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LINKING ENVIRONMENTAL AND BEHAVIOURAL PATHWAYS IN URBAN GREEN SPACE OPTIMISATION FOR WELL-BEING

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Contents

Acronyms

ANOVA: Analysis of Variance

AUSL: Azienda Unità Sanitaria Locale (Local Health Authority, Bologna)

BREQ-2: Behavioural Regulation in Exercise Questionnaire (version 2)

EDA: Electrodermal Activity

EAPRS: Environment Assessment of Public Recreation Spaces

EEG: Electroencephalogram

EMG: Electromyography

ENVI-met: Environmental Modelling Software for Microclimate Simulation

GHQ-12: General Health Questionnaire-12

GIS: Geographic Information System

GDS-15: Geriatric Depression Scale-15

GR/G: Gradi Giorno (Heating Degree Day value)

MHI-5: Mental Health Inventory-5

MPA: Moderate Physical Activities

NCDs: Noncommunicable Diseases

NEST: Natural Environment Scoring Tool

NGST: Neighbourhood Green Space Tool

PA: Physical Activity / Activities

PANAS: Positive and Negative Affect Schedule

PET: Physiological Equivalent Temperature

PGWB-S: Psychological General Well-Being Index - Short Form

PI: Physical Inactivity

POST: Public Open Space Tool (distinct from “post” used as a temporal word, e.g. “post-intervention”, “ex post”)

PPG: Photoplethysmography

PRS: Perceived Restorativeness Scale

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RESP: Respiration Sensor

SKT: Skin Temperature

SWB: Subjective Well-Being

UGS: Urban Green Space / Spaces

VIF: Variance Inflation Factor

VPA: Vigorous Physical Activities

WEMWBS: Warwick-Edinburgh Mental Well-Being Scale

WHO-5: World Health Organization-Five Well-Being Index

WOS: Web of Science

Abstract

Urban green spaces (UGS) are increasingly recognised as essential components of healthy and sustainable cities. Their potential to improve well-being, however, depends not only on their physical presence but also on how people interact with and perceive them. This thesis explores how the optimisation of UGS can enhance health and well-being through a multidimensional approach that integrates behavioural, perceptual and environmental perspectives. The work is explorative in nature but based on a coherent analytical framework, combining surveys, interventions and environmental modelling to understand how UGS function as settings for health promotion.

The first part of the thesis focuses on the relationship between UGS quality and residents' well-being. Using a PRISMA-guided search across major databases, the review organised evidence into three domains of quality: spatial features, natural elements and facilities/amenities, plus studies assessing combined quality. Consistent patterns emerged for biodiversity, greenery and good maintenance, which were most often linked to reduced stress, better mood and restoration; by contrast, accessibility and facilities showed mixed effects unless places were also perceived as safe, clean and pleasant. Measurement heterogeneity was substantial, underscoring the need to integrate objective audits/GIS with perceptual measures when assessing the links between quality and well-being.

The second part examines the behavioural dimension through the "Moving Parks" project (Parchi in Movimento), a park-based intervention promoting supervised physical activities (PA). Based on a cross-sectional study and two longitudinal studies, this thesis explores the behavioural pathway from everyday activity to well-being in green settings. The baseline cross-sectional survey in Bologna showed that being active at both moderate and vigorous levels was linked with higher subjective well-being, with age, health and work status shaping the strength of this link. The 2022 "Moving Parks" pre–post evaluation found general gains in self-reported well-being and a strong intention to keep exercising after the programme, especially among women and middle-aged adults, indicating that supervised activities in parks can support participation and motivation over a season. In contrast, a 2023 quasi-experimental study with a control group in middle-aged adults did not detect a clear intervention effect on overall mental well-being; only "usefulness" showed an interaction, and several dimensions improved more in controls, pointing to the role of seasonal context, baseline levels and measurement sensitivity.

The next analysis explored residents' perceptions and attitudes towards UGS, focusing on how demographic and household characteristics shape patterns of use. Results show that life stage and household composition strongly influence both frequency and purpose of visits, while education and employment status exert limited effects. People living with children or elderly dependents place more importance on accessibility and safety, while younger adults tend to value variety and cleanliness. These insights highlight the social dimension of green spaces as inclusive yet differentiated environments that respond to diverse everyday needs.

The final part of the thesis extends the analysis from human perception to environmental performance, using ENVI-met simulations of the Marconi district redevelopment in Imola. The results demonstrate that tree canopies play a decisive role in mitigating heat stress, reducing the Physiological Equivalent Temperature by up to 3.5 °C in shaded areas during heatwaves. However, building façades produced localised warming, illustrating the trade-off

between densification and liveability. These findings confirm that ecological structure supports the comfort and usability of urban environments, providing the physical foundation for health-promoting spaces.

Taken together, the studies form a coherent narrative that frames health promotion in cities as a multidimensional process linking environmental design, behavioural engagement and subjective experience. The thesis contributes both methodological and conceptual insights by integrating diverse forms of evidence within a unified framework, from subjective questionnaires to microclimate modelling. Although certain limitations remain, such as small sample sizes and short intervention durations, these reflect the complexity of studying human–environment interactions in real urban contexts rather than methodological weakness.

Overall, this work argues that UGS should be treated as public health infrastructure, where ecological quality and social accessibility jointly determine health outcomes. Future research will extend this multidimensional framework to address issues of equity, vulnerability and ecological value, exploring how UGS can simultaneously promote human well-being and environmental resilience. Ultimately, the thesis affirms that the optimisation of UGS is not merely about design or planning, but about shaping relationships between people, nature and the urban fabric that connects them.

Keywords: urban green spaces; green space quality; physical activity; mental well-being; health promotion

Chapter 1 – Introduction and Background

1.1 Urbanisation and the Challenges of Well-Being

Urbanisation is one of the essential dimensions of the sustainability challenge in the twenty-first century, with the proportion of the world's population living in cities projected to rise from 55% today to nearly 70% by 2050 [1-3]. The rapid expansion of urban areas is reshaping both landscapes and lifestyles by concentrating the population, resources and economic activity [4-7].

The consequences of urbanisation are ambivalent. On the one hand, urbanisation brings greater economic productivity, enhanced access to health and education services, and better availability of essential services and resources, which are often limited in rural areas [4, 8-10]. On the other hand, urbanisation causes environmental pressures such as overcrowding, land-use conflicts, pollution, and heat stress [11-14]. It also accelerates social rhythms, leading to reduced opportunities for rest, leisure, and contact with nature [15-20]. The paradox reflects the essence of urbanisation: while it is a driver of ecological degradation and psychosocial strain [13, 21-23], it is also where solutions can be most effectively designed and implemented [15, 24, 25].

However, traditional approaches to urban regeneration are narrow in scope and yield insufficient benefits. The updates based on grey infrastructures prefer to treat downstream symptoms rather than upstream drivers [26, 27]. Specifically, road widening may temporarily alleviate traffic congestion but forces cities into vehicle dependence and higher emissions [28]; river embankments may control local floods but make rivers more vulnerable to flow changes, increase sediment deposition, and shift flood risks downstream [29-31]; public or commercial squares usually prioritise commercial attributes over community functions, contributing to environments with excessive retail spaces, limited greenery and amenities, which constrain daily use [32, 33]; urban renewal projects often increase housing costs and expulse residents of low socio-economic status, while transferring industries to the suburbs to shift pollution problems elsewhere and increase the cost of travelling and transportation [34, 35]. Such solutions may be effective in the short term but are detrimental to the healthy and sustainable development of cities.

Thus, among the various proposals, nature-based solutions have gained increasing attention in recent years because of their multifunctionality, as they not only enhance human health and well-being but also contribute to environmental improvement and urban sustainability [26, 36-38].

1.2 Urban Green Spaces as Health Resources

Among the wide range of nature-based solutions, urban green spaces (UGS) represent one of the most common and widely studied resources for promoting health and well-being in urban areas, with an increasing number of studies demonstrating their benefits [39-41]. Based on this evidence, both European and global policymakers increasingly highlight the role of UGS in addressing sustainability challenges, from climate adaption to public health promotion [42-44].

“UGS” refer to green and blue infrastructures which can be accessed by the public in urban areas, including parks, gardens, squares, urban forests, and other open spaces with natural elements [43, 45]. Accordingly, this thesis adopts a definition that focuses on publicly accessible environments that integrate green and blue elements. Purely aquatic environments (e.g., rivers, lakes, or coastal waters) are excluded because the study aims to provide a theoretical basis for the planning and evaluation of urban parks, where water bodies alone are not the primary design target. Similarly, vertical greening and private gardens are not considered, as they are generally inaccessible to the public and fall beyond the scope of green space-based interventions examined in this research. Different from traditional solutions such as drainage systems for runoff control, wastewater treatment plants for pollution control, and air-conditioning systems for heat mitigation, UGS integrate the concept of ecological metabolism into the urban fabric, reducing urban environmental burdens while promoting both mental and physical health of residents [46-54].

The health benefits of UGS also arise from their multiple functions [55, 56]. Firstly, UGS provide healthy environment including vegetation and permeable surfaces, which contribute to the cleaner air, reduced noise, and cooler urban microclimates through shading and evapotranspiration [57-60]. By alleviating the urban environmental stressors, UGS lower residents’ exposure to heat-related risks, respiratory irritants, and cardiovascular strain [61-64]. Secondly, UGS supply the venues for daily leisure, thereby creating opportunities for social interactions. By enhancing social cohesion, connection, and a sense of belonging, UGS help to strengthen resilience against mental health challenges among residents [65, 66]. Thirdly, UGS promote the higher levels of physical activities such as walking, running or cycling by providing amenities. This behavioural pathway has been considered as a mediator between natural environments and a range of health outcomes, from reduced risks of cardiovascular and metabolic disease to improved life satisfaction and subjective well-being (SWB) [67, 68]. Finally, contact with UGS supports recovery from stress, fatigue, and attentional overload, and may also reduce the risk of depression and anxiety through several psychological pathways [69-71]. This mechanism has been described in several influential theories: Stress Reduction Theory [72] emphasises the immediate affective and physiological benefits of exposure to natural elements; Attention Restoration Theory [73] suggests that natural settings restore attentional resources capturing attention effortlessly through their softly fascinating qualities; and The Biophilia hypothesis [74] proposes that that humans are evolutionarily tend to connect with nature, which supports these restorative experiences.

In summary, as remnant patches or reconstituted patches embedded in urban landscapes, UGS provide multifunctional solutions that both alleviate environmental stressors and promote human well-being [75, 76]. Their health benefits operate through several complementary pathways: by improving the environment, providing opportunities for social connection and physical activity, and supporting psychological restoration. These mechanisms jointly explain the importance of UGS as a nature-based solution for sustainable urban development and public health promotion.

1.3 From Quantity to Quality

Research on the health benefits of UGS usually rely on quantity-based indicators, such as total green area, green coverage or vegetation indices (NDVI) [43, 77, 78]. These measures are based on the assumption that “greener” is generally linked with “healthier” [43, 56, 77]. Meanwhile, accessibility is also frequently used as a single indicator which reflects the spatial

availability of UGS, and is often applied in studies of environmental justice [79-81]. Although these measures have played an important role in linking green exposure to health, they remain relatively one-dimensional and cannot capture the specific features of UGS that benefit residents or the qualities that attract people to visit them [40, 82, 83].

Recognising that quantitative measures have yielded increasingly homogeneous findings, this topic has reached a bottleneck, driving a shift in focus towards the quality of UGS [84-86]. Features such as biodiversity, aesthetics, amenities, maintenance and safety affect the perception and engagement of residents with UGS, thereby influencing the extent of their health benefits. This means that not all UGS are equal in their capacity to promote well-being [40, 87-89].

However, despite growing scholarly interest, the definition of "quality" remains heterogeneous. Meanwhile, the empirical evidence on the relationship between UGS quality and mental well-being remains limited and fragmented, with variations in measurement tools, outcomes, and study design. This lack of consistency complicates the comparability of findings and covers the specific mechanisms through which quality contributes to mental well-being [40, 90-92]. To address this gap, there is a need for systematic frameworks that clearly define and measure UGS quality. This thesis synthesises existing evidence to provide a clearer understanding of how the quality of UGS affects human well-being.

1.4 Physical Activity and Subjective Well-Being in Urban Contexts

As mentioned above, physical activity (PA) is one of the most widely recognised behavioural pathways to health promotion. Aside from the widely acknowledged role in reducing the risk of chronic diseases, a growing number of studies have started to focus on psychological benefits [93, 94]. Various forms of PA have been linked to reductions in depression and anxiety, improved stress regulation, and enhanced life satisfaction or SWB [95-100]. In the context of urban life which is characterised by rising psychosocial stressors and sedentary routines, the psychological benefits of PA make it an effective intervention of supporting mental well-being [101-103].

Although the benefits of PA for SWB are well documented, findings across studies still vary in different aspects. The results depend on the type, intensity, frequency of PA, as well as demographic factors such as age, sex, socioeconomic status, and personal health conditions [101, 104]. For example, evidence indicates that short periods of vigorous PA can provide psychological benefits, whereas sustained and regular moderate activity is effective [105-108]. Moreover, the dose–response association between PA and SWB remains contested, with findings ranging from linear improvements to threshold or even U-shaped effects [104, 109, 110].

Although substantial progress has been made, several limitations remain in this field. Most of the existing evidence relies on cross-sectional designs which limit causal inference, and research concerning the socioeconomically disadvantaged such as the elderly, women and the minors remain limited [99, 101, 111, 112]. These gaps highlighted the need for more comprehensive investigations that address multiple dimensions and contexts.

1.5 Residents' Perceptions and Attitudes Towards Green Spaces

Objective assessments of quality, such as maintenance, biodiversity, or facilities, provide a limited perspective. Aside from the physical and ecological characteristics, the value of UGS also depends on the perception and attitudes of the residents [113, 114].

Usually, the benefits of UGS are mediated by participants' perceptions of accessibility, safety, comfort, and aesthetic appeal. The perceptions influence not only the frequency of visiting to green spaces but also the satisfaction within them, thereby contributing to psychological and social outcomes through nature contact. Thus, perception plays an important role between the objective environment and SWB [115-118].

On the other hand, people's attitudes toward UGS are highly related to perception, comprising values, preferences, and behavioural intentions. Although perceptions reflect immediate impressions and cognitive evaluations, attitudes describe people's longer-term ways of planning, participating to and maintaining UGS. Together, they determine the degree to which UGS are used, appreciated, and socially engaged into daily life [117, 119-121]. However, despite the increasing numbers of studies have examined objective and structural determinants of UGS quality, the combined influence of perceptions and attitudes remains limited. Neglecting these subjective dimensions may overlook the difference in responses between residents of different socio-economic levels (defined by age, income, or lifestyle) to the same UGS settings [119, 122-124].

Recognising the significance of these subjective processes extends the concept of UGS quality to include not only objective but also subjective attributes. Perceptions and attitudes jointly influence how residents understand the value and purpose of UGS. [125] Thus, integrating these perspectives into planning and evaluation can reveal mismatches between design and users' preferences, providing critical insight into how UGS can be built more inclusive and efficient to health promoting.

1.6 Green Space-Based Interventions

Based on the perceptual and behavioural dimensions mentioned above, a further step in understanding the relationship between UGS and health lies in exploring how intentional interventions can generate measurable improvements in well-being. Although cross-sectional studies have provided enough evidence of the association, they are limited in proving causality [40, 126]. The approaches based on interventions offer a more comprehensive framework for examining whether increased or structured engagement with UGS can directly influence physical and psychological outcomes [127-129].

Interventions involving UGS integrate environmental exposure with behavioural activation, thereby reinforcing the environmental and psychosocial dimensions previously discussed as essence of the health benefits of UGS [40, 130]. In this context, PA performed within UGS represents a promising perspective. It connects ecological science and public health by linking the body and the environment, thereby revealing pathways that purely spatial or purely behavioural models have often overlooked [131-133]. In this sense, PA in green settings provides a novel perspective for understanding how UGS becomes an important factor in promoting well-being.

Ultimately, the study of green space–based interventions advances the field from descriptive associations to applied, mechanism-based evidence. It underscores that UGS is not a passive background but an active setting through which behavioural engagement and environmental factors combine to promote human well-being. This perspective provides theoretical guidance for UGS planning and for the design of public health policies [130, 134].

1.7 Beyond Behaviour: Microclimate, ENVI-met, and Human Health

As discussed in the previous sections, the relationship between UGS and health has been mainly examined through behavioural, perceptual, and social perspectives. These approaches reveal how people perceive, value, and use UGS, yet they are inherently based on subjective accounts of experience [40, 114]. The behavioural studies rely on self-reported perceptions and observed activities, while the physical processes that determine comfort and exposure can be examined more objectively through environmental modelling [40, 114]. Using this approach makes it possible to quantify how vegetation, materials, and urban morphology interact to influence local thermal conditions, providing empirical evidence of the environmental mechanisms that support health and well-being in cities [51, 58, 59].

Therefore, to complement such perspectives, the final part of this thesis adopts a more environmentally objective approach, examining how the design and vegetation structure of UGS influence local microclimates, and eventually contribute to thermal comfort. For this purpose, the study employs ENVI-met, a three-dimensional microclimate simulation model widely used in environmental research[135, 136]. ENVI-met enables the quantitative assessment of air temperature, radiation, and wind interactions within complex urban settings, and allows the estimation of the Physiological Equivalent Temperature (PET): a comprehensive indicator of perceived thermal comfort that integrates both environmental and human physiological factors[137-139]. This approach provides a realistic representation of how greening interventions modify local thermal environments and affect comfort levels at the scale of daily human experience.

This final component therefore represents a conceptual turning point: from observing behaviour in UGS to exploring the environments themselves as active determinants of health. It situates urban greenery not merely as a stage for social and psychological processes, but as an ecological infrastructure whose physical qualities shape the possibility of comfort, activity, and restoration. Through this shift, the thesis seeks to bridge the experiential and environmental dimensions of urban health, reaffirming that well-being emerges from the continuous interplay between human life and the material conditions of the urban environment.

1.8 Justification and Aims

The growing urbanisation has changed how people experience and interact with nature. As urban areas become denser and more artificial, green areas have become essential for supporting public health and everyday well-being. UGS offer opportunities for exercise, relaxation, and social contact, and they can improve both mental and physical health.

However, although the benefits of contact with nature are well known, several gaps remain in current knowledge. First, most research has concentrated on how much green space cities provide, but less attention has been given to the quality and specific attributes that make

certain areas more supportive of health than others. Second, while physical activity (PA) is recognised as a major pathway linking UGS and well-being, the strength and pattern of this relationship are still debated. Third, residents' perceptions and attitudes, which influence how people value and use UGS are still underexplored, despite their importance for understanding public preferences. Fourth, the environmental mechanisms through which UGS affect well-being, such as microclimate regulation and thermal comfort, remain poorly understood and rarely combined with subjective perspective. Finally, there are relatively few intervention studies that test the real effects of organised or supervised activities in green spaces on well-being outcomes.

In response to these issues, this thesis takes a step-by-step approach to examine how UGS promote mental health through both environmental and behavioural pathways. It moves from reviewing existing research to analysing residents' experiences and evaluating practical projects. By combining these perspectives, the thesis aims to generate knowledge that can guide the planning and management of healthier urban environments.

Specifically, the thesis aims to:

a) Review the evidence on how UGS quality relates to mental well-being;
b) Examine the relationship between different levels of PA and SWB in urban residents;
c) Explore residents' perceptions and attitudes towards UGS and how these vary by demographic and household factors;
d) Assess the effectiveness of a supervised park-based PA programme in improving well-being and motivation of engagement;
e) Combine microclimate modelling with health-related data to explore how physical conditions of green spaces influence comfort and well-being.

Chapter 2 – Systematic Review of Urban Green Space Quality and Mental Well-being

This chapter is based on the article:

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Land 2025, 14(2), 381,

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Keywords: urban green spaces; quality; mental well-being; mental health benefits

Summary

Considering the shift from the quantity of urban green spaces (UGS) to their quality as a key factor for health promotion, this chapter is trying to understand what "quality" actually means and how it relates to people's mental well-being. It reviews existing research to understand which aspects of parks, such as their natural elements, maintenance, accessibility, and facilities. Rather than focusing on green coverage, the chapter gathers findings from studies conducted across different contexts to see how ecological, spatial, and perceptual factors interact in shaping the psychological benefits of UGS. The evidence shows that biodiversity, greenery, and good maintenance are consistently associated with reduced stress and improved mood, while factors like accessibility or the presence of facilities only bring benefits when people also perceive these places as safe and pleasant. Altogether, this chapter sets the conceptual foundation for the empirical studies that follow, helping to clarify what makes some green spaces truly health-promoting and how such qualities can guide both design and policy in urban context.

2.1 Introduction

Building on the discussion of urbanisation and health challenges presented in the previous chapter, this chapter examines the quality of urban green spaces (UGS) and their relationships with mental well-being [1, 4, 40, 88].

Although previous research has extensively confirmed that UGS contribute to health through psychological, behavioural, and social pathways, most evidence still focuses on quantity-based indicators such as area, greenness indices, or accessibility [43, 77, 140-142]. These proxies have established that "more green" often relates to "better health", yet they provide little insight into "why" some UGS promote well-being more effectively than others [40, 143, 144].

Meanwhile, recent studies indicates that the quality of the green spaces may play a important role in shaping their health impacts [40]. For example, ecosystem diversity can enhance health and well-being, while elements such as pollen may cause risks to human health [145]. Amenities and facilities in the parks also significantly attract residents to UGS, making green space development more utilitarian in nature [146]. In addition, maintaining cleanliness and safety in the park is also a crucial aspect of enhancing its appeal, requiring effective management, renovation, and maintenance [147-149].

Despite this growing recognition, the concept of UGS quality remains inconsistently defined across disciplines. For instance, environmental scientists prefer to equate quality to ecological indicators such as vegetation diversity or canopy cover [113, 150, 151]. In contrast, urban designers emphasise spatial configuration and provision of amenities [152-154], while public health researchers focus more on residents' subjective evaluations, including perceived safety, cleanliness, and aesthetic appeal [155-157]. These disciplinary differences illustrate the conceptual and methodological fragmentation that complicates cross-study comparison and limits the translation of evidence into planning practice [40, 91].

In compact cities where opportunities for creating new parks are limited, enhancing the quality of existing green spaces represents a realistic and equitable path to improve residents' mental well-being, aligning with the overarching goal of this thesis: to promote well-being through UGS. Therefore, from the perspective of urban planning and public health, clarifying the role of UGS quality is essential for developing evidence-based strategies to enchance well-being through urban greening. To support this objective, the present chapter provides a systematic review of empirical studies investigating associations between UGS quality and mental well-being. Specifically, it aims to:

a) Identify and categorise all qualities of UGS that have been investigated in previous primary studies;
b) Examine the associations between different UGS qualities and mental health outcomes.

2.2 Materials and Methods

This systematic review of the studies investigating the association of the UGS quality with mental well-being was conducted following the updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [158]. We searched the Web of Science (WOS) Core Collection and MEDLINE databases via the WOS platform, as well as

the PubMed, Scopus, and Cochrane Library databases for all the English publications starting from 2013 to capture the latest progress in this topic. The starting point of 2013 was chosen to ensure the inclusion of the most recent studies, reflecting the rapid development in research on the UGS quality and mental well-being, as well as the increasing refinement of measurement methodologies in this field [159]. We limited our search to research articles, including early-access articles up to 2025 using an article type filter if available. We did not apply any restrictions regarding geographical regions or study populations to maintain a comprehensive overview of the research topic. Additional eligible studies were identified through the reference list checking of included articles, the citation tracking of key papers, and consultation with field experts.

2.2.1 Search Strategy

The search strategy was developed through an iterative process of pilot searches in the WOS Core Collection, considering the theme and the purpose of this review. After finalising the most comprehensive and suitable strategy, we adapted and applied it to other databases. Our strategy was a combination of three relevant parts including mental well-being outcomes and green space quality and urban green space terms. Firstly, we simultaneously employed both general mental health terminology and specific terms related to psychological health issues for the mental well-being outcomes, including the following: mental health OR mental wellbeing OR psychological health OR psychological wellbeing OR mental state OR mental disorder* OR mental illness OR mood OR happiness OR emotion* OR depress* OR anxi* OR stress OR cognitive function* OR restoration OR recovery OR resilience OR psychological benefit* OR mental benefit* [40, 160, 161]. Secondly, multiple synonyms for green space quality were used to capture the "quality", including the following: "green space quality" OR "quality of green space*" OR "spatial feature*" OR "spatial character*" OR "landscape pattern*" OR "vegetation cover*" OR NDVI OR accessibility OR facility* OR amenit* OR maintenance OR safety feature*. Thirdly, green space types were limited to urban settings by describing UGS

, including the following terms: urban green space* OR urban park* OR urban garden* OR urban green infrastructure* OR city park* OR city garden* OR municipal park* OR community garden* OR neighbourhood green* OR urban forest*.

2.2.2 Eligibility Criteria

As inclusion criteria, we considered only articles published in English. Regarding publication types, we included only research articles and excluded reviews, letters to the editor, comments, editorials, recommendations, and all other document types unintentionally retrieved during the database search.

The PICOTS criteria drafted to address the primary search aim were the following:

- P (Patients): All the urban residents who can obtain access to the UGS. However, studies specifically targeting minors were excluded because studies targeting minors are usually conducted with data or survey results provided by parents or teachers as proxies.
- I (Interventions): Exposure to UGS with different aspects of quality. The definition of quality refers to features or characteristics that can impact the experiential aspects of users' park utilisation, including but not limited to the spatial features (e.g., the

size, accessibility, landscape patterns index, etc.), nature elements (e.g., blue elements inside green spaces, the tree canopy, biodiversity, etc.), and the existence and maintenance of facilities and amenities (e.g., playgrounds, sport fields/courts, walking paths/trails, etc.) [162]. In assessing the quality, blue elements within these green spaces were considered as criteria. Exclusions encompassed studies specifically targeting blue spaces, studies on a comparison between urban and rural green spaces, studies on the remote viewing of urban green spaces through windows, vertical greenery, or UGS not fully accessible to the public, and studies relying solely on methods of photographic or virtual reality or recorded soundtracks. Studies specifically focusing on the area of green spaces or accessibility were excluded because usually the area is a measurement of quantity and accessibility is a measurement of environmental justice if they exist independently. In addition, studies which only used subjective quality measurements such as perceptions and the satisfaction of participants were also excluded for the reason of logical uncertainty between the interventions and outcomes.

- (Outcomes): The general mental well-being status or specific psychological terms such as depression, anxiety, and stress, which are recognised as fundamental indicators of mental well-being. In contrast, studies addressing specific emotional states such as loneliness, self-esteem, and calmness were excluded because emotions represent transient, context-specific experiences rather than comprehensive indicators of mental well-being. This distinction ensured that the included studies aligned with the scope of the mental well-being assessment and avoided overly fragmented outcomes that may deviate from the research objectives.
- S (Study Design): All types of original studies, including cross-sectional studies, case-crossover studies, retrospective cohort studies, prospective cohort studies, quasi-experimental studies, before–after studies, and ecological studies, with the full text available, written in English, and published between 2013 and 2024 (including early-access publications for 2025).

2.2.3 Study Selection

After the duplicate records were removed, all retrieved records were screened for relevance based on titles, abstracts, and full texts following the eligibility criteria described above. Studies meeting the inclusion criteria were then examined in full text to confirm eligibility. Any uncertainties or disagreements during selection were discussed among reviewers until consensus was reached (Figure 2.1).

2.2.4 Quality Assessment and Data Extraction

Data were extracted from eligible articles into Table 2.1. The form included the author; year of publication; study location; study design; population description; measurements of quality; measurement instrument; mental well-being outcomes; outcome instrument; the moderator, mediator, and covariates; statistical methods; and key findings.

The assessment of the methodological quality of the included studies was carried out using a modified version of the Criteria for Quality Assessment of the Studies originally proposed by Gascon et al. in 2015 [161]. This framework was chosen as it aligned closely with the specific requirements of this review. To better suit the context of this review, three items (No. 7, No. 9, and No. 11) within the original framework were adjusted, ensuring that the criteria remained

appropriate for the studies included. Details of the adapted criteria are provided in Appendix A.

2.3 Results

In the initial search, 3813 articles were identified in five databases, with 12 articles from websites and 21 articles found by citation searching. A total of 1006 duplicates were removed, and 2840 articles were included for abstract and title screening. One hundred and seventy-five articles were selected for full-text screening, and twenty-two articles from 21 studies were included (Figure 2.1).

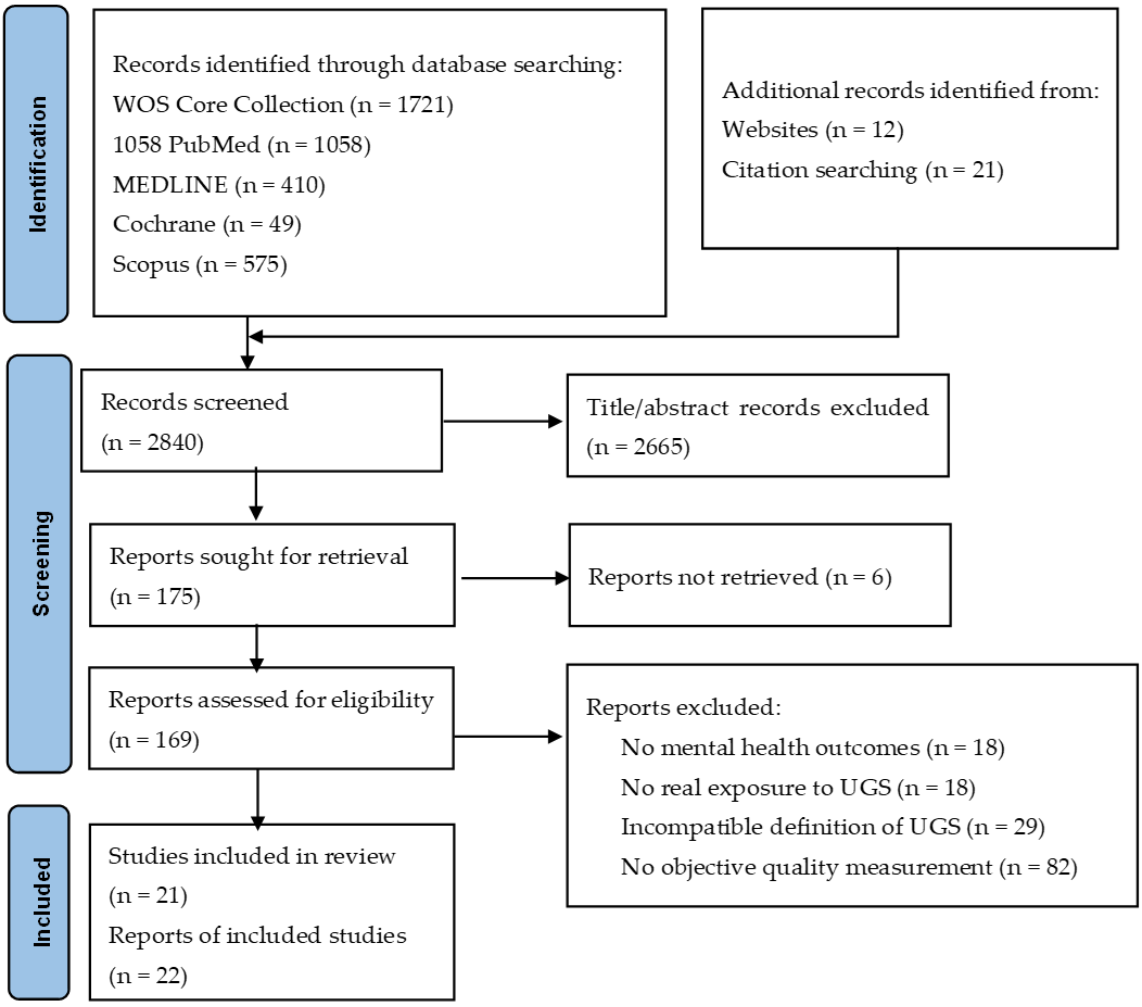

Figure 2.1. PRISMA flow diagram.

2.3.1 Study Characteristics

The key characteristics are shown in Table 2.1. The 22 articles published from 2017 to 2024 were conducted mainly in mainland China (n = 11) and the United Kingdom (n = 3), followed by Taiwan (n = 2), Hong Kong (n = 1), Australia (n = 1), Turkey (n = 1), Guyana (n = 1), and Pakistan (n = 1). One study was carried out in four European countries (the United Kingdom, the Netherlands, Spain, and Lithuania) [163]. The study populations comprised varying sample sizes, ranging from 30 to 3771. Most of the studies included general populations or adult populations. Three studies exclusively included the elderly [164-166], two articles on which belonged to the same study explicitly excluding students [167, 168]. Four of the selected studies were quasi-experimental studies [169-172]. One study employed a longitudinal design [166]. The remaining 18 studies were cross-sectional. Additionally, the sample sizes were relatively small and with similar characteristics, ranging from 33 to 80 participants, reflecting the controlled nature of experimental settings. On the contrary, the other studies usually included larger samples, with sizes ranging from 30 to 3771 participants, depending on the study scope and design (Table 2.1).

Table 2.1. Main characteristics of the studies on the urban green space (UGS) quality and mental well-being.

No.	Author	Year	Location	Study Design	Population Description	Moderator, Mediator, and Covariates	Statistical Methods
1	Abdul et al. [173]	2022	Peshawar, Pakistan	Cross-sectional	n = 200	Covariates: sociodemographic information	Chi-Square Tests
2	Cameron et al. [174]	2020	Sheffield, UK	Cross-sectional	n = 259	Covariates: sociodemographic information	Mixed-Effects Modelling
3	Chang et al. [164]	2020	Taichung, China	Cross-sectional	n = 769 age > 55	Mediator: place attachment; covariates: sociodemographic information	Structural Equation Models
4	Chu et al. [165]	2021	Taipei, China	Cross-sectional	n = 380 age > 55	Moderator: environmental perception, outdoor leisure; covariates: sociodemographic information	Hierarchical Linear Models
5	Deng et al. [169]	2020	Chengdu, China	Quasi-experimental	n = 60 age: 19-24	-	Repeated Measures ANOVA, Wilcoxon Signed-Rank Test
6	Dobbinson et al. [170]	2020	Melbourne, Australia	Quasi-experimental	n = 1670 median age: 34–37	-	Cluster-Level Analysis, Independent Sample t-Test
7	Duzenli et al. [175]	2017	Trabzon, Turkey	Cross-sectional	n = 375	-	One-Way ANOVA
8	Fisher et al. [176]	2021	Georgetown, Guyana	Cross-sectional	n = 478 age > 18	Moderator: blue spaces and green spaces; covariates: sociodemographic information on gender and age	Bivariate General Linear Mixed-Effect Models
9	Huang et al. [171]	2021	Fuzhou, China	Quasi-experimental	n = 33 age: 22–28	-	Kruskal–Wallis (K–W) Tests
10	Knight et al. [177]	2022	Greater London, UK	Cross-sectional	n = 1606 age > 16	Covariates: sociodemographic information	Fixed-Effects Regression Models
11	Li et al. [178]	2023	Shanghai, China	Cross-sectional	n = 478 without underlying medical conditions	Covariates: sociodemographic information	Ordered Logit Models
12	Liu et al. [166]	2023	Hong Kong, China	Longitudinal	n = 2081 age ≥ 65 without known dementia or another psychiatric disorder	Covariates: sociodemographic information	Latent Growth Curve Modelling
13	Meng et al. [179]	2024	Chengdu, China	Cross-sectional	n = 1124 age > 18	Covariates: sociodemographic information	Multilevel Linear Models

14	Ruijsbroek et al. [163]	2017	Stoke-on-Trent, UK; Doetinchem, Netherlands; Barcelona, Spain; and Kaunas, Lithuania	Cross-sectional	n = 3771 age = 18–75	Mediators: social cohesion, neighbourhood attachment, social contacts; covariates: sociodemographic information, neighbourhood socioeconomic status, cities	Multilevel Linear Models, Logistic Regression Models
15	Wan et al. [180]	2024	Chengdu, China	Cross-sectional	n = 135	Mediators: environmental preferences	Stepwise Regression Analysis, Path Analysis
16	Wang et al. [181]	2022	Shanghai, China	Cross-sectional	n = 496 age > 18	Mediator: use of parks; covariates: sociodemographic information	Multilevel Regression Models
17	Wang et al. [167]	2021	Guangzhou, China	Cross-sectional	n = 1003 age > 18 and not student	Mediators: PM 2.5, NO_2, perceived pollution, stress, life satisfaction, physical activity, social cohesion; covariates: sociodemographic information, neighbourhood deprivation index	Structural Equation Models, Parallel Mediation Models
18	Wang et al. [168]	2022	Guangzhou, China	Cross-sectional	n = 1003 age > 18 and not student	Moderator: blue space and green space indicators; covariates: sociodemographic information	Multilevel Linear Regression Models
19	Wood et al. [182]	2018	Bradford, UK	Cross-sectional	n = 128 age > 18	Moderator: use of the parks; covariates: sociodemographic information	Multilevel Linear Regression Models
20	Xu et al. [172]	2024	Nanjing, China	Quasi-experimental	n = 80 university students age: 19–25	-	One-Way ANOVA, Paired Sample t-Test, Multiple Linear Regression Models
21	Xu et al. [183]	2022	Fuzhou, China	Cross-sectional	n = 30 age > 18	Covariates: sociodemographic information	General Linear Models
22	Zhang et al. [184]	2022	Nanjing, China	Cross-sectional	n = 1984 age > 18	Mediator: physical activity, mental stress, environmental stressors, social cohesion	Multivariate Linear Regression Models, Multiple-Mediation Models

2.3.2 Quality Assessment

The quality assessment of the included studies was conducted using 11 criteria, with the total scores converted to percentages and categorised as poor (<40%), fair (40–60%), good (61–80%), or excellent (>80%). Among the twenty-two included studies, three studies (13.6%) were rated excellent [166, 171, 172], thirteen studies (59.1%) were rated as good, five studies (22.7%) were rated as fair, and one study (4.5%) was rated as poor [163]. No studies were categorised as very poor-quality. The detailed scoring can be found in Appendix A (Tables A1 and A2.).

2.3.3 Mental Well-being Outcomes

The selected studies reported a series of mental well-being outcomes (Table 2.2). The reviewed studies showed diverse methods of mental well-being measurement. The general mental well-being was frequently measured [167, 173, 177, 178, 184], commonly using standardised scales such as the World Health Organization-Five Well-Being Index (WHO-5) and General Health Questionnaire-12 (GHQ-12). The emotion status was another major focus, including the general emotional status ([173, 175] and positive/negative emotions [170, 174, 176, 183], mainly measured using the Positive and Negative Affect Schedule (PANAS). Depression was also a common measurement [163, 165, 166, 168, 181], usually evaluated using the Mental Health Inventory-5 (MHI-5) or Geriatric Depression Scale-15 (GDS-15). Attention restoration was another important mental well-being measurement, which appeared in several studies ([171, 172, 179, 180, 182] using the Perceived Restorativeness Scale (PRS) developed by Hatig et al. [185]. Stress and anxiety were also evaluated by several studies [163, 168, 171, 173, 176, 183], while some studies considered life satisfaction as a measurement [165, 177]. Most studies relied on psychological measurements, while some studies incorporated physiological indicators. For example, Deng et al. (2020) measured blood pressure, pulse rate, and electroencephalogram (EEG) data [169], while Huang et al. (2021) employed a wearable sensing device called an ErgoLAB (including measurements of the electrodermal activity (EDA), facial electromyography (EMG), a respiration sensor (RESP), measurements of the skin temperature (SKT), and photoplethysmography (PPG)), providing more objective assessment methods [169].

2.3.4 Quality of Urban Green Spaces Outcomes

The measurement of the quality of green spaces was divided into three domains, including spatial features, natural elements, and facilities and amenities. The studies which comprehensively considered the above domains but did not describe their conclusions according to specific indicators instead of using an overall evaluation were classified as the combination group (Table 2.2).

2.3.4.1 Spatial Features

Studies including the spatial features of UGS employed a variety of measurement instruments. Environmental audits were the most commonly used tools used to conduct an evaluation of green spaces' accessibility, spatial layout, and design features [164, 165, 171, 173, 180]. Standardised quantitative tools such as the Neighbourhood Green Space Tool (NGST), the Public Open Space Tool (POST), and the Environment Assessment of Public Recreation Scale (EAPRS) provided a structured framework to measure the quality of UGS [164-166]. The audits were often complemented by geographic information system (GIS) analyses to measure features like the green coverage and the size of the UGS [180, 184]. Most of the studies combined these with subjective measurements to capture user perceptions and experiences. Perceptions and satisfaction measured by Likert scales were commonly employed [164, 165, 173, 180, 181, 184].

Accessibility was the most commonly measured quality, but its effects were not entirely consistent across studies. For example, high accessibility was linked to reduced stress, less depression, and enhanced life satisfaction through improved convenience and increased recreational opportunities [165, 173, 178]. However, some studies found no significant association between accessibility and mental health outcomes [181]. Meanwhile, the benefits

of accessibility were often mediated by environmental perceptions and the quality of interactions with the UGS [165, 184]. Comprehensive parks located farther away (>3 km) provided stronger positive impacts on well-being than nearby smaller parks, indicating that the type and scale of accessibility also influenced outcomes [178]. Similarly, larger green and blue spaces offered greater restorative potential compared to smaller ones, by providing diverse recreational opportunities and a sense of immersion [180]. The green coverage and a rational spatial layout were associated with reductions in environmental stressors such as noise and pollution, and improvements in user satisfaction were achieved by providing increased physical activity opportunities [164, 184]. The topography showed a notable impact, with uneven terrain contributing to stress recovery and attention restoration [171]. However, this kind of impact was not applicable for the elderly [166]. Openness was found to have negligible effects, with no significant differences observed between open and enclosed spaces in terms of mental health outcomes [171].

2.3.4.2 Natural Elements

Similarly to spatial features, the measurement of nature elements in UGS primarily relied on environmental audits carried out by the researchers [164, 165, 171-173, 175, 179-182]. Different standardised tools such as the EAPRS, NGST, and The Natural Environment Scoring Tool (NEST) were applied to measure different indicators for quality assessment [164, 165, 182]. Specialised ecological surveys were conducted in several studies according to the study content. Avian surveys were carried out to measure the bird species diversity and abundance [174, 176, 183], sometimes combined with habitat surveys to better understand the ecological complexity [174]. Additionally, GIS analysis was a common, more objective method for the measurement of nature elements [169, 180, 184]. Many studies combined these methods with subjective measurements using perception- and satisfaction-based Likert scales to capture residents' perceptions of the biodiversity and natural features. This combination of objective and subjective measurements provided comprehensive insights into how natural elements influence mental well-being, with several studies revealing that the perceived biodiversity often mediated the psychological benefits of these elements [164, 165, 172-175, 179-181, 184].

Analysis of the 16 studies indicated that natural elements contributed to mental well-being through multiple pathways, with their effects varying according to the element type and quality. The most extensively investigated aspect was biodiversity (11 studies). Most of the studies showed that plant diversity and species richness generally showed positive associations with mental well-being [164, 171, 173, 179, 180], especially in terms of stress reduction and attention restoration. However, the relationship between avian diversity and well-being benefits appears complex. Studies on the avian diversity yielded mixed results [174, 176, 179, 182, 183]. Notably, several studies found that the perceived biodiversity often indicated stronger associations with mental health outcomes than actual biodiversity measures [174, 179]. Water features were found to be another significant contributor to restoration [169, 175, 178, 179]. Different types of water bodies seemed to offer distinct functions: dynamic features (streams, waterfalls) enhanced stress reduction and attention focusing, while still water (lakes, ponds) promoted meditation and emotional stability [169, 180]. Notably, spaces integrating both green and blue elements demonstrated enhanced restorative potential compared to those with single elements [169, 171]. The aesthetic quality and maintenance of natural elements were also important aspects [180, 181, 184]. Well-maintained vegetation with diverse colours and spatial arrangements enhanced the restorative potential [164, 172,

180], while poor maintenance decreased these benefits [173]. However, neither the quality nor maintenance of nature features showed significant effects on mental well-being in the study by Chu et al. (2021) [165]. Additionally, the visibility and accessibility of these natural elements significantly influenced their effectiveness in promoting mental well-being [184].

2.3.4.3 Facilities and Amenities

The measurement of facilities and amenities in UGS also used systematic diversity in its methodology. Unsurprisingly, environmental audits were the main assessment tool as well [164, 165, 169, 172, 173, 175, 180-182]. These audits evaluated various characteristics of facilities and amenities, such as walking paths, seating areas, recreational facilities, and supporting amenities. Specialised audit tools (EAPRS, POST, NEST) were employed to provide standardised frameworks for the assessment [164, 166, 182]. Some studies used planned refurbishment assessments and GIS analysis to evaluate the spatial distribution and usability of facilities and amenities [169, 170, 180]. Subjective measurements were commonly used to capture users' perception and satisfaction using self-developed Likert scales [164, 173, 175, 180, 181].

Diverse relationships were found between facilities and amenities in UGS and mental well-being. Walking-related facilities were the primary focus (seven studies). Well-maintained walking paths and comfortable pedestrian infrastructure indicated positive associations with attention restoration and stress reduction [164, 173, 180]. However, it is interesting that the effects were moderated by the design quality, with studies finding that road networks near UGS could increase stress levels and reduce the restorative potential [171]. The walking comfort and pathway accessibility significantly influenced the perceived restoration benefits [172, 180]. Recreational and rest facilities indicated mixed effects. Some studies found that sports facilities were positively associated with mental well-being [164, 178]; others reported negative correlations, particularly when facilities generated noise or crowding [181]. Rest facilities, including benches and sitting areas, showed more consistent positive effects, although their impact was often affected by the quality and maintenance [166, 173, 175]. Meanwhile, improvements of the facilities, including playgrounds, shade structures, and sporting facilities, increased park usage, but the results remained inconsistent [164, 170, 178]. Notably, the effects of facilities and amenities may not increase the mental well-being of the elderly [165, 166, 181]. In addition, adequate lighting, safety features, and general maintenance significantly increased the mental well-being benefits [175, 180, 181]. Conversely, incivilities and poor maintenance decreased the mental well-being benefits [165, 181]. Cultural landscape elements and non-natural aesthetic features contributed positively to attention restoration [169, 171], while spatial privacy and environmental cleanliness did not showed significant effects on well-being outcomes [172].

2.3.4.4 Combination

These studies employed different measurement methods. The studies used official databases [177], environmental audits [163], or GIS analyses [167, 168], usually combined with perception measurements using Likert scales [163, 167, 168].

The combined assessment of multiple UGS qualities demonstrated the overall effects of the UGS quality on mental well-being. The studies found that high-quality ecological spaces (recognised as Sites of Importance for Nature Conservation in the UK) significantly contributed to life satisfaction and general mental well-being, showing stronger effects than

those of ordinary open spaces [177]. The overall quality including the visibility and arrangement of green and blue spaces indicated varying associations with psychological outcomes, but with these relationships only being significant in specific urban areas [163]. Additionally, the street-view green space quality (SVG-Quality) influenced mental well-being through indirect pathways. Although not showing significant direct effects, higher quality UGS indirectly improved mental well-being by enhancing social cohesion, promoting physical activity, and reducing stress [167]. Similar comprehensive quality assessments revealed significant improvements in depression and anxiety symptoms [168].

Table 2.2. Main characteristics and results of the studies on urban green space (UGS) qualities' benefits on well-being outcomes.

No.	Measurements of Quality	Measurement Instrument	Combined with Subjective Measurements	Mental Well-being Outcomes	Outcome Instrument	Effects
Spatial Features						
1	Accessibility, spatial layout	Environmental audit	Perception and satisfaction measured by Likert scales	Stress reduction, emotional well-being, perception of overall well-being	Self-developed Likert scale	(+)
3	Green coverage, spatial layout	Environmental audit (EAPRS)	Perception and satisfaction measured by Likert scales	PERMA model	Self-developed Likert scale	(+) (-)
4	Accessibility	Environmental audits (NGST)	Environmental perception measured by Neighbourhood Open Space (NOS) scale	Life satisfaction, depression	SWLS, GDS-15	(+)
9	Openness, topography	Environmental audit		Stress recovery, attention restoration	ErgoLAB (electrodermal activity, facial electromyography, respiration sensor, skin temperature (SKT), photoplethysmography), PRS	(+) (○)
11	Accessibility	Official database		General mental well-being	Self-developed Likert scale	(+) (-) (○)
12	Accessibility, terrain slope	Environmental audit (POST)		Depression	GDS-15	(+) (○)
15	Site area	Environmental audit, GIS analysis	Perception and satisfaction measured by Likert scales	Attention restoration	Self-developed Likert scale	(+)
16	Accessibility	Environmental audit	Perception and satisfaction measured by Likert scales	Depression	MHI-5	(○)
22	Accessibility, NDVI	GIS analysis	Perception measured by Likert scales	General mental well-being	WHO-5	(+) (○)
Nature Elements						

1	Plant richness and distribution	Environmental audit	Perception and satisfaction measured by Likert scales	Stress reduction, emotional well-being, perception of overall well-being	Self-developed Likert scale	(+)
2	Avian diversity, habitat diversity	Avian survey, habitat survey	Perceived biodiversity measured by Likert scales	Positive emotion	Self-developed Likert scale, ReQoL-10	(+)
3	Plant diversity, landscape diversity, landscape maintenance	Environmental audit (EAPRS)	Perception and satisfaction measured by Likert scales	PERMA model	Self-developed Likert scale	(+)
4	Nature features (quality of grass, trees, and flower beds), maintenance of natural features	Environmental audit (NGST)	Environmental perception measured by Neighbourhood Open Space (NOS) scale	Life satisfaction, depression	SWLS, GDS-15	(○)
5	Green elements (lawn, bamboo forest, view of forest in distance, bushes, and flowers), blue elements (lake, stream, still pond, waterfall), mixed ecological areas, wetlands, topography	GIS analysis, environmental audit		Mood states, attention restoration	PRS, POMS, electronic blood pressure monitor (blood pressure, pulse rate), NeuroSky MindWave (electroencephalogram)	(+)
7	Plant materials (variety, appropriate species, colour and fragrance, avoidance of toxic plants), waterscape (types and quality), natural view	Environmental audit	Perception and satisfaction measured by Likert scales	Emotional status	Self-developed Likert scale, types of activities (positive and negative)	(+)
8	Avian diversity	Avian survey		Positive and negative emotions, anxiety	PANAS, STAI	(○)
9	Plant richness, water	Environmental audit		Stress recovery,	ErgoLAB	(+)

	landscape			attention restoration	(electrodermal activity, facial electromyography, respiration sensor, skin temperature (SKT), photoplethysmography), PRS	
11	Open lawns, blue spaces	Official database		General mental well-being	Self-developed Likert scale	(+) (-) (○)
13	Avian diversity, plant diversity, habitat diversity, water features	Environmental audit	Perception of biodiversity measured by self-developed Likert scale	Attention restoration	PRS	(+) (○)
15	Plant configuration	Environmental audit, GIS analysis	Perception and satisfaction measured by Likert scales	Attention restoration	Self-developed Likert scale	(+)
16	Aesthetics—natural features (trees, vegetation)	Environmental audit	Perception and satisfaction measured by Likert scales	Depression	MHI-5	(+)
19	Biodiversity (plant, avian, butterfly/bee, habitat)	Environmental audit		Attention restoration	Self-developed Likert scale	(+)
20	Vegetation coverage, plant diversity, plant colour	Environmental audit	Perception measured by Likert scales	Attention restoration	PRS, FS-14	(+)
21	Avian diversity	Avian survey		Positive and negative emotions, anxiety	PANAS, STAI	(○)
22	Green space visibility	GIS analysis	Perception measured by Likert scales	General mental well-being	WHO-5	(+)
Facilities and Amenities						
1	Jogging tracks, sitting areas, streetlights, parking areas	Environmental audit	Perception and satisfaction measured by Likert scales	Stress reduction, emotional well-being, perception of overall well-being	Self-developed Likert scale	(+) (-)
3	Trails and paths, signage, seating areas, drinking and	Environmental audits (EAPRS)	Perception and satisfaction measured by Likert scales	PERMA model	Self-developed Likert scale	(+)

	sanitation facilities, fitness equipment, shelter/pavilion, lighting facilities, etc. (including maintenance and convenience)					
4	Recreation (playgrounds, sports courts), facilities (benches, rubbish bins), incivilities (drinking, noise), usability (suitability for walking and playing)	Environmental audits (NGST)	Environmental perception measured by NOS scale	Life satisfaction, depression	SWLS, GDS-15	(-) (○)
5	Landscape constructions (pavilions, corridors, viewing platforms), roads and pavements (wooden walkways, flagstone paths), garden facilities (poetry wall, lamps, decorative openwork windows), convenient facilities (benches, trash bins, drinking fountains)	GIS analysis, environmental audit		Mood states, attention restoration	PRS, POMS, electronic blood pressure monitor (blood pressure, pulse rate), NeuroSky MindWave (electroencephalogram)	(+)
6	Refurbishments of amenities: playground, shade, paths, sporting facilities, fitness equipment, sitting and picnic areas, dog off-lead area, planned refurbishments	Environmental audit	Perception measured by intercept survey	Positive and negative emotions	PANAS	(○)

7	Furniture (sitting equipment, coverings, bins, signboards), enclosed bounded areas, lighting, parking, maintenance, access (parking, paths, barrier-free designs)	Environmental audit	Perception and satisfaction measured by Likert scales	Emotional status	Self-developed Likert scale, types of activities (positive and negative)	(+)
9	Road network, cultural landscape	Environmental audit		Stress recovery, attention restoration	ErgoLAB (electrodermal activity, facial electromyography, respiration sensor, skin temperature (SKT), photoplethysmography), PRS	(+)
11	Sports facilities	Official database		General mental well-being	Self-developed Likert scale	(+)
12	Types of facilities, shade, bench quality	Environmental audit (POST)		Depression	GDS-15	(○)
15	Walking comfort, facility accessibility (benches, rubbish bins, sport equipment, shade), site safety	Environmental audit, GIS analysis	Perception and satisfaction measured by Likert scales	Attention restoration	Self-developed Likert scale	(+)
16	Aesthetics—non-natural features (decorative water features, public artworks, lighting for aesthetics), recreational facilities (playgrounds, sports courts, fitness equipment),	Environmental audit	Perception and satisfaction measured by Likert scales	Depression	MHI-5	(+) (-) (○)

	usability (walking paths, bench availability, activity space), incivilities (litter count, graffiti presence, noise level)					
19	Site facilities (benches, rubbish bins, lighting, and maintenance)	Environmental audit (NEST)		Attention restoration	Self-developed Likert scale	(○)
20	Rest facilities, walking paths, spatial privacy, cleanliness, noise level	Environmental audit	Perception measured by Likert scales	Attention restoration	PRS, FS-14	(+) (○)
Combination						
10	Accessibility to Sites of Importance for Nature Conservation	Official database		Life satisfaction, general mental well-being	Life Satisfaction Scale, GHQ-12	(+)
14	Fraction of visible gardens, size of garden, garden arrangement, trees, size of green space, size of blue space	Environmental audit	Perception and satisfaction measured by Likert scales	Nervousness, depression	MHI-5	(+) (○)
17	Accessibility, maintenance, variation, naturalness, colourfulness, clear arrangement, shelter, cleanliness, safety, general impression	GIS analysis	Perception and satisfaction measured by Likert scales	General mental well-being	WHO-5	(+) (○)
18	Accessibility, maintenance, variation, naturalness, colourfulness, clear arrangement, shelter, cleanliness, safety, general impression	GIS analysis	Perception and satisfaction measured by Likert scales	Depression, anxiety	SCL-90	(+)

1. Environmental audit tools: EAPRS: Environment Assessment of Public Recreation Scale; NGST: Neighbourhood Green Space Tool; POST: Public Open Space Tool; NEST: Natural Environment Scoring Tool; NOS scale: Neighbourhood Open Space scale. 2. Scales for mental wellbeing: PERMA model: positive emotion, engagement, relationship, meaning, accomplishment; SWLS: Satisfaction with Life Scale; GDS-15: Geriatric Depression Scale-15; PRS: Perceived Restorativeness Scale; MHI-5: Mental Health Inventory-5; WHO-5: 5-item World Health Organization-Five Well-Being Index; ReQoL-10: 10-item Recovering Quality of Life Questionnaire; POMS: Profile of Mood States; PANAS: Positive and Negative Affect Schedule; STAI: State Trait Anxiety Inventory; FS-14: Chalder Fatigue Scale; GHQ-12: 12-item short form of General Health Questionnaire; SCL-90: Symptom Checklist-90. 3. Effects: (+): evidence of protective associations; (-): evidence of risk associations; (o): insignificant associations.

2.4 Discussion

2.4.1 Mental Well-being

This chapter synthesises current evidence on the links between UGS quality and mental well-being, forming the conceptual foundation for exploring how specific environmental attributes and human experiences interact in the following research. Due to the increasing prevalence of mental health issues, there has been a growing awareness of and emphasis on mental health in recent years, especially following the lockdowns resulting from the COVID-19 pandemic [186, 187]. Existing evidence has indicated the general benefits of UGS on mental health. By encouraging residents to engage in physical or social activities, UGS have the potential to reduce stress and enhance emotional restoration, which is consistent with the widely accepted theory [188].

This systematic review revealed several key methodological patterns in mental well-being assessments. Self-reported psychological scales were the primary method for assessing mental health, focusing on general well-being, positive and negative emotions, and attention restoration, as well as anxiety and depression. The diversity in outcome measures reflected both advantages and limitations in current research approaches. Although comprehensive in scope, ranging from general well-being to specific conditions like depression and anxiety, this variation creates challenges in cross-study comparisons and meta-analyses, especially since there were 22 studies considered. The predominant reliance on self-reported measures, though pragmatic for large-scale studies, raises concerns about response bias and the objectivity of the findings. There were only two studies incorporating physiological indicators such as the blood pressure, heart rate, and electroencephalograms [169, 171]. This highlights a significant methodological gap in current research, which limits the integration of objective measurements which may capture the immediate physiological responses to UGS exposure to better measure mental well-being promotion, particularly in terms of stress reduction and attention restoration processes. Although there has been a recent emergence of experimental studies measuring physiological responses to UGS in laboratory settings, these studies predominantly rely on simulated green environments (VR devices, pictures, or soundtracks) as experimental interventions [189, 190]. The portability of wearable devices, however, makes the objective measurement of mental well-being possible in real UGS, suggesting potential directions for a future research methodology.

2.4.2 Quality of Urban Green Spaces

Overall, various aspects of the UGS quality are associated with mental health benefits. Our analysis identified distinct patterns in how different aspects of quality domains contribute to mental well-being outcomes. The findings demonstrated complex and sometimes counterintuitive relationships between the quality and mental health benefits.

Within the domain of spatial features, accessibility was the most common quality considered in the studies. Remarkably, the included studies showed that the accessibility of UGS exhibited a certain level of inconsistency in its benefits to mental health. For example, the results showed that distant comprehensive parks sometimes provided stronger benefits than proximate smaller ones, which was inconsistent with the general understanding and

challenged traditional accessibility-based planning approaches [178]. This could be attributed to variations in the measurement scales used for assessing accessibility across different studies [191]. In terms of spatial patterns, it seems that a more complex spatial structure appears to imply higher green space quality [171, 192], although the evidence supporting this notion is not yet sufficient. This suggests the necessity of reconsidering how we conceptualise and measure accessibility and usability in urban planning, because different UGS cater to diverse user groups with varying usage patterns, influenced by individual preferences.

The variety of natural elements was also considered an important aspect in enhancing the quality of UGS. The assessment of natural elements provided the most consistent evidence for mental health benefits, particularly through the assessment of vegetation diversity and water features. An increase in the plant richness, blue space elements, and tree quantities in UGS can effectively contribute to the mental health of participants [164, 169, 171-175, 180-182]. The biophilia hypothesis suggests that human beings inherently have a natural inclination to establish connections with nature and other living entities: connecting to nature features potentially provided emotional support and mood restoration [193, 194]. However, the studies specifically focusing on avian diversity showed inconsistent results [174, 176, 179, 183]. The notable disparity between the effects of the perceived versus actual biodiversity raises important questions about the measurement validity and the role of user perceptions [174, 179]. This finding suggests that both objective quality metrics and subjective experiences should be considered in UGS planning. Compared to trees, shrubs exhibited negative mental health effects [178]. This could be attributed to the difficulties shrubs cause for accessibility or the impression of disorder and insecurity associated with dense and tangled shrubbery. There is limited evidence regarding the impact of vegetation types, necessitating further research.

The analysis of facilities and amenities showed complex trade-offs in the UGS quality. Walking-related facilities, the most extensively studied amenity type, demonstrated particularly nuanced effects. While well-maintained walking paths and comfortable pedestrian infrastructure generally showed positive associations with attention restoration and stress reduction, their benefits were dependent on the design context [164, 169, 171, 173, 180, 181]. Notably, the finding that road networks near UGS could increase stress levels and reduce the restorative potential highlights the critical importance of careful infrastructure planning and integration with the surrounding environment [171]. The impacts of recreational and rest facilities presented an interesting paradox in the UGS quality. On the one hand, some studies found that sports facilities were positively associated with mental well-being; on the other hand, the others reported negative correlations when these facilities generated noise or crowding, especially for the elderly, suggesting that the benefits of recreational amenities may be offset by their potential mental well-being benefits [164, 165, 170, 178, 181]. Regarding other facilities, benches and sitting areas demonstrated more consistently positive effects, though their impact was strongly moderated by the maintenance quality. Supporting amenities and maintenance were crucial mediating factors. The significant positive effects of adequate lighting and safety features underscore the importance of creating environments that feel secure and welcoming. Similarly, the negative impact of incivilities and poor maintenance on mental well-being benefits highlights the critical role of ongoing facility management. [164, 165, 172, 173, 175, 180] These contrasting findings emphasise the necessity of considering both the direct functional benefits of facilities and their potential indirect effects on the overall

user experience. Comprehensive quality assessments further illuminated the interconnected nature of these domains. The identification of indirect pathways, including social cohesion and physical activity, suggests that high-quality UGS influence mental well-being through multiple mechanisms. This complexity emphasises the need for integrated assessment approaches that can capture both the direct and indirect effects of the UGS quality on mental health outcomes [163, 167, 168, 177].

Limitations

In this chapter, we conducted a relatively comprehensive review of the association of the UGS quality with mental health. The findings provided a structured understanding of how ecological, managerial, and perceptual attributes collectively define the quality of urban green spaces. By identifying inconsistencies in the conceptualisation and measurement of "quality", the review clarified why subjective experiences—such as residents' perceptions, attitudes, and behavioural patterns—require further empirical investigation. These insights directly informed the design of the subsequent studies in this thesis, particularly those analysing how people interact with, evaluate, and benefit from green environments in practice.

Although our final sample of 22 studies might appear relatively small, this limited number reflects the rigorous inclusion criteria, focusing specifically on the quality measurements of UGS and their direct impacts on mental well-being outcomes. Many studies were excluded because they either examined only the quantity of green spaces or evaluated only the perception and satisfaction for quality measurements. This selective approach, while reducing our sample size, was necessary to ensure a focused analysis of quality–well-being relationships. Additionally, the included studies showed considerable heterogeneity in their measurements and mental well-being outcome assessments, making the comparisons challenging. The predominant use of cross-sectional designs (18 out of 22 studies) limits our ability to establish causal relationships between the UGS quality and mental health outcomes. Furthermore, while recent years have seen an emergence of experimental studies measuring physiological responses to green space exposure in laboratory settings, these studies predominantly rely on simulated green environments as experimental interventions, suggesting a need for more field-based experimental research examining real-world interactions with UGS. Lastly, this review only included English-language publications, which may have excluded potentially relevant studies in other languages. Although the preliminary search suggested that eligible studies in non-English languages were extremely scarce, future research may consider expanding the language inclusion criteria due to the explosive growth of this topic all over the world. This review also excluded studies focusing on minors, as many of these studies assess mental well-being through parental or guardian proxy reports instead of direct self-reports from the participants. Although this approach ensured consistency in measurements across the included studies, it may limit the applicability of our findings to minors. Future research could address this gap by including objective assessments of the mental well-being of minors.

Appendix A – Quality Assessment

Table A1. Criteria for quality assessment of the studies.

No.	Items	Scoring
1	Study design	0 = ecological, 1 = cross-sectional, 2 = longitudinal or experimental
2	Confounding factors	0 = no confounding factors considered, 1 = confounding factors considered but some key confounders omitted, 2 = careful consideration of confounders
3	Statistics	0 = flaws in or inappropriate statistical testing or interpretation of statistical tests that may have affected results, 1 = appropriate statistical testing and interpretation of tests
4	Potential bias	0 = other study design or conduct issues that may have led to bias, 1 = no other serious study flaws
5	Multiplicity	0 = exposure of interest one of the many variables being tested, 1 = exposure of interest the main variable tested
6	Outcome assessment	0 = self-reported questionnaires, 1 = interviews conducted by experts or clinical records or other objective measures (biomarkers such as cortisol) that support the results of the mental health tests conducted
7	Quality measurement assessment	0 = expert assessment (audit), 1 = satellite system, land-cover map, or other standardised assessment tools
8	Use of urban green space	0 = not measured and/or not included in the analysis, 1 = measured and included in the analysis
9	Comprehensiveness of urban green space quality indicators	0 = Single or specific indicator, 1 = Multiple indicators but lacking clarity or comprehensiveness, 2 = comprehensive and well-defined green space quality indicators
10	Effect size	0 = incomplete information, 1 = complete information (estimate and standard error or confidence interval)
11	Definition of urban green space in the study	0 = unclear or not clearly specified, 1= clear definition

Table A2. Detailed scores for items and final quality scores with categories.

No.	Studies	Study design	Confounding factors	Statistics	Potential bias	Multiplicity	Outcome assessment	Quality measurement assessment	Use of UGS	Comprehensiveness of UGS quality indicators	Effect size	Definition of UGS in the study	Total Score	%	Quality
1	Abdul et al.	1	0	1	0	1	0	0	1	1	0	1	6	42.9 %	Fair
2	Cameron et al.	1	1	1	1	1	0	1	1	1	1	1	10	71.4 %	Good
3	Chang et al.	1	2	1	0	1	0	1	1	2	1	1	11	78.6 %	Good
4	Chu et al.	1	2	1	0	1	0	0	1	2	1	1	10	71.4 %	Good
5	Deng et al.	2	1	1	0	1	1	0	NA	2	1	1	10	76.9 %	Good
6	Dobbinson et al.	2	2	1	0	1	0	0	NA	1	1	1	9	69.2 %	Good
7	Duzenli et al.	1	0	1	0	1	0	0	1	1	0	1	6	42.9 %	Fair
8	Fisher et al.	1	1	1	0	1	0	1	1	0	1	1	8	57.1 %	Fair
9	Huang et al.	2	2	1	0	1	1	0	NA	2	1	1	11	84.6 %	Excellent
10	Knight et al.	1	2	1	1	1	0	1	0	0	1	1	9	64.3 %	Good
11	Li et al.	1	2	1	0	1	0	1	0	1	1	1	9	64.3 %	Good

12	Liu et al.	2	2	1	1	1	0	1	1	1	1	1	12	85.7 %	Excellent
13	Meng et al.	1	1	1	0	1	0	1	0	1	1	1	8	57.1 %	Fair
14	Ruijsbroek et al.	1	2	1	0	0	0	0	0	0	1	0	5	35.7 %	Poor
15	Wan et al.	1	1	1	0	1	0	1	1	2	1	1	10	71.4 %	Good
16	Wang et al.	1	2	1	0	1	0	1	1	2	1	1	11	78.6 %	Good
17	Wang et al.	1	2	1	1	1	0	1	0	2	1	0	10	71.4 %	Good
18	Wang et al.	1	2	1	1	1	0	1	0	2	1	0	10	71.4 %	Good
19	Wood et al.	1	2	1	0	1	0	1	0	2	1	1	10	71.4 %	Good
20	Xu et al.	2	2	1	0	1	1	1	NA	2	1	1	12	92.3 %	Excellent
21	Xu et al.	1	1	1	0	1	0	1	1	0	1	1	8	57.1 %	Fair
22	Zhang et al.	1	2	1	1	0	0	1	1	2	1	1	11	78.6 %	Good

1. UGS: urban green spaces; 2. NA: not applicable. For the quasi-experimental studies which the participants are controlled, considering the use pattern of UGS is meaningless (maximum score = 13); 3. five categories to define the quality: excellent quality (score ≥81%), good quality (between 61 and 80%), fair quality (between 41 and 60%), poor quality (between 21 and 40%), and very poor quality (≤20%).

Chapter3 – Exploring Behavioural Pathways Linking Physical Activity and Well-being

This chapter is based on the article “Exploring the Impact of Physical Activities on Subjective Well-Being: A Cross-Sectional Study in Bologna, Italy”,

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Keywords: physical activities; moderate physical activities; vigorous physical activities; subjective well-being; mental health; sociodemographic factors

Summary

This chapter moves the focus from environmental attributes to behavioural pathways that link urban green spaces (UGS) with mental well-being. In this chapter we checked how different intensities of physical activity (PA) relate to well-being in their daily lives. Using baseline data collected in Bologna before the “Moving Parks” project, we explored whether both moderate and vigorous physical activities could shape people’s sense of well-being. The findings revealed a clear pattern: being active was generally linked with feeling better, regardless of intensity, while age, health, and work situation also played an important role. Although this study was cross-sectional and not intended to test causality, it highlights the behavioural pathway through which UGS may promote psychological health. Through this perspective, this chapter connects the conceptual framework of environmental qualities developed earlier with the following analyses that examine how green interventions can translate these behavioural mechanisms into measurable health benefits.

3.1 Introduction

The previous chapters introduced several attributes of urban green spaces (UGS) which are consistently associated with improved mental well-being, with physical activities PA emerging as one of the most feasible pathways through which these benefits are realised [131, 195]. As a behavioural mechanism, PA represent both an important and a practical means of enhancing psychological health in daily urban life. It connects individuals' physiological, cognitive and social processes, acting as an intermediary mechanism through which environmental opportunities can translate into improved subjective well-being (SWB) [132, 195]. Compared with infrastructural changes, encouraging regular PA is relatively achievable and cost-effective, making it a realistic strategy for public health promotion in compact cities where the creation of new UGS is often limited [36, 195, 196].

Previous studies have demonstrated that regular (PA) promote SWB by enhancing positive affect, psychological resilience, self-esteem, and reinforcing self-identity and social integration, which together contribute to improved quality of life [104, 197, 198]. Compared to reducing negative emotions, PA is more effective in enhancing positive emotions [104]. Nevertheless, there is a certain degree of heterogeneity among findings regarding the benefits of PA on mental health [199]. For example, PA may have a limited impact on people without clinical depression [200], and its effects of PA also vary depending on the intensity and duration of the exercise [201]. Moderate-intensity activities, such as walking or light cycling, are often associated with improved emotional stability and life satisfaction, while vigorous activities may produce stronger but less sustained psychological benefits through stress-regulation responses [108, 201, 202]. Furthermore, the impact of varying intensities of PA differs across individuals of different sexes and ages [203].

Additionally, there are multiple factors which influence people's mental health, making the identification of potential determinants of mental well-being complex. Among the possible determinants, SWB is typically associated with demographic factors such as sex and age, socio-economic status including educational level and income, as well as physical health status [204, 205]. Most studies show minimal sex differences in happiness, but regional variations exist, with women being happier in some areas and men in others [206]. The patterns of age's influence on SWB are complex [207]. On one hand, environmental and social pressures contribute to a relative decline in happiness among middle-aged individuals compared to younger cohorts, although this trend tends to ameliorate with further advancement in age [208]. On the other hand, age-related changes in physical health issues and social interactions are also essential determinants influencing SWB [209]. Regarding educational level, research shows some consistency: recent studies has found a negative relationship between education and SWB, while other evidence indicates that higher education correlates with increased happiness among individuals from their early to mid-30s. [210, 211]. In addition, individuals with higher educational level appear willing to sacrifice the satisfaction derived from leisure activities in exchange for a sense of socioeconomic achievement [212]. Additionally, lifestyle is also an important factor influencing SWB. Associations between occupational sedentary and poor mental well-being in employees were proved [213, 214]. Smokers enjoy lower levels of SWB than either ex-smokers or never-smokers [215].

Given the limited evidence on the determinants of SWB and the heterogeneity of existing findings, this chapter aims to clarify how different intensities of PA relate to SWB among residents with diverse sociodemographic and lifestyle profiles, in order to further examine how demographic and behavioural factors (age, sex, education, health status, smoking, and work situation) interact in shaping individual well-being. By addressing these questions, the chapter extends the theoretical framework established in the previous study, moving from environmental attributes of UGS to behavioural mechanisms that linked to psychological benefits. This chapter will provide an empirical basis for understanding how daily activity contributes to mental well-being, thereby informing analyses on how improvements in the quality and accessibility of UGS may strengthen these effects.

3.2 Methods

This investigation adopted a cross-sectional study design. A questionnaire survey was carried out from May to September 2023 in Bologna, Italy. This questionnaire survey was a pre-survey of a project called "The moving parks project" carried out by the Municipality of Bologna in collaboration with the Department of Public Health of the Bologna in order to encourage residents to engage in PA. The questionnaires were distributed by research teams both offline (with paper forms) and online (with Google Forms) to the participants. The trained instructors taught participants how to fill out the questionnaire and each participant could opt to complete it on paper or online. In the survey, the sociodemographic and lifestyle factors, the PA status and the subjective well-being (SWB) status were investigated by self-reported scales, for purpose of understanding the well-being conditions of residents before participating in "The moving parks project". The various sections of the questionnaire are described below.

3.2.1 Sociodemographic and Lifestyle Factors

The sociodemographic and lifestyle factors including the date of birth, sex, educational level, health issues, smoking condition and work situation were self-reported by participants. The ages were calculated using the date of birth then were classified into four age groups including "young adult" (age $\leqslant$ 35), "mature adult" (35 < age $\leqslant$ 50), "middle-aged adults" (50 < age $\leqslant$ 65) and "senior adult" (age > 65). Educational level was classified into five groups including "primary school or lower", "secondary school", "high school", "bachelor or master's degree" and "doctorate". Health issues and smoking condition were reported as "yes" or "no" to answer if the participants had health problems or if they smoked. In the event that participants reported a positive response regarding their health status, they were required to provide additional details specifying the type of health condition. Work situation was reported as "yes" or "no" to answer if they had a stable job. If the answer were yes, the type of work would be further described as "work of significant physical effort", "work of moderate physical effort", and "work without physical effort".

3.2.2 Physical Activity Engagement

The PA engagement was investigated by two self-reported questions: 1. "How much time do you do moderate physical activities a week?" 2. "How much time do you do vigorous physical activities a week?" For moderate physical activities (MPA) six categories of answers

were considered as "no", "< 1h", "around 1h", "around 2h", "around 2.5h", and "> 2.5h". While for vigorous physical activities (VPA) five categories of answers were considered as "< 0.5h", "around 0.5h", "around 1h", "around 1.25h", "> 1.25h". The setting of the categories of answers was based on the Guidelines on PA developed by the World Health Organization [216].

3.2.3 Subjective Well-being

SWB was assessed by the validated Italian version of the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS). The Italian version of WEMWBS is a self-report questionnaire using a 12-item Likert scale of 1 (not at all) to 5 (as always) to measure the positive attitude to life over the past two weeks. The reliability of the Italian version was valued by Gremigni & Stewart-Brown (2011) on two groups: the Cronbach alpha value was 0.86 for the group 1 (n=345) and 0.83 for group 2 (n = 52) [217]. Compared with the original English version, question No.4 and No.12 are excluded [218]. The total scores of the 12 items were summed to create a total score out of 60 for the final result. The score ranged from 12 to 60, the higher score represented the more positive result of SWB.

3.2.4 Data Analysis

The data analysis was performed using Stata for Windows, version 17 (2021 StataCorp LLC.). Descriptive statistics were computed to summarize the overview of the sample characteristics. Means and standard deviations were used for continuous variables, while frequencies and percentages were calculated for categorical variables. To examine the differences between males and females across various categorical parameters, Chi-Square tests of independence were conducted. This statistical test was employed to determine whether there were significant associations between sex and the categorical variables of interest. The two-way analysis of variance (ANOVA) was conducted to examine the interaction effects of age group and sex on the continuous variables of interest. The residual distribution was checked with the Kolmogorov-Smirnov test and approximated to the Gaussian curve. The collinearity was checked with the variance inflation factor (VIF), and a mean value lower than five has been accepted. The variance homoskedasticity was confirmed by the Breusch-Pagan test. Given the complexity of the relationships under investigation, three separate hierarchical regression analyses were used to explore to test the potential liner relationships between SWB and both MPA and VPA while controlling the various covariates. The first analysis included MPA as the predictor variable and WEMWBS score as the outcome variable. Likewise, in the second analysis, VPA was included as the predictor variable. Then the third analysis included both MPA and VPA. After conducting the multicollinearity diagnostics, the hour of MPA and VPA were summed as a new variable "physical activities (PA) hour" in the third step of the hierarchical regression analysis to further explore the potential composite effect of MPA and VPA on SWB.

3.3 Results

3.3.1 Descriptive Statistics and Correlation Analysis

A total of 1079 responses were received. After eliminating duplicates and excluding invalid questionnaires, a total of 1005 valid samples remained. Due to the substantial number of missing responses regarding the types of health issues, we excluded detailed classification but retained the binary variable (yes/no) for regression analysis. Table 3.1 reports the sample descriptive characteristics with sex stratification. More than half of the individuals were 50 years old or younger (51.1%), while only 2.39% (n = 24) were older than 75. Ninety-two point two percent of participants had at least a high school certificate, no significant differences appeared between sexes. Only 12.74% of the sample did work with physical effort and 39.87% of participants who didn't work were senior adults. The participation of both MPA and VPA was polarized: on one side 34.0% of the participants claimed they did not do MPA over the last 2 weeks and 31.8% of the participants declare to practice it "> 2.5h". The total number of participants selecting the remaining options accounted for 34.2%. Similar situation was found in VPA: more than half of the participants did less than 0.5h of VPA and more than one fourth of the participants did more than 1.25h of VPA. The duration of both MPA ($\chi2 = 16.91$, $p = 0.005$) and VPA ($\chi2 = 19.98$, $p < 0.001$) among females was significantly lower than that among males. The mean Warwick-Edinburgh Mental Well-Being Scale (WEMWBS) score was 43.94 (SD = 7.36). Except for the significantly better subjective well-being (SWB) of males compared to females in the "senior adult" age group, the result showed no significant differences between sexes in other age groups (Table 3.2).

Table 3.1. Sample descriptive statistics (n=1005)

Variables	Male (n = 153) n (%)	Female (n = 852) n (%)	χ^2
Age group			7.14
Young adult	39 (25.5%)	217 (25.5%)	
Mature adult	40 (26.1%)	218 (25.6%)	
Middle-aged adult	44 (28.8%)	311 (36.5%)	
Senior adult	30 (19.6%)	106 (12.4%)	
Education level			3.04
Primary school or lower	3 (2.0%)	9 (1.1%)	
Secondary school	11 (7.2%)	45 (5.3%)	
High school	56 (36.6%)	322 (39.0%)	
Bachelor or master's degree	80 (52.3%)	435 (51.1%)	

Doctorate	3 (2.0%)	31 (3.6%)	
Health issues			1.89
No	122 (79.7%)	635 (74.5%)	
Yes	31 (20.3%)	217 (25.5%)	
Smoke			0.54
No	134 (87.6%)	727 (85.3%)	
Yes	19 (12.4%)	125 (14.7%)	
Work situation			2.68
No work	49 (32.0%)	257 (30.2%)	
Work without physical effort	89 (58.2%)	482 (56.6%)	
Work of moderate physical effort	11 (7.2%)	97 (11.4%)	
Work of significant physical effort	4 (2.6%)	16 (1.9)	
MPA			16.91**
No	43 (28.1%)	299 (35.1%)	
< 1h	0 (0.0%)	11 (1.3%)	
Around 1h	10 (6.5%)	46 (5.4%)	
Around 2h	23 (15.0%)	131 (15.4%)	
Around 2.5h	10 (6.5%)	112 (13.1%)	
> 2.5h	67 (43.8%)	253 (29.7%)	
VPA			19.98***
< 0.5h	60 (39.2%)	475 (55.8%)	
Around 0.5h	7 (4.6%)	42 (4.9%)	
Around 1h	15 (9.8%)	84 (9.9%)	
Around 1.25 h	9 (5.9%)	46 (5.4%)	

> 1.25h	62 (40.5%)	205 (24.1%)

**p < 0.01, ***p < 0.001; MPA: moderate physical activities; VPA: vigorous physical activities.

Table 3.2. Two-way ANOVA results for subjective well-being (SWB) of males and females across different age groups

WEMWBS	Male mean (SD)	Female mean (SD)	F
Young adult	42.95 (8.34)	42.87 (7.36)	0.00
Mature adult	42.85 (6.20)	44.71 (7.37)	2.24
middle-aged adult	44.55 (7.51)	44.04 (7.37)	0.18
Senior adult	48.20 (7.90)	43.60 (6.68)	10.20**
Total	44.41 (7.69)	43.86 (7.31)	0.74

**p < 0.01; WEMWBS: Score of Warwick-Edinburgh Mental Well-Being Scale.

3.3.2 Hierarchical Regressions

3.3.2.1 Moderate Physical Activities

Table 3.3 presents the hierarchical regression results of the impact of MPA on SWB. The first step included age group, sex, educational level, health issues, smoking condition and work situation as covariates (Model 1). Compared to young adults, mature adults obtained higher WEMWBS scores. Middle-aged adults had slightly lower scores than mature adults, while older adults have the highest scores among the four age categories. Participants who engaged in work of moderate physical effort have significantly higher WEMWBS scores compared to those who without work. The WEMWBS scores of participants who engaged in work without physical effort or work involving significant physical effort showed no significant difference compared to those who did not work. Sex, educational level, and smoking condition did not show significant impact on SWB. In addition, participants with health issues had lower WEMWBS scores compared than those without health issues.

The second step included the MPA variable and the goodness of fit slightly increased (Model 2). The results indicated that compared with participants who didn't engage in PA, those who engaged in more than 2.5 hour of MPA per week gained significant higher WEMWBS scores.

Table 3.3. The Impact of moderate physical activities (MPA) on WEMWBS score

Dependent	Model 1	Model 2

variables	*β*	*SE*	*β*	*SE*
Age group				
Young adult	0.00		0.00	
Mature adult	1.66*	0.65	1.64*	0.65
Middle-aged adult	1.34*	0.66	1.32*	0.66
Senior adult	2.02*	0.95	1.96*	0.95
Sex				
Male	0.00		0.00	
Female	-0.46	0.64	-0.22	0.65
Educational level				
Primary school or lower	0.00		0.00	
Secondary school	2.39	2.33	2.31	2.33
High school	-0.29	2.16	-0.73	2.16
Bachelor or master's degree	-0.70	2.18	-0.96	2.17
Doctorate	-1.00	2.50	-1.18	2.49
Health issues				
No	0.00		0.00	
Yes	-1.14*	0.58	-1.03	0.58
Smoke				
No	0.00		0.00	
Yes	-0.42	0.67	-0.38	0.66
Work situation				

No work	0.00		0.00	
Work without physical effort	0.01	0.63	0.15	0.63
Work of moderate physical effort	2.46**	0.89	2.45**	0.88
Work of significant physical effort	1.91	1.74	2.27	1.73
MPA				
No			0.00	
< 1h			-1.83	2.23
Around 1h			0.35	1.05
Around 2h			-0.25	0.71
Around 2.5h			0.77	0.77
> 2.5h			1.88***	0.57
F	2.72		2.82	
Adjusted R^2	0.022		0.031	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; The F-value and adjusted R^2 represent the goodness of fit; MPA: moderate physical activities; WEMWBS: Warwick-Edinburgh Mental Well-Being Scale.

3.3.2.2 Vigorous Physical Activities

Table 3.4 shows the hierarchical regression results of the impact of VPA on SWB. Similarly, the covariates were included in the first step as model 1. The second step included the VPA variable (Model 3). The results showed increased WEMWBS scores of participants who engaged in more than 1.25h VPA per week compared to those who did not engage in VPA. Notably, “health issues” was no longer significant in Model 3.

Table 3.4. The Impact of vigorous physical activities (VPA) on WEMWBS score

Dependent	Model 1		Model 3	
variables	*β*	*SE*	*β*	*SE*
Age group				
Young adult	0.00		0.00	
Mature adult	1.66*	0.65	1.70**	0.65
Middle-aged adult	1.34*	0.66	1.43*	0.66
Senior adult	2.02*	0.95	2.26*	0.95
Sex				
Male	0.00		0.00	
Female	-0.46	0.64	-0.22	0.65
Educational level				
Primary school or lower	0.00		0.00	
Secondary school	2.39	2.33	2.61	2.33
High school	-0.29	2.16	-0.09	2.16
Bachelor or master's degree	-0.70	2.18	-0.54	2.18
Doctorate	-1.00	2.50	-0.94	2.50
Health issues				
No	0.00		0.00	
Yes	-1.14*	0.58	-1.06	0.58
Smoke				
No	0.00		0.00	
Yes	-0.42	0.67	-0.41	0.67

Work situation				
No work	0.00		0.00	
Work without physical effort	0.01	0.63	-0.01	0.63
Work of moderate physical effort	2.46**	0.89	2.42**	0.89
Work of significant physical effort	1.91	1.74	2.14	1.74
VPA				
< 0.5h			0.00	
Around 0.5h			1.60	1.09
Around 1h			0.88	0.80
Around 1.25 h			0.59	1.04
> 1.25h			1.47**	0.56
F	2.72		2.57	
Adjusted R^2	0.022		0.026	

*$p < 0.05$, **$p < 0.01$; The F-value and adjusted R^2 represent the goodness of fit; VPA: vigorous physical activities; WEMWBS: Warwick-Edinburgh Mental Well-Being Scale.

3.3.2.3 Composite Effect of MPA and VPA

Table 3.5 shows the hierarchical regression results considering the composite effect of MPA and VPA. Model 4 included both the MPA variable and the VPA variable. The goodness of fit reduced 0.1% compared to Model 2 and increased 0.5% compared to Model 3. However, both MPA and VPA became not significant. Collinearity diagnostics revealed the absence of multicollinearity between MPA (VIF = 1.81) and VPA (VIF = 1.86). Thus, Model 5 introduced the variable “physical activity (PA) hour”, which represented the total hours of MPA and VPA. The results revealed that for each increased hour of PA, the WEMWBS score increased by 0.40 points. The goodness of fit remained unchanged compared to Model 4. Health issues showed no significance in both Model 4 and 5.

Table 3.5. The combined impact of MPA and VPA on WEMWBS score

Dependent	Model 1		Model 4		Model 5	
variables	*β*	*SE*	*β*	*SE*	*β*	*SE*
Age group						
Young adult	0.00		0.00		0.00	
Mature adult	1.66*	0.65	1.66*	0.65	1.67**	0.65
Middle-aged adult	1.34*	0.66	1.42*	0.66	1.35*	0.66
Senior adult	2.02*	0.95	2.15*	0.96	2.05*	0.95
Sex						
Male	0.00		0.00		0.00	
Female	-0.13	0.65	-0.13	0.65	-0.26	0.65
Educational level						
Primary school or lower	0.00		0.00		0.00	
Secondary school	2.39	2.33	2.37	2.33	2.48	2.33
High school	-0.29	2.16	-0.67	2.17	-0.33	2.15
Bachelor or master's degree	-0.70	2.18	-0.96	2.18	-0.67	2.17
Doctorate	-1.00	2.50	-1.26	2.50	-1.03	2.49
Health issues						
No	0.00		0.00		0.00	
Yes	-1.14*	0.58	-0.96	0.58	-1.13	0.58
Smoke						
No	0.00		0.00		0.00	

Yes	-0.42	0.67	-0.41	0.67	-0.37	0.66
Work situation						
No work	0.00		0.00		0.00	
Work without physical effort	0.01	0.63	0.12	0.63	0.04	0.63
Work of moderate physical effort	2.46**	0.89	2.47**	0.88	2.40**	0.88
Work of significant physical effort	1.91	1.74	2.35	1.74	2.18	1.73
MPA						
No			0.00			
< 1h			-2.27	2.27		
Around 1h			-0.32	1.17		
Around 2h			-0.78	0.83		
Around 2.5h			0.15	0.91		
> 2.5h			1.28	0.80		
VPA						
< 0.5h			0.00			
Around 0.5h			1.75	1.21		
Around 1h			0.69	0.93		
Around 1.25 h			0.27	1.44		
> 1.25h			0.80	0.76		
PA hour					0.40**	0.13

F	3.87	2.43	3.23
Adjusted R^2	0.017	0.030	0.030

*$p < 0.05$, **$p < 0.01$; The F-value and adjusted R^2 represent the goodness of fit; MPA: moderate physical activities; VPA: vigorous physical activities; PA: physical activities; WEMWBS: Warwick-Edinburgh Mental Well-Being Scale.

3.4 Discussion

This chapter contributes to the overall thesis by providing behavioural evidence supporting the conceptual framework developed in the previous chapter, demonstrating that the psychological benefits of urban green spaces are partly realised through PA. Consistent with the hypothesis, the results indicated a positive relationship between WEMWBS and both MPA and VPA after controlling for a series of covariates including age, sex, educational level, health issues, smoking condition, and work situation, which proved the essential benefits of PA on SWB. Specifically, after controlling for other covariates, engaging in more than 2.5 hours of MPA per week or more than 1.25 hours of VPA per week significantly enhanced participants' WEMWBS scores. While participants who could not meet the level of 2.5 hours of MPA or 1.25h of VPA did not show significantly improvement on SWB. This result was consistent with the WHO's recommendation that sufficient PA involves engaging in more than 150 minutes of MPA or 75 minutes of VPA per week [196, 219]. Similar results had been reported in related studies. Gierc et al. (2021) found that during the COVID-19 pandemic, Participants who engaged in less moderate-to-vigorous PA were more likely to exhibit significant mental health symptoms compared to those who engaged more PA. On the contrary, participants who maintained sufficient PA levels (more than 150 minutes per week) during COVID-19 reported significantly lower levels of depression and anxiety, along with higher life satisfaction [220]. Nakagawa et al (2020) reported that, in young adults, more frequent moderate-to-vigorous physical activities were associated with better cognitive and mental health outcomes compared to low-to-moderate physical activities such as walking. However, contrary to our findings, this chapter highlighted that engaging in small amounts of PA, specifically just 1-2 days per week (with each session lasting more than 10 minutes), can also effectively provide multiple mental health benefits [221].

The mechanisms by which PA improves mental well-being are diverse. On the one hand, PA enhances participants' self-esteem and self-efficacy by improving physical fitness and body image, and fostering the sense of accomplishment [222-224]. On the other hand, existing studies highlighted the neurological benefits of PA on the brain. PA helps to strengthen the hippocampus and boost neuroplasticity, leading to better cognitive function, enhanced learning ability and memory capacity, and improved emotional regulation, ultimately promoting higher levels of mental health [225, 226]. Additionally, PA improves mental health by offering social support and engagement [224, 227], along with enhancing physical health [228].

When examining the composite effects of VPA and MPA (Model 5), we identified a dose-response relationship between the weekly total PA hour and SWB. Specifically, for each additional hour of PA, the WEMWBS score increased by 0.40 points (out of a total of 60 points). Similarly, Hsueh et al. (2021) found that increasing daily steps, particularly

accumulating 3,500–6,999 or more than 7,000 steps per day, was liner associated with a lower risk of depressive symptoms in older adults over a two-year period [229]. Meanwhile, the odds of meeting PA recommendations were significantly lower among those reporting more days of mental distress per month [230]. However, the dose-response association exhibits heterogeneity in related studies. For example, a study carried out in Canada found non-linear dose-response patterns between various types of PA activity and mental health, with optimal benefits observed at around 50 minutes of moderate-to-vigorous PA per day, a complex pattern for light PA, and an inverted U-shaped benefit for daily steps [231]. Shimura et al. (2022) found the U-shaped, quadratic equation models between PA levels and mental health measurements instead of linear associations [232]. The reasons for the results may be due to the influence of sedentary behaviour, and the causal relationship between excessive exercise and psychological impairment is unclear: it is possible that psychological impairment leads to excessive exercise [231, 232]. Besides, excessive exercise may lead to physical and mental fatigue, thereby increasing the risk of mental health [233]. Furthermore, when incorporating both MPA and VPA into a unified model (Model 4), the benefits of both MPA and VPA on SWB were found to become insignificant. However, no multicollinearity or strong interaction effects were detected, suggesting that this could result from the uneven sample distribution. Therefore, further longitudinal studies or rigorous cohort experiments should be carried out in future researches to further validate the dose-response relationship between PA and SWB. Nevertheless, present chapter still demonstrates the benefits of PA.

Additionally, the results of the considered socioeconomic demographic and lifestyle factors were also of significant importance. Firstly, although there was no significant difference in SWB between sexes, women participate significantly less in MPA and VPA compared to men. Meanwhile, existing researches suggested that compared with women, men needed more high intensity of PA to improve mental well-being [234, 235]. Secondly, the influence of age on SWB is also significant. Our results showed that SWB exhibits an upward trend in early adulthood, experiences a slight dip in middle age, and rises again in later years. Similar findings have been reported in other research studies [208, 209]. Furthermore, considering the different needs regarding the type and intensity of PA between different sexes and ages, as well as varying opportunities for participation, it is essential to develop more detailed guidelines for different individuals [236]. Thirdly, despite becoming insignificant after including PA indicators, health issues still showed significance for SWB in Model 1. Numerous studies had corroborated this finding, indicating that improving physical health is one of the primary pathways through which PA enhanced SWB [104]. Lastly, the better SWB was observed among the participants engaged in work of moderate physical effort compared to those who were not employed. It is generally due to the fact that moderate PA at work can reduce the occurrence of sedentary behaviour [237]. However, there was no evidence found regarding the impact of excessive physical exertion at work on SWB. However, no significant effects of educational level and smoking status on SWB were observed in our study, despite both of the two indicators are commonly considered important factors influencing mental health [211, 212, 215]. These findings provide behavioural evidence supporting the conceptual framework developed in the previous chapters, demonstrating that the psychological benefits of UGS are partly realised through increased opportunities for PA.

Limitations

This chapter demonstrated several strengths. Through a comprehensive comparison of various models, we proved that both moderate MPA and VPA significantly improve participants' subjective well-being (SWB) when the activity levels meet the WHO recommended standards. Furthermore, we identified three sociodemographic and lifestyle factors (age, health issues, and work situation) as significant variables influencing SWB. The study's robustness was further supported by an adequate sample size, ensuring the reliability of our findings. Nevertheless, there are some limitations. Firstly, the goodness of fit of the models were relatively poor, with R-squared values ranging from 0.017 to 0.031, indicating limited explanatory power. Secondly, the cross-sectional design hindered the ability to establish causal relationships between independent variables and SWB. Additionally, there might be unaccounted confounding variables. For example, income, a well-known determinant of SWB, was not included due to privacy concerns, which could have contributed to the low goodness of fit [238-240]. Furthermore, the reliance on self-reported data introduces potential biases and inaccuracies in both SWB and weekly PA measurements. Thus, longitudinal or cohort designs would be required to verify these associations and establish causality, which remains beyond the scope of this cross-sectional investigation. It is also essential to consider the variables representing socioeconomic status more comprehensively and to refine PA guidelines tailored to different population characteristics. These methodological reflections also informed the design of the following chapters, which explore how specific UGS attributes and green interventions influence residents’ engagement in PA and their well-being.

Chapter 4 – Understanding Perception and Attitudes of Residents towards Urban Green Spaces

This chapter is based on the article “Perception and Attitudes Towards Urban Green Spaces in Emilia-Romagna (Italy) – a case study”,

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Summary

Urban green spaces (UGS) represent vital components of daily urban life, providing settings where environmental and social dimensions of well-being converge. This chapter investigated residents’ perceptions and attitudes towards UGS in a neighbourhood of Imola, Emilia-Romagna Region, Italy, with the aim of understanding how people experience, evaluate, and use local green areas in their daily routines. A structured questionnaire survey was conducted to collect data on visiting frequency, motivations, perceived barriers, satisfaction levels, and suggestions for improvement. The analyses revealed that household composition and life stage were more influential than education or occupation in determining how residents engaged with UGS. Families with young children tended to use parks more frequently and for social or recreational purposes, whereas older adults emphasised accessibility, comfort, and maintenance. Across all groups, time constraints and limited facilities emerged as the main obstacles. These findings highlight that residents’ engagement with UGS depends not only on their physical availability but also on the alignment between environmental characteristics and residents’ daily needs, offering valuable insights for understanding inclusiveness and well-being within urban green environments.

4.1 Introduction

After discussing in the previous chapters how the quality of urban green spaces (UGS) and the engagement in physical activity (PA) contribute to residents' well-being, this chapter shifts the focus to the subjective dimension: residents' perception and attitude towards UGS. Although previous chapters have examined UGS as key nature-based resources for health promotion, the effectiveness of these spaces ultimately depends on how they are perceived, accessed, and valued by residents [66, 241]. Thus, perceptions and attitudes represent the human dimension of UGS quality, mediating between the physical characteristics of environments and the well-being outcomes they can provide [242, 243]. Therefore, this chapter takes the Emilia-Romagna region of Italy as a case study to explore how residents perceive and evaluate UGS within their local environments.

In the European context, Italy is now facing multiple challenges in managing UGS due to its unique urban pattern, which usually combines a dense historic centre with modern suburban development [244, 245]. The Emilia-Romagna Region, located in the northern part of Italy, exemplifies these challenges with its high population density and significant urbanisation pressures, which highlight the imbalance between supply and demand for UGS [246-248]. Additionally, Emilia-Romagna is at the forefront of ongoing initiatives aimed to promote the development of sustainability and adapt to the challenges of climate change, emphasising the need to balance ecological goals with the enhancement of green spaces, improving climate resilience, and increasing residents' quality of life [249-251]. Moreover, the region's rich historical and cultural heritage strongly influences urban planning decisions [150], while its Mediterranean climate shapes both the design and use of green spaces [252].

Meanwhile, despite the close relationship between UGS planning and residents' daily lives, and despite the importance of public participation in governance being emphasised for over two decades, progress in this area has remained slow [253]. Bureaucratic urban planning processes usually overlook residents' perceptions and attitudes towards UGS, focusing instead on macroscopic goals such as economic efficiency, spatial optimisation, and ecological functionality [254-256]. Although European policy makers have recognised the importance of shifting planning and management strategies, the lack of effective tools and limited resources hinder meaningful public participation [255]. This gap not only leads to mismatches between the supply of and demand for UGS but also raises significant concerns regarding environmental equity [255, 257-260]. In other words, residents' expectations and preferences for UGS vary across age, gender, health status and socioeconomic background [261-263]. Futhermore, due to the green gentrification, the allocation of high-quality green spaces can increase local living costs, potentially disadvantaging socially vulnerable groups [264-266]. When residents' needs and preferences are inadequately addressed, this can lead to reduced user satisfaction, lower utilisation, and weakened health benefits and community ties, resulting in inefficient use of valuable urban resources [267-270].

Therefore, this chapter focuses on residents' perceptions and attitudes towards UGS in a neighbourhood of an Italian city (Quartiere Marconi, a district in Imola, Emilia-Romagna Region) where a redevelopment of the area is currently under consideration, making residents' opinions particularly relevant. Through a comprehensive questionnaire survey, this research aims to:

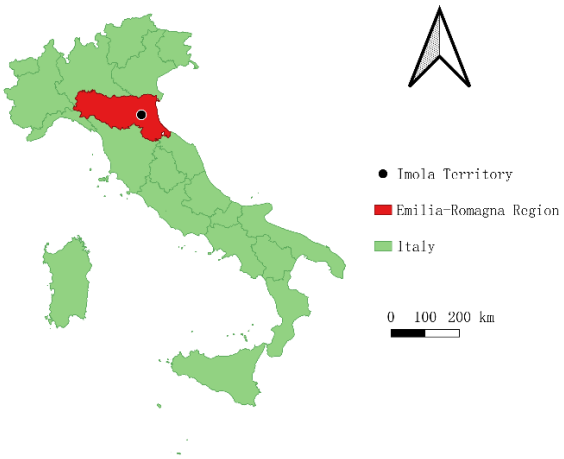
a) understand the strengths and limitations of existing UGS in the considered area from users' perspectives, including aspects such as spatial characteristics, biodiversity, recreational facilities, and accessibility;
b) by examining residents' motivations for UGS use and their suggestions for improvement, identify potential gaps between current provisions and community needs.

The findings will contribute to the broader thesis objective of understanding how residents' subjective experiences shape the relationship between urban environments and well-being, while offering practical insights for inclusive and high-quality UGS design in similar urban contexts.

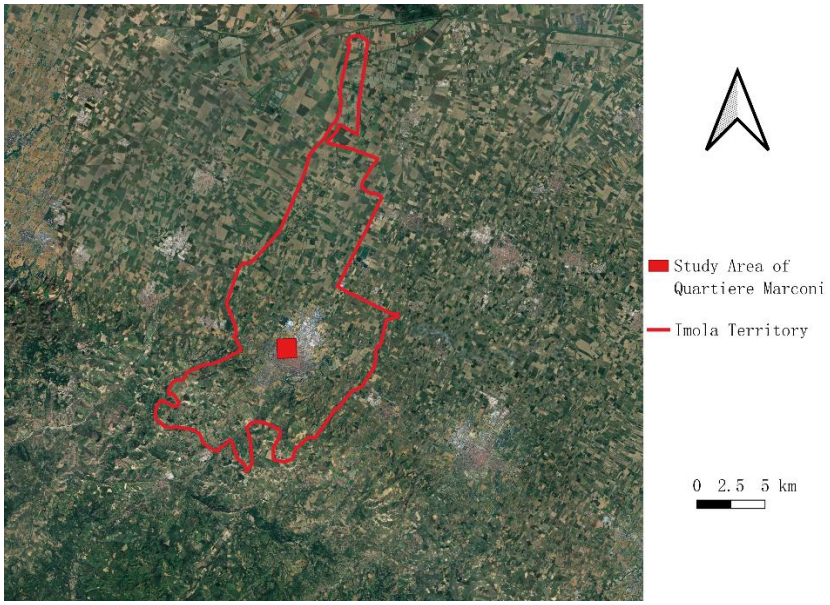
4.2 Methods

4.2.1 Study Area

Imola is one of the seven major cities of the Romagna subregion and the second-largest municipality in the Metropolitan City of Bologna after the regional capital. As a medium-sized municipality with a population of around 69,357 residents, Imola is situated along the Via Emilia in the Romagna subregion. The municipal territory is predominantly flat, with a hilly area in the southern part. According to the Italian National Climate Classification, Imola has a heating degree day value of 2292 GR/G, placing it in climate zone E [271]. This chapter concentrates on a residential neighbourhood (Quartiere Marconi) located in the northern part of Imola, which is currently undergoing urban redevelopment efforts led by the Imola municipal government. Figure 4.1 illustrates the geographic location of the study area within Italy, alongside the spatial distribution of UGS and trees in the area of Quartiere Marconi. These initiatives focus on renovating public housing, improving infrastructure, and expanding green spaces, all with active resident engagement to address local needs. Additionally, the considered neighbourhood exemplifies the mix of old and new urban areas common in medium-sized Italian cities, making it a valuable case for understanding green space perceptions and attitudes [272].



(a)



(b)

Figure 4.1. Description of the study area: (a) national geographic setting of the study area in Italy; (b) regional geographic setting of the study area in Imola; (c) spatial distribution of urban green spaces and trees in the study area.

4.2.2 Survey Design and Data Collection

The data was collected through a comprehensive questionnaire survey conducted with residents who live in the neighbourhood (Quartiere Marconi) in Imola. The questionnaire survey was designed based on existing literature and expert feedback to ensure its relevance and content validity, aiming to capture both quantitative and qualitative insights into participants' perceptions, attitudes and suggestions towards the neighbourhood's existing UGS.

The ad hoc questionnaire consisted of a mix of single-choice, multiple-choice and Likert-scale questions. Key topics covered included:

- Socio-demographic characteristics including sex, age, nationality, marital status, living arrangement, educational level, employment status, and housing type;
- Purpose and patterns of UGS usage;
- Satisfaction and unsatisfaction with existing UGS attributes in Quartiere Marconi (e.g., size, accessibility, facilities);
- Demands and suggestions for future UGS development and improvement.

The questionnaire was distributed randomly in collaboration with the Municipality of Imola, inviting residents to participate through a combination of neighbourhood association outreach and online promotion. The formal power analysis was not conducted due to time and resource constraints. The online survey was conducted from November 2023 to June 2024 using Google Forms, while the paper-based questionnaires were distributed on-site at random locations within the study area by four trained researchers from July 2024 to September 2024, with multiple sampling sessions, providing assistance as needed. We conducted sampling at different times of day and on different days of the period to maximize the diversity of respondents. The survey was approved by the bioethics Committee of the University of

Bologna (Prot. N 169182). All participants provided written informed consent prior to participation. To protect participants' privacy, all survey responses were anonymised before the analysis. A total of 144 residents completed the questionnaires (comprising 95 online responses and 49 on-site responses), but 18 on-site questionnaires were excluded due to the invalid response. Ultimately, 126 valid questionnaires were included.

4.2.3 Data Analysis

We performed all statistical analyses using Stata/SE 17.0 (StataCorp LLC, College Station, TX, USA). In order to prepare the data for analysis, several modifications were made to ensure clarity and facilitate interpretation. Age groups were categorised into four intervals based on participants' dates of birth: young (≤30), early middle-age (31-45), middle-age (46-60), and elderly (>60). The multiple-choice question regarding living arrangements was transformed into three binary variables: living with family (yes/no), living with children aged 12 or younger (yes/no), and living with elderly requiring assistance (yes/no). Due to small sample sizes, we combined primary school and secondary school education levels into a single category “below high school”. The variable “Housing characteristics” were generated by merging housing type and garden availability, resulting in three categories: “detached house” (all samples were with gardens), “apartment with private garden”, and “apartment without private garden”. Categories with zero response in other variables were omitted from the statistical analysis.

Socio-demographic characteristics were analysed across age groups (≤30, 31-45, 46-60, and >60 years). Descriptive statistics were presented as frequencies and percentages. Chi-square tests were conducted to examine the associations between age groups and categorical variables, including sex, marital status, educational level, employment status, and living arrangement. We removed the nationality because there were only 5 foreigners (3.97%) out of 126 samples. Statistical significance was set at $p < 0.05$.

The analysis of residents' preferences and attitudes was conducted in four main aspects, including the associations between socio-demographic characteristics and main reasons for visiting UGS, main barriers to visiting UGS, most satisfying aspects of existing UGS, and most unsatisfying aspects of existing UGS. The questions were structured as single-answer questions with an "Other" option. Due to the very low response rate for the "Other" option and the fact that the only responses in this category aligned with provided options, these responses were merged with their corresponding existing categories based on their content. Cross-tabulation analyses were performed using chi-square tests. For contingency tables with expected cell frequencies less than 5, we validated the results using Fisher's exact tests. As the results showed minimal differences between these two methods, we reported chi-square test results for all the tables, determining significant associations between socio-demographic characteristics and response.

To further understand the impact of socio-demographic factors on weekly time spent in UGS and overall satisfaction score, we conducted a backward stepwise regression analysis. For each dependent variable, a set of independent variables was tested for their ability to explain variance. The initial model for both dependent variables included socio-demographics including sex, age group, marital status, education level, employment status, living arrangement, housing type, time required to reach UGS, and transportation choice. The stepwise procedure was performed with a p-value threshold of 0.05 for variable inclusion and

removal. Following the stepwise regression, a mediation analysis was conducted to explore whether overall satisfaction acted as a mediator in the relationship between weekly time spent in UGS and other predictors.

Finally, to study resident's preferences and suggestions for the future UGS development, we analysed residents' priorities using a multiple-choice question where respondents selected and ranked their top three preferred features from 13 options and the results were presented as frequencies and percentages for each priority level. Thematic analysis of the open-ended supplementary suggestions was not pursued due to the extremely low response rate (18.3%).

4.3 Results

4.3.1 Socio-demographic Characteristics

The socio-demographic characteristics of participants across age groups are presented in Table 4.1. The sample shows a relatively balanced age distribution, with the majority falling into the early middle-age (31-45) and middle-age category (46-60). We found significant differences of age groups in marital status ($\chi^2 = 45.573$, $p < 0.001$), employment status ($\chi^2 = 132.569$, $p < 0.001$), and living arrangements with children aged 12 or younger ($\chi^2 = 15.027$, $p = 0.002$) and with elderly requiring assistance ($\chi^2 = 8.122$, $p = 0.044$). The 31-45 age group showed the highest proportion of full-time employment (90.4%) and living with children (48.1%). The 46-60 age group demonstrated the highest percentage of living with elderly requiring assistance (11.9%). Educational level differences across age groups approached but did not reach statistical significance ($\chi^2 = 19.797$, $p = 0.071$). Sex distribution and living with family or not showed no significant differences across age groups ($p > 0.05$).

Table 4.1. Socio-demographic characteristics by age group.

	Total (*N* = 126)	**≤30 (*n* = 17)**	**31–45 (*n* = 52)**	**46–60 (*n* = 42)**	**>60 (*n* = 15)**	**χ^2**	***p***
Sex						2.5	0.470
Male	49 (38.89%)	6 (35.29%)	17 (32.69%)	18 (42.86%)	8 (53.33%)		
Female	77 (61.11%)	11 (64.71%)	35 (67.31%)	24 (57.14%)	7 (46.67%)		
Marital status						46	<0.001 ***
Married	66 (52.38%)	2 (11.76%)	25 (48.08%)	27 (64.29%)	12 (80.00%)		
Unmarried	48 (38.10%)	15 (88.24%)	23 (44.23%)	10 (23.81%)	0 (0.00%)		
Divorced	10 (7.94%)	0 (0.00%)	4 (7.69%)	5 (11.90%)	1 (6.67%)		
Widowed	2 (1.59%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (13.33%)		
Educational level						20	0.071
Below high school	5 (3.97%)	0 (0.00%)	0 (0.00%)	3 (7.14%)	2 (13.33%)		
High school	48 (38.10%)	8 (47.06%)	14 (26.92%)	20 (47.62%)	6 (40.00%)		
Bachelor	16 (12.70%)	3 (17.65%)	7 (13.46%)	5 (11.90%)	1 (6.67%)		
Master	36 (28.57%)	6 (35.29%)	17 (32.69%)	10 (23.81%)	3 (20.00%)		
Doctorate	21 (16.67%)	0 (0.00%)	14 (26.92%)	4 (9.52%)	3 (20.00%)		
Employment status						133	<0.001 ***
Full-time/ self-employed	95 (75.40%)	10 (58.82%)	47 (90.38%)	33 (78.57%)	5 (33.33%)		
Part-time	12 (9.52%)	0 (0.00%)	4 (7.69%)	8 (19.05%)	0 (0.00%)		
Student	7 (5.56%)	7 (41.18%)	0 (0.00%)	0 (0.00%)	0 (0.00%)		
Unemployed	2 (1.59%)	0 (0.00%)	1 (1.92%)	1 (2.38%)	0 (0.00%)		

Retired	10 (7.94%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	10 (66.67%)		
Living with family						0.8	0.848
Yes	106 (84.13%)	14 (82.35%)	43 (82.69%)	37 (88.10%)	12 (80.00%)		
No	20 (15.87%)	3 (17.65%)	9 (17.31%)	5 (11.90%)	3 (20.00%)		
Living with children ≤12						15	0.002 **
Yes	37 (29.37%)	3 (17.65%)	25 (48.08%)	7 (16.67%)	2 (13.33%)		
No	89 (70.63%)	14 (82.35%)	27 (51.92%)	35 (83.33%)	13 (86.67%)		
Living with elderly requiring assistance						8.1	0.044 *
Yes	6 (4.76%)	1 (5.88%)	0 (0.00%)	5 (11.90%)	0 (0.00%)		
No	120 (95.24%)	16 (94.12%)	52 (100.00%)	37 (88.10%)	15 (100.00%)		

Values are presented as frequency (percentage); * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.3.2 The Main Reasons for Visiting UGS

The analysis of the most important reasons for visiting UGS revealed interesting patterns in residents' preferences and behaviours (Table 4.2). Nature enjoyment proved to be the primary motivation across all groups (42.9% of total respondents), followed by relaxation (24.6%) and social activities (15.9%). Meanwhile, the main reasons for visiting UGS revealed significant associations with family living arrangements. Residents living with family members significantly showed different visiting purposes compared to those living alone ($\chi^2 = 27.409$, $p < 0.001$), with the former group more inclined to nature enjoyment (47.2%) and social activities (17.9%), while the latter preferred relaxation (50.0%) and walking pets (20.0%). Similarly, the presence of children aged 12 or younger significantly influenced visiting purposes ($\chi^2 = 26.159$, $p < 0.001$), with these residents showing a strong preference for social activities (40.5%) compared to residents without children aged 12 or younger (5.6%). Most participants (94.4%) lived within 20 minutes of UGS, with 42.9% living within 5-minute and 51.5% within 5-20 minutes, suggesting high accessibility of UGS in the study area. The difference in time requirement for different reasons visiting UGS was approaching significant level ($\chi^2 = 14.413$, $p = 0.072$), with those living 5-20 minutes away more likely to engage in physical activities (PA) (18.5%), and those spending more time on the way showing increased preference for nature enjoyment (57.1% for 20-45 minutes distance). Other socio-demographic characteristics, including sex, age, marital status, educational level, employment status, living with elderly requiring assistance, housing type, and transportation choice showed no significant associations with visiting purposes (all $p > 0.05$).

Table 4.2. Socio-demographic differences in most important reasons for visiting UGS

	Physical activities	**Nature enjoyment**	**Relaxation**	**Social activities**	**Walking pets**	**χ^2**	**p**
Sex						4.255	0.373
Male	5 (10.2%)	23 (46.9%)	15 (30.6%)	5 (10.2%)	1 (2.0%)		
Female	11 (14.3%)	31 (40.3%)	16 (20.8%)	15 (19.5%)	4 (5.2%)		
Age group						13.105	0.361
≤30	3 (17.6%)	7 (41.2%)	4 (23.5%)	2 (11.8%)	1 (5.9%)		
31-45	6 (11.5%)	22 (42.3%)	9 (17.3%)	12 (23.1%)	3 (5.8%)		

46-60	5 (11.9%)	20 (47.6%)	15 (35.7%)	2 (4.8%)	0 (0.0%)		
>60	2 (13.3%)	5 (33.3%)	3 (20.0%)	4 (26.7%)	1 (6.7%)		
Marital status						17.181	0.143
Married	8 (12.1%)	28 (42.4%)	15 (22.7%)	14 (21.2%)	1 (1.5%)		
Unmarried	8 (16.7%)	22 (45.8%)	9 (18.8%)	6 (12.5%)	3 (6.3%)		
Divorced	0 (0.0%)	4 (40.0%)	5 (50.0%)	0 (0.0%)	1 (10.0%)		
Widowed	0 (0.0%)	0 (0.0%)	2 (100.0%)	0 (0.0%)	0 (0.0%)		
Educational level						19.131	0.262
Below high School	0 (0.0%)	4 (80.0%)	1 (20.0%)	0 (0.0%)	0 (0.0%)		
High school	5 (10.4%)	23 (47.9%)	10 (20.8%)	10 (20.8%)	0 (0.0%)		
Bachelor	3 (18.8%)	8 (50.0%)	4 (25.0%)	1 (6.3%)	0 (0.0%)		
Master	6 (16.7%)	15 (41.7%)	7 (19.4%)	5 (13.9%)	3 (8.3%)		
Doctorate	2 (9.5%)	4 (19.0%)	9 (42.9%)	4 (19.0%)	2 (9.5%)		
Employment status						9.202	0.905
Full-time/ self-employed	13 (13.7%)	38 (40.0%)	26 (27.4%)	15 (15.8%)	3 (3.2%)		
Part-time	2 (16.7%)	7 (58.3%)	1 (8.3%)	2 (16.7%)	0 (0.0%)		
Student	1 (14.3%)	3 (42.9%)	1 (14.3%)	1 (14.3%)	1 (14.3%)		
Unemployed	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)		
Retired	0 (0.0%)	5 (50.0%)	2 (20.0%)	2 (20.0%)	1 (10.0%)		
Living with family						27.409	<0.001
Yes	15 (14.2%)	50 (47.2%)	21 (19.8%)	19 (17.9%)	1 (0.9%)		
No	1 (5.0%)	4 (20.0%)	10 (50.0%)	1 (5.0%)	4 (20.0%)		
Living with children ≤12						26.159	<0.001
Yes	2 (5.4%)	14 (37.8%)	6 (16.2%)	15 (40.5%)	0 (0.0%)		
No	14 (15.7%)	40 (44.9%)	25 (28.1%)	5 (5.6%)	5 (5.6%)		
Living with elderly requiring assistance						0.659	0.956
Yes	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0.0%)		

No	15 (12.5%)	52 (43.3%)	29 (24.2%)	19 (15.8%)	5 (4.2%)		
Housing type						9.004	0.342
Apartment without garden	11 (14.3%)	32 (41.6%)	18 (23.4%)	11 (14.3%)	5 (6.5%)		
Apartment with garden	0 (0.0%)	13 (52.0%)	7 (28.0%)	5 (20.0%)	0 (0.0%)		
Detached house	5 (20.8%)	9 (37.5%)	6 (25.0%)	4 (16.7%)	0 (0.0%)		
Time to reach UGS						14.413	0.072
<5 minutes	4 (7.4%)	22 (40.7%)	17 (31.5%)	7 (13.0%)	4 (7.4%)		
5-20 minutes	12 (18.5%)	28 (43.1%)	12 (18.5%)	13 (20.0%)	0 (0.0%)		
20-45 minutes	0 (0.0%)	4 (57.1%)	2 (28.6%)	0 (0.0%)	1 (14.3%)		
Transportation						8.281	0.406
On foot	8 (10.0%)	31 (38.8%)	24 (30.0%)	12 (15.0%)	5 (6.3%)		
By bicycle	2 (16.7%)	7 (58.3%)	1 (8.3%)	2 (16.7%)	0 (0.0%)		
By car	6 (17.6%)	16 (47.1%)	6 (17.6%)	6 (17.6%)	0 (0.0%)		

Values are presented as frequency (percentage); *** $p < 0.001$.

4.3.3 The Main Barriers to Visiting UGS

The analysis of the most important barriers to visiting UGS showed different patterns across socio-demographic groups (Table 4.3). The lack of time was the most emphasised barrier (61.9% of total respondents), followed by poor cleanliness and maintenance (11.1%) and lack of public toilets (7.9%). Age group and employment status showed significant associations with visiting barriers ($\chi^2 = 61.922$ and 45.455, $p < 0.001$ and $p = 0.020$, respectively). In particular, the elderly group (>60) reported concerns with public toilets (40.0%) and health issues (20.0%) as their primary barriers rather than time constraints. Meanwhile, educational level demonstrated significant variations in perceived barriers ($\chi^2 = 43.214$, $p = 0.033$), with higher education groups predominantly citing time constraints (71.4% for doctorate holders), while those with lower educational levels reported more diverse barriers including cleanliness and maintenance issues (40.0%). Among those who live within 20 minutes of journey to UGS (94.4% of respondents), the lack of time remained the primary barrier regardless of transport mode choices, though those walking (63.5% of respondents) showed more concerns about cleanliness (12.5%) and security (7.5%). Notably, marital status revealed significant differences ($\chi^2 = 68.180$, $p < 0.001$), while other living arrangement factors, including living with family, children aged 12 or younger, or elderly requiring assistance, showed no significant associations with perceived barriers (all $p > 0.05$).

Table 4.3. Socio-demographic differences in most important barriers to visiting UGS

	Health problems	Lack of free time	Lack of public toilets	No desired facilities	Poor cleanliness	Poor accessibility	Sense of insecurity	Too crowded	χ^2	p
Sex									5.657	0.580
Male	1 (2.0%)	29 (59.2%)	6 (12.2%)	2 (4.1%)	7 (14.3%)	3 (6.1%)	1 (2.0%)	0 (0.0%)		
Female	3 (3.9%)	49 (63.6%)	4 (5.2%)	2 (2.6%)	7 (9.1%)	5 (6.5%)	6 (7.8%)	1 (1.3%)		
Age group									61.922	<0.001***
≤30	0 (0.0%)	10 (58.8%)	0 (0.0%)	2 (11.8%)	1 (5.9%)	2 (11.8%)	2 (11.8%)	0 (0.0%)		
31-45	1 (1.9%)	34 (65.4%)	2 (3.8%)	0 (0.0%)	8 (15.4%)	4 (7.7%)	3 (5.8%)	0 (0.0%)		
46-60	0 (0.0%)	32 (76.2%)	2 (4.8%)	2 (4.8%)	4 (9.5%)	0 (0.0%)	1 (2.4%)	1 (2.4%)		
>60	3 (20.0%)	2 (13.3%)	6 (40.0%)	0 (0.0%)	1 (6.7%)	2 (13.3%)	1 (6.7%)	0 (0.0%)		
Marital status									68.18	<0.001***
Married	1 (1.5%)	40 (60.6%)	8 (12.1%)	2 (3.0%)	8 (12.1%)	3 (4.5%)	3 (4.5%)	1 (1.5%)		
Unmarried	1 (2.1%)	31 (64.6%)	2 (4.2%)	2 (4.2%)	5 (10.4%)	4 (8.3%)	3 (6.3%)	0 (0.0%)		
Divorced	0 (0.0%)	7 (70.0%)	0 (0.0%)	0 (0.0%)	1 (10.0%)	1 (10.0%)	1 (10.0%)	0 (0.0%)		
Widowed	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		

Educational level									43.214	0.033*
Below high School	1 (20.0%)	1 (20.0%)	1 (20.0%)	0 (0.0%)	2 (40.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
High school	0 (0.0%)	29 (60.4%)	6 (12.5%)	1 (2.1%)	7 (14.6%)	2 (4.2%)	3 (6.3%)	0 (0.0%)		
Bachelor	0 (0.0%)	12 (75.0%)	1 (6.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (12.5%)	1 (6.3%)		
Master	2 (5.6%)	21 (58.3%)	1 (2.8%)	3 (8.3%)	2 (5.6%)	6 (16.7%)	1 (2.8%)	0 (0.0%)		
Doctorate	1 (4.8%)	15 (71.4%)	1 (4.8%)	0 (0.0%)	3 (14.3%)	0 (0.0%)	1 (4.8%)	0 (0.0%)		
Employment status									45.455	0.020*
Full-time/ self-employed	2 (2.1%)	64 (67.4%)	6 (6.3%)	2 (2.1%)	11 (11.6%)	3 (3.2%)	6 (6.3%)	1 (1.1%)		
Part-time	0 (0.0%)	8 (66.7%)	0 (0.0%)	1 (8.3%)	1 (8.3%)	2 (16.7%)	0 (0.0%)	0 (0.0%)		
Student	0 (0.0%)	3 (42.9%)	0 (0.0%)	1 (14.3%)	1 (14.3%)	1 (14.3%)	1 (14.3%)	0 (0.0%)		
Unemployed	0 (0.0%)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Retired	2 (20.0%)	1 (10.0%)	4 (40.0%)	0 (0.0%)	1 (10.0%)	2 (20.0%)	0 (0.0%)	0 (0.0%)		
Living with family									5.95	0.546
Yes	2 (1.9%)	67 (63.2%)	8 (7.5%)	3 (2.8%)	13 (12.3%)	7 (6.6%)	5 (4.7%)	1 (0.9%)		
No	2 (10.0%)	11 (55.0%)	2 (10.0%)	1 (5.0%)	1 (5.0%)	1 (5.0%)	2 (10.0%)	0 (0.0%)		

Living with children ≤12									7.658	0.364
Yes	2 (5.4%)	23 (62.2%)	1 (2.7%)	0 (0.0%)	7 (18.9%)	2 (5.4%)	2 (5.4%)	0 (0.0%)		
No	2 (2.2%)	55 (61.8%)	9 (10.1%)	4 (4.5%)	7 (7.9%)	6 (6.7%)	5 (5.6%)	1 (1.1%)		
Living with elderly requiring assistance									2.972	0.888
Yes	0 (0.0%)	5 (83.3%)	1 (16.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
No	4 (3.3%)	73 (60.8%)	9 (7.5%)	4 (3.3%)	14 (11.7%)	8 (6.7%)	7 (5.8%)	1 (0.8%)		
Housing type									14.349	0.424
Apartment without garden	2 (2.6%)	44 (57.1%)	6 (7.8%)	4 (5.2%)	10 (13.0%)	6 (7.8%)	5 (6.5%)	0 (0.0%)		
Apartment with garden	2 (8.0%)	16 (64.0%)	1 (4.0%)	0 (0.0%)	2 (8.0%)	1 (4.0%)	2 (8.0%)	1 (4.0%)		
Detached house	0 (0.0%)	18 (75.0%)	3 (12.5%)	0 (0.0%)	2 (8.3%)	1 (4.2%)	0 (0.0%)	0 (0.0%)		
Time to reach UGS									7.199	0.927
<5 minutes	2 (3.7%)	34 (63.0%)	4 (7.4%)	1 (1.9%)	6 (11.1%)	2 (3.7%)	4 (7.4%)	1 (1.9%)		
5-20 minutes	2 (3.1%)	38 (58.5%)	6 (9.2%)	3 (4.6%)	8 (12.3%)	5 (7.7%)	3 (4.6%)	0 (0.0%)		
20-45 minutes	0 (0.0%)	6 (85.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	0 (0.0%)	0 (0.0%)		

Transportation									12.095	0.599
On foot	4 (5.0%)	47 (58.8%)	5 (6.3%)	2 (2.5%)	10 (12.5%)	6 (7.5%)	6 (7.5%)	0 (0.0%)		
By bicycle	0 (0.0%)	7 (58.3%)	2 (16.7%)	1 (8.3%)	1 (8.3%)	0 (0.0%)	1 (8.3%)	0 (0.0%)		
By car	0 (0.0%)	24 (70.6%)	3 (8.8%)	1 (2.9%)	3 (8.8%)	2 (5.9%)	0 (0.0%)	1 (2.9%)		

Values are presented as frequency (percentage); * $p < 0.05$, *** $p < 0.001$.

4.3.4 The Most Satisfying Aspect of the Existing UGS

The analysis of the most satisfying aspects of existing UGS presented different positive attitudes to UGS across different socio-demographic groups (Table 4.4). Among all aspects, accessibility and size of UGS were considered consistently to be the most satisfying aspects, accounting for 34.9% and 22.2% of total responses respectively. Significant difference between sexes were observed ($\chi^2 = 16.356$, $p = 0.012$), with female expressing more diverse satisfaction patterns, particularly in landscape features (15.6%) and abundance of greenery (19.5%), while males concentrated their satisfaction on accessibility (38.8%) and UGS size (36.7%). The children aged 12 or younger in households significantly influenced satisfaction patterns of the residents ($\chi^2 = 19.620$, $p = 0.003$). Residents with children aged 12 or younger showed most satisfaction with size (29.7%), while residents without children aged 12 or younger reported most satisfaction with accessibility (40.4%). Time spent on the way to UGS also demonstrated significant associations with satisfaction aspects ($\chi^2 = 25.761$, $p = 0.012$), with an interesting pattern where those spending more time on the way (20-45 minutes) expressed highest satisfaction with greenery abundance (71.4%), indicating the possible value that high-quality UGS compensate for longer traveling. The factors, including age, marital status, educational level, employment status, and housing type, showed no significant associations with satisfaction aspects (all $p > 0.05$).

Table 4.4. Socio-demographic differences in the most satisfying aspect of the current UGS

	Abundance of greenery	**Accessibility**	**Facilities**	**General cleanliness**	**Sense of security**	**Size of UGS**	**Landscape features**	χ^2	**p**
Sex								16.356	0.012**
Male	6 (12.2%)	19 (38.8%)	3 (6.1%)	1 (2.0%)	0 (0.0%)	18 (36.7%)	2 (4.1%)		
Female	15 (19.5%)	25 (32.5%)	6 (7.8%)	5 (6.5%)	4 (5.2%)	10 (13.0%)	12 (15.6%)		
Age group								24.339	0.144
≤30	3 (17.6%)	3 (17.6%)	1 (5.9%)	2 (11.8%)	1 (5.9%)	6 (35.3%)	1 (5.9%)		
31-45	5 (9.6%)	17 (32.7%)	7 (13.5%)	3 (5.8%)	1 (1.9%)	12 (23.1%)	7 (13.5%)		
46-60	11 (26.2%)	14 (33.3%)	1 (2.4%)	1 (2.4%)	1 (2.4%)	8 (19.0%)	6 (14.3%)		
>60	2 (13.3%)	10 (66.7%)	0 (0.0%)	0 (0.0%)	1 (6.7%)	2 (13.3%)	0 (0.0%)		
Marital status								11.445	0.875
Married	10 (15.2%)	27 (40.9%)	5 (7.6%)	2 (3.0%)	2 (3.0%)	12 (18.2%)	8 (12.1%)		
Unmarried	9 (18.8%)	12 (25.0%)	4 (8.3%)	3 (6.3%)	1 (2.1%)	14 (29.2%)	5 (10.4%)		
Divorced	2 (20.0%)	3 (30.0%)	0 (0.0%)	1 (10.0%)	1 (10.0%)	2 (20.0%)	1 (10.0%)		

Widowed	0 (0.0%)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Educational level								21.152	0.630
Below high School	1 (20.0%)	3 (60.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	0 (0.0%)		
High school	6 (12.5%)	17 (35.4%)	2 (4.2%)	1 (2.1%)	3 (6.3%)	13 (27.1%)	6 (12.5%)		
Bachelor	3 (18.8%)	6 (37.5%)	1 (6.3%)	0 (0.0%)	0 (0.0%)	3 (18.8%)	3 (18.8%)		
Master	9 (25.0%)	12 (33.3%)	4 (11.1%)	2 (5.6%)	0 (0.0%)	8 (22.2%)	1 (2.8%)		
Doctorate	2 (9.5%)	6 (28.6%)	2 (9.5%)	3 (14.3%)	1 (4.8%)	3 (14.3%)	4 (19.0%)		
Employment status								26.062	0.350
Full-time/ self-employed	13 (13.7%)	30 (31.6%)	8 (8.4%)	5 (5.3%)	3 (3.2%)	23 (24.2%)	13 (13.7%)		
Part-time	4 (33.3%)	4 (33.3%)	1 (8.3%)	1 (8.3%)	0 (0.0%)	2 (16.7%)	0 (0.0%)		
Student	2 (28.6%)	2 (28.6%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	2 (28.6%)	0 (0.0%)		
Unemployed	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (50.0%)		
Retired	1 (10.0%)	8 (80.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (10.0%)	0 (0.0%)		
Living with family								5.071	0.535

Yes	15 (14.2%)	37 (34.9%)	9 (8.5%)	5 (4.7%)	4 (3.8%)	24 (22.6%)	12 (11.3%)		
No	6 (30.0%)	7 (35.0%)	0 (0.0%)	1 (5.0%)	0 (0.0%)	4 (20.0%)	2 (10.0%)		
Living with children ≤12								19.62	0.003***
Yes	3 (8.1%)	8 (21.6%)	7 (18.9%)	3 (8.1%)	0 (0.0%)	11 (29.7%)	5 (13.5%)		
No	18 (20.2%)	36 (40.4%)	2 (2.2%)	3 (3.4%)	4 (4.5%)	17 (19.1%)	9 (10.1%)		
Living with elderly requiring assistance								4.789	0.571
Yes	1 (16.7%)	1 (16.7%)	1 (16.7%)	0 (0.0%)	0 (0.0%)	1 (16.7%)	2 (33.3%)		
No	20 (16.7%)	43 (35.8%)	8 (6.7%)	6 (5.0%)	4 (3.3%)	27 (22.5%)	12 (10.0%)		
Housing type								10.86	0.541
Apartment without garden	16 (20.8%)	25 (32.5%)	5 (6.5%)	4 (5.2%)	3 (3.9%)	18 (23.4%)	6 (7.8%)		
Apartment with garden	2 (8.0%)	10 (40.0%)	1 (4.0%)	2 (8.0%)	0 (0.0%)	7 (28.0%)	3 (12.0%)		
Detached house	3 (12.5%)	9 (37.5%)	3 (12.5%)	0 (0.0%)	1 (4.2%)	3 (12.5%)	5 (20.8%)		

Time to reach UGS								25.761	0.012*
<5 minutes	7 (13.0%)	21 (38.9%)	3 (5.6%)	4 (7.4%)	3 (5.6%)	14 (25.9%)	2 (3.7%)		
5-20 minutes	9 (13.8%)	23 (35.4%)	6 (9.2%)	2 (3.1%)	1 (1.5%)	13 (20.0%)	11 (16.9%)		
20-45 minutes	5 (71.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (14.3%)	1 (14.3%)		
Transportation								15.259	0.228
On foot	16 (20.0%)	31 (38.8%)	4 (5.0%)	4 (5.0%)	4 (5.0%)	17 (21.3%)	4 (5.0%)		
By bicycle	1 (8.3%)	3 (25.0%)	2 (16.7%)	0 (0.0%)	0 (0.0%)	3 (25.0%)	3 (25.0%)		
By car	4 (11.8%)	10 (29.4%)	3 (8.8%)	2 (5.9%)	0 (0.0%)	8 (23.5%)	7 (20.6%)		

Values are presented as frequency (percentage); * $p < 0.05$, ** $p < 0.01$.

4.3.5 The Most Unsatisfying Aspect of the Existing UGS

The analysis of the most unsatisfying aspects of existing UGS emphasised significant variations across marital status ($\chi^2 = 31.957$, $p = 0.022$) and households with children aged 12 or younger ($\chi^2 = 18.154$, $p = 0.006$) (Table 4.5). Notably, households with children aged 12 or younger expressed distinct dissatisfaction patterns, particularly regarding facilities (35.1%) and general cleanliness (32.4%), while households without children showed more concern about greenery abundance (28.1%). Among marital groups, unmarried respondents were particularly dissatisfied with greenery abundance (37.5%), while married respondents expressed more diverse dissatisfactions, primarily about cleanliness (28.8%) and facilities (21.2%). This pattern suggests that the perception of UGS inadequacies varies by user groups, with maintenance and facility-related issues being very important among family users, while ecological aspects concern more individual users. Despite being a well-known barrier to visiting UGS, accessibility was rarely cited as a most unsatisfying aspect across all groups, indicating that existing UGS in Imola locations generally meet user expectations.

Table 4.5. Socio-demographic differences in the most unsatisfying aspect of the current UGS

	Abundance of greenery	**Accessibility**	**Facilities**	**General cleanliness**	**Sense of security**	**Size of UGS**	**Landscape features**	χ^2	**p**
Sex								3.846	0.698
Male	12 (24.5%)	2 (4.1%)	12 (24.5%)	11 (22.5%)	6 (12.2%)	3 (6.1%)	3 (6.1%)		
Female	14 (18.2%)	4 (5.2%)	14 (18.2%)	21 (27.3%)	13 (16.9%)	2 (2.6%)	9 (11.7%)		
Age group								17.712	0.475
≤30	6 (35.3%)	0 (0.0%)	5 (29.4%)	2 (11.8%)	2 (11.8%)	1 (5.9%)	1 (5.9%)		
31-45	9 (17.3%)	4 (7.7%)	10 (19.2%)	17 (32.7%)	6 (11.5%)	0 (0.0%)	6 (11.5%)		
46-60	8 (19.1%)	0 (0.0%)	9 (7.1%)	9 (7.1%)	9 (7.1%)	3 (2.4%)	4 (3.2%)		
>60	3 (20.0%)	2 (13.3%)	2 (13.3%)	4 (26.7%)	2 (13.3%)	1 (6.7%)	1 (6.7%)		
Marital status								31.957	0.022*
Married	6 (9.1%)	4 (6.1%)	14 (21.2%)	19 (28.8%)	11 (16.7%)	2 (3.0%)	10 (15.2%)		
Unmarried	18 (37.5%)	1 (2.1%)	11 (22.9%)	10 (20.8%)	5 (10.4%)	4 (4.2%)	3 (2.1%)		
Divorced	0 (0.0%)	1 (10.0%)	1 (10.0%)	3 (30.0%)	3 (30.0%)	1 (10.0%)	1 (10.0%)		
Widowed	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		

Educational level								15.730	0.898
Below high School	3 (60.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	1 (20.0%)	0 (0.0%)	0 (0.0%)		
High school	10 (20.83%)	1 (2.1%)	9 (18.8%)	11 (22.9%)	10 (20.8%)	2 (4.2%)	5 (10.4%)		
Bachelor	3 (18.8%)	1 (6.3%)	2 (12.5%)	5 (31.3%)	3 (18.8%)	1 (6.3%)	1 (6.3%)		
Master	6 (16.7%)	2 (5.6%)	11 (30.6%)	9 (25.0%)	2 (5.6%)	2 (5.6%)	4 (11.1%)		
Doctorate	4 (19.1%)	2 (9.5%)	4 (19.1%)	6 (28.6%)	3 (14.3%)	0 (0.0%)	2 (9.5%)		
Employment status								20.911	0.644
Full-time/ self-employed	18 (19.0%)	4 (4.2%)	20 (21.1%)	26 (27.4%)	15 (15.8%)	4 (4.2%)	8 (8.4%)		
Part-time	2 (16.7%)	1 (8.3%)	2 (16.7%)	0 (0.0%)	4 (33.3%)	0 (0.0%)	3 (25.0%)		
Student	3 (42.9%)	0 (0.0%)	2 (28.6%)	2 (28.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Unemployed	0 (0.0%)	0 (0.0%)	1 (50.0%)	1 (50.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
Retired	3 (30.0%)	1 (10.0%)	1 (10.0%)	3 (30.0%)	0 (0.0%)	1 (10.0%)	1 (10.0%)		
Living with family								1.865	0.932
Yes	20 (18.9%)	5 (4.7%)	22 (20.8%)	28 (26.4%)	16 (15.1%)	4 (3.8%)	11 (10.4%)		
No	6 (30.0%)	1 (5.0%)	4 (20.0%)	4 (20.0%)	3 (15.0%)	1 (5.0%)	1 (5.0%)		

Living with children ≤12								18.154	0.006**
Yes	1 (2.7%)	2 (5.4%)	13 (35.1%)	12 (32.4%)	4 (10.8%)	0 (0.0%)	5 (13.5%)		
No	25 (28.1%)	4 (4.5%)	13 (14.6%)	20 (22.5%)	15 (16.9%)	5 (5.6%)	7 (7.9%)		
Living with elderly requiring assistance								4.596	0.597
Yes	1 (16.7%)	0 (0.0%)	1 (16.7%)	1 (16.7%)	1 (16.7%)	0 (0.0%)	2 (33.3%)		
No	25 (20.8%)	6 (5.0%)	25 (20.8%)	31 (25.8%)	18 (15.0%)	5 (4.2%)	10 (8.3%)		
Housing type								5.195	0.951
Apartment without garden	15 (19.5%)	3 (3.9%)	15 (19.5%)	22 (28.6%)	12 (15.6%)	4 (5.2%)	6 (7.8%)		
Apartment with garden	6 (24.0%)	2 (8.0%)	6 (24.0%)	6 (24.0%)	3 (12.0%)	0 (0.0%)	2 (8.0%)		
Detached house	5 (20.8%)	1 (4.2%)	5 (20.8%)	4 (16.7%)	4 (16.7%)	1 (4.2%)	4 (16.7%)		
Time to reach UGS								11.008	0.528
<5 minutes	14 (25.9%)	0 (0.0%)	12 (22.2%)	15 (27.8%)	5 (9.3%)	2 (3.7%)	6 (11.1%)		
5-20 minutes	11 (16.9%)	5 (7.7%)	12 (18.5%)	16 (24.6%)	12 (18.5%)	3 (4.6%)	6 (9.2%)		
20-45 minutes	1 (14.3%)	1 (14.3%)	2 (28.6%)	1 (14.3%)	2 (28.6%)	0 (0.0%)	0 (0.0%)		

Transportation								12.397	0.414
On foot	17 (21.3%)	1 (1.3%)	17 (21.3%)	23 (28.8%)	10 (12.5%)	4 (5.0%)	8 (10.0%)		
By bicycle	2 (16.7%)	1 (8.3%)	2 (16.7%)	3 (25.0%)	4 (33.3%)	0 (0.0%)	0 (0.0%)		
By car	7 (20.6%)	4 (11.8%)	7 (20.6%)	6 (17.7%)	5 (14.7%)	1 (2.9%)	4 (11.8%)		

Values are presented as frequency (percentage); * $p < 0.05$, ** $p < 0.01$.

4.3.6 Overall Satisfaction Score and Weekly Time Spent in UGS

Stepwise regression on “weekly time spent in UGS” revealed that only one variable, “the presence of children aged 12 or younger”, remained as a significant predictor. The model was statistically significant (F (1, 124) = 4.87, p = 0.029), though with limited explanatory power (R2 = 0.038). The coefficient for “the presence of children aged 12 or younger” was 0.4382, indicating that households with children reported a modestly higher weekly time spent in UGS compared to those without.

For “overall satisfaction score” revealed no significant predictors remaining in the model, suggesting that none of the predictors explained any variance in “overall satisfaction score”. This suggests that after stepwise selection, there was no included variables influencing overall satisfaction.

A regression analysis examining the relationship between “weekly time spent in UGS” and “overall satisfaction score” showed no significant association (F (1, 124) = 1.19, p = 0.277). The model explained very little of the variance (R2 = 0.010), suggesting that overall satisfaction does not significantly predict time spent in UGS. Thus, the assumed mediating effect was not observed.

4.3.7 Suggested Features in Future UGS

Analysis of suggested features in new green spaces reported clear priorities among residents (Table 4.6). Open areas shaded by trees receiving the highest first-priority selection (27.78%) and shaded paths maintaining relative importance across all three priorities (11.90%, 12.70%, 11.90%). The priority patterns demonstrated a hierarchical structure of needs, from essential comfort features to recreational amenities. Although children's playgrounds showed high first-priority (13.49%), its importance decreased in second and third choices. Conversely, some amenities gained importance in subsequent priorities, notably benches (6.35% to 13.49%) and picnic areas (1.59% to 9.52%), suggesting their value as complementary features. Basic infrastructure such as parking area and public toilets received lower priority across all three choices, indicating residents' preference for recreational features over basic facilities.

Table 4.6. Priority Ranking of Desired Features in new UGS

Desired Features	1st Priority	2nd Priority	3rd Priority	Total Times Selected
Open area shaded by trees	35 (27.78%)	17 (13.49%)	10 (7.94%)	62 (16.40%)
Children's playground	17 (13.49%)	12 (9.52%)	11 (8.73%)	40 (10.58%)
Shaded paths	15 (11.90%)	16 (12.70%)	15 (11.90%)	46 (12.17%)
Benches	8 (6.35%)	17 (13.49%)	16 (12.70%)	41 (10.85%)
Ponds or small lakes	11 (8.73%)	4 (3.17%)	8 (6.35%)	23 (6.08%)
Fountains	8 (6.35%)	15 (11.90%)	9 (7.14%)	32 (8.47%)
Security cameras	7 (5.56%)	8 (6.35%)	11 (8.73%)	26 (6.88%)
Sports courts	7 (5.56%)	6 (4.76%)	4 (3.17%)	17 (4.50%)
Floral landscape	6 (4.76%)	6 (4.76%)	14 (11.11%)	26 (6.88%)
Fitness equipment	5 (3.97%)	7 (5.56%)	3 (2.38%)	15 (3.97%)
Public toilets	4 (3.17%)	9 (7.14%)	7 (5.56%)	20 (5.29%)
Areas for picnic or BBQ	2 (1.59%)	5 (3.97%)	12 (9.52%)	19 (5.03%)
Parking facilities	1 (0.79%)	4 (3.17%)	6 (4.76%)	11 (2.91%)

Values are presented as frequency (percentage). Total percentage represents the proportion of times each feature was selected across all three priorities.

4.4 Discussion

For the purpose of understanding how residents experience and evaluate UGS as everyday environments, this chapter examines a neighbourhood of an Italian city (Quartiere Marconi, Imola, Emilia-Romagna Region) as a case study. Rather than addressing planning strategies, the focus lies on how people perceive and assess the existing UGS in their living context. Through comprehensive analyses of usage patterns, visiting motivations, satisfaction levels, and future suggestions, we focused on investigating perceptions and attitude of residents towards UGS, in order to understanding both the advantages and limitations of existing UGS in the study area from users' perspectives. In general, our results showed the interesting relationships between perception and attitudes towards UGS and factors such as age, employment status and living arrangement, which indicated that life stage seems to play a crucial role.

The analysis of socio-demographic characteristics revealed distinct generational patterns that potentially shape UGS utilisation. The 31-45 age group is characterised by high rates of living with young children and full-time employment. This suggests that their UGS needs might be particularly affected by the pressures from work or the responsibility for the family. The 46-60 age group showed a different pattern, taking the responsibility of caring the elderly while maintaining career commitments, indicating different demands on their time and potentially different preferences for UGS [273, 274]. The continues rising educational level in generations and the progression of marital status across age groups further reflect the evolving life patterns in modern urban settings [275, 276]. These generational differences in family

structure and daily responsibilities provide important context for understanding the varying perception and attitudes of UGS across different residents.

The most important motivation for UGS visits is to enjoy the nature environment, reflecting a fundamental human need for nature-connection which is one of the basic functions of UGS in theory of the green benefits [277, 278]. However, this general preference manifests differently across family structures. It seems that families with younger children transform this nature interaction into social activities, demonstrating that UGS serve as leisure venues for family and children. This multiple functions of UGS including providing both natural elements and social venues deserves particular attention in UGS designs [279-281]. In the aspect of accessibility, the relationship between travel time and visiting motivation suggests that some residents might choose to travel longer distances for specific experiences, particularly nature enjoyment. A qualitative study in Reykjavik found similar results [282]. On the contrary, the nearby UGS seem to become the choice for daily activities like PA. A study in Denmark indicated that individuals who perceive better access to local parks are likely to participate more frequently in PA within these environments [283]. The finding challenges the simple distance-based assumptions about UGS use and suggests that future planning should focus more on creating flexible and diverse UGS that can adjust different usage patterns. Unfortunately, simple accessibility or demographic-specific features are inevitably emphasised in many researches [284, 285].

There are several barriers caused by problems with residents themselves or the UGS existed to prevent residents from visiting UGS. Being lack of time dominated across most groups, which reveals a most serious problem of urban life. All the residents who need to work or study, especially those with higher education level, considered the lack of time as their primary barrier. It reflects the intense competition between work commitments and leisure time in urban life [286]. The fact that the lack of time limitation even bothers residents who spend less than 5 minutes on the way to UGS, suggesting that simple accessibility alone doesn't guarantee utilisation in another perspective. This points to a broader challenge: the competition between green space usage and other daily activities in urban life. A potential effective solution could be organizing community activities in parks, such as regular parent-child events [287]. On the contrary, elderly residents showed different concerns, focusing on practical issues like public toilet availability or be prevented from visiting UGS by health problems. Notably, although physical distance was not a major barrier for most residents, the concerns about cleanliness and security among walking users highlight how the quality of both the journey to and experience within UGS can affect the utilisation of UGS [288, 289].

The analysis of satisfaction and dissatisfaction aspects indicated how residents of different socio-demographic evaluate and experience UGS. The high satisfaction with accessibility across groups, combined with its low ranking as an aspect of dissatisfaction, demonstrated that the spatial distribution of UGS in the study area effectively serves the community's basic needs. This might be the potential reason why accessibility cannot be summarised as important in the analysis of the usage patterns and motivations. However, the different satisfaction patterns between family and individual users highlighted how living arrangement shapes UGS expectations. While families with young children showed high satisfaction with size and facilities but expressed concerns about maintenance and cleanliness, individual users focused more on ecological aspects such as greenery abundance. These findings suggest that while existing UGS successfully meets basic accessibility needs, the quality and maintenance

of facilities, particularly for family users, and the richness of natural features for individual users, represent areas for potential enhancement. This viewpoint was also proved in the residents' suggestions for future UGS planning, which indicates the importance of high-quality natural elements and scenery and user-friendly facilities for recreation, suggesting that successful UGS should integrate natural landscape features as the primary framework while incorporating supportive amenities to enhance user experience and meet diverse recreational needs. Similar results can be found in existing researches which evaluated quality by focus on the multiple features, such as facilities and amenities, aside the accessibility [170, 178].

The chapter's findings, however, should be interpreted within certain limitations. First, the survey was conducted in a specific urban context during a single season, which might affect residents' perceptions and reported behaviours. For instance, the high priority placed on shaded areas might reflect seasonal weather conditions, and preferences might vary across different times of the year. Second, while the presence of children emerged as a significant predictor of weekly UGS use, the relatively low R^2 value suggests that other unmeasured factors, such as personal habits, weather conditions, or specific site characteristics, might play important roles in determining usage patterns. In connection, the cultural heritage and the consequent different mother tongue could have influenced questionnaire and urban planning perceptions [290, 291].

The lack of significant predictors for overall satisfaction scores, coupled with the absence of correlation between satisfaction and usage time, raises intriguing questions about how residents evaluate green spaces. This finding challenges the intuitive assumption that higher satisfaction leads to increased usage, suggesting that UGS utilisation might be more strongly influenced by practical constraints and lifestyle factors than by satisfaction levels. This disconnection between satisfaction and usage merits further investigation, particularly in understanding how to translate positive attitudes into actual utilisation.

The analytical approach developed in this chapter offers several directions for further investigation within the broader framework of this thesis. Longitudinal or repeated cross-sectional studies could provide a deeper understanding of how seasonal changes and life-course transitions influence UGS use and preferences over time. In addition, quantitative analyses combining objective indicators of green-space characteristics with subjective evaluations would help clarify how different dimensions of perceived quality—such as comfort, maintenance, and accessibility—shape residents' satisfaction and use frequency. Such extensions would strengthen the methodological bridge between perceptual assessments and the intervention-based approaches explored in the following chapters.

Beyond its empirical contributions, the chapter also offers conceptual insights into what makes UGS genuinely inclusive and meaningful for residents. The findings suggest that providing accessible UGS alone is insufficient to ensure engagement or satisfaction. While basic comfort features—shade, seating, and cleanliness—emerge as recurrent priorities, the diversity of needs across age and household groups underscores that inclusiveness depends on flexibility rather than uniformity. The central challenge is therefore not merely to increase physical access, but to sustain the ecological and social qualities that allow people to experience green spaces as restorative, safe, and personally relevant environments.

Limitations

Several limitations of this chapter should be acknowledged. First, due to the lack of labour and sources, the sample size was relatively small (n=126), which may limit the generalisability of our findings. Second, the survey was conducted in a specific urban context during a single season, which might affect residents' perceptions and reported behaviours. For instance, the high priority placed on shaded areas might reflect seasonal weather conditions, and preferences might vary across different times of the year. Third, although the questionnaire effectively captured qualitative insights into residents' perception and attitudes, the lack of Likert-scale measurements for individual UGS elements prevented more detailed quantitative analysis of factors affecting user experiences. Fourth, our tentative analysis of mediation effect showed the presence of young children was a significant predictor of weekly UGS use, the extremely low R^2 value suggested that other unmeasured factors, such as personal habits, weather conditions, or specific site characteristics, might play important roles in determining usage patterns. The lack of significant predictors for overall satisfaction scores, along with the absence of correlation between satisfaction level and usage time, raises some questions about how residents evaluate green spaces. This finding challenges the intuitive assumption that higher satisfaction leads to increased usage, suggesting that UGS utilisation might be more strongly influenced by practical limitations and lifestyle factors than by satisfaction levels. This disconnection between satisfaction and usage needs further investigation, especially in understanding how to translate positive attitudes into actual utilisation. These limitations also indicate the exploratory nature of this chapter within the broader framework of the thesis. Aside from providing planning guidance, the results refine the conceptual and methodological understanding of how residents interact with UGS. Future extensions of this work could incorporate objective measurements using tools such as Public Participation Geographical Information Systems (PPGIS) and ENVI-met to analyse spatial characteristics and environmental performance of UGS. PPGIS could capture spatially explicit community preferences and usage patterns through map-based surveys [292, 293], while ENVI-met simulations would enable assessment of urban microclimate conditions that influence user thermal comfort and experience [294, 295]. Integrating participatory spatial data with environmental modelling would complement the subjective evaluations presented here and contribute to the overall thesis aim of understanding how the qualities of UGS shape residents’ perceptions and experiences.

Chapter 5 – Bringing Green Exercise into Practice: Evaluating the “Moving Park” Project for Well-being and Motivation

This chapter is based on the article “Impact on well-being and motivation to physical activity practice by 'Moving Park' project in Italy”,

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Summary

Urban parks can play an active role in promoting physical activity (PA) and well-being when combined with supervised community programmes. This chapter evaluates the “Parchi in Movimento” (Moving Parks) project, promoted by the Municipality of Bologna in collaboration with the Local Health Authority (AUSL), which provides free outdoor PA sessions conducted under qualified supervision. Two questionnaire surveys were administered before and after participation in the 2022 edition, and 126 valid responses were analysed. Results showed a general improvement in self-reported well-being and a strong intention to continue exercising after the programme, particularly among women and middle-aged adults. These outcomes highlight the potential of long-term, inclusive initiatives in urban green spaces (UGS) to enhance community health and contribute to the thesis objective of promoting UGS as environments for well-being.

5.1 Introduction

Evidence reviewed in the previous chapters indicates that PA enhance well-being. Unfortunately, approximately 27.5% of adults and 81% of adolescents do not meet the WHO recommendations for adequate PA [296-298]. To reduce the mortality rates resulting from physical inactivity (PI), a set of evidence-based guidelines on PA has been developed by the World Health Organization (WHO) and should be incorporated into public health frameworks worldwide, with the goal of achieving a 15% reduction in PI by 2030 [299].

In this regard, urban parks represent a particularly promising resource, as they combine convenience, social participation, and contact with nature. Building on previous evidence regarding the benefits of PA and urban green spaces (UGS) for well-being, recent approaches have increasingly explored their integration within community-based interventions [131, 300, 301]. In other word, rather than serving only as passive infrastructures for leisure or aesthetic value, parks are being used as active settings for community-based interventions that encourage PA and foster social cohesion[301, 302]. In this perspective, UGS are not only environmental assets but also active arenas where PA can take place with both social support and an ecological backdrop, highlighting the potential of UGS to support well-being through both perceptual and behavioural pathways [303, 304].

Therefore, a growing body of research has examined how the design and management of UGS can be optimised to promote residents' participation in PA. [305, 306]. However, the actual frequency of UGS use remains low, particularly among females and older adults [307]. Moreover, the visiting frequency varies considerably by accessibility, gender, ethnicity and socioeconomic status, implying potential environmental inequality [305, 308]. In response, several studies have attempted to improve UGS accessibility, environmental quality, and infrastructures, to increase residents' participation in PA [309-311]. However, these strategies primarily address the physical environment rather than behavioural engagement. Only a few studies have attempted to develop interventions from participants' perspective. Given the effectiveness of supervised PA prescription in different chronic noncommunicable diseases (NCDs), similar approaches have been tested in UGS contexts. [312-316]. For example, a community-based PA programmes with a supervisor, named Recreovía, proved effective in increasing the use percentage of the parks, especially among female participants [317]. Likewise, park prescription interventions have shown significant contributions to improving UGS use and PA participation, although they did not show consistent evidence of mental health and cardio-metabolic benefits [318, 319].

Nevertheless, studies focusing on supervised intervention in UGS remain scarce, especially in Italy. Furthermore, most studies mentioned above are based on the cross-sectional design, which could introduce bias due to limited sample size or unclear causalities. Thus, longitudinal studies are usually strongly recommended to provide more robust evidence on the effectiveness of supervised PA programmes in UGS. To address these research gaps, the Municipality of Bologna, in collaboration with the Local Health Authority (AUSL), launched the "Parchi in Movimento" (Moving Parks) project in 2010. The project provides free, supervised outdoor PA sessions in several public parks, with the aim of promoting active lifestyles and improving residents' well-being. It represents one of the few long-standing community-based interventions in Italy that explicitly integrates PA within UGS as a public

health strategy. Within this context, the present study examined the 2022 edition of the "Moving Parks" project to investigate the effects of supervised PA in UGS on:

a) self-reported well-being; and
b) participants' motivation to engage in PA in the future.

In this way, the study strengthens the broader argument of the thesis by showing how UGS can be activated to promote well-being through structured and supervised PA programmes.

5.2 Methods

5.2.1 The Project and the Participants

The "Moving Parks" project was carried out by the Municipality of Bologna in collaboration with the Department of Public Health of Bologna, starting in 2010. Through this project, the Authorities provide opportunities for residents to do PA in seven urban parks under the coordination of qualified supervisors from the 30th of May to the 4th of October so that every participant can obtain a healthy and active lifestyle to counteract the health risks brought by sedentary behaviour. The parks include the following: Parco Nicholas Green (District Borgo Panigale – Reno), Parco di Villa Angeletti (District Navile), Giardino del Velodromo (District Porto-Saragozza), Parco San Donnino (District San Donato-San Vitale), Parco dei Cedri-Lungosavena (District Savena), Giardino Lunetta Gamberini (District Santo Stefano), Parco Pier Paolo Pasolini (District San Donato-San Vitale) (Appendix B).

In the project 2022, seventeen health associations provide various activities of which walking, jogging, resistance exercise with park equipment, stretching exercise and meditation. Each participant could select which activity to perform, supervised by one kinesiologist. Each activity lasted about one hour, including both a warm-up (10 minutes) and a cool-down (10 minutes) period. All the activities were planned to achieve a moderate intensity (5-6 of the 10 points Borg's rate perceived exertion scale). The project was promoted to recruit participants through multiple forms and channels, such as flyers/posters, advertisements inside the park, Word of Mouth advertising, newsletter, social media (e.g. Facebook), Internet websites, and notification by associations. The detailed schedule of activities provided in each park is presented in Appendix C.

5.2.2 Questionnaire

To develop the longitudinal study, two surveys (a pre-intervention and a post-intervention) were conducted both at the beginning (pre-in-May 2022) and the end of the project (post-in-October 2022). Pre-intervention questionnaires were distributed during participants' first attendance at the programme, while post-intervention questionnaires were completed during their final session. Each participant could choose to complete the questionnaire either online using Google Forms or on-site using paper version, taking approximately 15-20 minutes. Several trained instructors were present during questionnaire completion to assist participants and answer any questions. The inclusion criteria were the following:

1. not less than 18 years old;
2. be able to write and read in Italian.

All participants were informed and gave us privacy consent to handle their personal data by signing an informed consent form. All data were collected anonymously using participant identification codes, and personal information was stored separately in compliance with privacy regulations. Each completed survey was saved on a Google database, and exported to Excel sheets for further analyses. The study obtained approval from the University of Bologna Bioethics Committee (Prot. n. 169182).

The questionnaire was designed to investigate the health status and PA habits of participants before and after their participation in the project. The questionnaire mainly contains three parts: (1) basic information about the participants, (2) information about the project participation status, and (3) the health status and the motivation to participate. The entire content of the questionnaire is presented in Italian.

The first part contains demographic information such as the identity code and the date of birth, as well as other information such as the habit of smoking the name of the association and the related activity in which participated. The second part is about the course participation status such as the quantity of the courses, the frequency, the duration, the satisfaction, the willingness to participate in the next period of the project, etc. In the third part of pre- and post-intervention, there are two separate Likert scales about the well-being and the PA motivation of participants. A short form of the Psychological General Well-Being Index questionnaire (PGWB-S) was used to evaluate the self-reported health status of participants over the past four weeks [320], which contains six questions separately related to anxiety, depressed mood, self-control, positive well-being, and vitality. The response scores range from 0= “not true at all” to 4= “very true”. Five questions were selected from the Behavioural Regulation in Exercise Questionnaire (BREQ-2) to investigate the motivation of PA participation [321], which are specifically: “I exercise because other people say I should”, “I feel guilty when I don’t exercise”, “I value the benefits of exercise”, “I get pleasure and satisfaction from exercising”, “I think that exercising is a waste of time”, covering the five aspects of “intrinsic”, “identified”, “introjected”, “external” and “motivation”. The answers to “never”, “hardly ever”, “part of the time”, “lots of time”, “almost always” and “always” were assigned into values from 0 to 5 with a Likert scale. Concerning the post-activity survey, an additional Likert scale about the reasons for participating in the project regularly is included, consisting of five reasons: “the low cost of the activity”, “the proximity from home”, “the pleasure that comes from the practice”, “the people I practise with together”, and “the achievement of my personal goals”. The response scores from 0 (“not true at all”) to 4 (“very true”).

5.2.3 Statistical Analysis

All the statistical analysis was completed in Statistica for Windows, version 8.0 (Stat Soft Italia SRL, Vigonza, Padua, Italy). The sample was divided by sex, age, and the practice of PA outside the project. In terms of age, we subdivided participants into three age classes: 18-44, 45-64, and >65. For moderate PA we considered four categories (none, <1h-1h, 2-2.5h, >2.5h), while for vigorous PA we considered three categories (none, <0.5h-1.25h, >1.25h). The mean and standard deviation (SD) were calculated to describe continuous variables. The normality of continuous variables was tested using the Shapiro-Wilk test. As the residuals did not meet the normality assumption, the non-parametric paired samples Wilcoxon test was conducted to assess the differences between the two measurements. The discrepancies between the pre- and

post-survey are considered as the measurements of the outcomes. The categorical and Bernoulli variables were described with absolute (n) and relative frequencies (%) and the differences in the frequencies were tested by the chi-squared test (χ^2). The results with a p-value (p) lower than 0.05 were considered significant.

5.3 Results

Figure 5.1 shows the sample flowchart. The pre-intervention evaluation was conducted in May 2022 while the follow-up was performed in October 2022. The identity of 147 participants, who filled both pre- and post-intervention, was matched. Among these, five duplications and four invalid questionnaires were excluded. The remaining 138 valid questionnaires were included in the final analysis.

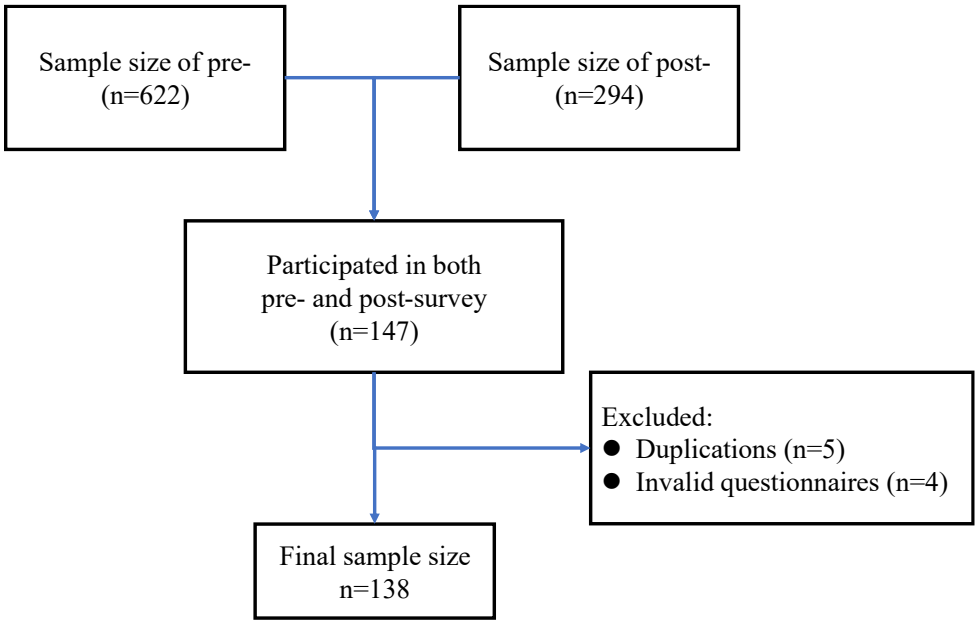

Figure 1. The sample flowchart.

Table 5.1 shows the sample characteristics of the participants. 86.23% of the participants were female and 53.28% had at least one academic title. The age distribution is relatively balanced, with individuals aged 45-64 forming the largest proportion. The educational level of the participants is generally high, as only 10 individuals reported having a 1st grade secondary school diploma (eighth grade) or below. Most of the participants do not smoke (n = 121, 87.68%) and nearly one-fourth of them suffer from chronic pathologies.

Table 5.1. Characteristics of participants

	Total		Females		Males			
	n	**%**	**n**	**%**	**n**	**%**	χ^2	**p**
Age classes								
18-44	39	28.26	35	29.41	4	21.05		
45-64	59	42.75	48	40.34	11	57.89		
>65	40	28.99	36	30.25	4	21.05		
							2.07	0.356
Education								
Elementary school diploma	3	2.17	2	1.69	1	5.26		
1st grade secondary school diploma (eighth grade)	7	5.07	5	4.24	2	10.53		
2nd grade secondary school diploma (high school or technical/vocational institute)	54	39.13	46	38.98	8	42.11		
Bachelor, Master, or PhD	73	52.90	65	55.08	8	42.11		
							2.78	0.427
Smoker								
No	121	87.68	105	88.24	16	84.21		
Yes	17	12.32	14	11.76	3	15.79		
							0.25	0.620
Chronic pathologies (e.g., diabetes, hypertension, osteoporosis, heart disease, neurodegenerative diseases)								
No	106	76.81	92	77.31	14	73.68		
Yes	32	23.19	27	22.69	5	26.32		
							0.12	0.728

n, number of observations; %, percentage; χ^2, chi-squared; p, p-value; *, statistically significant.

Table 5.2 shows the General questions about the “Moving Parks” project of the pre- and post-intervention, separately. The pre-intervention part shows that most of the participants (54.44%) became aware of the project through social strategies such as associations, word-of-mouth marketing, flyers/posters, and parks, whereas digital communication such as Internet/websites social media and newsletters involved 61 citizens (44.86%). Also, it shows the reason and previous experiences of participating in the project. Most of the female subjects declared to

felt good when participating in the activities, while 63.16% of males reported participating due to the outdoor spaces and the proposed activities. The post-intervention part in Table 5.2 shows the responses on smoking status, activity participation, satisfaction, and attitude to future participation. Regarding smoking, it indicates that male participants are less willing to give up smoking than female ones after joining the project. Although many subjects prefer less than two different activities (n = 88), 64.23% practised two or more days of activity per week. In addition, 88.97% of participants want to continue the activity practice during the autumn/winter period. As regards satisfaction, 89.08% of females and 84.22% of males selected “much” or “very much” answers. Accordingly, only 7 participants (5.07%) admitted that they would not continue for all kinds of reasons such as tiredness/laziness (n = 2), economic availability (n = 1), health reasons (n = 1), environmental unsatisfaction (n = 1), lack of interest (n = 1), or lack of time (n = 1). However, males were less inclined to associate their psychophysical well-being with project activities than the female sample.

Table 5.2. General questions about the Moving Parks project

	Total		**Females**		**Males**			
	n.	**%**	**n.**	**%**	**n.**	**%**	χ^2	***p***
Pre-intervention								
How did you hear about Moving Parks?								
Internet / Websites	37	27.21	33	28.20	4	21.05		
From the parks	8	5.89	7	5.98	1	5.26		
Social media (es. Facebook, Instagram)	17	12.50	16	13.67	1	5.26		
Associations	17	12.50	15	12.82	2	10.53		
Word-of-mouth marketing	40	29.43	32	27.34	8	42.11		
Flyer / Poster	9	6.62	6	5.13	3	15.79		
Newsletter	7	5.15	7	5.98	0	0.00		
Television	1	0.74	1	0.85	0	0.00		
							6.63	0.468
Why do you participate in the initiative of Moving Parks?								
I feel good when I participate.	49	36.03	45	38.46	4	21.05		
It allows me to be outdoors and in the green.	36	26.47	30	25.64	6	31.58		
The proposed activities are to my liking.	28	20.60	22	18.79	6	31.58		
The parks where I go are easy to reach.	13	9.57	12	10.24	1	5.26		
It's free of charge.	8	5.90	8	6.82	0	0.00		
For the people who hang out with me.	2	1.47	0	0.00	2	10.53		

							17.75	0.013*
Have you previously participated in Moving Parks?								
No	54	39.13	47	39.50	7	36.84		
Yes	84	60.87	72	60.50	12	63.16		
							0.05	0.826
Post-intervention								
Since Moving Parks started, have you ever thought about giving up smoking?								
No	4	23.53	1	7.69	3	75.00		
Yes	13	76.47	12	92.31	1	25.00		
							7.70	0.006*
How many activities did you attend during Moving Parks?								
1	54	39.13	50	42.02	4	21.05		
2	34	24.64	26	21.85	8	42.11		
3	23	16.67	21	17.65	2	10.53		
4	6	4.35	4	3.36	2	10.53		
more than 4	21	15.22	18	15.13	3	15.79		
							7.01	0.136
How much did you participate in the activities during the period of Moving Parks?								
One day a week for every week	26	18.98	21	17.80	5	26.32		
One day a week for a few weeks	23	16.79	19	16.10	4	21.05		
Two or more days a week for every week	38	27.74	33	27.97	5	26.32		
Two or more days a week for a few weeks	50	36.50	45	38.14	5	26.32		
							1.51	0.681
If Moving Parks also continued in autumn/winter:								
I would continue to participate if the activity were still free	49	36.03	40	34.19	9	47.37		
I would continue to participate in the activity and would be willing to make a contribution	72	52.94	65	55.56	7	36.84		
I would not continue	15	11.03	12	10.26	3	15.79		
							2.32	0.313
How satisfied are you with the activity proposed and carried out in Moving Parks?								
Little	1	0.72	0	0.00	1	5.26		

Enough	15	10.87	13	10.92	2	10.53		
Much	66	47.83	58	48.74	8	42.11		
Very much	56	40.58	48	40.34	8	42.11		
							6.43	0.093
Now that Moving Parks is finished or almost finished, how much do you think attendance at activities has affected your psychophysical well-being?								
Little	2	1.46	0	0.00	2	10.53		
Enough	38	27.74	34	28.81	4	21.05		
Much	68	49.64	60	50.85	8	42.11		
Very much	29	21.17	24	20.34	5	26.32		
							13.30	0.004*
Now that Moving Parks is finished or almost finished, do you think you will continue to practise physical activities on a regular basis?								
No	7	5.07	6	5.04	1	5.26		
Yes	131	94.93	113	94.96	18	94.74		
							0.00	0.967
If not, why?								
Tiredness/ laziness	2	28.57	2	33.33	0	0.00		
Economic availability	1	14.29	1	16.67	0	0.00		
Health reasons	1	14.29	1	16.67	0	0.00		
The park is too dirty or too hot to exercise this year	1	14.29	0	0.00	1	5.26		
The lack of interesting courses that stimulate me	1	14,29	1	16,67	0	0,00		
Lack of time	1	14,29	1	16,67	0	0,00		
							7.00	0.221

n, number of observations; %, percentage; χ^2, chi-squared; p, p-value; *, statistically significant.

Tables 5.3-5.6 show the comparison between the pre-and post-intervention to well-being and PA motivation over the past four weeks among age classes (Table 5.3), PA practice (Table 5.4), and level of PA practised (Tables 5.5 and 5.6).

Concerning the well-being of the age classes (Table 5.3), general female participants showed significant well-being improvement in most of the questions ($p_{Q10} = 0.035$, $p_{Q12} = 0.001$, $p_{Q13} = 0.004$, $p_{Q14} < 0.001$, $p_{Q15} = 0.008$). Female participants who were older than 45 years old felt more cheerful and light-hearted in the post-intervention. Specifically, for the 45-64-year-old class, results of Q10 ($p = 0.029$), Q12 ($p = 0.029$) and Q14 ($p < 0.01$) showed statistically significant differences. For females who were more than 65 years old, the results indicated a

significant difference at the 5% level for Q15 ($p = 0.050$) and a significant difference at the 1% level for Q14 ($p = 0.005$), which means they also felt less tired and were more aware of regular exercise practice benefits. On the contrary, female participants aged 18-44 did not show significant improvement in well-being. The feeling of guilt for not exercising became the first motivation for doing PA after participating ($p_{Q17} = 0.026$), while similar results can only be found in the females who are older than 65 years old ($p_{Q17} = 0.046$) if the age classes were taken into consideration. According to males, the general male sample indicated a significant improvement in the feeling of energy or vitality ($p_{Q11} = 0.026$). Younger men (18-44 years old) did not exhibit significant improvements despite wide differences that appeared in health status questions 13 ($\Delta_{post-pre} = 1.25$) and 15($\Delta_{post-pre} = -1.25$). Differently, significant differences were found in the "energy or vitality" of males who were 45-64 years old ($p_{Q11} = 0.043$). No significant differences were found in the motivation of males.

As regards PA practice, females who practised regular PA outside the project perceived better well-being after the project ($p_{Q10} = 0.028$, $p_{Q13} = 0.047$, $p_{Q15} = 0.017$, $p_{Q12} = 0.007$, $p_{Q14} < 0.001$). Females who did not do regular PA only became more cheerful ($p_{Q14} = 0.041$) and more self-confident ($p_{Q13} = 0.008$). In addition, women who regularly practiced PA were concerned more about the feelings of guilt for not doing exercises after the participation ($p_{Q17} = 0.016$). However, women who did not regularly practise PA became more aware of PA's importance in post-intervention ($p_{Q18} = 0.041$). On the other hand, although men who were previously less active reported wide differences in health status ($\Delta_{Q10} = -1.00$; $\Delta_{Q12} = -0.75$; $\Delta_{Q13} = 1.5$), no significant changes appeared. Likewise, participation also has no significant effects on male motivation (Table 5.5).

Considering PA intensity, women who performed 2-2.5 hours ($p_{Q14} = 0.002$) or more than 2.5 hours of moderate PA per week ($p_{Q10} = 0.005$, $p_{Q12} = 0.009$, $p_{Q14} = 0.038$; Table 5.5) exhibited improvements in health status after the project, while less than 1.25 h of vigorous activity better affected female health status ($p_{Q10} = 0.050$, $p_{Q12} = 0.002$, $p_{Q13} = 0.032$, $p_{Q14} < 0.001$; Table 5.6). Although the motivation was less affected by PA intensity, females who practised more than 2.5 h of moderate PA became more concerned about feeling guilty for not exercising ($p_{Q17} = 0.006$) while females who did more than 1.25 h of vigorous PA tended to focus more on the pleasure and satisfaction given by the exercising ($p_{Q19} = 0.043$). Differently, no effects on motivations were found in male participants.

Table 5.7 shows the reasons leading people to participate in the "Moving Parks". The most important motivation is the pleasure that comes from the project. The short distance of the park from home and the achievement of personal goals are also important reasons. In addition, female participants care more about the cost and the proximity compared with men ($p < 0.01$).

Table 5.3. The differences of well-being and motivation in the pre- and post-intervention by age classes

Females	18-44 (n = 35)				45-64 (n = 48)				≥65 (n = 36)				General (n=119)			
	Mean pre ± SD	Mean post ± SD	Z	*p*	Mean pre ± SD	Mean post ± SD	Z	*p*	Mean pre ± SD	Mean post ± SD	Z	*p*	Mean pre ± SD	Mean post ± SD	Z	*p*
Well-being																
Q10. Have you been bothered by nervousness or your "nerves"?	1.83 ± 1.15	1.63 ± 1.09	0.82	0.414	1.79 ± 1.30	1.33 ± 1.00	2.19	0.029*	0.97 ± 0.86	0.89 ± 0.67	0.50	0.615	1.56 ± 1.19	1.29 ± 0.98	2.11	0.035*
Q11. How much energy or vitality did you have or feel?	2.24 ± 1.02	2.37 ± 0.81	0.56	0.573	2.83 ± 1.15	3.06 ± 1.08	0.73	0.465	2.69 ± 0.93	2.72 ± 0.85	0.38	0.705	2.61 ± 1.07	2.76 ± 0.97	1.09	0.275
Q12. Did you feel discouraged and sad?	1.77 ± 1.14	1.54 ± 0.74	1.42	0.156	1.62 ± 1.07	1.21 ± 0.97	2.19	0.029*	1.26 ± 0.89	0.92 ± 0.73	1.93	0.053	1.56 ± 1.05	1.22 ± 0.87	3.21	0.001*
Q13. Did you feel emotionally stable and self-confident?	2.29 ± 1.12	2.66 ± 1.06	1.76	0.078	2.85 ± 1.18	3.15 ± 1.22	1.48	0.139	2.59 ± 1.18	3.03 ± 1.01	1.80	0.072	2.61 ± 1.18	2.97 ± 1.12	2.85	0.004*
Q14. Did you feel cheerful and lighthearted?	2.37 ± 0.97	2.60 ± 0.85	1.66	0.096	2.55 ± 1.16	3.13 ± 1.10	2.95	0.003*	2.46 ± 1.09	3.03 ± 1.11	2.81	0.005*	2.47 ± 1.08	2.94 ± 1.05	4.37	0.000*
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.97 ± 1.15	1.71 ± 0.89	1.14	0.256	1.81 ± 1.02	1.52 ± 0.95	1.58	0.114	1.43 ± 0.70	1.14 ± 0.80	1.96	0.050*	1.75 ± 1.00	1.46 ± 0.91	2.64	0.008*
Motivation																
Q16. I exercise because other people say I should.	1.86 ± 0.97	1.91 ± 1.15	0.00	1.000	1.51 ± 1.04	1.73 ± 1.11	1.31	0.191	1.58 ± 1.03	1.58 ± 0.87	0.53	0.594	1.63 ± 1.02	1.74 ± 1.05	1.32	0.188
Q17. I feel guilty when I'm not exercising.	2.83 ± 1.12	2.94 ± 0.97	0.54	0.590	2.74 ± 1.44	3.02 ± 1.33	1.25	0.210	2.33 ± 1.27	2.89 ± 1.35	2.00	0.046*	2.65 ± 1.30	2.96 ± 1.23	2.23	0.026*
Q18. It's important for me to exercise regularly.	4.00 ± 1.26	4.17 ± 0.98	1.26	0.209	4.38 ± 0.91	4.54 ± 0.71	1.11	0.266	4.37 ± 0.84	4.31 ± 0.79	0.61	0.541	4.26 ± 1.02	4.36 ± 0.83	1.10	0.271
Q19. I get pleasure and satisfaction from exercising.	4.09 ± 1.09	4.23 ± 1.03	1.24	0.214	4.52 ± 0.82	4.58 ± 0.79	0.52	0.600	4.33 ± 0.89	4.06 ± 0.92	1.76	0.079	4.34 ± 0.94	4.32 ± 0.93	0.14	0.888
Q20. I think exercise is a waste of time.	1.11 ± 0.40	1.17 ± 0.45	0.91	0.361	1.09 ± 0.46	1.15 ± 0.46	1.10	0.273	1.09 ± 0.29	1.14 ± 0.35	0.73	0.463	1.09 ± 0.40	1.15 ± 0.42	1.54	0.124
Males	**18-44 (n = 4)**				**45-64 (n = 11)**				**≥65 (n = 4)**				**General (n = 19)**			
Well-being																
Q10. Have you been bothered by nervousness or your "nerves"?	1.75 ± 1.26	1.50 ± 1.91	-	-	0.64 ± 0.67	0.55 ± 0.52	0.40	0.686	1.25 ± 0.50	1.00 ± 0.00	-	-	1.00 ± 0.88	0.84 ± 0.96	0.84	0.401
Q11. How much energy or vitality did you have or feel?	2.25 ± 0.50	2.50 ± 0.58	0.53	0.593	2.36 ± 1.12	3.27 ± 0.90	2.03	0.043*	2.50 ± 0.58	2.75 ± 0.96	-	-	2.37 ± 0.90	3.00 ± 0.88	2.22	0.026*
Q12. Did you feel discouraged and sad?	2.00 ± 0.00	1.25 ± 0.96	-	-	1.00 ± 0.63	0.82 ± 0.87	0.91	0.361	1.00 ± 0.00	1.25 ± 0.50	-	-	1.21 ± 0.63	1.00 ± 0.82	1.18	0.237
Q13. Did you feel emotionally stable and self-confident?	2.00 ± 0.82	3.25 ± 1.26	-	-	3.36 ± 1.12	3.55 ± 0.93	0.67	0.500	3.00 ± 0.82	3.50 ± 1.00	-	-	3.00 ± 1.11	3.47 ± 0.96	1.84	0.066
Q14. Did you feel cheerful and lighthearted?	2.25 ± 0.50	2.75 ± 0.96	-	-	2.73 ± 0.90	3.36 ± 1.21	1.62	0.106	3.00 ± 0.82	3.25 ± 0.96	0.53	0.593	2.68 ± 0.82	3.21 ± 1.08	1.95	0.051
Q15. Did you feel tired. burnt out. worn out or exhausted?	2.75 ± 0.96	1.50 ± 1.29	1.60	0.109	1.27 ± 0.65	1.27 ± 0.65	0.00	1.000	1.50 ± 0.58	1.50 ± 0.58	-	-	1.63 ± 0.90	1.37 ± 0.76	1.24	0.214

Motivation																
Q16. I exercise because other people say I should.	2.00 ± 1.15	2.75 ± 1.71	-	-	1.55 ± 0.93	1.55 ± 0.93	0.00	1.000	2.50 ± 1.73	1.00 ± 0.00	-	-	1.84 ± 1.17	1.68 ± 1.16	0.56	0.575
Q17. I feel guilty when I'm not exercising.	2.25 ± 1.50	2.50 ± 1.29	-	-	2.27 ± 1.10	2.82 ± 1.33	1.15	0.249	2.75 ± 1.50	3.50 ± 1.91	0.109	1.60	2.37 ± 1.21	2.89 ± 1.41	1.73	0.083
Q18. It's important for me to exercise regularly.	4.25 ± 0.96	4.25 ± 0.96	-	-	4.45 ± 0.69	4.45 ± 0.82	0.00	1.000	4.50 ± 0.58	4.75 ± 0.50	-	-	4.42 ± 0.69	4.47 ± 0.77	0.24	0.813
Q19. I get pleasure and satisfaction from exercising.	4.50 ± 1.00	3.50 ± 1.73	0.80	0.423	4.27 ± 0.65	4.55 ± 0.69	1.21	0.225	4.50 ± 0.58	4.75 ± 0.50	-	-	4.37 ± 0.68	4.37 ± 1.01	0.53	0.594
Q20. I think exercise is a waste of time.	1.00 ± 0.00	1.00 ± 0.00	-	-	1.00 ± 0.00	1.09 ± 0.30	-	-	1.00 ± 0.00	1.00 ± 0.00	-	-	1.00 ± 0.00	1.05 ± 0.23	-	-

n, number of observations; SD, standard deviation; t, student's t-test; p. Z, Z-Score; *p*, p-value; *, statistically significant.

Table 5.4. The differences of well-being and motivation in the pre- and post-intervention by doing regular physical activities or not

Females	**Do physical activities regularly (n = 94)**				**Not do physical activities regularly (n = 25)**			
	Mean pre ± SD	**Mean post ± SD**	**Z**	***p***	**Mean pre ± SD**	**Mean post ± SD**	**Z**	***p***
Well-being								
Q10. Have you been bothered by nervousness or your "nerves"?	1.49 ± 1.18	1.19 ± 0.94	2.19	0.028*	1.80 ± 1.22	1.64 ± 1.04	0.41	0.683
Q11. How much energy or vitality did you have or feel?	2.76 ± 1.01	2.85 ± 0.98	0.62	0.538	2.08 ± 1.12	2.40 ± 0.87	1.15	0.249
Q12. Did you feel discouraged and sad?	1.45 ± 0.99	1.13 ± 0.87	2.69	0.007*	1.96 ± 1.21	1.56 ± 0.77	1.77	0.078
Q13. Did you feel emotionally stable and self-confident?	2.77 ± 1.19	3.06 ± 1.17	1.98	0.047*	2.04 ± 0.93	2.60 ± 0.87	2.67	0.008*
Q14. Did you feel cheerful and lighthearted?	2.59 ± 1.09	3.09 ± 1.04	3.87	0.000*	2.04 ± 0.93	2.40 ± 0.91	2.10	0.036*
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.69 ± 0.94	1.41 ± 0.93	2.39	0.017*	1.96 ± 1.17	1.64 ± 0.81	1.10	0.272
Motivation								
Q16. I exercise because other people say I should.	1.46 ± 0.88	1.54 ± 0.86	1.08	0.280	2.28 ± 1.24	2.48 ± 1.36	0.76	0.445
Q17. I feel guilty when I'm not exercising.	2.63 ± 1.31	3.00 ± 1.23	2.40	0.016*	2.72 ± 1.31	2.80 ± 1.26	0.17	0.865
Q18. It's important for me to exercise regularly.	4.52 ± 0.80	4.52 ± 0.71	0.06	0.953	3.32 ± 1.18	3.76 ± 0.97	2.04	0.041*

Q19. I get pleasure and satisfaction from exercising.	4.54 ± 0.80	4.44 ± 0.87	1.12	0.264	3.56 ± 1.04	3.88 ± 1.01	1.58	0.114
Q20. I think exercise is a waste of time.	1.08 ± 0.37	1.13 ± 0.39	1.27	0.203	1.16 ± 0.47	1.24 ± 0.52	0.91	0.361
Males	**Do physical activities regularly (n = 15)**				**Not do physical activities regularly (n = 4)**			
Well-being								
Q10. Have you been bothered by nervousness or your "nerves"?	0.93 ± 0.88	1.00 ± 1.00	0.40	0.686	1.25 ± 0.96	0.25 ± 0.50	1.60	0.109
Q11. How much energy or vitality did you have or feel?	2.47 ± 0.99	3.13 ± 0.92	1.95	0.051	2.00 ± 0.00	2.50 ± 0.58	-	-
Q12. Did you feel discouraged and sad?	1.07 ± 0.59	1.00 ± 0.65	0.53	0.593	1.75 ± 0.50	1.00 ± 1.41	1.10	0.273
Q13. Did you feel emotionally stable and self-confident?	3.33 ± 0.98	3.53 ± 0.92	0.94	0.345	1.75 ± 0.50	3.25 ± 1.26	1.60	0.109
Q14. Did you feel cheerful and lighthearted?	2.87 ± 0.83	3.40 ± 1.06	1.68	0.093	2.00 ± 0.00	2.50 ± 1.00	-	-
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.47 ± 0.92	1.40 ± 0.63	0.40	0.686	2.25 ± 0.50	1.25 ± 1.26	1.28	0.201
Motivation								
Q16. I exercise because other people say I should.	1.67 ± 1.11	1.27 ± 0.59	1.15	0.249	2.50 ± 1.29	3.25 ± 1.50	-	-
Q17. I feel guilty when I'm not exercising.	2.47 ± 1.19	3.00 ± 1.46	1.43	0.154	2.00 ± 1.41	2.50 ± 1.29	-	-
Q18. It's important for me to exercise regularly.	4.53 ± 0.52	4.67 ± 0.62	0.73	0.463	4.00 ± 1.15	3.75 ± 0.96	0.27	0.789
Q19. I get pleasure and satisfaction from exercising.	4.53 ± 0.52	4.67 ± 0.62	0.73	0.463	3.75 ± 0.96	3.25 ± 1.50	0.00	1.000
Q20. I think exercise is a waste of time.	1.00 ± 0.00	1.07 ± 0.26	-	-	1.00 ± 0.00	1.00 ± 0.00	-	-

n, number of observations; SD, standard deviation; t, student's t-test; p. Z, Z-Score; p, p-value; *, statistically significant.

n, number of observations; SD, standard deviation; t, student's t-test; p. Z, Z-Score; p, p-value; *, statistically significant.

Table 5.5. The differences of wellbeing and motivation in the pre- and post-intervention by different length of time doing moderate physical activities

Females	<1h, 1h (n = 9)				2h, 2.5h (n = 39)				> 2.5h (n = 43)			
	Mean pre ± SD	Mean post ± SD	Z	p	Mean pre ± SD	Mean post ± SD	Z	*p*	Mean pre ± SD	Mean post ± SD	Z	*p*
Well-being												
Q10. Have you been bothered by nervousness or your "nerves"?	0.78 ± 0.83	0.89 ± 0.60	0.31	0.753	1.27 ± 0.99	1.15 ± 0.87	0.71	0.478	1.86 ± 1.30	1.26 ± 1.03	2.80	0.005*
Q11. How much energy or vitality did you have or feel?	2.50 ± 0.93	3.00 ± 0.87	1.48	0.138	2.73 ± 0.99	2.74 ± 0.94	0.00	1.000	2.79 ± 1.08	2.95 ± 1.07	0.63	0.530
Q12. Did you feel discouraged and sad?	1.44 ± 0.73	0.78 ± 0.67	1.68	0.093	1.30 ± 0.97	1.13 ± 0.73	1.16	0.247	1.63 ± 1.02	1.16 ± 0.97	2.60	0.009*
Q13. Did you feel emotionally stable and self-confident?	2.50 ± 1.07	3.22 ± 0.97	1.36	0.173	2.78 ± 1.20	3.18 ± 1.11	1.48	0.140	2.76 ± 1.21	2.93 ± 1.24	0.76	0.449
Q14. Did you feel cheerful and lighthearted?	2.67 ± 1.32	3.33 ± 0.87	1.26	0.208	2.54 ± 1.02	3.15 ± 0.96	3.08	0.002*	2.60 ± 1.14	2.98 ± 1.12	2.07	0.038*
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.67 ± 0.71	1.22 ± 0.83	1.47	0.142	1.68 ± 0.96	1.41 ± 0.88	1.87	0.061	1.72 ± 0.96	1.42 ± 0.96	1.49	0.135
Motivation												
Q16. I exercise because other people say I should.	1.44 ± 0.73	1.33 ± 0.50	-	-	1.36 ± 0.72	1.59 ± 0.94	1.68	0.093	1.55 ± 1.04	1.58 ± 0.88	0.34	0.737
Q17. I feel guilty when I'm not exercising.	2.33 ± 1.50	2.56 ± 0.88	0.73	0.463	2.71 ± 1.27	2.95 ± 1.15	0.76	0.449	2.62 ± 1.32	3.21 ± 1.34	2.75	0.006*
Q18. It's important for me to exercise regularly.	3.89 ± 1.17	3.89 ± 0.93	0.00	1.000	4.29 ± 0.93	4.56 ± 0.72	1.59	0.112	4.84 ± 0.37	4.65 ± 0.57	1.77	0.078
Q19. I get pleasure and satisfaction from exercising.	3.78 ± 1.09	3.56 ± 1.13	0.80	0.423	4.44 ± 0.88	4.51 ± 0.76	0.56	0.576	4.81 ± 0.45	4.60 ± 0.79	1.72	0.086
Q20. I think exercise is a waste of time.	1.22 ± 0.44	1.22 ± 0.44	-	-	1.05 ± 0.23	1.08 ± 0.27	0.53	0.593	1.07 ± 0.46	1.16 ± 0.48	1.35	0.178
Males		**<1h, 1h (n = 3)**				**2h, 2.5h (n = 6)**				**> 2.5h (n = 6)**		
Well-being												
Q10. Have you been bothered by nervousness or your "nerves"?	0.67 ± 0.58	0.67 ± 0.58	-	-	1.33 ± 1.03	1.50 ± 1.22	0.53	0.593	0.67 ± 0.82	0.67 ± 0.82	-	-
Q11. How much energy or vitality did you have or feel?	3.00 ± 1.00	3.33 ± 0.58	-	-	1.67 ± 0.52	2.67 ± 1.03	1.60	0.109	3.00 ± 0.89	3.50 ± 0.84	0.94	0.345

Q12. Did you feel discouraged and sad?	1.00 ± 0.00	1.00 ± 0.00	-	-	1.33 ± 0.52	1.33 ± 0.52	-	-	0.83 ± 0.75	0.67 ± 0.82	-	-
Q13. Did you feel emotionally stable and self-confident?	3.67 ± 0.58	3.67 ± 0.58	-	-	2.67 ± 0.82	3.17 ± 0.98	-	-	3.83 ± 0.98	3.83 ± 0.98	-	-
Q14. Did you feel cheerful and lighthearted?	3.33 ± 0.58	3.33 ± 1.15	-	-	2.50 ± 0.84	3.00 ± 0.89	1.07	0.285	3.00 ± 0.89	3.83 ± 1.17	1.60	0.109
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.00 ± 0.00	1.00 ± 0.00	-	-	2.00 ± 1.10	1.67 ± 0.82	-	-	1.17 ± 0.75	1.33 ± 0.52	0.53	0.593
Motivation												
Q16. I exercise because other people say I should.	1.33 ± 0.58	1.33 ± 0.58	-	-	1.50 ± 1.22	1.17 ± 0.41	-	-	2.00 ± 1.26	1.33 ± 0.82	-	-
Q17. I feel guilty when I'm not exercising.	2.00 ± 0.00	2.00 ± 1.00	-	-	2.33 ± 1.51	3.50 ± 1.38	1.60	0.109	2.83 ± 1.17	3.00 ± 1.67	0.40	0.686
Q18. It's important for me to exercise regularly.	4.67 ± 0.58	5.00 ± 0.00	-	-	4.17 ± 0.41	4.50 ± 0.84	0.91	0.361	4.83 ± 0.41	4.67 ± 0.52	-	-
Q19. I get pleasure and satisfaction from exercising.	4.67 ± 0.58	5.00 ± 0.00	-	-	4.17 ± 0.41	4.50 ± 0.84	0.91	0.361	4.83 ± 0.41	4.67 ± 0.52	-	-
Q20. I think exercise is a waste of time.	1.00 ± 0.00	1.00 ± 0.00	-	-	1.00 ± 0.00	1.17 ± 0.41	-	-	1.00 ± 0.00	1.00 ± 0.00	-	-

n, number of observations; SD, standard deviation; t, student's t-test; p. Z, Z-Score; p, p-value; *, statistically significant; PA, physical activities.

Table 5.6. The differences of wellbeing and motivation in the pre- and post-intervention by different length of time doing vigorous PA

Females	**<30min, 30min, 1h, 1.25h (n = 65)**				**>1.25h (n = 25)**			
	Mean pre ± SD	**Mean post ± SD**	**Z**	***p***	**Mean pre ± SD**	**Mean post ± SD**	**Z**	***p***
Well-being								
Q10. Have you been bothered by nervousness or your "nerves"?	1.45 ± 1.08	1.14 ± 0.86	1.96	0.050*	1.68 ± 1.41	1.40 ± 1.15	1.07	0.286
Q11. How much energy or vitality did you have or feel?	2.65 ± 0.95	2.89 ± 1.00	1.81	0.071	2.92 ± 1.15	2.80 ± 1.00	1.12	0.263
Q12. Did you feel discouraged and sad?	1.50 ± 0.87	1.11 ± 0.81	3.04	0.002*	1.40 ± 1.26	1.28 ± 1.02	0.03	0.972
Q13. Did you feel emotionally stable and self-confident?	2.65 ± 1.12	3.02 ± 1.12	2.15	0.032*	3.00 ± 1.32	3.12 ± 1.30	0.16	0.875

Q14. Did you feel cheerful and lighthearted?	2.50 ± 0.99	3.06 ± 1.01	3.55	0.000*	2.72 ± 1.28	3.16 ± 1.11	1.61	0.108
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.65 ± 0.86	1.43 ± 0.98	1.87	0.061	1.88 ± 1.13	1.44 ± 0.82	1.56	0.118
Motivation								
Q16. I exercise because other people say I should.	1.46 ± 0.78	1.62 ± 0.93	1.34	0.179	1.50 ± 1.14	1.44 ± 0.71	0.05	0.959
Q17. I feel guilty when I'm not exercising.	2.73 ± 1.33	3.05 ± 1.20	1.65	0.099	2.50 ± 1.22	3.00 ± 1.19	1.86	0.063
Q18. It's important for me to exercise regularly.	4.36 ± 0.88	4.46 ± 0.73	0.74	0.459	4.92 ± 0.28	4.72 ± 0.61	1.48	0.138
Q19. I get pleasure and satisfaction from exercising.	4.40 ± 0.88	4.38 ± 0.93	0.04	0.968	4.88 ± 0.44	4.64 ± 0.70	2.02	0.043*
Q20. I think exercise is a waste of time.	1.11 ± 0.44	1.15 ± 0.40	0.89	0.374	1.00 ± 0.00	1.08 ± 0.40	-	-
Males	**<30min, 30min, 1h, 1.25h (n = 9)**					**>1.25h (n = 5)**		
Well-being								
Q10. Have you been bothered by nervousness or your "nerves"?	0.78 ± 0.67	0.78 ± 0.44	0.00	1.000	1.20 ± 1.30	1.40 ± 1.67	-	-
Q11. How much energy or vitality did you have or feel?	2.56 ± 1.01	3.00 ± 0.87	1.35	0.178	2.60 ± 0.89	3.20 ± 1.10	1.07	0.285
Q12. Did you feel discouraged and sad?	0.89 ± 0.33	1.00 ± 0.50	-	-	1.20 ± 0.84	1.00 ± 1.00	-	-
Q13. Did you feel emotionally stable and self-confident?	3.33 ± 0.87	3.44 ± 0.88	0.53	0.593	3.60 ± 1.14	3.60 ± 1.14	-	-
Q14. Did you feel cheerful and lighthearted?	3.00 ± 0.87	3.33 ± 1.12	0.94	0.345	2.80 ± 0.84	3.40 ± 1.14	-	-
Q15. Did you feel tired. burnt out. worn out or exhausted?	1.22 ± 0.44	1.33 ± 0.50	-	-	1.80 ± 1.48	1.60 ± 0.89	0.53	0.593
Motivation								
Q16. I exercise because other people say I should.	1.89 ± 1.27	1.22 ± 0.44	1.15	0.249	1.40 ± 0.89	1.40 ± 0.89	-	-
Q17. I feel guilty when I'm not exercising.	2.33 ± 1.12	2.78 ± 1.64	0.94	0.345	3.00 ± 1.22	3.20 ± 1.30	0.53	0.593

Q18. It's important for me to exercise regularly.	4.44 ± 0.53	4.67 ± 0.71	0.91	0.361	4.80 ± 0.45	4.60 ± 0.55	-	-
Q19. I get pleasure and satisfaction from exercising.	4.44 ± 0.53	4.67 ± 0.71	0.91	0.361	4.80 ± 0.45	4.60 ± 0.55	-	-
Q20. I think exercise is a waste of time.	1.00 ± 0.00	1.00 ± 0.00	-	-	1.00 ± 0.00	1.00 ± 0.00	-	-

n, number of observations; SD, standard deviation; t, student's t-test; p. Z, Z-Score; p, p-value; *, statistically significant; PA, physical activities.

Table 5.7. The reasons for participating in the Moving Park project regularly.

	Total		**Females**		**Males**		
	n.	**%**	**n.**	**%**	**n.**	**%**	χ^2
The proximity to home							
1 (not true at all)	0	0.00	0	0.00	0	0.00	
2	3	2.17	0	0.00	3	15.79	
3	14	10.14	11	9.24	3	15.79	
4	34	24.64	30	25.21	4	21.05	
5 (very true)	87	63.04	78	65.55	9	47.37	
							20.46
The low cost of the activities							
1 (not true at all)	2	1.45	0	0.00	2	10.53	
2	3	2.17	2	1.68	1	5.26	
3	29	21.01	24	20.17	5	26.32	
4	41	29.71	34	28.57	7	36.84	

5 (very true)	63	45.65	59	49.58	4	21.05	
							17.09
The pleasure that comes from practicing it							
1 (not true at all)	0	0.00	0	0.00	0	0.00	
2	1	0.72	1	0.84	0	0.00	
3	7	5.07	7	5.88	0	0.00	
4	28	20.29	23	19.33	5	26.32	
5 (very true)	102	73.91	88	73.95	14	73.68	
							1.67
The people with whom I find myself practicing it							
1 (not true at all)	1	0.72	1	0.84	0	0.00	
2	8	5.80	7	5.88	1	5.26	
3	29	21.01	28	23.53	1	5.26	
4	46	33.33	39	32.77	7	36.84	
5 (very true)	54	39.13	44	36.97	10	52.63	
							3.88
The achievement of my personal goals (e.g. fitness. health. ....)							
1 (not true at all)	0	0.00	0	0.00	0	0.00	
2	1	0.72	1	0.84	0	0.00	

3	11	7.97	8	6.72	3	15.79	
4	45	32.61	37	31.09	8	42.11	
5 (very true)	81	58.70	73	61.34	8	42.11	
							3.49

n, number of observations; %, percentage; χ^2, chi-squared; p, p-value; *, statistically significant.

5.4 Dsicussion

The “Moving Parks” project was designed to actively promote community PA through the provision of differentiated and supervised PA programmes for adults. In previous studies, we demonstrated the effectiveness of the project in improving participants' psychological well-being [322, 323]. These preliminary positive results have indicated the need to investigate its lasting impact on health outcomes and the aspects that motivate people to participate in PA. Since the project was carried out in 2010, it has been annually implemented to meet the evolving needs of the communities it serves, based on the analysis of the questionnaires that are administered each year. In this edition, the questionnaire includes a section investigating the motivation aspects, aimed to explore the driving factors behind individuals' engagement in PA and the extent to which such activity can influence these factors. In the meantime, to verify if the effects of PA practice had influenced adherence and mood among participants, we evaluated the effectiveness of supervised PA on psychosocial well-being and the motivation of PA participation during the period following the pandemic.

Overall, women showed greater participation in the project, confirming what was observed before and immediately after the pandemic period [322, 323]. Similar results have been indicated in other studies on the administration of outdoor structured supervised PA programmes [324, 325]. The main reason for women to participate is linked to the pleasure of practicing it, while for men to be outdoors and to the enjoyment of the activities. This difference reflects gendered preferences in activity types and settings, as also highlighted in previous chapters. In general, women are more likely than men to prefer activities that are supervised, with people of the same sex and the same age and at a fixed time, while men prefer activities that are done outdoors, competitive, vigorous, and that require skill and practice [326]. However, generally lower activity in females than in males could be caused by sex differences in domains, intensities, or habits [297]. It indicates that the supervision of PA could be an effective way to decrease this inequality. In addition, female participants' willingness to quit smoking increased significantly after participation. The reduction in tobacco use has been related to the increase in PA levels [327].

The first aspect considered the effectiveness of project participation in affecting psychophysical well-being. The effects of PA emerged more clearly in women than in men regardless of age. A similar stronger association between positive mental impact and PA in women than men was also indicated in related studies [328, 329], which suggests that PA is an effective way to improve mental well-being, especially for females. As regards age, the greatest effects were shown in the older age groups. In particular, in the 45-65 age class a significant improvement was perceived in cheerfulness with a reduction in nervousness and sadness. In the >65 age class, on the other hand, the enhancement was detected for cheerfulness and the reduction of tiredness. This finding is consistent with the results of a comparative study that focused on the mental well-being effect of PA on different age groups [330]. Within the broader framework of this thesis, these results further support the notion that UGS can function as socially and emotionally restorative environments for mid-aged and elderly populations.

As far as PA outside the project is concerned, those who do it habitually showed an improvement in all the items related to psychosocial well-being, while those who do not practise it habitually improved only in self-confidence and cheerfulness. This may suggest that people who do not usually practise PA need more attention and probably more supervision in the practice than those who practise it regularly. However, this statement needs to be further validated in future studies. Regarding PA itself, Kelley et al. (2022) in their meta-analysis on the effects of PA in the natural outdoor environment on well-being in adults conclude that researchers should strive to carefully document various characteristics of PA—including, at minimum, frequency, intensity, and duration—such that any effects of these issues on well-being can be considered in replication and extension studies [331]. Sylvester et al. (2012) also illustrate the importance of carefully documenting features of PA in research using well-being as the outcome of interest [332]. Therefore, in this study, the categories of moderate and vigorous PA were considered. For moderate intensity, as the hours of activity practiced increase, the improvement in well-being increases: no improvement was observed in women who do less than 2 hours of PA practice, while those who do between 2 and 2.5 hours a week showed an improvement in cheerfulness. Who, on the other hand, spent more than 2.5 hours presented a decline in nervousness and sadness and an increase in joy. Opposite results were obtained concerning the frequency of vigorous PA. Except for vitality and tiredness, most improvements were observed only for those who did PA for less than 1 hour and 15 minutes. This result may be since those with a high level of practice had already realised the benefits expected from the PA outside the project. The results regarding men were less consistent, highlighting improvements only for the levels of energy or vitality in the total sample and, in particular, in subjects aged between 45 and 65 and in those who practised PA, while those who practise it more frequently did not show changes in well-being. However, the results are not entirely consistent with the findings of other literature. A systematic review focused on the benefits of PA in the prevention of depression highlights that mental health benefits may be obtainable at lower doses [333, 334]. In contrast, another study indicated low associations between moderate PA and psychological well-being. In this research, however, the participants felt more optimistic and showed fewer depressive symptoms when they met the vigorous PA and moderate to vigorous PA recommendations [335]. The possible reason for the inconsistency is the different levels of adaptation and preference to different intensities of exercise among the samples with different physical conditions [336, 337]. Another possible reason is the discrepancy in the description or definition of moderate and vigorous PA.

The second aspect considered by the present study concerns the motivation to practise PA. Our findings indicated an interesting sex-specific pattern regarding exercise guilt, particularly among female participants. The data showed that feeling of guilt for not exercising became a significant motivator for PA participation after the intervention, especially among females over 65 years old and those who regularly practised PA. This suggests that participation in the project may have increased awareness of PA benefits, leading to heightened exercise consciousness. This is similar to the findings of a recent study which showed that 66% of female participants were aware of the benefits of exercise, primarily influenced by guidance from doctors and fitness professionals [338]. Interestingly, this motivational aspect varied with activity intensity, as females who practised more than 2.5 hours of moderate PA showed increased concern about exercise guilt, while those engaging in vigorous PA focused more on exercise enjoyment and satisfaction.

Through the before-and-after comparison, the present chapter provides longitudinal evidence supporting the psychological benefits of supervised PA in UGS, particularly for female participants who are slightly older. The *"Moving Parks"* programme offers an effective model for cities seeking to promote active lifestyles, social inclusion, and mental well-being through accessible green infrastructure. In the context of this thesis, it illustrates how sustained, supervised PA programmes embedded in urban parks can strengthen residents' attachment to place, enhance perceived well-being, and provide a replicable approach for integrating public health goals within urban planning.

Limitations

Several limitations of this chapter should be acknowledged. First, the absence of a control group limits the interpretability of the results and prevents a clearer attribution of the observed effects to the intervention itself. Second, the use of self-reported measures exposes the data to potential reporting and recall bias, which may affect the accuracy and reliability of the findings [339]. Third, the PA patterns of participants were not objectively monitored, making it difficult to determine whether individual differences in frequency or intensity of PA influenced the outcomes. In addition, the limited number of male participants may have contributed to bias in the gender-related results and reduced the representativeness of the sample. Finally, as the present analysis was primarily qualitative, the findings should be interpreted with caution. Further studies employing quantitative or mixed-method designs are needed to validate these results and to provide clearer, evidence-based guidance for exercise promotion among different demographic groups. Taken together, these reflections underline the need to interpret the results of this chapter as part of a broader and evolving understanding of how supervised PA within UGS can contribute to well-being. This chapter adds a piece to the cumulative argument developed throughout the thesis, which is promoting inclusive and accessible UGS remains a promising pathway to foster healthier and more resilient urban communities.

Appendix B

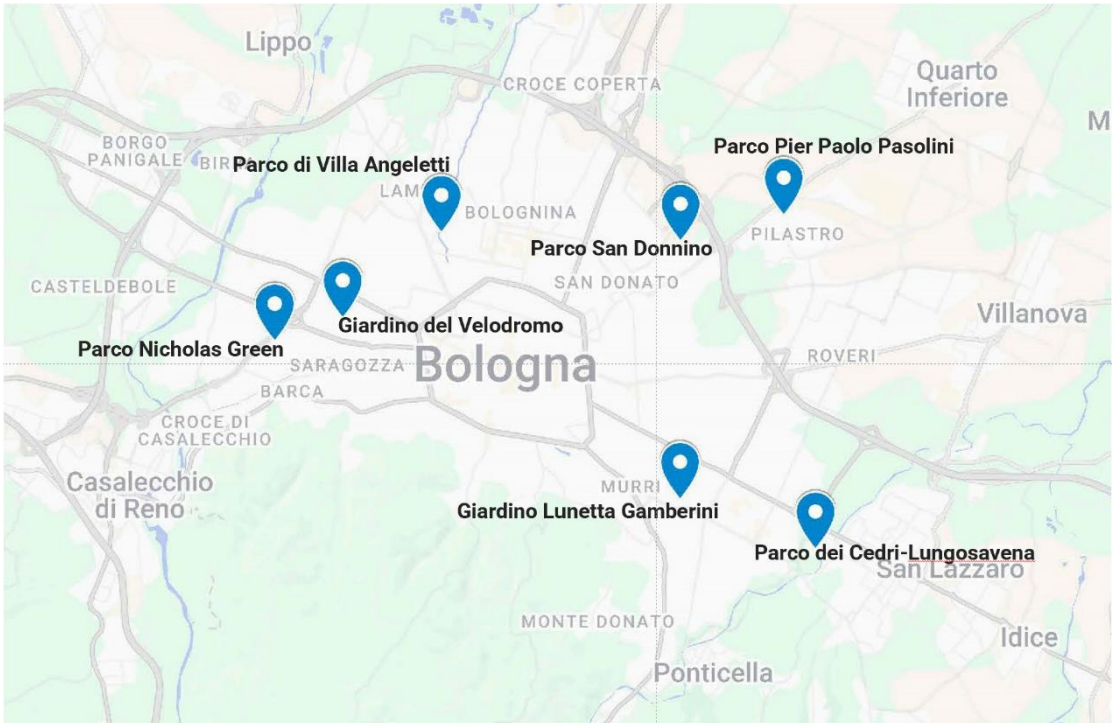

Figure B1. Map of Bologna, with the seven parks included in the project.

- **Parco Nicholas Green (District Borgo Panigale – Reno)**

This park spans approximately 8 hectares and features multiple recreational zones, including dedicated children's playgrounds and a section of community vegetable gardens. The park is characterised by expansive lawn areas intersected by pedestrian pathways, although tree coverage is relatively sparse.

- **Parco di Villa Angeletti (District Navile)**

Situated along the right bank of the Navile Canal, this 8.5-hectare park features an extensive corridor of natural vegetation that provides opportunities for wildlife observation and nature experience.

- **Giardino del Velodromo (District Porto-Saragozza)**

Covering approximately 3 hectares, this park features diverse recreational facilities including sports amenities, a children's playground, and open grasslands, complemented by an on-site café. A distinctive feature is its "Ability Park" - an inclusive fitness zone designed for accessible physical activities, enabling users of all abilities to exercise without barriers.

- **Parco San Donnino (District San Donato-San Vitale)**

Covering approximately 8 hectares between the ring road and railway line, this park was developed as part of an urban regeneration initiative. The park comprises extensive green spaces intersected by pedestrian pathways and designated rest areas. A notable feature is its educational garden, alongside a wooden pavilion that serves as the headquarters for a local community association dedicated to the park's maintenance.

- **Parco dei Cedri-Lungosavena (District Savena),**

Covering 11 hectares, this park combines open lawns with woodland areas, highlighted by a riverside grove along the Savena River which defines its borders. The park boasts a rich variety of plant species and includes visitor amenities such as a children's playground, benches, and water fountains.

- **Giardino Lunetta Gamberini (District Santo Stefano),**

This 14.5-hectare park is home to multiple community facilities, including sports venues, four schools, a community centre, and a youth centre. The park is notably surrounded by a dense mixed hedge that serves as a natural buffer against traffic noise from adjacent streets. Additional recreational features include a children's playground, a skating rink, and a designated dog area.

- **Parco Pier Paolo Pasolini (District San Donato-San Vitale)**

Covering 16 hectares, this park features a distinct geometric design, highlighted by a long, linear avenue of Lombardy poplars that extends from the San Donato entrance to Via Negri. Along this avenue lies a remarkable sculptural complex comprising approximately 200 life-sized human figures, a sculpture-theater, and a necropolis-like installation set within two grass-covered basins. Created between 1974 and 1984 by Nicola Zamboni, this artistic installation represents the most significant artistic intervention in Bologna's green spaces in recent decades. The park also includes a playground area.

Appendix C

Table C1. Overview of Physical Activities Offered in Seven Parks included in the project

Parks & Activities	Parco Nicholas Green	Parco di Villa Angeletti	Giardino del Velodromo	Parco San Donnino	Parco dei Cedri-Lungosavena	Giardino Lunetta Gamberini	Parco Pier Paolo Pasolini
Full Body Workout	✔	-	-	-	-	-	-
Stretching	✔	-	-	✔	✔	-	-
Functional Training	✔	-	-	-	-	✔	✔
Tabata	✔	-	-	-	-	-	-
Yoga	✔	✔	-	✔	-	✔	✔
Pilates	✔	-	✔	✔	-	✔	-
Body-Mind Energy Balance	✔	-	-	-	✔	-	-
Krav Maga	✔	-	-	-	-	-	-
Capoeira	✔	✔	✔	✔	✔	-	✔
Belly Dancing	✔	-	-	-	-	-	-
Green Volleyball	-	✔	-	-	-	-	-
Dance	-	✔	✔	-	✔	✔	-

Urban Trekking	-	✔	-	-	-	-	-
Juggling	-	✔	-	-	-	-	-
Popular Fitness	-	✔	-	-	-	-	-
Qi Gong	-	✔	-	-	-	-	-
Self Defence	-	✔	-	-	-	-	-
Aikido	-	✔	-	-	-	-	-
Postural Gymnastics	-	✔	-	-	-	-	-
Athletic Games	-	✔	-	-	-	-	-
Parkour	-	✔	-	-	-	-	✔
Judo Games	-	✔	-	-	-	-	-
Wing Tsun	-	✔	-	-	-	-	-
Walking	-	✔	-	-	✔	✔	-
Badminton	-	✔	-	-	-	-	-
Nordic Walking	-	✔	-	-	✔	-	-
Body Weight Training	-	✔	-	-	-	-	-
Karate	-	✔	-	-	-	-	-
Total Body	✔	✔	✔	-	✔	-	-
Pregnancy Exercise	-	-	✔	-	-	-	-
Multisport Activities	-	-	✔	-	-	-	-
Gentle Gymnastics	-	-	✔	✔	✔	✔	✔
Handstand Training	-	-	✔	-	-	-	-
Muscle Strengthening	-	-	-	✔	-	-	-
Gyrokinesis	-	-	-	✔	-	-	-
Tone Up	-	-	-	-	✔	-	-
Run and Sparta	-	-	-	-	✔	-	-
Feldenkrais	-	-	-	-	-	✔	-
Argentine Tango	-	-	-	-	-	✔	-
Performance Workshop	-	-	-	-	-	-	✔
Pre-boxing Training	-	-	-	-	-	-	✔

"✔" means offered; "-" means not offered.

Chapter 6 – A Quasi-experimental Study on Supervised Green Exercise and Mental Well-being among Middle-aged Adults

This chapter is based on the article “The Impact of Supervised Physical Activity in Urban Green Spaces on Mental Well-Being Among Middle-Aged Adults: A Quasi-Experimental Study”,

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Keywords: supervised physical activities; green spaces; mental health; WEMWBS assessment

Summary

This chapter assessed the impact of supervised physical activity (PA) carried out in urban green spaces (UGS) on the mental well-being of middle-aged adults (45–65 years). The study adopted a quasi-experimental design with a control group, conducted as part of the “Parchi in Movimento” (Moving Parks) project in Bologna, Italy. Mental health was measured before and after the intervention using the Italian version of the Warwick–Edinburgh Mental Well-being Scale (WEMWBS). A total of 340 participants (258 in the intervention group and 82 in the control group) were included. The analysis, based on a two-way repeated-measures ANOVA, revealed no significant interaction effects between group and time, although general improvements over time were observed in optimism, perceived usefulness, energy, and cheerfulness. The only significant interaction emerged for perceived usefulness. These results do not confirm the hypothesised benefits of supervised PA in UGS but highlight the influence of contextual and methodological factors—such as seasonal variation, baseline well-being, and measurement sensitivity—on the evaluation of nature-based interventions. Within the broader framework of this thesis, the chapter refines the methodological understanding of how UGS contribute to mental well-being through real-world, community-based programmes.

6.1 Introduction

Urban green spaces (UGS) are increasingly recognised as settings where physical activities (PA), contact with nature, and social interaction take place, with potential benefits for psychological well-being [340-343].

Beyond general associations, theoretical perspectives such as Self-Determination Theory and Attention Restoration Theory suggest that natural environments may support autonomy, competence and relatedness and reduce attentional fatigue, thereby enhancing cognitive and emotional improvement [344-348]. Nevertheless, although the therapeutic benefits of PA are widely reported [93, 349, 350], developing evidence demonstrates that the environmental context in which these PA occur may significantly modulate the mental health outcomes [351, 352]. For example, parks with nature-based attributes and opportunities for PA were associated with positive mental health outcomes [349, 353-355].

Meanwhile, supervision is another relevant component for real-world effectiveness. Prior work shows that supervised PA can improve adherence and technique, reduce injury risk, and enhance motivation via group dynamics and social support [356-359]. However, whether these advantages translate into measurable gains in mental well-being when supervision occurs specifically within UGS is still lacking sufficient evidence, particularly in longitudinal designs [129, 360-362].

Addressing these gaps, this chapter focuses on middle-aged adults (45–65 years), a life stage that is both psychologically vulnerable and particularly responsive to the psychosocial benefits of PA. To strengthen causal interpretation, the study adopts a quasi-experimental design with a parallel control group, and employs a validated mental well-being scale (WEMWBS) at pre- and post-assessment. The intervention was implemented within the "Parchi in Movimento" (Moving Parks) project of 2023. Accordingly, this chapter aims to:

a) evaluate changes in WEMWBS scores from pre- to post-assessment among participants in supervised PA within UGS compared to a control group of non-participants;
b) explore whether demographic factors (e.g., sex, education) moderate these effects. By integrating a control condition and a standardised psychological instrument, the chapter adds methodological depth to the thesis and clarifies under which conditions UGS-based, supervised PA may influence mental well-being.

6.2 Methods

6.2.1 Study design

This chapter employed a quasi-experimental pre–post design with a parallel control group, conducted within the framework of the "Parchi in Movimento" (Moving Parks) of 2023. The intervention took place between May and October 2023, following the same organisational structure as described in Chapter 5. The inclusion of a control group allowed for the assessment of time (pre–post) × group (intervention vs. control) effects on mental well-being. The "Moving Parks" project 2023 operates across 12 public parks in the city (Appendix D), where multiple sport associations offer different free organised PA (Appendix E).

All participants were selected according to two criteria:

1. Aged 45 to 65 years old;
2. Able to write and read in Italian.

The University of Bologna Bioethics Committee granted approval for the study (Prot. No. N 169182).

6.2.2 The Questionnaire

Before and after the intervention, participants completed self-administered questionnaires to assess demographic, behavioural, and psychological variables. The same questionnaire structure described in Chapter 5 was used, with the addition of a validated measure of mental well-being. In particular, the questionnaires were composed of three parts: the first part on general demographic information about the participants, such as sex, age, and educational level; the second part regarding information about the behavioural variables, such as smoking status, working status, and pathological status; and the third part about subjective mental health, assessed by the validated Italian version of the Warwick–Edinburgh Mental Well-Being Scale (WEMWBS) [217]. The Italian version of the WEMWBS is a self-reported questionnaire using a 12-item Likert scale of 1 (not at all) to 5 (as always) to measure the positive attitude to life over the past two weeks. The reliability of the Italian version was valued by Gremigni and Stewart-Brown (2011) on two groups: the Cronbach alpha value was 0.86 for group 1 (n = 345) and 0.83 for group 2 (n = 52) [217]. Compared with the original English version, question No. 4 and No. 12 were excluded due to weak item–total correlations and a negative impact on the overall factor structure [363], so the total scores of the 12 items ranged from 12 to 60, with a higher score representing a more positive mental health result.

6.2.3 Data Analysis

We used Stata for Windows, version 19 (StataCorp LLC, College Station, TX, USA), to perform all the data analysis. Descriptive statistics were developed to summarise WEMWBS scores across the group, sex, and assessment phase by reporting means and standard deviations (SD). Aside from the total scores, item-level means were also examined to explore the response distribution and variability across different dimensions of mental health.

The two-way repeated measures ANOVA analysis was conducted to examine the effects of supervised PA on mental health in order to further investigate the effects of the intervention on mental health, including the main effect of time (assessment phase), the main effect of group, and the interaction effect between group and time. The analysis included two independent factors: group (control and intervention, between-subject factor) and assessment phase (pre vs. post, within-subjects factor). The main effect of time examined whether the WEMWBS scores changed between assessments across all participants. The main effect of group evaluated overall differences between control and intervention groups. Notably, the interaction effect (group × time) was also determined to understand whether the intervention group showed a different pattern of change compared to controls, indicating any potential effectiveness of the supervised PA intervention. The longitudinal plots were used to visualise the interaction between group and time, demonstrating estimated means of total score and each item over time with 95% confidence intervals. For interpretation, partial eta squared values of 0.01, 0.06 were considered to represent small, moderate, and large effects,

respectively ($\eta 2 < 0.01$ considered small, $0.01 \leq \eta 2 < 0.06$ moderate, and $\eta 2 \geq 0.06$ large) [364].

6.3 Results

A total of 340 participants were included in this study, with 258 participants in the intervention group and 82 participants in the control group. Regarding the age distribution, the mean age in the intervention group was 58.01 years old (SD = 5.690), ranging from 45.09 to 65.87 years old. In the control group, the mean age was 56.36 years old (SD = 5.370), with a range of 45.13 to 65.08 years old.

6.3.1 Descriptive Analysis

Table 6.1 presents the descriptive statistics for the WEMWBS scores, categorised by group (control and intervention), sex (female and male), and assessment phase (pre and post). In the control group, the mean total score of the female participants was 41.68 ± 6.68 in the pre-assessment and 43.44 ± 6.65 in the post-assessment. The item-level means ranged from 3.00 to 4.00 in the pre-assessment and from 2.96 to 4.20 in the second. The highest mean score was observed in Q11 (decisiveness), with scores of 4.00 ± 0.65 (pre) and 4.20 ± 0.58 (post). The lowest mean score was found in Q3 (relaxed) during the pre-assessment (3.08 ± 0.64) and Q5 (energetic) in the post (3.32 ± 0.95). The highest variability, as indicated by the standard deviation, was observed for Q5 (energetic) in the pre-assessment (SD = 1.16) and Q13 (explorative) in the post (SD = 0.99). Male participants in the control group showed a higher mean total score of 43.06 ± 4.99 in the pre-assessment and 45.75 ± 5.27 in the post. The item means ranged from 3.06 to 4.06 in the pre and from 3.44 to 4.19 in the post-assessment. Similarly to female participants, Q11 (decisiveness) had the highest mean scores in both assessments (4.06 ± 0.57 and 4.19 ± 0.54), while Q3 (relaxed) exhibited the lowest mean scores (3.06 ± 0.77 and 3.44 ± 0.51). The greatest variability was found in Q5 (energetic) in the pre-assessment (SD = 1.11) and Q13 (explorative) in the post (SD = 0.98).

In the intervention group, females exhibited total scores of 44.13 ± 7.93 (pre) and 44.67 ± 6.82 (post), respectively, with individual item means ranging from 3.13 to 3.99 in the pre-assessment and 3.29 to 4.10 in the post-assessment. Q11 (decisiveness) consistently showed the highest scores in both assessments (3.99 ± 0.78 and 4.10 ± 0.85), while Q5 (energetic) showed the lowest (3.13 ± 1.09 and 3.29 ± 0.95). The highest variability was observed in Q5 (energetic) in the pre-assessment (SD = 1.09) and Q10 (confident) in the post (SD = 0.88). Males in the intervention group had a mean total score of 44.94 ± 7.15 in the pre-assessment and 45.06 ± 6.10 in the post, with item means ranging from 3.47 to 3.94 in the pre and 3.53 to 4.12 in the post-assessment. Consistent with other subgroups, Q11 (decisiveness) had the highest mean scores (3.94 ± 0.75 and 4.12 ± 0.78), while Q5 (energetic) reported the lowest scores (3.47 ± 0.72 and 3.53 ± 0.51). The highest variability was observed in Q3 (relaxed) and Q8 (self-satisfied) in the first assessment (both SD = 0.90) and Q11 (decisiveness) in the second (SD = 0.78).

Across all groups and assessments, Q11 (decisiveness) consistently had the highest mean scores, ranging from 3.94 to 4.20, while Q5 (energetic) had the lowest scores, ranging from 3.00 to 3.53. Standard deviations varied between 0.44 and 1.16, reflecting differences in item-level response variability. Total scores ranged from 41.68 ± 6.68 to 45.75 ± 5.27, with

intervention group participants generally tending to score higher than those in the control group.

Table 6.1. Descriptive statistics of WEMWBS scores by group, sex, and assessment phase.

WEMWBS Dimensions	Control Group				Intervention Group			
	Female		Male		Female		Male	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Q1. Optimistic	3.20 ± 0.82	3.56 ± 0.92	3.50 ± 0.73	3.75 ± 0.58	3.61 ± 0.96	3.67 ± 0.79	3.77 ± 1.03	3.82 ± 0.81
Q2. Useful	3.68 ± 0.85	3.84 ± 0.69	3.50 ± 0.82	4.00 ± 0.63	3.72 ± 0.79	3.74 ± 0.74	3.82 ± 0.95	3.71 ± 0.69
Q3. Relaxed	3.08 ± 0.64	2.96 ± 0.84	3.06 ± 0.77	3.44 ± 0.51	3.52 ± 0.98	3.78 ± 0.80	3.77 ± 0.90	3.77 ± 0.66
Q5. Energetic	3.00 ± 1.16	3.32 ± 0.95	3.19 ± 1.11	3.50 ± 0.82	3.13 ± 1.09	3.29 ± 0.95	3.47 ± 0.72	3.53 ± 0.51
Q6. Capable	3.52 ± 0.77	3.68 ± 0.63	3.81 ± 0.66	3.81 ± 0.83	3.69 ± 0.83	3.61 ± 0.72	3.77 ± 0.66	3.77 ± 0.56
Q7. Clear-minded	3.72 ± 0.68	3.72 ± 0.61	3.94 ± 0.57	4.00 ± 0.63	3.88 ± 0.76	3.79 ± 0.66	3.82 ± 0.73	3.77 ± 0.44
Q8. Self-satisfied	3.44 ± 0.92	3.56 ± 0.82	3.69 ± 0.70	3.63 ± 0.81	3.81 ± 1.01	3.88 ± 0.87	3.77 ± 0.90	3.71 ± 0.59
Q9. Connected	3.92 ± 0.91	3.96 ± 0.79	3.81 ± 0.54	3.88 ± 0.62	3.81 ± 0.77	3.66 ± 0.67	3.82 ± 0.81	3.77 ± 0.66
Q10. Confident	3.20 ± 0.91	3.36 ± 0.81	3.63 ± 0.62	3.88 ± 0.62	3.49 ± 1.01	3.54 ± 0.88	3.59 ± 0.80	3.71 ± 0.59
Q11. Decisive	4.00 ± 0.65	4.20 ± 0.58	4.06 ± 0.57	4.19 ± 0.54	3.99 ± 0.78	4.10 ± 0.85	3.94 ± 0.75	4.12 ± 0.78
Q13. Explorative	3.48 ± 1.01	3.68 ± 0.99	3.38 ± 1.03	3.81 ± 0.98	3.70 ± 0.87	3.77 ± 0.84	3.65 ± 0.79	3.71 ± 0.77
Q14. Cheerful	3.44 ± 0.58	3.60 ± 0.71	3.50 ± 0.73	3.88 ± 0.50	3.80 ± 0.78	3.86 ± 0.72	3.77 ± 0.75	3.71 ± 0.59
Tot Score	41.68 ± 6.68	43.44 ± 6.65	43.06 ± 4.99	45.75 ± 5.27	44.13 ± 7.93	44.67 ± 6.82	44.94 ± 7.15	45.06 ± 6.10

Values are presented as mean ± standard deviation (SD) for each item and total score.

6.3.2 Two-Way Repeated Measures ANOVA Analysis

Two-way repeated measures ANOVA were employed to examine the effects of group (intervention vs. control) and time (pre- and post-assessment) on mental health (subscales and total score of the WEMWBS).

6.3.2.1 Main Effect of Group

The statistical analysis revealed mixed findings regarding the impact of the intervention. Most variables showed no significant group effects except Q3 (relaxed: $F = 22.70$, $p < 0.001$, $\eta 2 = 0.120$) and Q9 (connected: $F = 4.50$, $p = 0.034$, $\eta 2 = 0.027$) (Table 6.2). The visualisation analysis of Q3 demonstrated that participants in the intervention group reported a higher relaxation score compared to the control group (Figure 6.1a,b). However, the result of Q9 (Connected) showed a different pattern. The intervention group reported higher scores in the pre-assessment, but the scores decreased in the post. Instead, the control group maintained relatively stable scores. The unexpected trend challenges the initial hypothesis about the intervention's impact on social connectedness.

Table 6.2. Repeated measures ANOVA results for WEMWBS scores.

	Main Effect (Group)			Main Effect (Time)			Main Effect (Sex)			Interaction (Group × Time)		
WEMWBS Dimensions	***F***	***p***	**Effect Size (Partial η^2)**	***F***	***p***	**Effect Size (Partial η^2)**	***F***	***p***	**Effect Size (Partial η^2)**	***F***	***p***	**Effect Size (Partial η^2)**
Q1. Optimistic	2.96	0.087	0.017	5.13	0.025 *	0.030	0.57	0.450	0.003	2.32	0.129	0.014
Q2. Useful	0.02	0.898	<0.001	4.05	0.046 *	0.024	0.76	0.385	0.005	4.05	0.046 *	0.024
Q3. Relaxed	22.7	<0.001 ***	0.120	2.59	0.110	0.015	0.47	0.495	0.003	0.67	0.414	0.004
Q5. Energetic	0.23	0.631	0.001	8.11	0.005 **	0.046	1.62	0.205	0.010	1.91	0.169	0.011
Q6. Capable	0.03	0.860	<0.001	0.03	0.858	<0.001	0.67	0.415	0.004	1.16	0.283	0.007
Q7. Clear-minded	0.07	0.787	<0.001	0.19	0.662	0.001	0.83	0.363	0.005	0.62	0.431	0.004
Q8. Self-satisfied	3.52	0.062	0.021	0.39	0.531	0.002	0.00	1.000	<0.001	0.00	0.973	<0.001
Q9. Connected	4.50	0.036 *	0.027	0.18	0.669	0.001	0.78	0.378	0.005	2.19	0.141	0.013
Q10. Confident	0.92	0.340	0.005	2.37	0.125	0.014	0.61	0.435	0.004	0.76	0.386	0.004
Q11. Decisive	0.32	0.570	0.002	3.56	0.061	0.021	0.00	1.000	<0.001	0.13	0.721	0.001
Q13. Explorative	0.98	0.324	0.006	3.88	0.050	0.023	0.47	0.492	0.003	1.47	0.227	0.009
Q14. Cheerful	3.48	0.064	0.021	6.50	0.012 *	0.037	0.89	0.348	0.005	3.48	0.064	0.020
Tot Score	1.38	0.243	0.008	6.82	0.010 **	0.039	0.89	0.346	0.005	3.32	0.070	0.019

Statistical significance is indicated as follows: $p < 0.05$: *, $p < 0.01$: **, and $p < 0.001$: ***; values with $p \geq 0.05$ are considered not statistically significant;-partial η^2 represents effect size, with $\eta^2 < 0.01$ considered small, $0.01 \leq \eta^2 < 0.06$ moderate, and $\eta^2 \geq 0.06$ large.

6.3.2.2 Main Effect of Time

The statistical analysis indicated significant time effects across several mental health dimensions, including total score ($F = 6.82$, $p = 0.010$, $\eta2 = 0.039$), Q1 (optimistic: $F = 5.13$, $p = 0.025$, $\eta2 = 0.030$), Q2 (useful: $F = 4.05$, $p = 0.046$, $\eta2 = 0.024$), Q5 (energetic: $F = 8.11$, $p = 0.005$, $\eta2 = 0.046$), and Q14 (cheerful: $F = 6.50$, $p = 0.012$, $\eta2 = 0.038$) (Table 2). The visualisation analysis showed a detailed pattern of different dimensions (Figure 6.1a,b). The control group exhibited increased means between the two assessments in dimensions such as total score, Q1 (optimistic), Q5 (energetic), and Q14 (cheerful). Surprisingly, the intervention group showed relatively stable scores over time. In Q7 (connected) and Q9 (clear-minded), the scores even showed the tendency to decrease, suggesting that the mental health may be influenced by external factors such as seasonal variations, rather than being affected by the PA intervention.

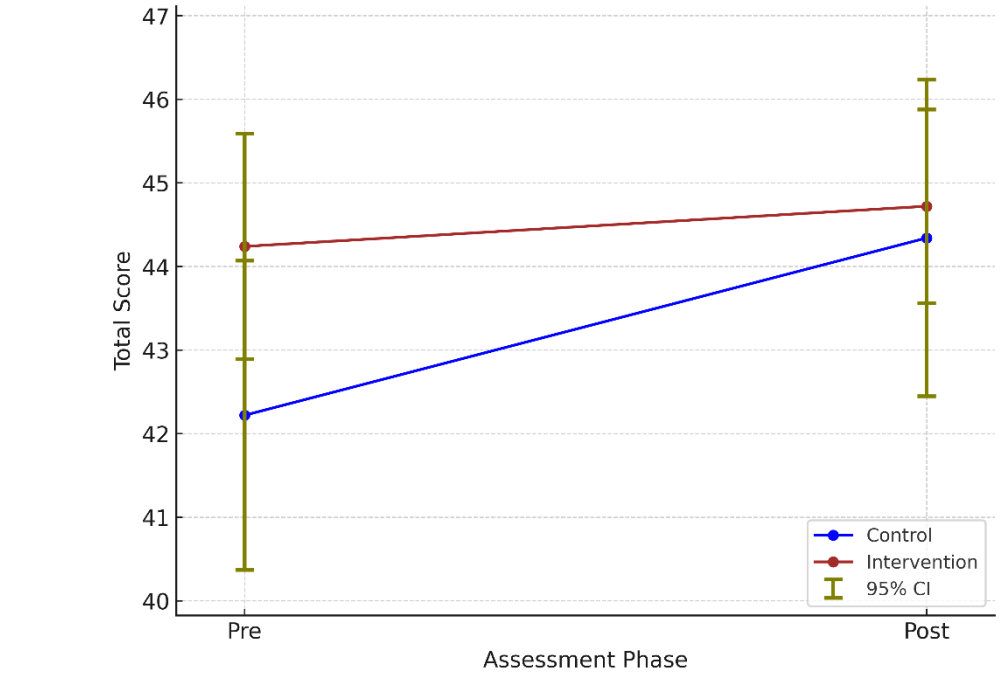
On the contrary, several dimensions did not show significant time effects. For example, Q3 (relaxed: $F = 2.59$, $p = 0.110$, $\eta2 = 0.015$), Q10 (confident: $F = 2.37$, $p = 0.125$, $\eta2 = 0.014$), and Q13 (explorative: $F = 3.88$, $p = 0.050$, $\eta2 = 0.023$) reported relatively stable scores across both groups. Despite the intervention group having higher scores in pre-assessment in some of these dimensions, the lack of significant time effects suggests that the PA intervention's impact may be more complex than the initial hypothesis.

6.3.2.3 Main Effect of Sex

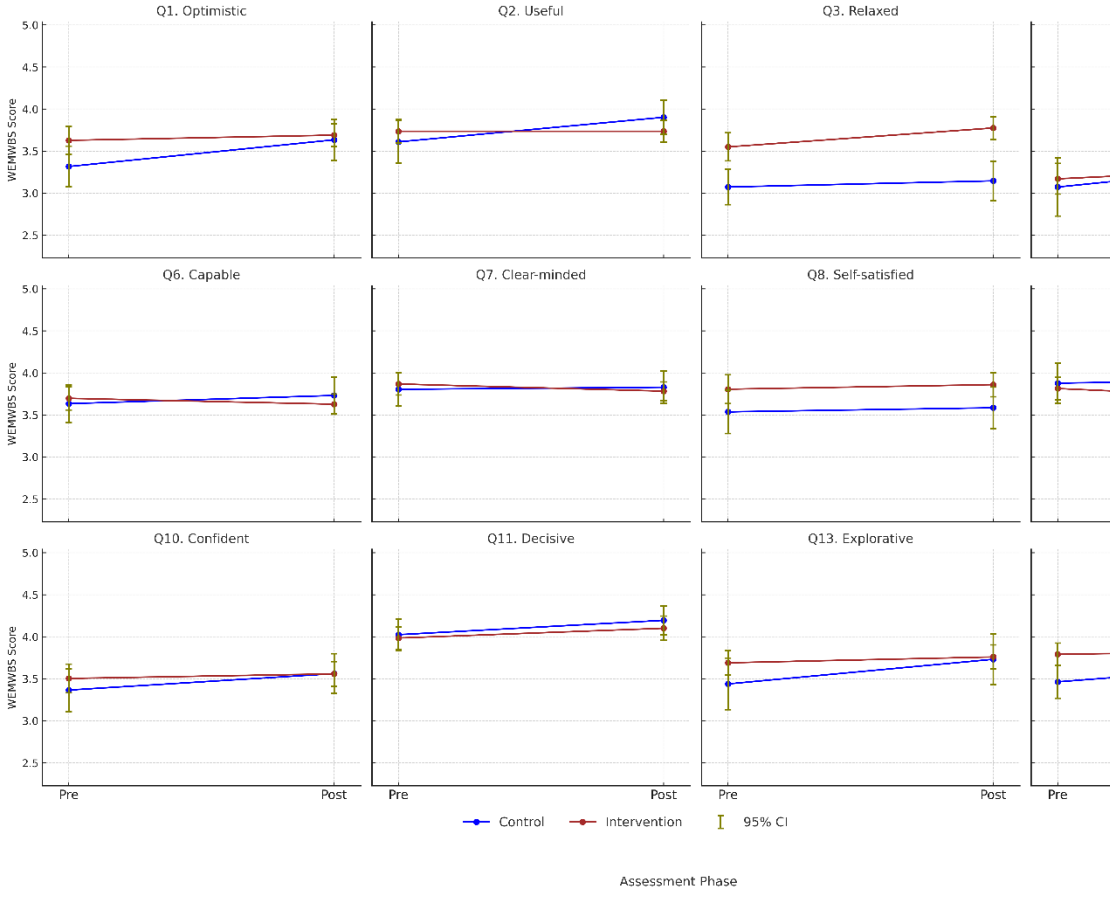
The influence of sex on mental health showed no significant main effects across any of the WEMWBS subscales or the Total Score ($p > 0.05$). The effect sizes measured by partial eta squared were consistently small ($\eta2 < 0.01$), indicating that there were no significant differences between males and females (Table 6.2).

6.3.2.4. Interaction Effect Between Group and Time

The analysis of the interaction effect between group and time showed a statistically significant result for Q2 (useful: $F = 4.05$, $p = 0.046$, $\eta2 = 0.024$), while total score ($F = 3.32$, $p = 0.070$, $\eta2 = 0.020$) and Q14 (cheerful) ($F = 3.48$, $p = 0.064$, $\eta2 = 0.020$) approached statistical significance (Table 6.2). The visualisation analysis also revealed interaction patterns (Figure 6.1a,b). For the total score, the control group showed a marked increase after the post-assessment, while the intervention group showed minor change. Similarly, Q2 (useful) and Q14 (cheerful) also showed significant improvement in the control group, while the scores of the intervention group remained stable, further supporting the potential role of environmental factors during the study period. Hence, the PA intervention did not provide additional mental health benefits for usefulness and cheerfulness in the intervention group, possibly due to higher baseline levels or ceiling effects.



(**a**)



(**b**)

Figure 6.1. (**a**) Total WEMWBS score over time. (**b**) WEMWBS dimension scores over time.

6.4 Discussion

This chapter examined the extent to which the supervised PA intervention carried out in UGS could improve mental health, as measured by the WEMWBS. In contrast to the positive outcomes reported in the previous chapter, the control group unexpectedly showed greater improvements over time than the intervention group on several dimensions, indicating that no significant intervention effect was observed. However, the prevailing studies have reported the positive mental health effects of PA interventions conducted in UGS [365]. For example, Rogerson et al. (2020) reported the significant contribution of medium-term green exercise interventions to participants' well-being, with particularly strong effects among those with low baseline well-being [366]. Similarly, Zuo et al. (2024) found that UGS contributes to improved mental health in older adults, through mediating pathways involving PA and perceived social inequality. [367]. Therefore, the counterintuitive results challenge general assumptions about PA interventions on mental health and suggest that multiple interacting factors aside from the intervention, such as seasonal variations, baseline effects, ceiling effects, instrument sensitivity, or intervention duration, may have contributed to the results. In the following paragraphs, we explore the possible explanations of the unusual findings in greater detail.

6.4.1 Potential Influence of Seasonal Variations

A rational explanation of the results is the influence of seasonal variations. The PA intervention was conducted from May to October 2023. During this period, there were changes in weather, temperature, and other environmental conditions which may have affected participants' perception, behaviours, and mental health status [368]. Previous studies have indicated seasonal influence on mental health. For example, the high temperatures in summer are associated with increased mental health problems including depression, stress, anxiety, and suicide rate [369-372]. Notably, Garriga et al. (2021) found that PA engagement typically increases during summer, particularly among more active populations. [373]. This suggests that seasonal temperature or humidity variations may have naturally affected the PA patterns of the participants, especially for the control group, potentially diminishing the observable effect of the supervised intervention. Therefore, considering seasonal variation may be essential for nature-based PA programmes aiming to improve mental health, as it can affect both participation patterns and psychological outcomes.

6.4.2 Baseline Effect and Ceiling Effect

Another potential explanation for the lack of significant intervention effects is the presence of baseline and ceiling effects in the intervention group. When participants begin with relatively high levels of mental health at pre-assessment, the potential for further improvement can be limited, both statistically and psychologically. This reflects the baseline effect, where dimensions with lower pre-assessment scores tended to show greater improvements [374]. In our sample, several dimensions with relatively high pre-assessment scores in the intervention group might limit the extent of measurable improvements. Specifically, the Q3 scores (relaxed) of the intervention group were already initially higher than the control group, with unobvious changes in the post-assessment. For Q1 (optimistic), Q5 (energetic), and Q14 (cheerful), the variables showed significant main effects of time, but the intervention group also showed little change. Meanwhile, a few other dimensions such as Q10 (confident), Q11 (decisive),

Q14 (cheerful), and especially Q11 (decisive) had mean scores approaching the maximum score of 5 on the scale. This pattern suggests a potential ceiling effect, where the 5-point Likert scale may lack the sensitivity to capture further improvements once scores approach the upper limit. As a result, even if participants experienced greater psychological benefits, these changes may not have been captured in the measurement [375].

6.4.3 Sensitivity of the WEMWBS

In addition, the findings also raise the question of the sensitivity of the WEMWBS in capturing mental health improvements induced by supervised PA interventions. In our previous longitudinal studies of the "Moving Park" project, simpler Likert scales reported significant effects of PA on well-being [322, 323]. Therefore, the WEMWBS may have relatively low sensitivity to the effects of PA on mental health. Similar results in sensitivity have also been observed in other existing studies. For example, Bell et al. (2019) found no association between PA and mental health when measured by WEMWBS, but did report significant associations with emotional symptoms using a Strengths and Difficulties Questionnaire (SDQ), highlighting that the WEMWBS may underestimate specific psychological changes related to PA interventions. [376]. A possible explanation for this limitation is the design of the scale, as WEMWBS measures subjective general mental well-being over two weeks rather than the stress reduction and mood diversion induced by PA [377, 378]. Considering that overall well-being is affected by various domains, including social interactions, environmental factors, and life events, the impact of PA may be diluted within this more comprehensive framework [379-381]. In future studies, alternative psychological assessment scales which focus on mood fluctuations, stress reduction, or cognitive function should be used to improve the sensitivity. Additionally, portable assessment devices are also a reasonable approach [382, 383].

6.4.4 Duration and Dosage of the PA Intervention

The limited duration and dosage of the PA intervention may have also caused the unexpected results. Existing research has shown that the psychological benefits of PA require long-term engagement, and it is possible that the few months of intervention in this study were not enough to provide substantial and lasting improvements in mental health [233, 384]. Evidence suggests that the psychological benefits of PA often require sustained engagement over several months or longer, particularly when aiming to influence general well-being rather than immediate mood states [385-387]. Meanwhile, one of our cross-sectional studies of the "Moving Parks" project revealed a dose–response relationship between the duration and intensity of PA and the MWBS score [388], which also highlights the critical role of PA dosage. Future research should consider extending the PA intervention duration and monitoring participants over a longer follow-up period to determine whether long-term engagement in supervised PA provides better mental health effects. At the same time, the intensity of the PA should also be taken into the consideration as a parameter. The findings contribute to the broader thesis objective by providing a rigorous, quasi-experimental examination of supervised PA in UGS. They complement the previous chapter's positive outcomes by illustrating the methodological and contextual challenges of demonstrating causal links between UGS exposure and well-being. This chapter therefore refines the understanding of how UGS promote mental health, emphasising that their benefits depend not

only on access and participation, but also on engagement duration, environmental context, and appropriate measurement tools.

Limitations

Several limitations of this chapter should be acknowledged. Firstly, the intervention and control groups differed in terms of sample size and certain baseline characteristics. Although this reflects the constraints of the participant recruitment, this difference may have affected the statistical power and introduced bias. Future experiments should improve the matching of participant characteristics between groups. Secondly, the study did not collect detailed information on participants' PA patterns beyond project attendance, particularly in the control group. This limits the ability to isolate the effects of the supervised PA from general lifestyle factors. Meanwhile, due to practical limitations, details about participants' attendance and engagement with specific PA types were not collected. This limited our ability to analyse dose–response relationships. Future studies should consider monitoring attendance to better understand how participation level influences outcomes. Thirdly, although seasonal variation was discussed as a possible influencing factor, the study design did not control for environmental variables such as temperature or daylight hours. However, these factors are inherent to UGS settings and are a part of the ecological context of the intervention. Rather than viewing them only as confounding variables, they reflect the complexity and value of natural green spaces outside of laboratory conditions. Nevertheless, future research may consider seasonal adjustments or conduct interventions across different months to better understand its potential influence. Fourth, although the WEMWBS is a widely used assessment tool, it may not be the most sensitive instrument for detecting short-term or activity-specific psychological benefits. Future studies could consider alternative measures, such as portable devices, for more objective results. Lastly, the relatively short intervention duration or the low intensity of the PA may not have been sufficient to produce measurable improvements in mental health. Future studies should consider extending the intervention period and incorporating follow-up assessments to capture longer-term effects.

Appendix D

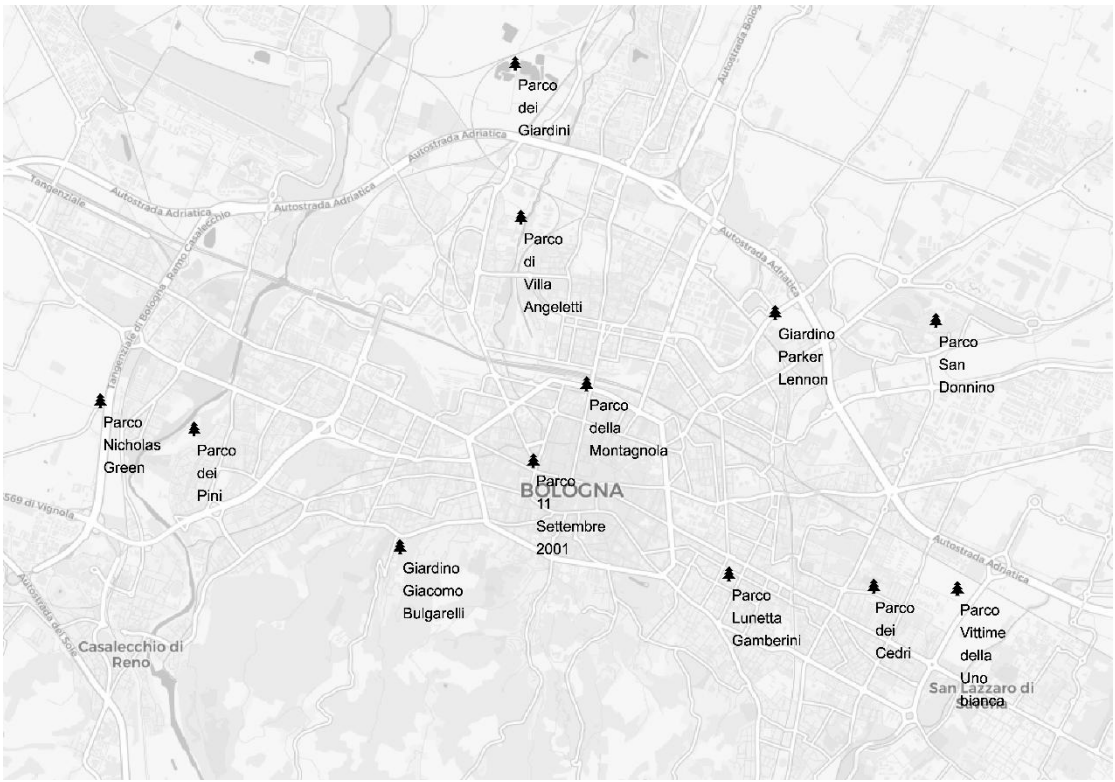


Figure D1. Map of Bologna, with the parks included in the project.

- **Parco dei Cedri (District Savena)**

Covering approximately 11 hectares, this park is one of Bologna's main green areas, located in the Savena district along the Savena River and inaugurated between the 1970s and 1980s. The park boasts a rich variety of plant species such as cedars, pines, and firs, and includes visitor amenities such as a children's playground, benches, and water fountains.

- **Parco Vittime della Uno bianca (District Savena)**

This park is a significant memorial park, located in Bologna, with a solemn monument dedicated to the 24 victims who tragically lost their lives due to the criminal activities of the "Banda della Uno Bianca" between 1987 and 1994. Beyond its role as a memorial, the park functions as a community space for public events and activities.

- **Parco della Montagnola (District Santo Stefano)**

Covering an area of 6 hectares, this park is the oldest public park in the city, inaugurated in 1662. Over the centuries, the park has undergone various transformations, including the adoption of a French-style garden design in the 19th century. Today, the park features wide avenues, a central fountain, and a monumental staircase that offers a panoramic view of the city.

- **Parco Lunetta Gamberini (District Santo Stefano)**

Covering approximately 14.5 hectares, the Giardino Lunetta Gamberini is a large public park that hosts several facilities for all ages, including four school complexes, a sports centre, and children's playgrounds. The park is surrounded by a dense mixed hedge made up of Judas trees, forsythia, blood plums, spiny brooms, and other ornamental shrubs, which shield it from

surrounding traffic noise. Easily accessible, this green area is a reference point for both residents and visitors for relaxing, sports, and socialising.

- **Parco San Donnino (District San Donato-San Vitale)**

Inaugurated in 2013, the Parco San Donnino is a large green space created through collaboration between residents, associations, and institutions to provide a place for gathering and well-being. With its 14.5 hectares, the park offers expansive green spaces for outdoor activities, including an outdoor gym dedicated to callisthenics and street workout.

- **Giardino Parker Lennon (District San Donato-San Vitale)**

Covering approximately 4.8 hectares, the Giardino Parker Lennon, known also as the Giardino Charlie Parker—John Lennon, offers green spaces, sport facilities, and cultural activities for residents and visitors. In recent years, the park has undergone revitalization efforts thanks to collaboration between citizens, associations, and local institutions. Improvements have been made to lighting, security, and park maintenance, with the goal of making the space more liveable and welcoming to the community.

- **Parco di Villa Angeletti (District Navile)**

Situated along the right bank of the Navile Canal, this 8.5-hectare park features wide open meadows, wooded areas with native broadleaf trees, and a tinwork of cycling paths. The park preserves the natural morphology of the area, with fruit trees and native vegetation along the canal.

- **Parco dei Giardini (District Navile)**

Covering approximately 9 hectares, this park is a large green space located bewteen Via dell'Arcoveggio and Via dei Giardini, near the historic centre of Corticella. Created in 1990s, the park is an important green lung for the city with many trees, a central pond, children's play areas and fitness trails.

- **Parco 11 Settembre 2001 (District Porto—Saragozza)**

Located in the heart of Bologna, this park covers an area of about 2 hectares, offering children's play area and dogs area. The park is a peaceful and social green space, ideal for families, students and anyone looking to enjoy a moment of relaxation outdoors.

- **Giardino Giacomo Bulgarelli (District Porto—Saragozza)**

Covering approximately an area of 3.3 hectares, this urban park is inaugurated in 2015 and named in honour of the legendary captain of Bologna F.C. The park provides wide grassy spaces with a variety of vegetation and sports areas for outdoor activities.

- **Parco Nicholas Green (District Borgo Panigale—Reno)**

With its 8 hectares, the Parco Nicholas Green is a recreational park equipped with various sports facilities, including a basketball court, a skating ring, a football field, and a bocce court. Furthermore, multiple playgrounds are available, making it an ideal spot for families with children. For relaxing and social gatherings, the park offers benches and fountains.

- **Parco dei Pini (District Borgo Panigale—Reno)**

Covering approximately 4 hectares, the park is located on an area that originally belonged to the municipal aqueduct. The park is characterised by a dense and constant tree cover: the name of the park comes from the large number of domestic and maritime pine trees. Furthermore, this green area offers playgrounds for children, benches, drinking fountains, and tree-lined paths.

Appendix E

Table E1. Overview of physical activities offered in 12 parks included in the project.

Parks and Activities	Parco Nicholas Green	Parco di Villa Angeletti	Parco Della Montagnola	Parco San Donnino	Parco dei Cedri	Giardino Lunetta Gamberini	Parco Vittime Della Uno Bianca	Giardino Parker Lennon	Parco dei Giardini	Giardino Giacomo Bulgarelli	Parco 11 Settembre 2001	Parco dei Pini
Aikido	-	✓	✓	-	-	-	-	-	-	-	-	-
Aerial Silks	-	✓	-	-	-	-	-	-	-	-	-	-
Argentine Tango	-	-	-	-	-	✓	-	✓	-	-	-	-
Badminton	-	-	✓	-	-	-	-	-	-	-	-	-
Belly Dancing	✓	-	-	-	-	-	-	-	-	-	-	-
Body Weight Training	-	-	-	-	-	-	✓	-	-	-	-	-
Body–Mind Energy Balance	✓	-	-	-	-	-	-	-	-	-	-	-
Capoeira	-	✓	✓	-	-	✓	✓	✓	✓	✓	✓	-
Contemporary Dance	-	-	-	-	-	-	✓	-	-	-	-	-
Contemporary Dance Kids	-	-	-	-	-	-	✓	-	-	-	-	-
Creative and Movement Workshops	-	-	-	✓	-	-	-	-	-	-	-	-
Cxworx	-	-	-	✓	-	-	-	-	-	-	-	-
Dance	-	-	-	✓	✓	✓	✓	-	✓	-	✓	-
Feldenkrais	-	-	✓	-	-	✓	-	-	-	✓	✓	-

Functional Training	✓	✓	-	-	-	-	-	-	-	-	✓	-
Gentle Gymnastics	-	✓	-	✓	✓	✓	✓	-	-	✓	-	-
Gymnastics	-	-	-	-	✓	✓	-	-	-	-	-	✓
Gyrokinesis	-	✓	-	✓	-	-	-	✓	-	-	-	-
Handstand Training	-	-	-	-	-	-	-	-	-	✓	✓	-
Judo Games	-	✓	-	-	-	-	-	-	-	-	-	-
Juggling	-	-	✓	-	-	-	-	-	-	✓	✓	-
Karate	-	✓	-	-	-	-	-	-	-	-	-	-
Kinesis	-	✓	-	-	-	-	-	✓	-	-	-	-
Krav Maga	✓	-	-	-	-	-	-	-	-	-	-	-
Kung Fu	-	-	✓	-	-	✓	-	✓	-	-	-	-
Low-Intensity Movement	-	-	-	-	✓	-	✓	-	-	-	-	-
Meditation	-	-	-	-	-	-	-	-	✓	-	-	-
Morning Stretching	✓	-	-	-	-	-	✓	-	-	-	-	-
Multisport Activities	✓	✓	✓	-	-	✓	-	-	-	-	-	-
Muscle Strengthening	-	-	-	✓	-	-	✓	-	-	-	-	-
Nordic Walking	-	✓	-	-	✓	-	-	-	✓	-	-	✓
Orienteering	✓	-	-	-	-	-	-	-	-	-	-	-
Pilates	-	-	-	✓	✓	✓	✓	✓	-	✓	✓	✓
Popular Fitness	-	✓	-	-	-	-	-	-	-	-	-	-

Postural Gymnastics	✓	✓	✓	-	-	-	-	-	-	✓	-	-
Pre-boxing Training	-	✓	-	-	-	-	-	-	✓	-	-	-
Power Hit		-	✓	-	-	-	-	-	-	-	-	-
Qi Gong	-	✓	✓	-	✓	✓	-	-	✓	-	-	-
Rugby	✓	-	-	-	-	-	-	-	-	-	-	-
Run Game	-	-	✓	-	-	-	-	-	-	-	-	-
Self Defence	-	✓	✓	-	-	-	-	-	-	-	-	-
Stretching	✓	-	-	✓	✓	-	-	-	-	-	-	-
Tabata	✓	-	-	-	-	-	-	-	-	-	-	-
Tai Chi	✓	-	-	-	-	-	✓	✓	-	-	-	-
Tone Up	-	-	-	-	✓	-	-	-	-	-	-	-
Total Body	✓	-	-	✓	-	✓	-	-	-	✓	✓	-
Ultimate Frisbee	-	-	-	-	-	-	-	-	-	-	-	✓
Walking	✓	✓	-	✓	✓	-	-	-	✓	-	-	-
Walking and English talking	-	-	-	-	✓	-	-	-	-	-	-	-
Wing Tsun	-	-	✓	-	-	-	-	-	-	-	-	-
Yoga	✓	✓	-	✓	✓	✓	✓	-	-	✓	-	-

“✓” means offered; “-” means not offered.

Chapter 7 – Beyond Behaviour: Microclimate Evidence from a Green Redevelopment

This chapter is based on the manuscript which is currently under preparation and will be submitted to a peer-reviewed journal.

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Keywords: urban microclimate; ENVI-met; green redevelopment; thermal comfort; health promotion

Summary

This chapter shifts the focus from behavioural perspective of urban green spaces (UGS) to the environments that sustain those experiences. Through the case of the Marconi district in Imola, it explores how urban form and vegetation structure shape local thermal comfort during periods of extreme heat. Using microclimate simulation (ENVI-met) as a tool, the analysis contrasts current conditions with those expected after the planned redevelopment of the area. The modelling allows an interpretation of how design choices (such as the placement of trees and buildings) can alter the balance between comfort and exposure, revealing both opportunities and constraints within the evolving urban landscape. Rather than seeking numerical precision, the study illustrates how the physical environment forms the basis on which health-promoting spaces can exist. In doing so, it completes the thesis' overall narrative, connecting the behavioural and environmental dimensions of urban well-being within a single, integrative framework.

7.1 Introduction

Urban environments are increasingly challenged by the intensification of heatwaves and the progressive densification of built areas, which together increase local thermal stress and threaten urban liveability [389-391]. As discussed in the previous sections of this thesis, the health-promoting potential of urban green spaces (UGS) has often been examined through behavioural and perceptual perspectives [40, 66, 114]. However, these approaches alone cannot fully capture the physical mechanisms that underpin comfort and well-being. The microclimatic properties of UGS, particularly their capacity to moderate air temperature, radiation, and wind flow, form the environmental foundation upon which subjective benefits can manifest [252, 392, 393]. In this context, assessing the physical performance of green infrastructure becomes essential to understanding how design and vegetation structure translate into tangible improvements in human comfort.

In recent years, the increase in extreme heat events across European cities has intensified the need to understand how urban green spaces contribute to local thermal regulation [394-396]. Although the cooling benefits of vegetation are widely acknowledged, the magnitude and spatial distribution of these effects often vary across different urban settings, depending on built density, surface materials, and the configuration of open areas [295, 397, 398]. Consequently, the role of UGS in mitigating heat cannot be assumed to be uniform or universally effective [295, 393, 399]. A more spatially explicit and model-based approach is therefore needed to examine whether the presence and arrangement of green spaces genuinely improve thermal conditions within a specific neighbourhood context [295, 399, 400].

To address this gap, the present chapter focuses on examining the microclimatic performance of UGS within the neighbourhood of the Marconi district (Quartiere Marconi) in Imola, where an ongoing redevelopment project is reshaping both the spatial configuration and the vegetation structure of the area. Through ENVI-met simulation of two scenarios (ex ante and ex post), the study aims to:

a) analyse the spatial patterns of Physiological Equivalent Temperature (PET) across the neighbourhood under extreme-heat conditions, providing an overview of how thermal comfort varies with land cover and built form;
b) evaluate the thermal effects of the regenerated block, assessing whether the newly introduced trees and design modifications can alleviate heat stress or generate localised warming near new façades; and
c) compare thermal comfort between the standard adult and elderly models, highlighting age-related differences in vulnerability to microclimatic exposure.

By linking thermal mapping with design intervention and demographic vulnerability, this chapter complements the behavioural and perceptual findings presented earlier in the thesis, thereby situating health promotion within the physical and spatial realities of the urban environment.

7.2 Methods

7.2.1 Study Area and Scenario Setup

This chapter reports two ENVI-met simulations conducted in the Marconi district (Quartiere Marconi) of Imola, within the Bologna Metropolitan Area. As described in Chapter 4, this district is a residential neighbourhood in Imola undergoing urban redevelopment with green space expansion. The primary aim of public administration concerning this area is the regeneration of the disused site, which will be achieved by the construction of a residential complex comprising four-storey buildings. In addition, plans for the area include new sports facilities for general interest, as well as green spaces for public use. The project site is subject to a public-private partnership and covers an area of 123,115 square metres. The area had previously been home to a butchery, a municipal warehouse, open spaces and a recycling centre. The sports facilities (namely, the municipal swimming pool and the gyms with public car parks) and the railway underpass for cyclists and pedestrians (built in 2022 and co-financed by the Periferie Call for Proposals) have already been constructed in the vicinity of the residential area covered by the simulation. The demolition of the disused buildings of the former recycling centre is currently ongoing, while the municipal warehouse, open spaces and associated facilities remain extant[401].

Two ENVI-met scenarios were developed to assess the potential impact of the planned regeneration project on local microclimatic conditions. The project involves transforming a block in the north-eastern section of the study area into a planned public green area, as this block was identified by the Municipality as a priority site for urban renewal. Specifically, the ex ante represents the current configuration of the area, while the ex post reflects the planned condition after the proposed regeneration. Both scenarios were simulated under identical meteorological forcing, allowing a direct comparison between pre- and post-intervention microclimatic conditions (Figure 7.1).

7.2.2 Meteorological Forcing and Simulation Period

To reproduce the extreme thermal conditions characteristic of summer heatwaves, the simulations focused on the 22nd of July, 2022, identified as a peak day within one of the regional heatwave episodes recorded in recent years in northern Italy (the 22nd–25th of July). Hourly meteorological data were obtained from the Scarabelli Institute weather station in Imola (location: 44.36° N, 11.72° E) and used to initialise the ENVI-met model under Full Forcing mode. The forcing dataset included air temperature, relative humidity, wind speed and direction, and global radiation, covering a 24-hour period from 00:00 to 24:00 local time. These parameters provided the boundary conditions required to simulate the diurnal evolution of air temperature and thermal comfort. Outputs were generated for 13:00, 15:00 and 17:00, representing the main hours of afternoon heat stress. Among them, 15:00 was selected for detailed spatial analysis, as it corresponds to the maximum air temperature and the most critical conditions for outdoor thermal comfort.

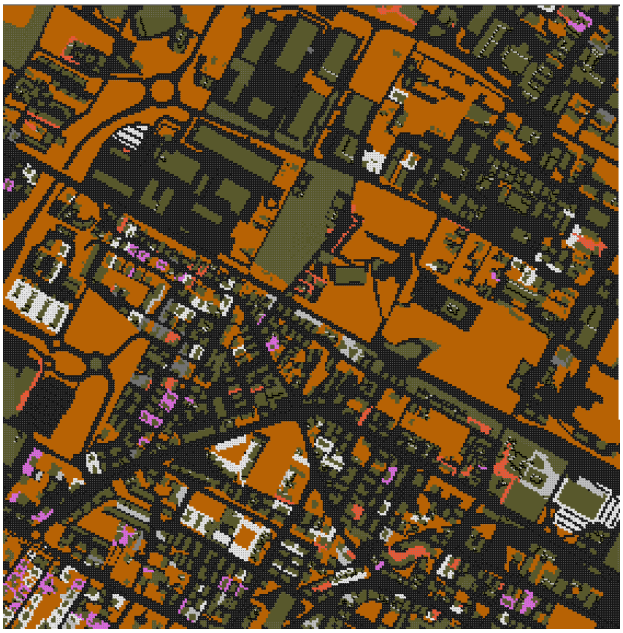
7.2.3 Model Configuration and Parameterisation

The computational domain covered an area of approximately 1400 × 1400 m, with a horizontal resolution of 5 m, discretised into 300 × 300 grid cells (Figure 7.1). The model

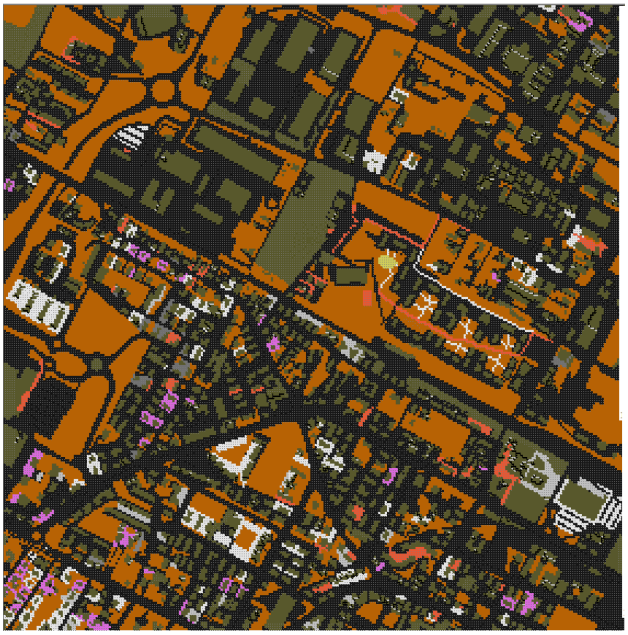
included 30 vertical layers, with the first grid cell height of 0.2 m to resolve near-surface gradients. Building attributes were sourced from the GIS database provided by the Municipality of Imola. The dataset including footprints, heights and material classes (façade and roof), which were directly imported into the ENVI-met model to reproduce the actual building morphology (Figure 7.3). Surface data, including artificial surfaces, bare soil and green areas, were taken from the GIS database provided by the Municipality of Imola and verified through on-site observations. The dataset was further refined using Google Maps, and the final land cover layers were redrawn in ArcMap to ensure accurate representation of surface types (Figure 7.2). Vegetation data were collected by manually marking individual trees on Google Maps and verifying each position through Google Street View and on-site observation. For every tree within the study area, species and height were recorded, and the complete dataset was then digitised and mapped in ArcMap for model input. Each recorded species was then matched with the corresponding or most similar vegetation type available in the ENVI-met plant database and entered into the model (Figure 7.3). These data were used to parameterise the spatial distribution and physical attributes of surfaces and vegetation in the ENVI-met model.

(**a**) Ex ante (**b**) Ex post

Figure 7.1. Study area in the Marconi neighbourhood, Imola (1400 × 1400 m)



(**a**) Ex ante



(**b**) Ex post

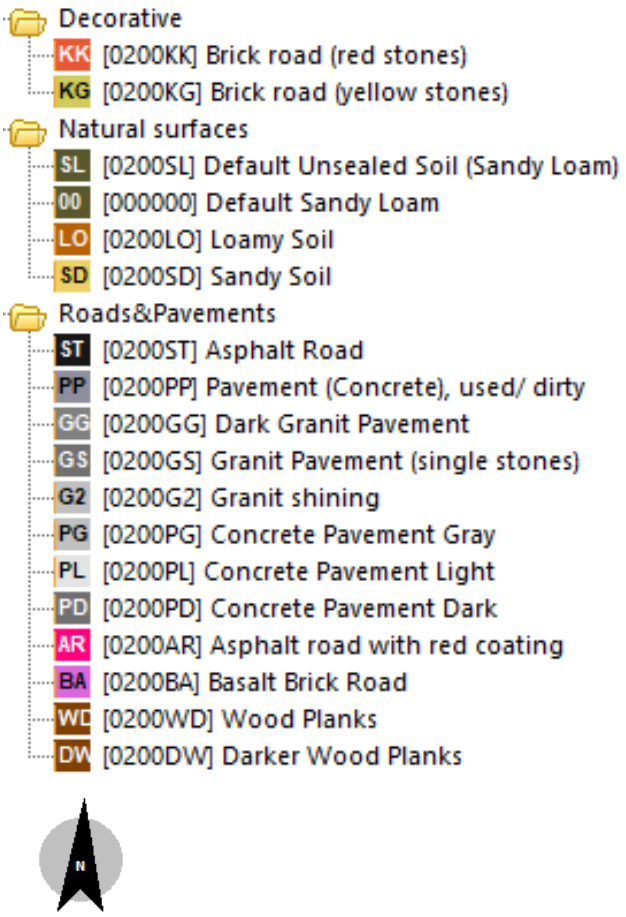


Figure 7.2. Classification of surfaces in the study area.

(**a**) Ex ante (**b**) Ex post

Figure 7.3. Vegetation distribution in the study area.

7.2.4 Output Variables and Analysis

The analysis focused on Physiological Equivalent Temperature (PET) as the primary outcome, with air temperature and surface temperature used as contextual variables. PET was computed at pedestrian level (1.8 m) for two representative subjects: (i) a standard adult (35 years old, 1.8 m, 80 kg), and (ii) an elderly adult (> 80 years old, 1.8 m, 80 kg), both in typical summer clothing (short-sleeved attire). Under identical anthropometric and clothing settings, the differences between males and females in the modelled PET were negligible, so results are reported without separating by sex.

The analysis focused on the time of maximum thermal stress (15:00). For each scenario (ex ante, ex post) and each modelled subjects (35 and 80 years old), PET maps were produced, together with difference maps to visualise the spatial extent of temperature reduction across the study area, capturing both the direct cooling of the regenerated block and the secondary effects on adjacent urban surfaces. Wind vectors at 1.8 m were inspected to characterise the background flow; as no material scenario-driven changes were observed, wind is not discussed further beyond qualitative reference.

7.3 Results

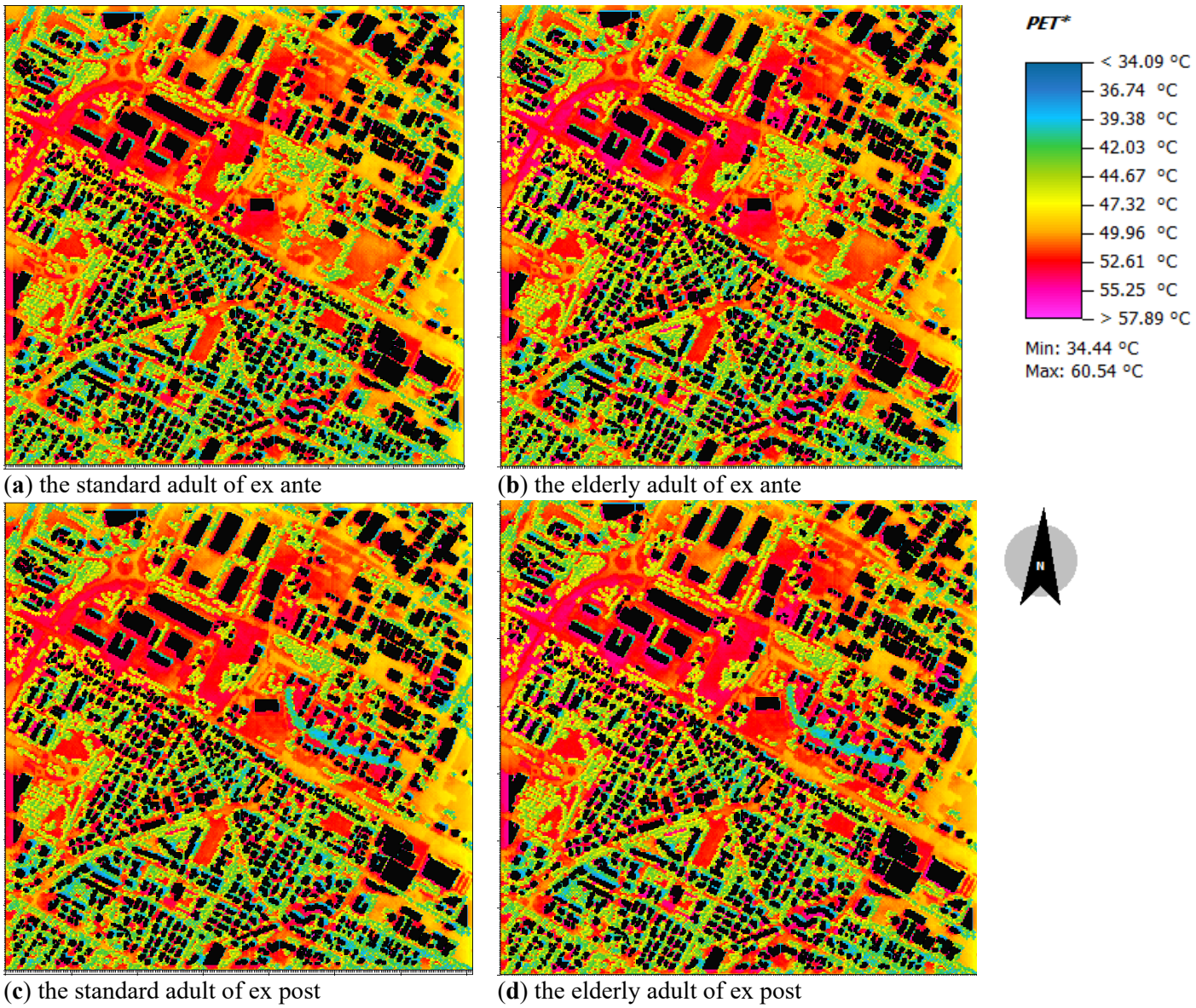
7.3.1 Visualisation Analysis

The analysis focused on the PET, which was used to represent the spatial distribution of outdoor thermal comfort across the study area. As described in the Methods, the simulation outputs at 15:00 were selected to capture the peak thermal load of the heat wave. Both the ex ante and ex post PET maps (Figure 7.4) reveal strong spatial contrasts associated with land-cover heterogeneity, consistent across both the standard and elderly adult models.

Specifically, the hottest zones extend across impervious surfaces, such as roads, paved courtyards and parking areas, and also across open grasslands or bare soil where they are fully

exposed to sunlight. Within these zones, the PET frequently reaches 49-53 °C, with local peaks approaching approximately 60 °C. Among artificial materials, slight differences appear. Darker asphalt and concrete retain the highest PET, while semi-paved or lighter pavements are slightly cooler by about 1-1.5 °C, insufficient to alter the overall pattern of thermal stress. The coolest zones coincide precisely with existing tree crowns, where PET drops into the lowest class (< 38.3 °C), with edge zones occasionally entering the 39-41 °C bands. Between buildings, narrow shaded corridors produce intermediate values, and local heat accumulation near façades reflects limited ventilation and multiple reflections of short-wave radiation (Figure 7.4).

At the broader scale, a clear north–south contrast characterises the overall spatial pattern, divided by the railway. The persistence of high PET values is particularly evident in the northern area, where large industrial blocks and extensive artificial surfaces create a continuous belt of thermal stress. In contrast, the southern residential area characterised by abundant street trees and courtyard vegetation shows distinctly lower PET values. The continuous canopies formed by street trees keep PET mostly lower than 41 °C, supporting a cooler and more comfortable thermal environment throughout the southern residential area. Altogether, the results landscape show that neither grass nor high-albedo or permeable pavements could compensate for direct solar exposure. Genuine cooling affect occurs almost exclusively under tree cover (Figure 7.4).



(**a**) the standard adult of ex ante (**b**) the elderly adult of ex ante

(**c**) the standard adult of ex post (**d**) the elderly adult of ex post

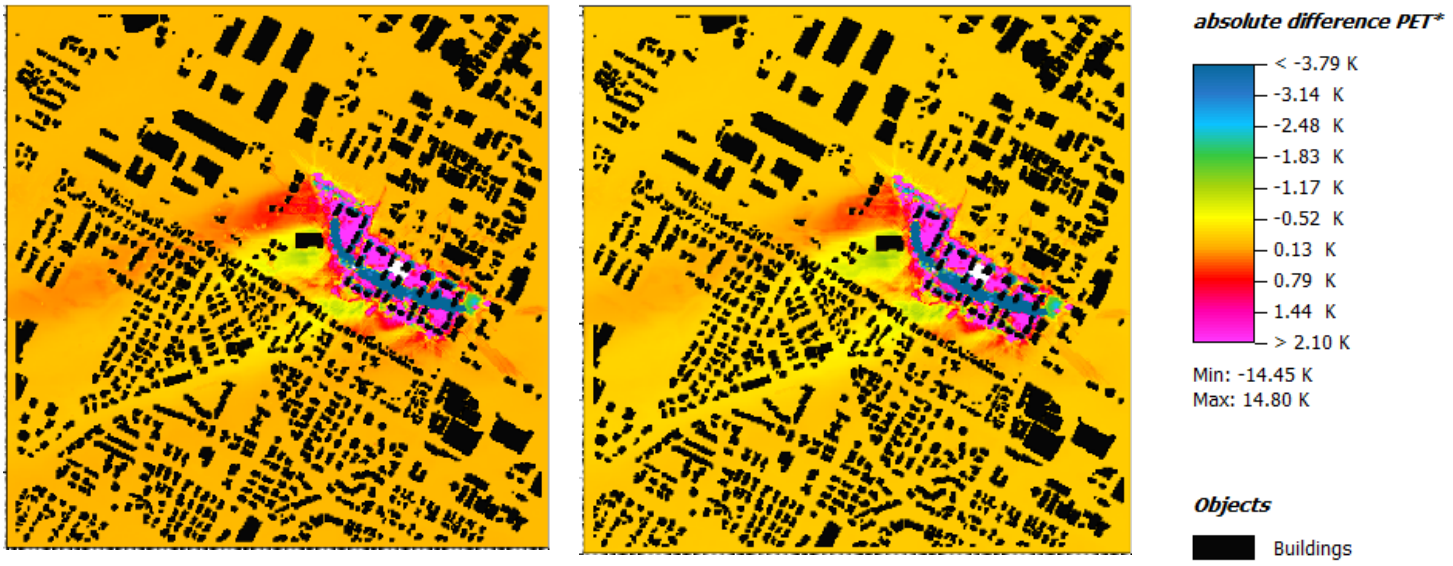
Figure 7.4. Physiological Equivalent Temperature (PET) maps for the standard adult and elderly models under ex ante and ex post scenarios.

7.3.2 Comparison between Two Scenarios

The comparison between ex ante and ex post shows that the regenerated block distinctly changed in the thermal conditions, regardless the modelled subjects. Specifically, PET beneath the newly planted canopy generally remains below 41 °C, whereas on exposed pavements and lawns elsewhere frequently exceeds 49 °C. The cooling effect extended several metres beyond the canopy line, lowering PET by around 1-2 °C along adjacent courtyards and pavements (Figure 7.4).

The PET difference map (ex post minus ex ante) (Figure 7.5) indicates that the PET response is spatially heterogeneous. Within the regenerated block, the PET beneath the newly planted tree canopies decreases by 1 °C to 3 °C, with a maximum local drop of about 3.5 °C at the park core. Paved surfaces surrounding the canopy zone show only minor changes (≤ -0.5 °C). In contrast, the distinctly increased PET of about 0.5 to 2 °C is observed along both sides of

the newly planned canopy, coinciding with the positions of newly introduced buildings. The PET rise extends onto the adjacent pavements, where values remain about 0.5 to 1 °C higher than the ex ante. South-west of the regenerated block, the PET difference map displays a distinctive radial pattern. A narrow warm streak, with increases of about 1 to 2 °C, extends westward from the block's upper boundary, forming a gentle arc across the study area. Just below it, along the south-western edge of the regenerated area, lies a thin belt of slight cooling, where PET decreases by around 0.5 to 1 °C.

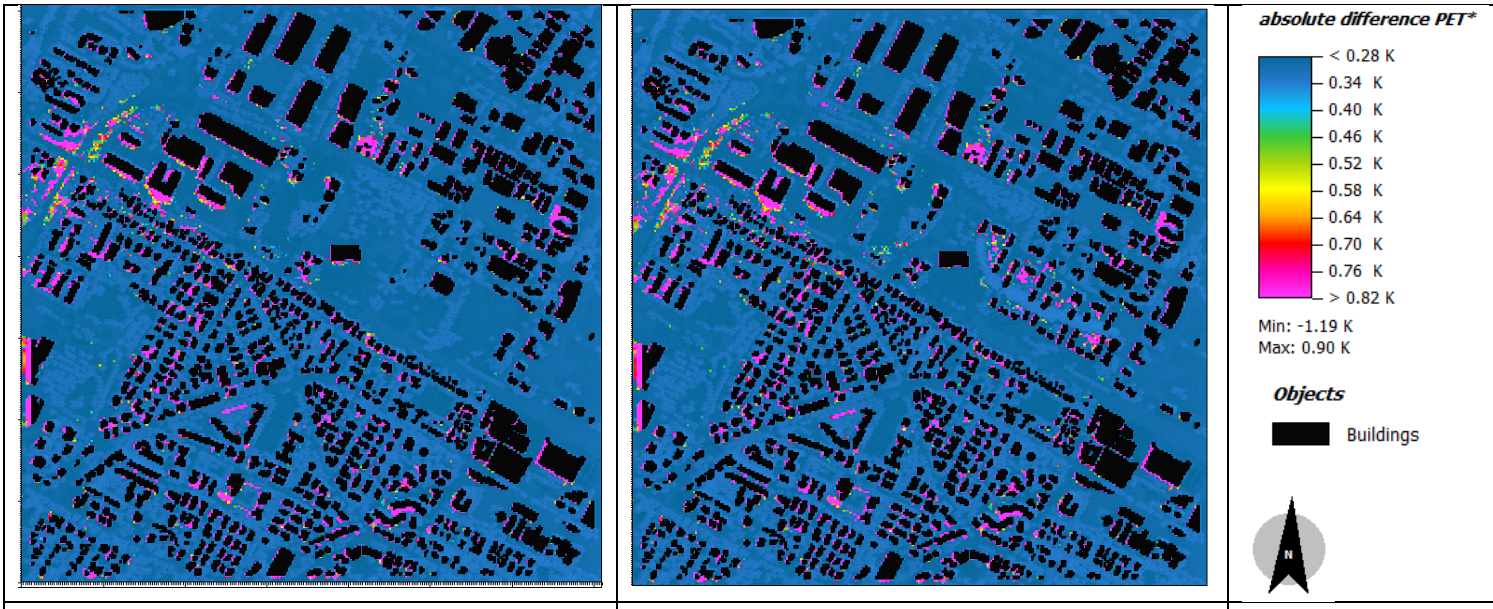


(**a**) the standard adult model (**b**) the elderly adult model

Figure 7.6. Difference in Physiological Equivalent Temperature (PET) between two scenarios (ex post minus ex ante)

7.3.3 Comparison between Two Modelled Subjects

Across the study area, differences between the elderly and standard adult models are minimal. Across the study area, in both the ex ante and ex post maps, the difference in PET between the elderly and standard adult models remains minimal, generally below 0.5 °C, with slightly higher values (around 0.8-0.9 °C) occurring along building edges and courtyards. The lowest differences generally occur in continuous canopies, whereas slightly higher values align with façade lines. These areas of increased PET typically appear along the south-western sides of buildings, coinciding with the extent of their projected shadows. The regeneration does not change the overall pattern comparable to the baseline. The field remains dominated by < 0.5 °C differences, and there is no coherent, overall narrowing or widening of the PET gap. Within and around the regenerated block, small patches of change appear near façades and openings, but they are localised and do not form a systematic trend (Figure 7.6).



(**a**) ex ante (**b**) ex post

Figure 7.6. Difference in Physiological Equivalent Temperature (PET) between the modelled subjects (the elderly adult minus the standard adult)

7.4 Discussion

The simulations demonstrated that tree canopies provide the most decisive influence on local thermal comfort. In both the current (ex ante) and regenerated (ex post) configurations, meaningful cooling occurred almost exclusively beneath continuous canopies, while grass or other low vegetation produced negligible mitigation [402, 403]. The newly planted trees in the regenerated block reduced PET by up to 3.5 °C at the core area and by 1-2 °C along the surrounding pavements, confirming the capacity of trees to buffer heat exposure at pedestrian level [403-405]. In contrast, newly introduced buildings generated small but consistent warming bands along façades, consistent with previous findings on heat accumulation heat accumulation near façades. [406, 407]. Although the overall PET differences between the elderly and standard adult models remained modest, heat amplification near buildings had a relatively stronger impact on the elderly, highlighting the spatial concentration of thermal vulnerability [408-410]. These findings reveal a dual condition: effective greening can substantially alleviate local heat stress, yet architectural densification may counteract such benefits, particularly for more sensitive groups.

Tree canopy density was identified as the principal determinant of thermal improvement [402]. The simulated reduction in PET beneath the canopies corresponds with the mechanisms of shading and evapotranspirative cooling. Shaded zones interrupt short-wave radiation exchange and reduce mean radiant temperature, while transpiration enhances latent heat flux and moderates air temperature [402, 404]. The combined effect is a marked lowering of physiological heat load even under extreme meteorological forcing [411]. In contrast, lawns and permeable surfaces displayed limited influence. Without overhead shading, the PET remains limitedly altered, and surface albedo differences of 1-2 °C cannot compensate for direct solar exposure. Similar conclusions were reached in empirical and modelling studies [412, 413]. This distinction underscores that qualitative greening, in terms of vertical structure and foliage cover, is more relevant to human comfort than mere quantitative expansion of

vegetated area. Hence, from the perspective of urban planning and public health, these results reinforce the need to prioritise tree planting and canopy management. Increasing canopy continuity not only mitigates urban heat but also enhances the usability of outdoor spaces during hot periods, thereby indirectly supporting physical activities (PA) and social interaction, which are two behavioural pathways leading to health promotion [402, 414]. In this sense, the environmental achievement forms the ecological foundation for the broader well-being outcomes which are discussed throughout this thesis.

Although the canopies can effectively alleviate heat stress, the built-up areas exhibit a modest but coherent rise in PET, particularly along the south-western façades which coincide the building projection areas. This pattern reflects the well-known processes of radiative trapping and heat storage associated with dense urban forms. Building envelopes with low albedo and high thermal inertia absorb short-wave radiation throughout the day and release it later as long-wave flux, sustaining elevated thermal loads even after peak solar hours [415, 416]. Moreover, façade alignments and limited ventilation corridors can locally concentrate heat, producing micro-zones of discomfort [417, 418]. Meanwhile, the observed subtle radial pattern with a narrow zone of warming extending westward and a small cooling sector to the south-west indicates that the locally regenerated block can redistribute surface heat and airflow in the broader scale [419, 420].

The elderly model responded slightly more strongly to these unfavourable microclimates. Although the PET difference rarely exceeded 1 °C, even small increments may translate into disproportionately higher physiological strain for older adults, whose thermoregulatory capacity and sweat response are reduced [421-423]. The results therefore highlight a spatial dimension of vulnerability: thermal disadvantage tends to cluster around architectural masses. These findings are consistent with recent studies on thermal inequity in compact cities, suggesting that socially or physiologically vulnerable groups often occupy or traverse spaces most affected by heat accumulation [424-426]. Addressing such localised risks requires an integrated approach. For example, implementing vertical or façade greening near building fronts, applying reflective or permeable surface materials, and preserving open ventilation corridors can effectively reduce near-wall warming and improve outdoor thermal conditions [427, 428]. Importantly, these strategies do not merely improve thermal indices but also advance health equity, ensuring that the protective effects of urban greening extend to populations with limited adaptive capacity [259, 429].

Overall, the simulations highlight how microclimatic design strengthens the environmental foundations of health promotion in cities. By confirming the cooling efficiency of tree canopies and identifying spatial pockets of thermal vulnerability, this chapter demonstrates that ecological structure plays a decisive role in shaping comfortable and equitable urban environments. The persistence of local heat around buildings also demonstrates the need to balance densification and liveability through integrated design approaches that treat greening as part of public-health infrastructure. In this sense, the present chapter complements the behavioural evidence discussed in earlier parts of the thesis. Whereas those studies addressed how individuals use and perceive green spaces, the current results demonstrate the environmental preconditions that enable such benefits to manifest. Together, they advance the understanding that health promotion in cities depends on both behavioural engagement and environmental design, with urban greening serving as the connective element.

Limitations

This chapter remains limitations. Although the ENVI-met simulations provided valuable insight into the environmental mechanisms of local thermal comfort, the model represents a simplified reconstruction of complex urban dynamics. Its static boundary conditions, uniform clothing and activity parameters, and limited ability to capture adaptive behaviour mean that the simulated comfort indices may not fully reproduce the diversity of real thermal experiences. Besides, the analysis covered a single day representing an extreme heatwave. While this approach isolates the spatial influence of vegetation and built form, it cannot account for temporal variability such as seasonal canopy changes, soil moisture fluctuations, or behavioural adaptation. Furthermore, this chapter was developed within the same research framework as Chapter 4, which investigated residents' perceptions and attitudes towards UGS in the same neighbourhood. Ideally, subjective perceptions and physiological comfort estimates would be jointly analysed to provide a comprehensive understanding of how environmental performance aligns with user experience. However, in practice, this integration was constrained by insufficient and incomplete survey data. The modest sample size and missing information in the questionnaire responses prevented robust linkage between the microclimatic model outputs and residents' reported perceptions, attitudes, or mental-health indicators. As a result, it was not possible to examine how individual exposure or perceived comfort corresponded with spatial heat patterns.

Therefore, future work should reconsider the survey strategy to enable stronger cross-referencing between subjective and objective datasets. This may include increasing the sample size, simplifying question structures to reduce non-responses, and collecting spatially explicit answers. Such an approach would allow a more direct integration of environmental modelling, behavioural data, and well-being outcomes within a unified analytical framework. Finally, extending the simulations to include physiological or behavioural feedback loops, or validating PET estimates through on-site measurements, would further strengthen the explanatory power of this environmental pathway. Despite these limitations, the present study demonstrates the methodological feasibility and conceptual relevance of coupling microclimate modelling with health-promotion research. It highlights that effective greening strategies depend not only on measurable cooling but also on their capacity to support equitable, health-promoting environments for all residents.

Chapter 8 – Conclusion

This thesis set out to explore how the optimisation of urban green spaces (UGS) can enhance health and well-being. Although the guiding question was simple, the path to address it required a multidimensional approach. The work combined behavioural, perceptual and environmental perspectives to understand how UGS design and management influence both individual experiences and collective health outcomes. In this sense, the research has been explorative rather than conclusive, yet grounded in a coherent framework that connects human behaviour, spatial perception and ecological processes. Across its chapters, the thesis examined different but complementary aspects of the same issue. The early studies focused on how the quality and accessibility of urban green spaces affect residents' well-being. Results showed that quality indicatorsare more closely associated with psychological benefits than mere proximity, such as maintenance, biodiversity and naturalness. UGS that are perceived as well cared for and rich in natural elements are more likely to support relaxation, optimism and social connection. These findings suggest that the benefits of greenery emerge not only from the amount of vegetation but from the meanings and experiences that people attach to it.

Subsequent chapters shifted towards the behavioural pathway, investigating the role of physical activities (PA) in mediating the health benefits of green environments. The studies related to the "Parchi in Movimento" project showed that supervised PA programmes in parks can foster participation, social cohesion and mental well-being, even if the statistical effects were not always significant. Such results highlight that the relationship between nature and health is shaped by multiple factors: seasonality, baseline conditions, and the sensitivity of the tools used to measure well-being. They also remind us that in real-world interventions, the absence of strong effects may still carry important practical meaning, revealing how environmental, methodological and human factors interact. Building on these behavioural insights, the following investigation focused on residents' perceptions and attitudes towards UGS. It found that household composition, age and life stage strongly influence both the frequency and form of green space use. People living with children or older dependents tend to value accessibility and safety, while younger adults give greater importance to variety and maintenance. In contrast, education and employment showed limited influence, suggesting that the emotional and practical relevance of green areas cuts across socioeconomic boundaries. These findings emphasised that well-being outcomes depend on how urban residents perceive the relationship between their living context and the opportunities that UGS provide. The final empirical contribution expanded the discussion from human perception to environmental preconditions, analysing the microclimatic performance of a green redevelopment in Imola through ENVI-met simulation. The results demonstrated that tree canopies played a decisive role in improving outdoor thermal comfort, reducing physiological heat load by up to 3.5 °C during heatwave conditions. Meanwhile, new building structures produced narrow bands of warming along façades, underlining the tension between densification and liveability. Together, these findings confirmed that ecological structure could support the comfort and health benefits observed at the behavioural level. UGS thus functions as both a physical and social infrastructure, cooling the environment while enabling health-promoting behaviours. Taken together, the different chapters form a coherent narrative on how health promotion through UGS is a multi-dimensional process, grounded in the interaction between environmental design, behavioural engagement and subjective perception. Each dimension reveals a partial truth: without supportive environments, behavioural

initiatives may struggle; without active participation, well-designed spaces remain underused; and without positive perceptions, ecological improvements may not translate into well-being. The thesis therefore contributes to an integrated understanding of how the physical and psychological domains of urban life are interwoven through green infrastructure.

Methodologically, the thesis demonstrates the value of combining quantitative and qualitative approaches across scales: from questionnaire surveys and longitudinal interventions to microclimate simulations. This plural perspective made it possible to link subjective experiences with objective environmental data, illustrating how each type of evidence informs the others. While the studies were limited by sample size, intervention duration and instrument sensitivity, these constraints are inherent to real-world experimentation and do not weaken the coherence of the overall framework. Instead, they highlight the complexity of studying the relationships between human and environment. The explorative nature of this thesis should therefore be read as an invitation to deepen, rather than to close, the inquiry it has opened. From a practical perspective, the findings support the idea that UGS should be recognised as a form of public health infrastructure. Strategies that focus on the quality and structure of UGS are likely to generate the greatest social and environmental returns, particularly tree canopy continuity, maintenance and accessibility. Integrating such considerations into urban design can help cities mitigate heat stress, increase PA engagement and create inclusive spaces for interaction and rest. Health promotion, in this sense, is not only a behavioural challenge but an environmental one, calling for planners, ecologists and public health professionals to work within a comprehensive framework.

The multidimensional approach developed here provides contributions to further exploration. Future research will extend this framework towards issues of equity, vulnerability and value of ecosystem services. The next step is to examine how UGS distribution and quality influence health equity, particularly among groups with limited access or adaptive capacity. Meanwhile, attention should be given to the ecological and climate regulating functions of UGS, bridging human well-being with ecosystem sustainability. By addressing these interconnected dimensions, future work can move beyond describing benefits to designing truly equitable and resilient urban environments.

Ultimately, this thesis argues that the promotion of UGS is not simply about planting trees or creating parks. It is about enabling relationships between people, their environments and the ecological systems that sustain them. Health and well-being emerge where these relationships are supported through thoughtful design, inclusive access and long-term ecological care. In embracing this multidimensional vision, cities can evolve not only as habitats for humans, but as liveable spaces of balance between life, environment and meaning.

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