = 0.028^*$).

On average, older adults within all groups avoid sunlit environments during days, mainly squares and city streets in the sun. In addition, older adults within all groups prefer to seek places with wind/good ventilation and green areas in the shade, see table 9. The post-hoc test results showed statistically significant differences between the health groups in two of the nine outdoor environment types: places by the water ($p = 0.021^*$) and places with wind/good ventilation ($p = 0.03^*$). On average, the group with very good health has a stronger preference to seek places near water (0.68) and places with wind/good ventilation (0.83) in comparison to the group with worsened health (0.32, 0.53).

Table 9: *Omnibus test in ANOVA for comparison of the independent groups worsened, good and very good health. Levels of significance (p) between groups; * p-value < 0.05; **p-value < 0.01; ***p-value < 0.001.*

Health status	**Worsened health**		**Good health**		**Very good health**		
	M (SD)	*N*	*M (SD)*	*N*	*M (SD)*	*N*	*P*
1. When there is a heat wave, I want to be...	-0.51 (0.77)	37	-0.18 (0.91)	95	-0.06 (0.87)	139	0.019*
2. When there is a heat wave, I avoid outdoor activities.	-0.70 (0.78)	37	-0.31 (0.92)	95	-0.01 (0.90)	139	<0.001***
3. Urban environments (avoid or seek) during a heat wave:							
a) City streets in the sun	-1.11 (0.82)	36	-1.19 (0.72)	89	-1.08 (0.74)	132	0.572
b) City streets in the shade	0.49 (0.95)	35	0.18 (1.07)	90	0.32 (0.96)	129	0.276
c) Squares in the sun	-1.29 (0.71)	35	-1.31 (0.73)	90	-1.11 (0.78)	131	0.111
d) Squares in the shade	0.32 (0.98)	34	0.09 (1.00)	89	0.23 (0.92)	128	0.403
e) Green areas (park/grove) in the sun	-0.33 (1.12)	36	-0.45 (1.02)	88	-0.23 (0.97)	130	0.275
f) Green areas in the shade	0.69 (0.93)	35	0.60 (0.86)	90	0.75 (0.72)	130	0.414
g) Other places, by water	0.32 (0.91)	34	0.43 (0.90)	91	0.68 (0.76)	130	0.021*
h) Other places, with wind/good ventilation	0.53 (0.77)	36	0.67 (0.65)	91	0.83 (0.64)	130	0.03*
i) Other places, in the lee (next to a house wall or similar)	-0.39 (1.05)	36	-0.31 (1.06)	90	-0.18 (1.07)	128	0.481

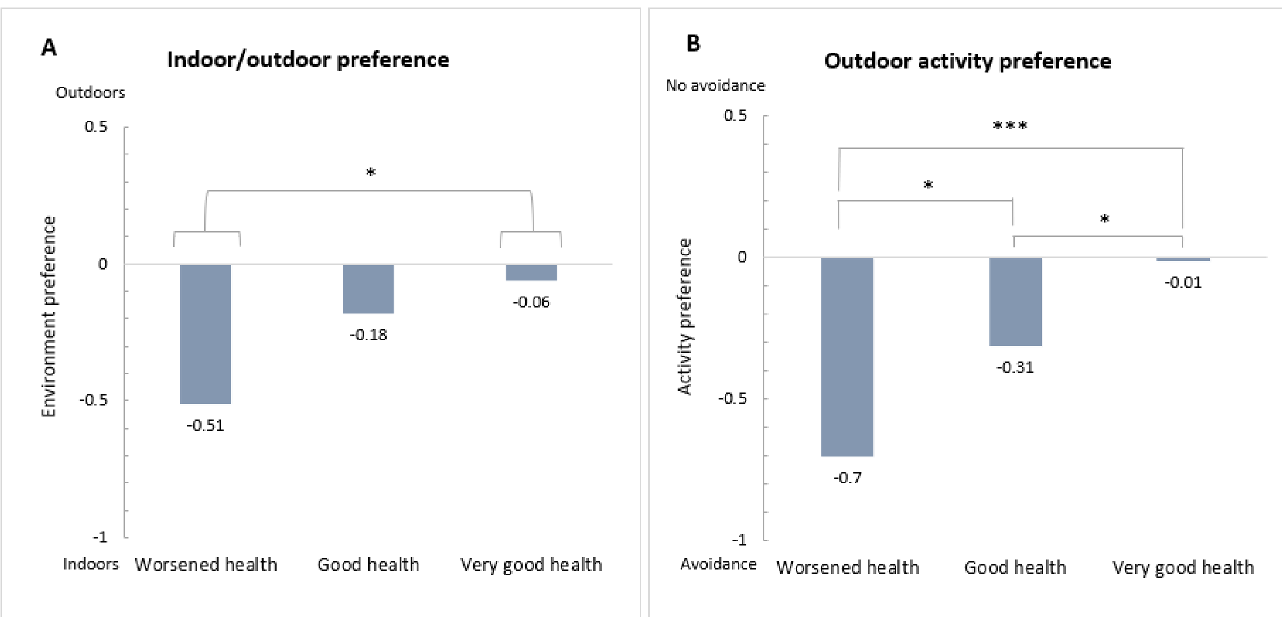

Figure 7: *Environment preference (A) and outdoor activity preference (B) during warm days between health status groups. Negative mean values represent preference of staying indoors and avoiding outdoor activities, and positive values represent preference of being outdoors and not avoiding outdoor activities during warm days. Levels of significance (p) between groups; * p-value < 0.05; **p-value < 0.01; ***p-value < 0.001.*

5.8 Desirable urban outdoor environments during warm days

Out of the total sample of 348 respondents, answers from 223 respondents were collected in the results of the content analysis regarding environmental needs of older adults during warm days. Some respondents provided several concepts in their answers that fell into different categories. Therefore, a total number of 338 concepts were analyzed. According to figure 8, the majority of all respondents considered shade (n = 190/348) an essential factor in the local outdoor environment to carry out activities during warm weather. The second and third most considered factor was greenery (n = 54/348) and accessibility to water (n = 52/348). The greenery category mainly consisted of concepts referring to trees, parks, and forests. The water category mainly consisted of concepts referring to the sea or lakes. The categories with the lowest frequency rates were rest areas and windy/ventilated areas.

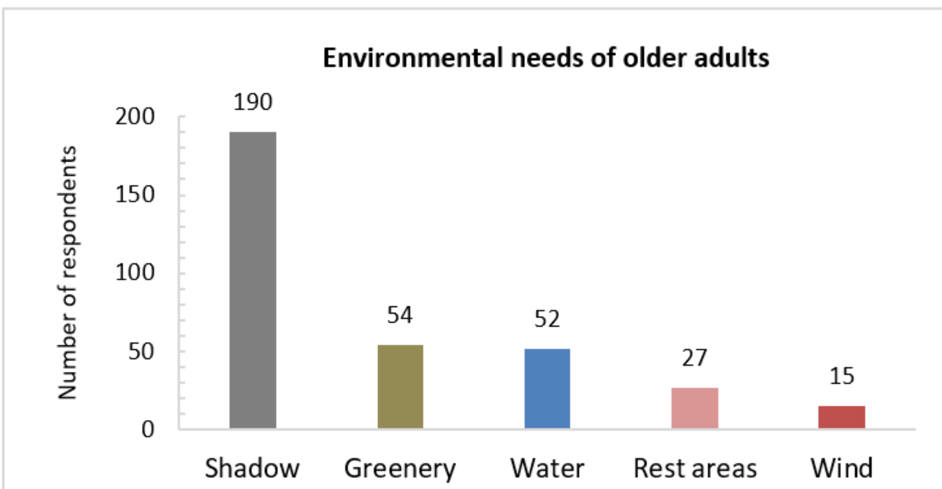

Figure 8: *Environmental needs in the local environment for older adults to be able to carry out outdoor activities during warm days.*

5. Discussion

5.1 Behaviour of older adults in urban outdoor environments

The general results of the whole population of older adults showed relatively neutral preferences since they, on average, prefer to stay both indoors and outdoors and sometimes chose to avoid outdoor activities during warm days. In contrast, more apparent patterns emerged about which outdoor environments older people, on average, prefer to avoid or seek during warm days. Some of these findings are consistent with previous studies which found that heat can be experienced differently between older adults. In their study, some respondents described feeling uncomfortable during warm weather, while others reported that they enjoyed the heat and did not experience discomfort (Abrahamson et al., 2009). Therefore, to better understand outdoor thermal comfort, it is essential to consider various groups of older adults, such as different individual factors and spatial characteristics in their local outdoor environment (Lai et al., 2020). By examining the complex relationships between these variables and older adults' preferences regarding their use of outdoor space, this study has found several significant patterns that could have an influence on the behaviour between different groups of older adults during warm days.

When studying the preference for staying indoors or outdoors during warm days, the variable health status was the only one of the six independent variables that showed a statistical difference between groups. On average, older adults with worsened health have a stronger preference to stay indoors compared to older adults with very good health. This can be explained since people with chronic illnesses in most cases have a reduced ability to regulate body temperature and to protect themselves from heat stress (Public Health Agency of Sweden, 2018: Åström et al., 2015). Thus, the results suggest that older adults with worsened health may be experiencing higher thermal discomfort during warmer weather, leading them to have a higher level of preference to stay indoors during warm outdoor conditions. However, staying indoors during these circumstances could imply negative consequences to both mental and physical health, since they refrain from both physical activity and social interaction, which in turn could lead to loneliness and anxiety (Yung, Wang & Chau, 2019). Therefore, it is essential to recognize the consequences of warm warm weather and heat wave events on vulnerable populations, particularly older adults with higher risk factors due to health problems.

Regarding outdoor activity preferences during warm days, statistical differences were found between groups for both individual variables and one of four spatial characteristic variables, including age, health status and the level of tree canopy fraction. Regarding groups within the individual variables, it was found, on average, that older age groups and adults with worsened health had a stronger preference to avoid outdoor activities compared to younger age groups and adults with very good health. Interestingly, the strongest statistical differences between groups were found for the health status variable. Apart from older populations and people with cardiovascular diseases being vulnerable groups to thermal discomfort (Yung, Wang & Chau, 2019; Public Health Agency of Sweden, 2018; Klemm et al., 2015), it can also be added that increasing age and worsening health implies reduced mobility (Public Health Agency of Sweden, 2018), which may be an additional co-varying factor of why these groups on average have a stronger preference to avoid outdoor activities. Another explanation for these results is that age can be considered a kind of attitude due to age-related experiences at different stages in life, which may affect their expectations towards the weather and outdoor thermal environment (Knez et al., 2009). This statement aligns with the discussion regarding the complexity of thermal comfort (Lai et al. 2020), where age-related experiences could also be related to other indirect influences such as thermal history and cultural factors.

On average, a stronger preference to not avoid outdoor activities was shown for older adults living in areas with high tree canopy coverage compared to areas with low tree canopy coverage. The results may be explained by the thermal benefits that vegetation provides during warm weather conditions due to its cooling effect from transpiration and shading (Oke et al., 2017), which in turn may encourage adults to visit these types of outdoor environments (Cheung & Jim, 2018; Thorsson et al., 2004; Yung, Wang & Chau, 2019). Thus, the results suggest that older adults living in areas with a low tree canopy cover may experience higher thermal discomfort during warm days due to the lack of shade and transpiration, leading them to have a stronger preference to avoid outdoor activities to prevent heat stress. In contrast, older adults living in areas with a high tree canopy cover may experience higher thermal comfort due to the cooling effect from shade and transpiration, leading them to have a stronger preference to perform outdoor activities during warm days since the risk for heat stress is not as prominent. However, it is essential to notice that the high degree of tree canopy fraction (15-25%), on average, showed relatively neutral preference values (0.02) regarding outdoor activities. Despite this, a significant pattern was discovered in the results by comparing means between groups; the preference for performing outdoor activities increased with the degree of tree canopy fraction. An assumption is that if the tree canopy fraction had been higher, for example, the recommended fraction of 30 percent (Iungman et al., 2023), the difference in means regarding outdoor activity preference may have been even more significant.

Moreover, it is essential to highlight that vegetation has many beneficial properties which can explain the statistical relationships of activity preferences. Besides thermal benefits, green space encourages social interaction and improves physical and mental health (Baldwin, Matthews & Byrne, 2020; Yung, Wang & Chau, 2019). This implies that the preferences for performing outdoor activities in areas with access to high amounts of vegetation could also have a relationship, or possibly a stronger relationship, with the social and recreational benefits. The socio-economic status could also have had a co-varying effect on the result since a high canopy cover often corresponded to residential areas, according to the GIS analysis in this study. Older adults living in residential areas could possibly imply a better health of these respondents, which could have influenced their stronger preference for outdoor activities in these areas.

The results confirmed that older adults, on average, have a preference to seek places with wind/good ventilation and green areas in the shade in urban outdoor environments. The cooling characteristics that older adults experienced regarding wind corresponds to recent trends in urban planning that have begun to raise the importance of urban ventilation corridor planning as an effective adaptation measure to reduce the intensity from the UHI effect (Bing et al., 2021). Additionally, the results regarding the importance of greenery are similar to previous findings, since green environments are more often preferred for thermal comfort by the urban population than other outdoor environments (Klemm et al., 2015). Another study, which specifically focused on the thermal preferences of older adults, found that shaded areas in urban green spaces were considered the most desirable environment during summer (Yung, Wang & Chau, 2019). Thus, it is recognized that thermal properties in terms of wind and shade provided by greenery are essential to consider in urban design when the aim is to provide thermally comfortable environments and encourage the use of outdoor space of the urban population during warm days, specifically vulnerable populations such as older adults. The content analysis results further strengthen the findings in the statistical analysis, since shade was valued as the most essential factor to enhance the use of outdoor space during warm days. These findings are consistent with previous research as older adults tend to adapt to their outdoor thermal environment by changing their surrounding microclimate, and seeking shade has previously been found as a common adaptive behaviour during warm weather (Lai et al., 2020; Abrahamson et al., 2009).

In regards to urban outdoor environments that older adults prefer to avoid during warm days, it was found that sunlit environments, such as city streets and squares, were perceived as undesirable during warm days. This effect can be explained by the thermal properties of paved materials when exposed to high solar radiation as they contribute to release of stored heat which can create unpleasant microclimates (Oke et al., 2017; Kim & Brown, 2021). These results indicate that the thermal environment at city streets and squares with the absence of shade is perceived as less desirable by older adults during warm days and may therefore be more prone to heat stress than other environments in the urban environment examined in this study.

Regarding relationships between different spatial and individual variables and the use of various urban outdoor environments, statistical differences were found between four different groups of variables; urban areas, proximity to water, age, and health status, in four different types of outdoor environments; wind/good ventilation, places by the water, places in the leeward, and city streets in the sun. These results suggest that there is a difference between groups, based on where they live as well as individual aspects, and their preferences regarding different outdoor environments. For instance, it was found that the group with very good health and the younger age group, on average, preferred to seek places near water and places in comparison to the group with worsened health or older age. Another example is that older people living close to water and those with very good health, on average, preferred places with wind/good ventilation than those living within a medium distance to water or have worsened health. Due to these results and the complexity of thermal comfort, it has been acknowledged that older adults may have different requirements and expectations of thermal conditions in the outdoor environment. The results from this study can therefore suggest that diverse microclimate conditions should be provided through urban design within different outdoor environments so that older adults can adjust to different thermal environments to meet their expectations and preferences (Yung, Wang & Chau, 2019; Aghamolaei & Lak, 2022).

5.2 Discussion of methods

The strength of applying quantitative methods to this study was its possibility of analyzing a large sample size of data and thus being able to perform a broad geographical comparison between respondents. By including GIS in the method, it was possible to connect the spatial aspect into the analysis, instead of only studying the individual aspects, and see if spatial variables could be connected to the behaviour of older adults during warm days. Using statistical methods made it possible to determine whether there were any relationships and clear patterns between dependent and independent variables of spatial characteristics and individual factors of older adults. However, it is essential to consider that the data collection was based on a non-probability sample, which may have caused certain groups to be over- or under-represented in the survey, which may have affected the generalizability of the results to the entire population of older adults. On the other hand, this is assumed to have a minimal impact on the overall results since the sample consisted of a wide age range of older adults and a broad spatial distribution as respondents from both larger and smaller urban areas were included in the analysis.

There were several cases where no statistical significance was found between spatial characteristics and individual factors and preferences regarding the use of outdoor space during warm days. However, the absence of statistical significance of these variables does not necessarily mean that they do not influence older adults' preferences which in turn affects their behaviour in the urban outdoor environment. Due to the complexity of thermal comfort (Lai et al., 2020), one variable alone is insufficient to explain the degree of influence on the behaviour of older adults. Instead, there are possibilities that other direct or indirect factors co-vary or are more significant which cast shade on the effects from the studied variables. Another reason which could have affected the results is the grouping of variables. If variables are grouped in a way that results in high variation within groups and low variation between groups, the probability of finding statistically significant differences between groups decreases (Fogarty, Rensing & Stuckey, 2017).

Regarding the data used for the GIS analysis, the generated DSMs and land cover data showed some limitations when compared to datasets available from 2010. For instance, smaller urban structures such as bus shelters and statues were found to be wrongfully classified as trees in the land cover model. A reason to explain this could be because of the lower point density of the LiDAR data (1-2 points per m2). With higher point densities, more detailed and accurate representations of the ground surface can be obtained (Grönlund, 2016). However, these minor limitations have been considered to have a negligible impact on the study results on a broad scale. The strength of using the LiDAR data from Lantmäteriet (2018) is that it is the newest updated open-source LiDAR data available. Older versions of geodata, for example, the dataset from 2010, could have caused newly built infrastructures and newly planted vegetation to be missed, which in turn would have caused wrongly classified data. Thus, due to the rapid development in urban areas, it is essential to consider using updated geodata to classify the land cover correctly.

5.3 Further research

Further research regarding direct and indirect factors should be considered to gain a broader understanding of the complex factors that influence outdoor thermal comfort (Lai et al., 2020). One way to include direct factors in the analysis could be to examine the urban outdoor environment by calculating the meteorological variable mean radiant temperature (Tmrt), and further by applying the Physiological Equivalent Temperature (PET) index (Lindberg et al., 2018). By connecting the survey data with Tmrt models and PET, it could be possible to gain a more in-depth understanding of usage patterns and the impacts of built environments on the outdoor thermal comfort of older adults.

Other ways to deepen the understanding of behaviour of older adults, in relation to the chosen independent variables, is to apply other statistical methods such as regression models (Esaiasson et al., 2017). In regression models, the independent variables are calculated on a continuous scale, in contrast to groups in one-way ANOVA tests, which makes it easier to identify breaking points between relationships of independent and dependent variables. Additionally, it could be interesting to study the relationships between several independent variables at the same time, through a multivariate analysis (ibid). For instance, this could imply adding several individual factors into the same model to better understand the relative importance of various factors and in turn estimate which factor between age and health status may have a stronger influence on preferences of older adults regarding their use of urban outdoor space.

This study has used quantitative methods to investigate issues that one could argue also require a qualitative perspective, for instance, through interviews and observations (Esaiasson et al., 2017; Harris & Jarvis). In further studies, a qualitative understanding would increase the possibility of a deeper understanding and a complete picture of why older adults' particular preferences and attitudes affect their behaviour in urban outdoor environments during warm days. In addition, it would be easier to discover other underlying factors that influence their behaviour apart from the variables investigated in this study.

6. Conclusions

This study has found several significant patterns that could have an influence on the behaviour of different groups of older adults during warm days. In terms of individual aspects, the study's main finding was that the preference for staying indoors and avoiding outdoor activities during warm days, on average, increased with older age and worsening health. In terms of spatial characteristics in the urban outdoor environment, it was found that the willingness to perform outdoor activities, on average, increased with the degree of tree canopy fraction within the local area.

Additional findings in the study were that older adults found sunlit places in the city, such as streets and squares, undesirable during warm days. In contrast, places with wind/good ventilation and shade provided by greenery were considered desirable environments for older adults during warm days. These findings highlight the importance of including urban elements that promote wind and green infrastructure in urban design to encourage the use of outdoor space by older adults during warm days.

The findings in this study have contributed to a better understanding of how older adults behave in various urban outdoor environments during warm days and which environments may be more prone to heat stress than others. However, since populations experience thermal comfort differently and since some populations are more vulnerable to heat than others, it is necessary to examine various influential factors within different population groups, as well as their needs, to enhance their use of outdoor space during warm days and in turn create sustainable and resilient cities that include all urban residents.

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8. Appendix:

Extended version of outputs from statistical analysis in SPSS regarding omnibus tests in ANOVA for comparison of independent groups of spatial and individual variables. Tables showing F-value (F), degree of freedom (df), p-value and effect size in Eta-squared (η2).

Urban areas	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	1.559	2	0.212	0.009
2. When there is a heat wave, I avoid outdoor activities.	1.213	2	0.299	0.007
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	0.023	2	0.977	0
b) City streets in the shade	0.048	2	0.953	0
c) Squares in the sun	1.517	2	0.221	0.009
d) Squares in the shade	0.164	2	0.849	0.001
e) Green areas (park/grove) in the sun	1.541	2	0.216	0.010
f) Green areas in the shade	1.018	2	0.362	0.006
g) Other places, by water	0.495	2	0.61	0.003
h) Other places, with wind/good ventilation	2.603	2	0.076	0.016
i) Other places, in the lee (next to a house wall or similar)	3.591	2	0.029*	0.022

Tree canopy fraction	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	1.561	2	0.211	0.009
2. When there is a heat wave, I avoid outdoor activities.	3.748	2	0.025*	0.022
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	1.235	2	0.292	0.008
b) City streets in the shade	1.043	2	0.354	0.007
c) Squares in the sun	1.240	2	0.291	0.008
d) Squares in the shade	0.704	2	0.495	0.005
e) Green areas (park/grove) in the sun	0.465	2	0.629	0.003
f) Green areas in the shade	0.452	2	0.637	0.003
g) Other places, by water	0.095	2	0.909	0.001
h) Other places, with wind/good ventilation	0.045	2	0.956	0.000
i) Other places, in the lee (next to a house wall or similar)	0.106	2	0.899	0.001

Normalized building volume	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	0.588	2	0.556	0.004
2. When there is a heat wave, I avoid outdoor activities.	2.064	2	0.129	0.012
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	0.473	2	0.623	0.003
b) City streets in the shade	0.790	2	0.455	0.005
c) Squares in the sun	0.596	2	0.552	0.004
d) Squares in the shade	0.914	2	0.511	0.004
e) Green areas (park/grove) in the sun	0.914	2	0.402	0.006
f) Green areas in the shade	0.009	2	0.991	0.000
g) Other places, by water	1.061	2	0.347	0.007
h) Other places, with wind/good ventilation	1.629	2	0.198	0.010
i) Other places, in the lee (next to a house wall or similar)	0.244	2	0.784	0.002

Proximity to water	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	0.080	2	0.923	0.000
2. When there is a heat wave, I avoid outdoor activities.	0.290	2	0.749	0.002
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	0.358	2	0.699	0.002
b) City streets in the shade	0.238	2	0.788	0.001
c) Squares in the sun	1.267	2	0.283	0.008
d) Squares in the shade	0.236	2	0.79	0.001
e) Green areas (park/grove) in the sun	1.409	2	0.246	0.009
f) Green areas in the shade	1.555	2	0.213	0.010
g) Other places, by water	0.523	2	0.593	0.003
h) Other places, with wind/good ventilation	4.621	2	0.011*	0.028
i) Other places, in the lee (next to a house wall or similar)	0.223	2	0.801	0.001

Age groups	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	2.024	1	0.156	0.006
2. When there is a heat wave, I avoid outdoor activities.	7.485	1	0.007**	0.022
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	0.314	1	0.576	0.001
b) City streets in the shade	4.383	1	0.037*	0.014
c) Squares in the sun	0.248	1	0.619	0.001
d) Squares in the shade	1.087	1	0.298	0.003
e) Green areas (park/grove) in the sun	0.375	1	0.541	0.001
f) Green areas in the shade	0.023	1	0.879	0.000
g) Other places, by water	8.315	1	0.004**	0.025
h) Other places, with wind/good ventilation	3.623	1	0.058	0.011
i) Other places, in the lee (next to a house wall or similar)	6.070	1	0.014*	0.019

Health status	*F*	*dF*	*p*	*η2*
1. When there is a heat wave, I want to be...	4.042	2	0.019*	0.029
2. When there is a heat wave, I avoid outdoor activities.	10.209	2	<0.001***	0.071
3. Urban environments (avoid or seek) during a heat wave:				
a) City streets in the sun	0.560	2	0.572	0.004
b) City streets in the shade	1.293	2	0.276	0.010
c) Squares in the sun	2.214	2	0.111	0.017
d) Squares in the shade	0.911	2	0.403	0.007
e) Green areas (park/grove) in the sun	1.296	2	0.275	0.010
f) Green areas in the shade	0.885	2	0.414	0.007
g) Other places, by water	3.940	2	0.021*	0.030
h) Other places, with wind/good ventilation	3.553	2	0.03*	0.027
i) Other places, in the lee (next to a house wall or similar)	0.734	2	0.481	0.006