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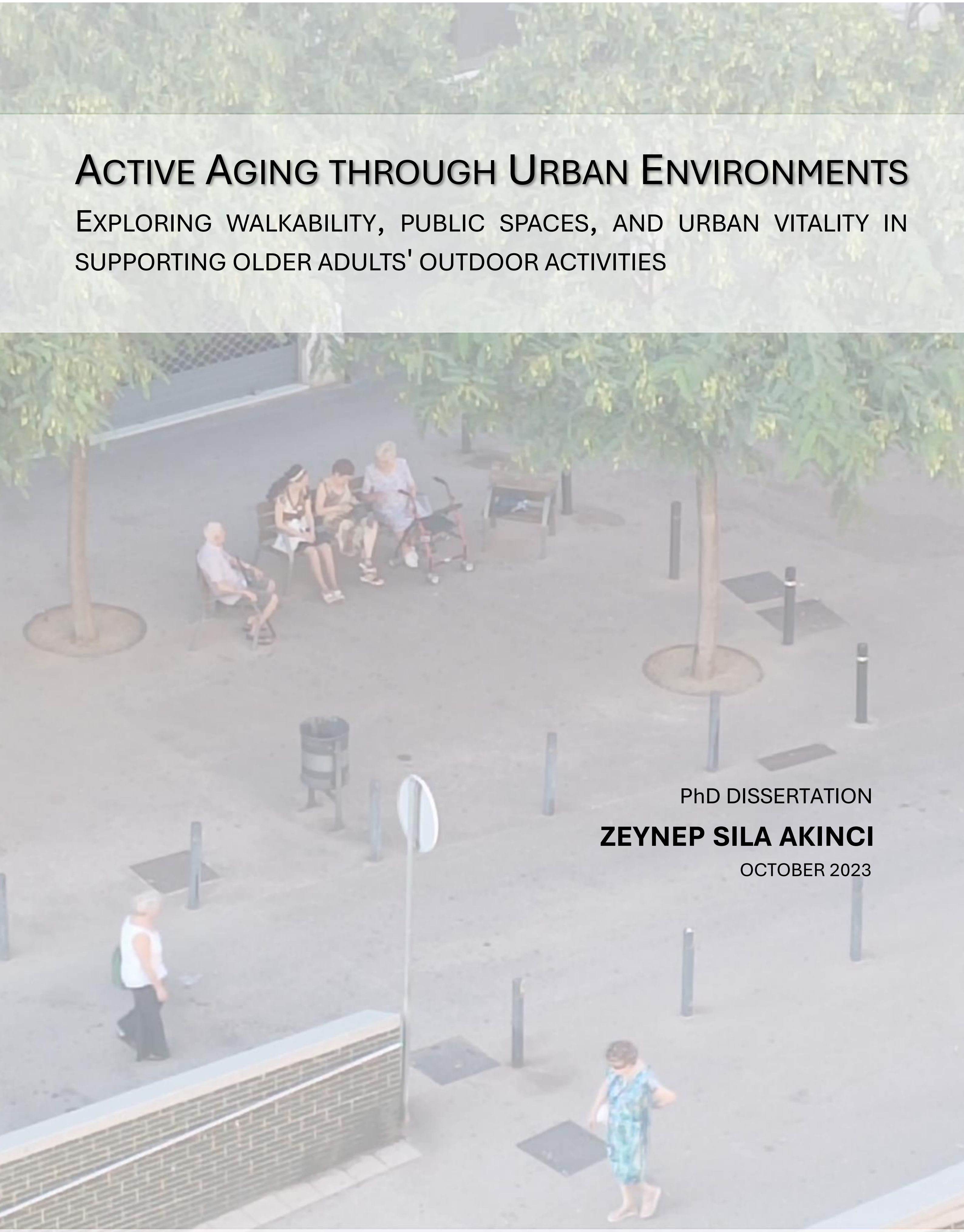
ZEYNEP SILA AKINCI



ACTIVE AGING THROUGH URBAN ENVIRONMENTS

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PhD DISSERTATION

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GEMOTT Grupo de Estudios de Movilidad Transporte y Territorio

Departament de Geografia

UAB Universitat Autònoma de Barcelona

Ph. D. Dissertation

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Ph. D. Program in Geography

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Cover photo by Zeynep S. Akinci -2023

To my grandparents

PREFACE

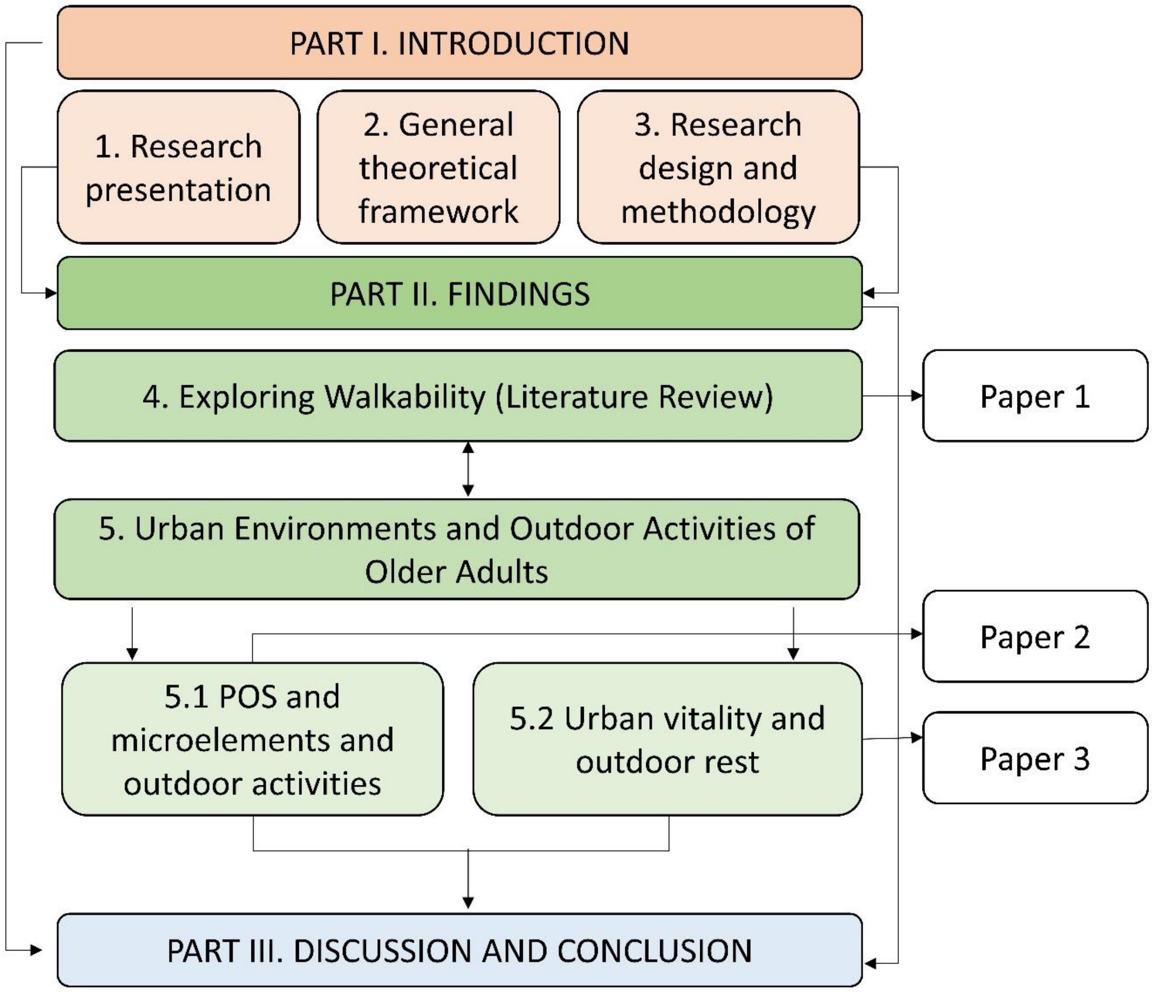
This thesis consists of academic publications. Thus, it is structured following the regulation approved by the Academic Committee of the Doctoral Program (CAP) of the Department of Geography of the Universitat Autònoma de Barcelona (UAB), regulated by RD 99/2011 and according to the transitory disposition approved by the CAP on October 13th, 2022.

Following the specific regulation RD 99/2011, all article-based dissertations must be constituted by at least three scientific contributions authored by the candidate (published in academic journals or in the form of books or book chapters, among others). Contributions included in the dissertation should be published or at least accepted before the deposit.

Based on this regulation, as presented in Figure 1, this dissertation is structured as follows:

- Part I presents the research presentation, general theoretical framework and the research design and methodology.
- Part II consists of the findings of the thesis, based on three studies published in academic journals.
- Part III covers the discussion and conclusion.
- Part IV includes the references and annexes.

Figure 1 Thesis Structure



Source: own production

This doctoral thesis is based on three academic papers published in international journals, as approved by the CAP of the UAB Department of Geography on November 24th, 2021. These papers are listed below:

1) **Akinci, Zeynep S.,** Xavier Delclòs-Alió, Guillem Vich, Deborah Salvo, Jesús Ibarluzea, and Carme Miralles Guasch. 2022. "How Different Are Objective Operationalizations of Walkability for Older Adults Compared to the General Population? A Systematic Review." *BMC Geriatrics* 22(673):1–22. https://doi.org/10.1186/s12877-022-03233-x . ***JCR (2022):*** *Impact Factor =* ***4.1****, Journal Rank (JCI)=* ***Q1*** *(Gerontology),* ***Q2*** *(Geriatricas & Gerontology)*
2) **Akinci, Zeynep S.,** Xavier Delclòs-Alió, Guillem Vich, and Carme Miralles-Guasch. 2021. "Neighborhood Urban Design and Outdoor Later Life: An Objective Assessment of out-of-Home Time and Physical Activity among

Older Adults in Barcelona." *Journal of Aging and Physical Activity* 1–12. https://doi.org/10.1123/japa.2020-0254 . ***JCR (2021):*** *Impact Factor =* ***2.1****, Journal Rank (JCI)=* ***Q2*** *(Gerontology),* ***Q3*** *(Geriatricas & Gerontology),*

3) **Akinci, Zeynep S.,** Oriol Marquet, Xavier Delclòs-Alió, and Carme Miralles-Guasch. 2022. "Urban Vitality and Seniors' Outdoor Rest Time in Barcelona." *Journal of Transport Geography* 98. https://doi.org/10.1016/j.jtrangeo.2021.103241 . ***JCR (2022):*** *Impact Factor =* ***6.1****, Journal Rank (JCI)=* ***Q1*** *(Geography, Transportation, Economics)*

The present work was supported by the Generalitat de Catalunya through an **AGAUR-FI grant (2019 FI_B 00039)**. This grant has allowed for a total of 4 years and 5 months[1] of full-time dedication to the research project.

This doctoral thesis has also had support from the following research projects at the Research Group on Mobility, Transportation and Territory (GEMOTT), of the Universitat Autònoma de Barcelona, led by Prof. Carme Miralles-Guasch:

- **Ciudad, calidad de vida y movilidad activa en la tercera edad. Un análisis multimetodológico a través de Tracking Living Labs (City, quality of life and active mobility in the third age. A multi-methodological analysis through Tracking Living Labs) – 2016ACUP30 –** Programa RecerCaixa 2016. Period: 01/02/2017 – 12/31/2018. Lead researcher: Dr. Carme Miralles-Guasch (Universitat Autònoma de Barcelona).
- **Electric, light and Shared. The rise of micromobility in Spain and its environmental, social and Health consequences. A multimethod study using GIS, tracking and accelerometry (MICROMOV). PID2019-104344RB-I00.** Spanish Ministry of Science and Innovation (Ministerio de Ciencia i Innovación). Period: 01/06/2020 – 01/06/2023. Lead researcher: Dr. Carme Miralles-Guasch (Universitat Autònoma de Barcelona).
- **Inclusiva, sostenible, saludable i resilient. La mobilitat i la ciutat en l'escenari postpandèmia (2020 PANDE 00023). Convocatòria Replegar-se per créixer: l'impacte de les pandèmies en un món sense fronteres visibles (Pandèmies 2020) -** AGAUR, Generalitat de Catalunya. Period: 14/05/2021-13/11/2022. Lead researcher: Dr. Carme Miralles-Guasch (Universitat Autònoma de Barcelona).

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[1] The original AGAUR-FI grant, awarded by the Generalitat de Catalunya, initially covered a period of 3 years. Subsequently, the UAB facilitated an extension for an additional year, which was further prolonged by 5 months due to the impact of the COVID-19 pandemic.

ACKNOWLEDGMENTS

I extend my heartfelt appreciation to the multitude of individuals and organizations whose support and contributions have shaped this thesis. Financial support was provided by Generalitat de Catalunya- AGAUR (2019 FI_B 00039). Additionally, I received a grant from Societat Econòmica Barcelonesa d'Amics del País for my research stay.

While my name appears on this document, the realization of this work owes much to the assistance of numerous individuals. I wish to express my gratitude to all, and I apologize in advance for any inadvertent omissions.

Foremost, I am deeply indebted to my first supervisor, Prof. Carme Miralles-Guasch. Our journey together began during the master's program. One day I asked her for a recommendation letter for a PhD and she invited me to join GEMOTT and since then she has been an unwavering pillar of support, both academically and personally. Carme, your assistance, and encouragement have been invaluable – thank you! My sincere gratitude also goes to Dr. Xavier Delclòs-Alió, my second supervisor, without whose guidance and support I would not have been here today. From the very beginning, the enrolment process, to the end, the submission process, you have always been there and supported me, taught me numerous things. Without you, I would not have acquired these skills, and succeed in completing this thesis. Your constant support, especially during challenging times, has been indispensable. I also extend my thanks to Dr. Oriol Marquet, who, while not an official supervisor, has been a consistent source of guidance throughout. Your practical insights have been truly enriching. To all three of you, I am immensely grateful.

I owe a debt of gratitude to my previous supervisors during my two master's studies – Prof. Pelin Tan, Prof. Joost Jongerden, Dr. Antònia Casellas, and Dr. Arda Bilgen – whose teachings laid the foundation for my research abilities. Thank you all so much for your endless guidance and support.

I express my gratitude to Dr. Vanessa Stjernborg and Dr. Till Koglin, and other colleagues at Lund University's Transport & Roads research group, for their warm welcome during my research stay. I also would like to thank to my coauthors, Dr. Deborah Salva and Dr. Jesús Ibarluzea Maurolagoitia for their indispensable support and guidance. I also extend my deepest appreciation to Assoc. Prof. Dr. Ömer Bilen, Assoc. Prof. Dr. Erhan Kurtarır, and Assoc. Prof. Dr. Ersan Koç for writing external evaluation reports, contributing to the international recognition of the thesis. Additionally, I would like to thank Dr. Özgür Akçalı for his genuine support. I would be remiss if I don't mention the participants of the RecerCaixa project. Thank you so much for your invaluable contribution to this thesis. I would also like to thank to Núria González Duch and Sara Duch Guillot for their assistance in reviewing and refining the translations of the abstract in Catalan and Spanish.

Being a part of GEMOTT has been an enriching experience. My sincere thanks to my past and present colleagues for helping me get started at the department, the group, and in research, for shared lunches, interesting discussions, and activities of the newly established juniors' group. Special thanks to Jerònia Cubells for her incredible assistance and support, both academically and personally. I also extend my appreciation to colleagues at the Department of Geography, especially to Núria C., Cristian P., Mario P., Oscar G., Guillem C., Rafa, Vero, and Joan C.. Your responses to my endless questions, your insights, our brief chats in the corridors, gatherings, and our hiking adventure have consistently been supportive and uplifting for me. With the positive environment fostered by these wonderful individuals and the support I've received from them, the entire process became significantly smoother.

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Lastly, I wish to extend my deepest gratitude to my family for their unwavering support throughout my life. I dedicate this thesis to the memory of my grandparents Nezahat and Muzaffer Akıncı, and Zahide and Kemaleddin Akçay, who instilled in me the enduring value of education. While my aunts Ülker Akçalı, Ayfer Elgün, Canan Arıtman and my grand aunt Nazmiye Güngör, are no longer with us, their influence on me continues to resonate. I offer a special acknowledgement to my aunts Reyhan Akçay and Özden Onur, whose reminders about the significance of benches for older adults directly contributed to this thesis. To all my cousins, despite infrequent conversations and meetings, I have keenly felt your unwavering support throughout. Finally, to my nuclear family – Dilhan Akçay, Anita Akıncı, and Ahmet Kemal Akıncı – your enduring love, support, and patience, spanning any distance, have been the very bedrock of my journey. Without you, none of this could have transpired. I love you all! (-TUR-) Son olarak, hayatım boyunca desteklerini esirgemeyen aileme en derin şükranlarımı sunarım. Bu tezi, bana eğitimin kalıcı değerini aşılayan babaannem, anneannem, ve dedelerim Nezahat ve Muzaffer Akıncı ile Zahide ve Kemaleddin Akçay'ın anısına ithaf ediyorum. Halalarım Ülker Akçalı, Ayfer Elgün, teyzelerim Canan Arıtman ve Nazmiye Güngör artık aramızda olmasalar da, üzerimdeki etkileri yankılanmaya devam ediyor. Bankların yaşlı yetişkinler için önemini hatırlatarak bu teze doğrudan katkıda bulunan teyzem Reyhan Akçay ve halam Özden Onur'a özel teşekkürlerimi sunuyorum. Tüm kuzenlerime, seyrek konuşmalarımıza ve buluşmalarımıza rağmen, sarsılmaz desteğinizi her zaman içtenlikle hissettim. Son olarak, çekirdek aileme - Dilhan Akçay, Anita Akıncı ve Ahmet Kemal Akıncı - her türlü mesafeyi aşan sonsuz sevginiz, desteğiniz ve sabrınız yolculuğumun temelini oluşturdu. Siz olmasaydınız bunların hiçbiri gerçekleşemezdi. Hepinizi çok seviyorum!

ABSTRACT

Understanding the relationship between human outdoor behavior and environmental characteristics is crucial, especially among older adults (≥65 years old) who can experience improved health and overall wellbeing through outdoor activities. The main hypothesis of this doctoral thesis is that the characteristics of urban environments have a significant impact on older adults' outdoor activities, and this plays an essential role on their physical and mental health. Therefore, this dissertation aims to explore the relationship between the characteristics of urban environments and outdoor activities of older adults, while considering individual differences. The research consists of three studies, one systematic literature review, and two empirical studies conducted in Barcelona.

The first study establishes a foundation for subsequent research by conducting a comprehensive literature review on walkability measures. This systematic review informs the background of the thesis and provides the context for other studies. The two empirical studies are based on GPS-tracking data gathered from a sample of older adults residing in Barcelona. These studies investigate the relationship between older adults' outdoor activities and specific characteristics of urban environments (e.g., urban vitality, the provision of public open spaces and urban microelements) at different scales, as well as the impacts of individual characteristics (e.g., age and gender) on this relationship.

The findings strongly supported the hypotheses by demonstrating a significant relationship between outdoor activities of older adults and characteristics of the environment. Individual differences also played a crucial role in shaping this relationship. The results of the empirical studies revealed that urban vitality and the presence of certain public open spaces and microelements have a considerable impact on older adults' outdoor physical activity time, overall time spent outdoors, and outdoor resting, at the neighborhood and city scales. Additionally, the systematic literature review on walkability provided evidence of this relationship in the context of walking as an outdoor physical activity. However, striking similarities were observed in terms of how walkability has been operationalized for older adults

and the general population. Nevertheless, all the studies included in this thesis consistently supported the main hypothesis and demonstrated how outdoor behaviors of older adults are influenced by the features of urban environments and the characteristics of individuals.

The outcomes of these studies offer valuable insights for future research on urban aging, as well as informing urban planners and designers in decision-making and policy formulation processes. By considering individual differences and the characteristics of outdoor environments, urban planners and designers can develop more tailored strategies that promote outdoor activities and enhance the health and wellbeing of older adults in urban environments.

Overall, this research contributes to a better understanding of the complex relationship between urban environments and older adults' outdoor behavior, shedding light on potential avenues for enhancing urban planning and design strategies that cater to the diverse needs and preferences of aging populations.

RESUM

La comprensió de la relació entre el comportament humà a l'aire lliure i les característiques dels entorns és cabdal, especialment entre la gent gran (≥65 anys), que pot experimentar una millora de la salut i el benestar general a través d'activitats a l'aire lliure. La principal hipòtesi d'aquesta tesi doctoral és que les característiques dels entorns urbans tenen un impacte significatiu en les activitats a l'aire lliure de les persones grans, i això juga un paper essencial en la seva salut física i mental. Per tant, aquesta dissertació té com a objectiu explorar la relació entre les característiques dels entorns urbans i les activitats a l'aire lliure de la gent gran, tenint en compte les diferències individuals. La recerca consta de tres estudis, una revisió sistemàtica de la literatura i dos estudis empírics realitzats a Barcelona.

El primer estudi estableix una base per a la recerca posterior mitjançant la realització d'una revisió exhaustiva de la literatura sobre les mesures de caminabilitat. Aquesta revisió sistemàtica serveix de base a la tesi i proporciona el context per a altres estudis. Els dos estudis empírics es basen en dades de GPS-'tracking' recollides d'una mostra d'adults majors residents a Barcelona. Aquests estudis investiguen la relació entre les activitats a l'aire lliure de la gent gran i les característiques específiques dels entorns urbans (per exemple, la vitalitat urbana, la provisió d'espais públics oberts i els microelements urbans) a diferents escales, així com els impactes de les característiques individuals (per exemple, l'edat i el gènere) en aquesta relació.

Els resultats van donar suport ferm a les hipòtesis demostrant una relació significativa entre les activitats a l'aire lliure dels adults majors i les característiques de l'entorn. Les diferències individuals també van exercir un paper crucial en la configuració d' aquesta relació. Els resultats dels estudis empírics van revelar que la vitalitat urbana i la presència de determinats espais públics oberts i microelements tenen un impacte considerable en l'activitat física a l'aire lliure de la gent gran, el temps total que hi passen i el seu descans a l'aire lliure a escala de barri i de ciutat. Per altra banda, la revisió bibliogràfica sistemàtica sobre

caminabilitat va aportar proves d'aquesta relació en el context de caminar com a activitat física a l'aire lliure. No obstant això, es van observar similituds sorprenents quant a com s’ha operacionalitzat la caminabilitat per la gent gran i la població en general. Ara bé, tots els estudis inclosos en aquesta tesi van donar suport de forma consistent a la hipòtesi principal i van demostrar com els comportaments a l'aire lliure de les persones grans es veuen influïts per les característiques dels entorns urbans i les característiques dels individus.

Els resultats d’aquests estudis ofereixen valuoses perspectives per a futures investigacions sobre l’envelliment urbà, així com per informar els planificadors i dissenyadors urbans en els processos de presa de decisions i formulació de polítiques. Tenint en compte les diferències individuals i les característiques dels entorns a l' aire lliure, els planificadors i dissenyadors urbans poden desenvolupar estratègies més adaptades que promoguin les activitats a l'aire lliure i millorin la salut i el benestar de les persones grans en els entorns urbans.

En general, aquesta recerca contribueix a una millor comprensió de la complexa relació entre els entorns urbans i el comportament a l’aire lliure de les persones grans, abocant llum sobre les possibles vies per millorar la planificació urbana i les estratègies de disseny que atenen les diverses necessitats i preferències de les poblacions envellides.

RESUMEN

Comprender la relación entre el comportamiento humano al aire libre y las características del entorno es crucial, especialmente entre los adultos mayores (≥65 años). Estos pueden experimentar una mejora de la salud y el bienestar general a través de actividades al aire libre. La principal hipótesis de esta tesis doctoral es que las características de los entornos urbanos tienen un impacto significativo en las actividades al aire libre de los adultos mayores, y esto juega un papel esencial en su salud física y mental. Por lo tanto, esta disertación tiene como objetivo explorar la relación entre las características de los entornos urbanos y las actividades al aire libre de los adultos mayores, teniendo en cuenta las diferencias individuales. La investigación consta de tres estudios, una revisión sistemática de la literatura y dos estudios empíricos realizados en Barcelona.

El primer estudio establece una base para la investigación posterior mediante la realización de una revisión exhaustiva de la literatura sobre las medidas de caminabilidad. Esta revisión sistemática sirve de base a la tesis y proporciona el contexto para otros estudios. Los dos estudios empíricos se basan en datos de GPS-'tracking' recogidos de una muestra de adultos mayores residentes en Barcelona. Estos estudios investigan la relación entre las actividades al aire libre de los adultos mayores y las características específicas de los entornos urbanos (por ejemplo, la vitalidad urbana, la provisión de espacios públicos abiertos y los microelementos urbanos) a diferentes escalas, así como los impactos de las características individuales (como la edad y el género) en esta relación.

Los resultados respaldaron firmemente las hipótesis al demostrar una relación significativa entre las actividades al aire libre de los adultos mayores y las características del entorno. Las diferencias individuales también desempeñaron un papel crucial en la configuración de esta relación. Los resultados de los estudios empíricos revelaron que la vitalidad urbana y la presencia de determinados espacios públicos abiertos y microelementos tienen un impacto considerable en el tiempo de actividad física al aire libre de los adultos mayores, el tiempo total pasado al aire libre y el descanso al aire libre, a escala de barrio y

de ciudad. Además, la revisión bibliográfica sistemática sobre la caminabilidad aportó pruebas de esta relación en el contexto de caminar como actividad física al aire libre. Por otro lado, se observaron similitudes sorprendentes en cuanto a la forma en que se ha operacionalizado la caminabilidad en los adultos mayores y la población en general. No obstante, todos los estudios incluidos en esta tesis apoyaron de forma consistente la hipótesis principal y demostraron cómo los comportamientos al aire libre de los adultos mayores se ven influidos por las características de los entornos urbanos y las características de los individuos.

Los resultados de estos estudios ofrecen valiosas perspectivas para futuras investigaciones sobre el envejecimiento urbano, así como para informar a los planificadores y diseñadores urbanos en los procesos de toma de decisiones y formulación de políticas. Al tener en cuenta las diferencias individuales y las características de los entornos al aire libre, los planificadores y diseñadores urbanos pueden desarrollar estrategias más adaptadas que promuevan las actividades al aire libre y mejoren la salud y el bienestar de los adultos mayores en los entornos urbanos.

En general, esta investigación contribuye a una mejor comprensión de la compleja relación entre los entornos urbanos y el comportamiento al aire libre de los adultos mayores, arrojando luz sobre las posibles vías para mejorar la planificación urbana y las estrategias de diseño que atienden a las diversas necesidades y preferencias de las poblaciones envejecidas.

ÖZET

İnsanların dış mekan davranışı ile çevre özellikleri arasındaki ilişkiyi anlamak, özellikle yaşlı yetişkinler (≥65 yaş) arasında oldukça önemlidir, çünkü yaşlı yetişkinler, açık alan aktiviteleri aracılığıyla sağlık ve genel refah düzeylerini artırabilirler. Bu doktora tezinin ana hipotezi, kentsel alan özelliklerinin yaşlı yetişkinlerin açık alan aktiviteleri üzerinde ciddi bir etkiye sahip olduğu ve bunun fiziksel ve zihinsel sağlıkları üzerinde önemli bir rol oynadığıdır. Bu nedenle, bu tez, bireysel farklılıkları dikkate alarak, kentsel çevre özelliklerinin yaşlı yetişkinlerin açık alan aktiviteleri üzerindeki etkilerini araştırmayı amaçlamaktadır. Bu tez, bir sistematik literatür taraması ve Barselona'da gerçekleştirilen iki ampirik çalışma olmak üzere üç çalışmadan oluşmaktadır.

İlk çalışma, yürünebilirlik (walkability) ölçümleri hakkında kapsamlı bir literatür incelemesi yaparak, sonraki araştırmalar için temel bir zemin oluşturur. Bu sistematik inceleme, tezin arka planını bilgilendirir ve diğer çalışmalar için bağlam sağlar. İki ampirik çalışma, Barselona'da yaşayan yaşlı yetişkin örnekleminden toplanan GPS takip (GPS-tracking) verilerine dayanmaktadır. Bu çalışmalar, yaşlı yetişkinlerin açık alan aktiviteleri ile kentsel çevre özellikleri (örneğin, kentsel canlılık (vitality), kamusal açık alanların ve kentsel mikro elemanların varlığı) arasındaki ilişkiyi farklı ölçeklerde incelemektedir. Aynı zamanda bireysel özelliklerin (yaş ve cinsiyet gibi) bu ilişki üzerindeki etkilerini de ele almaktadır.

Bulgular, yaşlı yetişkinlerin açık alan aktiviteleri ile kentsel çevre özellikleri arasında anlamlı bir ilişki olduğunu göstererek hipotezleri güçlü bir şekilde desteklemiştir. Bireysel farklılıklar da bu ilişkiyi şekillendirmede önemli bir rol oynamıştır. Ampirik çalışmaların sonuçları, kentsel canlılığın ve çeşitli kamusal açık alanlar ile mikro elemanların yaşlı yetişkinlerin mahalle ve şehir ölçeklerinde açık alan fiziksel aktivite süreleri, açık alanda geçirilen toplam süre ve açık alanda dinlenmeleri üzerinde önemli bir etkisinin olduğunu ortaya koymuştur. Ayrıca, yürünebilirlik üzerine yapılan sistematik literatür incelemesi, bir dış mekan fiziksel aktivitesi olan yürüyüş bağlamında, bu ilişkiyi destekleyen kanıtlar sunmuştur. Fakat, yaşlı

yetişkinler ve genel nüfus için yürünebilirliğin nasıl ölçüldüğü konusunda dikkate değer benzerlikler gözlemlenmiştir. Yine de, bu tezde yer alan tüm çalışmalar, temel hipotezi tutarlı bir şekilde desteklemiş ve yaşlı yetişkinlerin dış mekan davranışlarının kentsel çevre özellikleri ve bireysel özellikler tarafından nasıl etkilendiğini göstermiştir.

Bu çalışmaların sonuçları, gelecekteki kentsel yaşlanma (urban aging) araştırmalarına yönelik değerli öngörüler sunmanın yanı sıra, şehir plancıları ve kensel tasarımcıları karar alma ve politika oluşturma süreçlerinde bilgilendirmektedir. Şehir plancıları ve kentsel tasarımcılar, bireysel farklılıkları ve kentsel açık alanların niteliklerini dikkate alarak, yaşlı yetişkinlerin açık alan aktivitelerini teşvik eden ve kentsel çevrelerde yaşlı yetişkinlerin sağlık ve refahını artıran daha özelleştirilmiş stratejiler geliştirebilirler.

Genel olarak, bu araştırma, kentsel alanlar ile yaşlı yetişkinlerin dış mekan davranışları arasındaki karmaşık ilişkinin daha iyi anlaşılmasına katkıda bulunmaktadır ve yaşlanan nüfusun çeşitli ihtiyaç ve tercihlerine yönelik kentsel planlama ve tasarım stratejilerini geliştirmek için potansiyel yolları aydınlatmaktadır.

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ABBREVIATIONS

PA: Physical activity

TOT: Total outdoor time

TOH: Time out-of-home

POS: Public open spaces

PAS: Pedestrian activity spaces

WHO: World Health Organization

SES: Socioeconomic status

GPS: Global Positioning System

GIS: Geographic Information Systems

LIST OF TERMINOLOGY

Age and aging: Age is defined as the length of time (in years) that a person or a thing existed, while aging is the process to grow old. Thus, aging starts with birth and continues till that person or thing stops existing. Since people can age in different ways, aging does not directly depend on age (Lindelöw, 2016).

Older adults: In this thesis older adults included people who are 65 years old or older. However, as Sabahattin Ali said in his book *Madonna in a Fur Coat (Kürk Mantolu Madonna)*, "human life is a single path from birth to death, and any division of it is artificial."(Ali, 2015). The age division in this thesis was only used for the sake of the analyses. The author acknowledges individual differences (e.g., physical conditions or level of engagement in outdoor activities) and does not support any generalization or homogenization of age groups.

Gender and sex: Although the term *gender* is preferred in place of *sex* in this thesis, the data (secondary data) included only two options (women and men) for the "gender" section. The author admits and apologizes for the limitations of this binary data and consequently excluding LGBTQIA+ people and their potential contributions to this research.

Health and wellbeing: The World Health Organization (WHO) defines health as "a state of complete physical, mental, and social wellbeing and not merely the absence of disease or infirmity".[2] While the definition of wellbeing is a subject of debate, the WHO's definition encompasses a state in which individuals can fulfill their personal potentials, effectively manage stress, engage in productive work, and contribute meaningfully to their community (Nicholas, 2019).

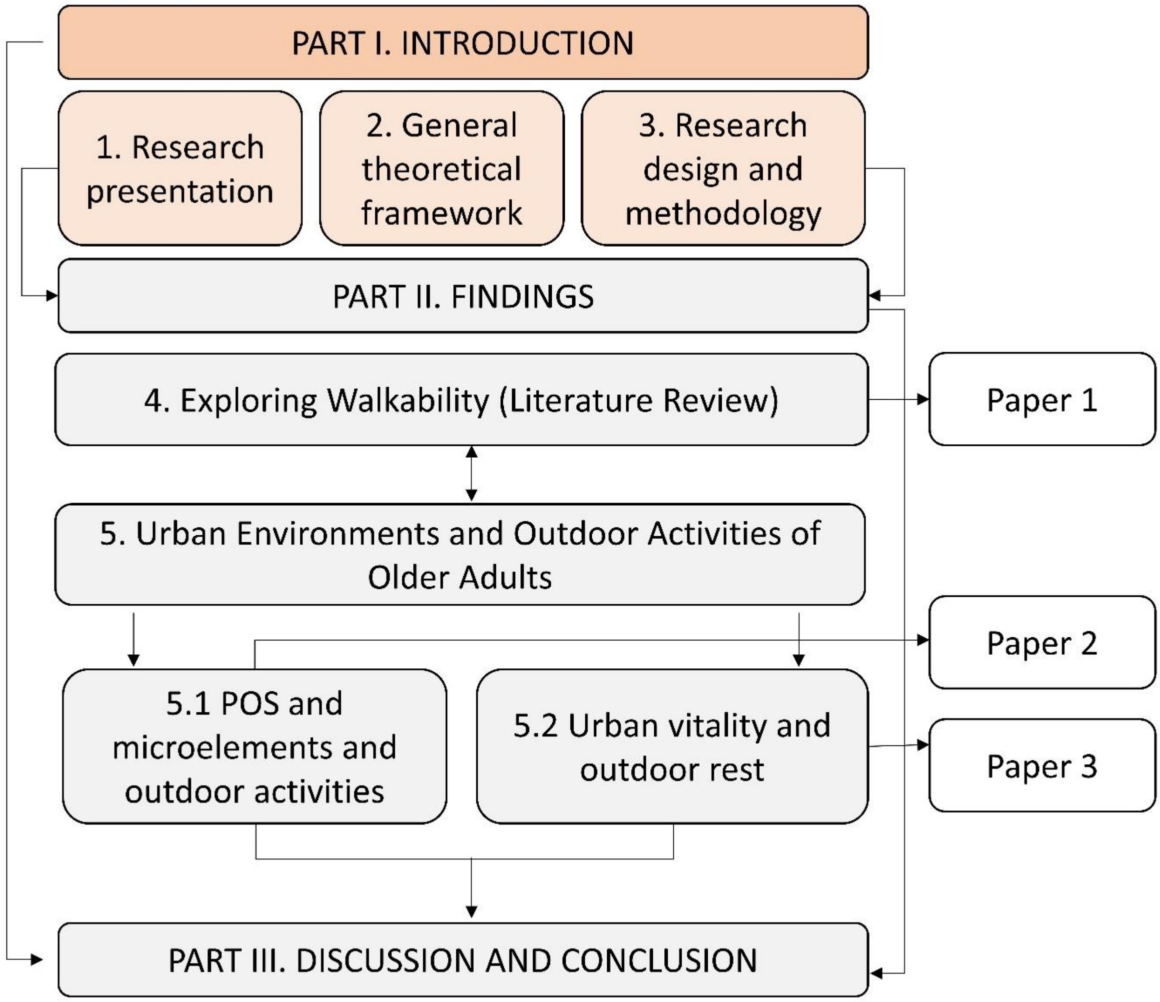
Outdoor Activities: In this thesis, outdoor activities included any pedestrian activity that takes place outdoors.

[2] https://www.who.int/about/governance/constitution

Outdoor Physical activity: Any movement of the body that is generated by skeletal muscles and necessitates the use of energy (World Health Organization, 2020) which occurs outdoors.

Outdoor Resting: Any awake outdoor activity that involves sitting, reclining, or lying down and does not involve energy expenditure (World Health Organization, 2020).

PART I. INTRODUCTION



1. Research presentation

1.1. Context

Outdoor activities play an essential role in promoting overall health. However, several factors, such as age and gender of individuals as the actors of these activities, as well as the characteristics of urban outdoor spaces as their venues, can significantly influence participation. In the light of these, the presented dissertation aims to explore the relationship between urban environments and outdoor activities, with a particular focus on older adults (≥65 years old).

Engagement in outdoor activities holds greater significance for older adults due to the positive impacts on physical and mental health. Additionally, most older adults benefit from increased leisure time compared to their younger counterparts, who are typically engaged in work or school commitments. Consequently, older adults emerge as the primary users of public open spaces, especially during daytime hours, further underscoring the significance of the space characteristics on their activity patterns. To further explore the correlation between urban environments and outdoor activities, this thesis includes a systematic literature review and two empirical studies. The empirical studies were conducted in Barcelona —an excellent urban laboratory for investigating this relationship— with a unique blend of elements, including a mild climate, lively street culture, and a diverse range of public open spaces, making it an ideal setting for examining human outdoor behavior.

The health benefits of physical activity (PA), as an outdoor activity, have been the subject of extensive research (Nelson et al., 2007; Warburton & Bredin, 2017) and are well-established facts. In contrast, extended periods of time spent indoors, particularly alone and in front of screens, have been associated with higher mortality rates (Jacobs, Hammerman-Rozenberg, & Stessman, 2018), cognitive decline, social isolation, and depression (Petersen, Austin, Mattek, & Kaye, 2015). On the other hand, numerous studies highlighted that 150-300 minutes of moderate-intensity physical activity (e.g., brisk walking, aerobics) per week among adults aged 18-64 years, and a minimum of 150 minutes per week for older adults

(World Health Organization, 2011) play essential roles in reducing the risk of having cardiovascular diseases (Haennel & Lemire, 2002), type 2 diabetes (Colberg et al., 2016), obesity (Frank, Andresen, & Schmid, 2004; Gretebeck, Sabatini, Black, & Gretebeck, 2017), depression, and even some types of cancer (Cunningham, O' Sullivan, Caserotti, & Tully, 2020).

While there is no doubt that being physically active is preferable to being sedentary for all age groups but particularly for older adults, outdoor activities that do not involve physical exertion can still offer numerous health benefits. For instance, resting outdoors while being exposed to natural light can increase vitamin D intake (Bouillon, 2017) and improve sleep quality (Hood, Bruck, & Kennedy, 2004). Additionally, outdoor resting can enhance opportunities for socialization and inclusion in social life (Cao, Heng, & Fung, 2019; Sugiyama & Thompson, 2007), thereby reducing the feeling of loneliness and the risk of depression, ultimately contributing to better mental health (Luhmann & Hawkley, 2016; Sugiyama & Thompson, 2007). It is also worth noting that outdoor rest can even increase overall daily physical activity levels, as rest is an essential part of physical activity, particularly for older adults (Ståhl, Carlsson, Hovbrandt, & Iwarsson, 2008). Therefore, not only being physically active but also resting outdoors can provide various health benefits to individuals.

However, involvement in outdoor activities depends on various factors. For instance, weather conditions or geography have been found to impact outdoor activities, with rain, ice, snow, and heat, or hilly urban areas were reported as reasons for delaying or shortening the time spent in certain outdoor activities (Delclòs-Alió, Marquet, et al., 2020; Jano-Reiss, Tchetchik, & Flint-Ashery, 2022; Wagner, Keusch, Yan, & Clarke, 2019). In connection with these factors, individual differences (such as age and gender) and the characteristics of the built environment, which are the foci of this thesis, have also been identified as essential influential factors in engaging in outdoor activities (Joseph, Zimring, Kiefer, & Harris-Kojetin, 2006; Musselwhite, 2017; Notthoff, Reisch, & Gerstorf, 2017). Therefore, understanding the characteristics of urban public open spaces (POS) or pedestrian activity spaces (PAS), as the venues of these outdoor activities, along with the characteristics of individuals engaging in these activities, is crucial for enhancing outdoor activity participation and promoting the health and wellbeing of individuals.

Moreover, when designed in an inclusive manner, POS and their components can also contribute to establishing social cohesion and creating more diverse environments, ensuring the visibility and inclusion of all individuals regardless of age, gender, or socioeconomic status (SES) (Burns, Lavoie, & Rose, 2012; Gehl, 2010). Well-planned and adequately vegetated POS can also help reduce land consumption for motorized vehicles (Faiz, 1993; Litman, 2017), mitigate heat island impact (Shishegar, 2014), improve air quality (von Schneidemesser et al., 2019), and minimize the adverse impacts of urbanization on climate change (Hoornweg, Freire, Lee, Bhada-Tata, & Yuen, 2011). Therefore, cities, with their POS, have the potential to contribute not only to the better health of individuals but also foster healthier societies and environments (Cooper Marcus & Francis, 1998; Gehl, 2010, 2011).

1.2. General aim, research questions, and hypothesis

The general objective of this research is to comprehend the relationship between urban environments and outdoor activities among older adults. **The main hypothesis of this dissertation is that the characteristics of urban environments significantly influence the outdoor activities of older adults across different scales, and this can have direct impacts on their physical and mental health (H0).** Therefore, the research aims to enhance our understanding of how spatial factors impact outdoor activities among older adults, with a specific focus on Barcelona, a Mediterranean city that is compact, walkable, and lively.

Building upon this, a set of research questions (RQ1-RQ4) and corresponding hypotheses (H1-H4) have been developed, which serve as the basis for the analyses conducted in this dissertation. While briefly mentioned below, each of these questions will be thoroughly explored in Chapter 4 and Chapter 5 in Part II.

- **RQ1:** How does operationalization of walkability differ between older adults and the general population?
    - **H1: The operationalization of walkability for older adults differs from that of the general population, taking into consideration the specific needs of this age group.**
- **RQ2:** How does urban design impact older adults' outdoor activities at the residential neighborhood level?
    - **H2: The availability of public open spaces and urban microelements in residential neighborhoods influences the outdoor activities of older adults, leading to increased time spent out-of-home and greater engagement in physical activity.**
- **RQ3:** How does urban vitality impact outdoor resting among older adults?
    - **H3: People like watching one another and empty streets are less appealing. Consequently, older adults in Barcelona would prefer high vitality areas for outdoor rest, where they can observe more people passing by and witness various activities taking place.**
- **RQ4:** How do individual differences impact the relationship between the characteristics of urban environments and older adults' outdoor activities?
    - **H4**: **Individuals have varying relationships with urban spaces which results in diverse levels and types of involvement in outdoor activities. Therefore, individual differences, such as age and gender, significantly influence the relationship between the characteristics of urban environments and outdoor activities among older adults.**

1.3. Overview of the thesis

This dissertation is organized around three studies that form the central focus of the research project. Taking into account the aforementioned objectives and the structure outlined in the preface of this document (Figure 1), the dissertation is structured as follows:

Following the introductory chapter (Chapter 1) that outlines the research project, Chapter 2 summarizes the theoretical concepts that serve as a foundation for comprehending the objectives and significance of the studies. In Chapter 3, research design and methodologies are covered. It begins with the general research design and continues with the details of the methodologies employed in two empirical studies, including the setting, sample, data collection, measures, key definitions, and analyses.

Studies are presented in two chapters within Part II. Chapter 4 is dedicated to the systematic literature review, which constitutes the base of the thesis as well as the empirical studies by providing background knowledge on the field. Chapter 5 presents empirical studies focusing on the impacts of certain features of urban environments on outdoor activities among older adults.

In Part III, a combined discussion of the findings from all the presented studies, the strengths and limitations of the study, possible future research areas (Chapter 6) and the final reflections are presented (Chapter 7). Finally, in Part IV, the references used in this research are included in Chapter 8, while additional information on the studies and annexes are provided in Chapter 9.

2. General theoretical framework

This chapter provides a theoretical framework to better understand the studies presented in this dissertation. The aim is to examine the determinants of urban outdoor activities by reviewing relevant concepts. These theories shed light on the factors that influence individuals' engagement in outdoor activities and provide a foundation for the subsequent studies.

2.1. Mobility, outdoor activities, and aging

Mobility traditionally referred to the ability and ease of movement of people, ideas, objects and information from one place to another (Miralles-Guash, 2002; Urry, 2007). It is related to time and space as movements happen within certain spaces and at certain times (Cresswell, 2006; Stjernborg, 2014). In response to the criticism of traditional definitions, more recently mobility has been acknowledged as both "a product and a producer of time and spaces, emotions, and power relations" (Berg, 2016, p. 35; Cresswell, 2006, 2010). More than a physical movement, it is recognized as having full of meaning and playing great roles in crucial aspects of life, such as enabling an autonomous life, fostering social connections, or enhancing overall health and wellbeing (Cresswell, 2006; Hallgrimsdottir, 2016). Consequently, many studies adopted a holistic approach that integrates the concepts of movement, representation, and the practice of mobility, and this shift has led to a greater focus on individuals as mobile bodies (Cresswell, 2010; Sheller & Urry, 2006). Therefore, mobility can be understood as "a thoroughly social facet of life imbued with meaning and power" and "is composed of elements of social time and social space" (Cresswell, 2006, p. 4; Miralles-Guasch, 2011) which impacts individuals and their everyday lives.

Everyday mobility encompasses the regular movements, including time and spaces, emotions, and power relations, that people engage in as part of their daily routines (Miralles-Guasch & Cebollada, 2009). These movements can involve activities such as commuting to work, running errands, visiting family or friends, and participating in recreational activities. These activities could be conducted by various modes of transportation, including but not limited to, walking, cycling, public transportation, or private vehicles. Regardless of the chosen mode, walking typically serves as the initial and the final part of everyday mobility journeys for all population groups (Hallgrimsdottir, 2016).

Some studies showed that older adults, especially after retirement, tend to prefer walking for their everyday mobility (Hallgrimsdottir, 2016). However, private car usage remains the predominant mode of transportation among this age group (Berg, 2016; Hallgrimsdottir, 2016). Yet, it is important to note that preferences and behaviors may vary in different contexts. For example, in Barcelona, 69% of older adults walk on a daily basis (IERMB, 2021). However, in Queensland, Australia older adults have been found to rely heavily on driving due to the difficulties in accessing vehicles or carrying heavy loads, as well as issues with bus routes (Buys, Snow, van Megen, & Miller, 2012). Although some older adults often opt for the relative ease, comfort and privacy offered by car usage, it is worth considering that this mode of transportation may result in a loss of social interactions which is particularly essential for older adults given the shrinking of their social circles (Musselwhite, Holland, & Walker, 2015). Additionally, this mode of transportation can decrease the overall health and wellbeing of older adults, by being physically inactive.

Outdoor activities are closely intertwined with mobility, as individuals often need to move —and engage in physical movement— from one location to another to participate in various utilitarian, recreational, leisure, or fitness-related pursuits. Engaging in daily outdoor activities play a vital role in enhancing individuals' physical and mental health by providing opportunities for exercise, relaxation, socialization, and exposure to nature (Berg, 2016; Hallgrimsdottir, 2016). However, as individuals age, their outdoor activities can undergo changes in type, timing, domain, or scope. Older adults, especially after retirement, have more personal time available to them, although they may face other constraints, such as reduced financial means or increased care-related responsibilities, like taking care of grandchildren (Berg, 2016). Activities such as leisure pursuits, shopping, and running errands are no longer bound by traditional work schedules. This newfound flexibility allows individuals to engage in their preferred outdoor activities at times that suit them best (Berg, 2016). Consequently, they establish a new structure for their everyday lives, including new social and physical activity patterns.

With aging, changes occur in both physical and mental health, and these changes can have an impact on individuals' involvement in outdoor activities. The decline of the body becomes tenfold at the age of 90 compared to 65 (Hallgrimsdottir, 2016). As a result, older adults may experience a decrease in their physical and cognitive capabilities, such as hearing and vision loss, impaired balanced, reduced muscle mass, weakened muscle strength or diminished stamina (Hallgrimsdottir, 2016). Moreover, challenges may arise in navigating unfamiliar outdoor environments or reduced attention span and slower information processing. These changes can lead to difficulties in carrying out activities that include multitasking or quick decision-making, walking fast (e.g., to cross a road in green light), walking long distances, ascending or descending a slope, or climbing stairs (Hallgrimsdottir, 2016). Cognitive changes, combined with physical decline, may necessitate modifications in outdoor activities of older adults to accommodate their abilities or require them to seek assistance. In conclusion, the physical and cognitive changes that come with aging can have a profound impact on older adults' mobility and outdoor activities. These changes can influence lifestyle choices such as relying on cars instead of walking, or spending prolonged periods indoors, which can contribute to worsened health conditions. Therefore, active mobility and regular involvement in outdoor activities become even more vital, particularly for older adults for maintaining a healthy life.

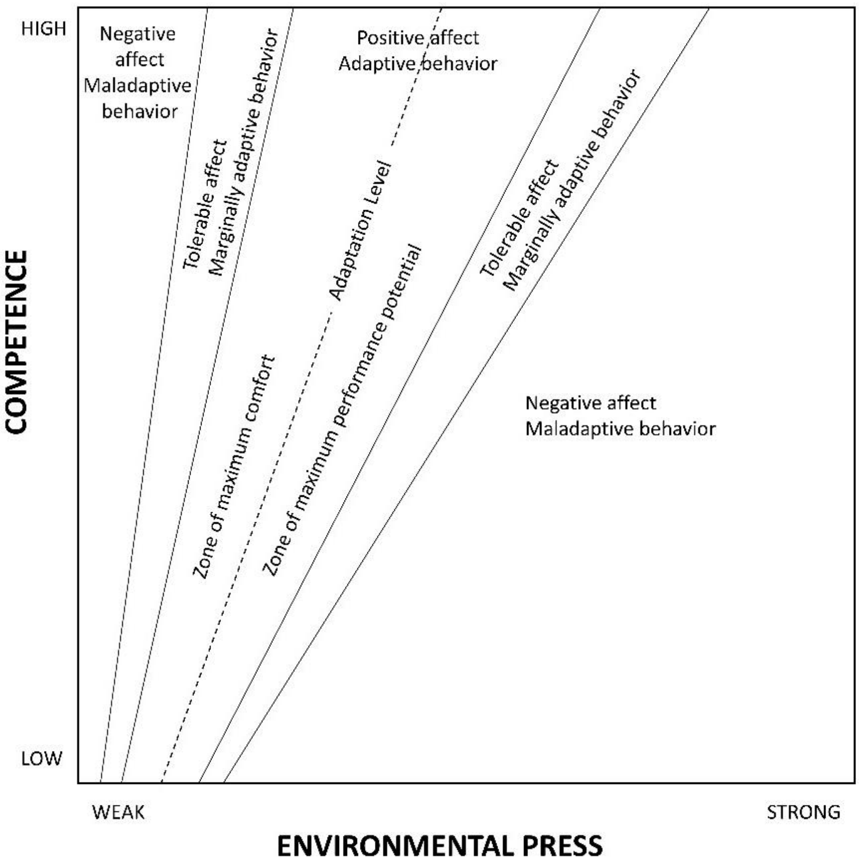
Several theoretical frameworks offer valuable insights into the intricate relationship among outdoor activities, and the influence of environmental and individual characteristics. These frameworks help us understand how individual factors, such as physical and mental changes associated with aging, intersect with outdoor activities, while also recognizing the significant impact of the environment on shaping and facilitating these activities. One such framework is the press-competence theory, developed by Lawton and Nahemow (1973) and Nahemow (1982). This theory highlights the interaction between environmental demands and individuals' competencies, which can change with aging. Additionally, the social-ecological framework proposed by Bronfenbrenner (1977, 1979) offers insights into the dynamic interaction between individuals and their environment in outdoor behaviors by recognizing the influence of various systems. Moreover, the ecological model for health promotion, proposed by McLeroy et al. (1988) and Stokols (1992, 1996), provides a comprehensive framework that considers the multiple levels of influence on individual's health behaviors, which can be utilized to promote health and wellbeing within a social-ecological framework. The following subsections aim to provide detailed information about these theories and how they can enhance the understanding of the relationship between older adults' outdoor activities and the characteristics of individuals and environments.

2.2. Press-Competence Theory

Lawton & Nahemov's press-competence theory (Lawton, 1982; Lawton & Nahemow, 1973) provides a framework for understanding how personal characteristics and the characteristics of the environment interact. It suggests that the characteristics of individuals and environment do not act independently but rather interact with each other. This means that the impact of personal characteristics (such as age) on competence is influenced by the specific characteristics of the environment (such as the presence of POS or slopes), and vice versa.

From the perspective of individual differences and the characteristics of urban environments influencing outdoor activities among older adults, the press-competence theory provides valuable insights into the dynamic interplay between personal and environmental factors. According to this theory, when older adults are within the zone of maximum comfort or the zone of maximum performance (referred to as Positive affect Adaptive behavior zone in Figure 2), they experience a notable sense of ease while engaging in outdoor activities. Conversely, when they venture outside of these zones, their participation in outdoor activities become more challenging. For example, older adults may encounter difficulty in taking part in outdoor physical activities due to the absence of microelements, such as benches. These microelements become particularly relevant for their outdoor pursuits because extended periods of walking can pose challenges for them given the possible decline in their physical capabilities (competence) and the increase in perceived environmental barriers (press), such as sloped streets.

Figure 2 Illustration of Press-Competence Theory



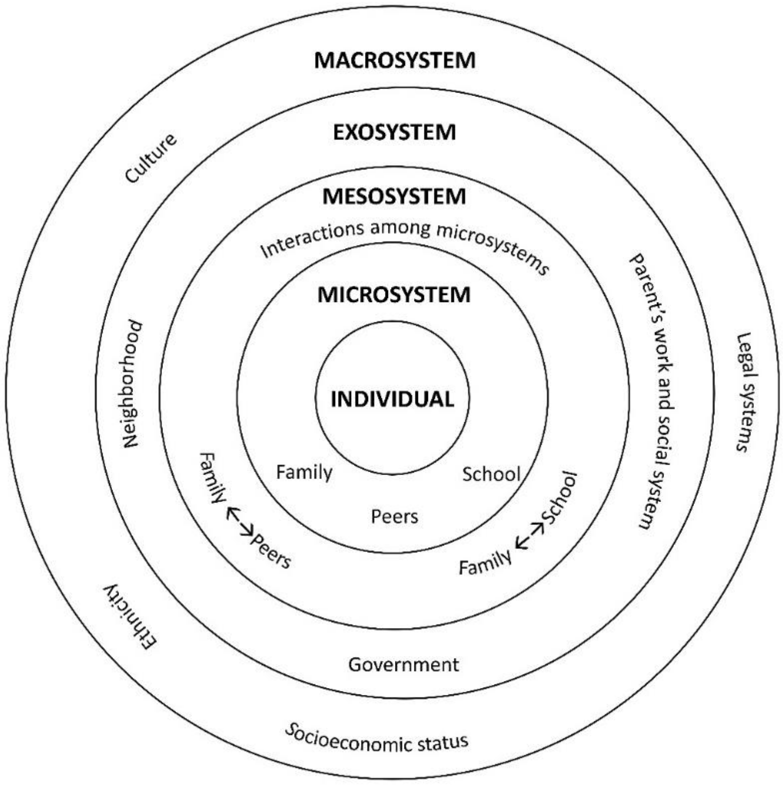
Source: own production adapted from Lawton and Nahemow (1973)

By considering the press-competence theory, research can gain a deeper understanding of the intricate relationship between personal factors, environmental characteristics, and the outdoor activities of older adults. This knowledge is also crucial in creating age-friendly urban environments that promote maximum comfort and performance potential for older adults.

2.3. Social-ecological framework

Social-ecological models are particularly essential in social sciences by seeing the "behavior as being affected by, and affecting the social environment" (Mcleroy et al., 1988, p. 355). One model was proposed by Bronfenbrenner (Bronfenbrenner, 1977, 1979) and was primarily established for a deeper understanding of child development (Figure 3). However, it has since been widely used in physical activity studies among adults due to its comprehensive framework for understanding the influence of various interconnected systems on individuals and their outdoor behavior (Alfonzo, 2005; Bornstein & Davis, 2014; Lindelöw, 2016; Ward Thompson, 2013). These systems, according to Bronfenbrenner (1977), include the microsystem, mesosystem, exosystem, and macrosystem.

Figure 3 Illustration of Bronfenbrenner's Ecological Framework



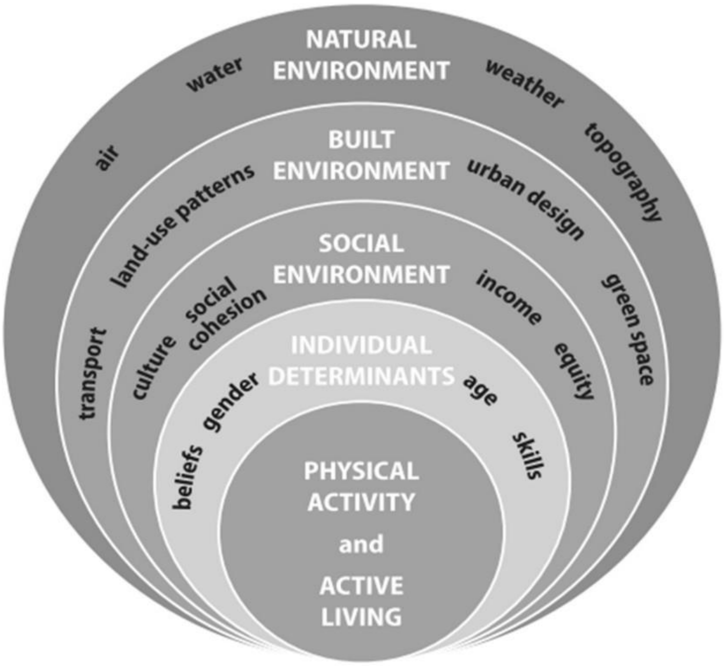
Source: (Ebrary) *adapted from Bronfenbrenner (1977)*

- The microsystem encompasses immediate surroundings such as home, and individuals with whom the person interacts, such as family, friends, and neighbors.
- The mesosystem involves the relationship between two or more interconnected systems, such as the interactions between the individual and the neighborhood or family and peers.
- The exosystem refers to the institutions, policies, or spaces like neighborhood that affect individuals.

- The macrosystem includes cultural values, societal norms, and ideologies that shape individuals' behaviors at all levels.

Within the context of older adults' outdoor activities, the social-ecological framework adapted for physical activity and active living (Bornstein & Davis, 2014) offers valuable insights into how various factors influence individual's decision to engage in outdoor activities (Figure 4).

Figure 4 Illustration of Social-Ecological Model Adapted for Physical Activity and Active Living



Source: Bornstein, Daniel B., and William J. Davis (2014)

This model helps us understand the interplay between physical activity and active living, and the characteristics of individuals, natural, built, and social environment. For example, individual determinants, such as age and gender, can significantly influence older adults' decision-making processes regarding outdoor activities as older adults tend to be involved in physical activities less compared to younger adults, or women being involved in leisure outdoor activities less than men (Azevedo et al., 2007). Moreover, the social environment, including cultural beliefs, societal norms, such as gendered activities where certain tasks are traditionally assigned to women even in older ages (Ortiz, Garcia-Ramon, & Prats, 2016), or the availability of community institutions, like senior centers (Marquet et al., 2020), further shape the decisions in involvement in outdoor activities. The built environment, comprising public open spaces and microelements like parks, plazas, trees and benches, can also significantly impact older adults' participation in outdoor activities (Giles-Corti et al., 2005; Miralles-Guasch et al., 2019; Strath, Isaacs, & Greenwald, 2007; Zhai & Baran, 2017). Availability, accessibility, and the quality of these spaces influence the likelihood of engaging in physical activity. Furthermore, the natural environment, encompassing factors such as weather and topography, also affects older adults' outdoor activity engagement (Delclòs-Alió, Marquet, et al., 2020; McCormack & Shiell, 2011).

The social-ecological framework recognizes that the factors influencing older adults' decision-making process and participation in outdoor activities are not independent but interconnected. The various components of the framework — characteristics of individuals, natural, built, and social environments— do not exist in isolation but interact with and influence each other. For example, the availability of public open spaces, as part of the built environment, can influence older adults' outdoor activities. However, the design, maintenance or the use of these spaces are impacted by social factors, institutions, or the natural environment, and these can also influence outdoor activity engagement among older adults.

Understanding the interconnectedness of these factors is crucial for comprehending how older adults' decision-making processes are shaped and how interventions and policies can effectively support engagement in outdoor activities, which would contribute to older adults' overall health and wellbeing.

2.4. Ecological model for health promotion

Employing the principles of the social-ecological framework, the socioecological theory of health behavior was developed (McLeroy, Bibeau, Steckler, & Glanz, 1988; Stokols, 1992, 1996). This theory recognizes that behavior is influenced by factors at multiple levels, which interact and create a dynamic and reciprocal relationship (Stokols, 1992). The model emphasizes the health-promotive capacity of immediate and more distant environments (Stokols, 1992), as outdoor activities occur within physical space that can either encourage or discourage outdoor activities (Oluyomi et al., 2014).

The socioecological model of health behavior has been widely applied in physical activity studies (Curl, Kearns, Macdonald, Mason, & Ellaway, 2018; Oluyomi et al., 2014) and is particularly relevant to the studies presented in this dissertation, as outdoor activities are closely associated with improved health conditions, especially among older adults (World Health Organization, 1998). For example, designing safe pedestrian infrastructure to reduce falls and injuries or establishing high-quality public open spaces can modify individual's health habits and lifestyles positively. On the other hand, environments can also act as stressors, causing emotional distress due to chronic exposure to undesirable characteristics of the environments, like noise or heavy traffic (Stokols, 1992).

According to McLeroy and colleagues (McLeroy et al., 1988) the factors contributing to the adoption and maintenance of health behaviors, such as regular involvement in outdoor activities, can be categorized as follows:

- Intrapersonal factors: Personal characteristics, including age and gender, play a role in shaping behavior.
- Interpersonal factors: Relationships with family and friends can either encourage or discourage healthy behaviors.
- Organizational factors: Institutions can influence health behaviors through policies, programs, and the provision of supportive environments, such as public open spaces.
- Community factors: Characteristics of the community, such as social networks, or access to resources can shape health behaviors.
- Public policy factors: Local, regional, or national regulations, policies, as well as media, can impact health behaviors.

Understanding the interplay between individual factors, such as age and gender, social relationships including family, friends and neighbors, physical environments encompassing presence of POS, and broader societal influences like psychosocial experiences or social programs for community group activities is crucial for informed decision making in urban planning and design. This is particularly essential to promote outdoor activities for healthy aging.

In conclusion, the socioecological model of health behavior, the social-ecological theory, and the press-competence theory provide a comprehensive framework that emphasize the significance of considering various factors that influence an individual's decision to engage in outdoor activities. By taking into account the complex interplay of personal characteristics, and the features of natural, built and social environments, research can lead policymakers and urban planners develop effective strategies to promote outdoor activities among older adults, benefiting their physical and mental health and wellbeing. Moreover, the implications of these theories extend beyond older adults and have relevance for promoting active aging across diverse population groups and society as a whole.

3. Research design and methodology

This chapter describes the methodologies used in conducting the research presented in this dissertation to contribute responding to the research questions. The chapter includes the general research design, methods used in the systematic literature review and two empirical studies, even though they all have their methodologies explained in related sections in Chapter 4 and Chapter 5.

3.1. General research design

As mentioned in various studies, a literature review is considered as the first step in any research, mainly to understand the topic, know what has already been studied, how they were studied, and what still needs to be addressed in the field (Hart, 2018). Literature reviews are particularly essential when working with secondary data (Doolan & Froelicher, 2009). Thus, this dissertation, also started with a systematic literature review focusing on the objective operationalizations of walkability, or in other words, the level of walking-friendliness of a place. Following this, two empirical analyses were conducted to better understand the impacts of urban environments on outdoor activities among older adults.

Walking, as one of the most accessible forms of PA and the healthiest modes of transport, is particularly essential for older adults. Understanding how walkability is defined, and for whom and how it is operationalized matters greatly since walking, as an outdoor activity depends on the characteristics of individuals as well as the environment in which it takes place. To gain insights into the differences in objective operationalizations of walkability for older adults compared to the general population, a systematic review was conducted (See Chapter 4). The review followed the PRISMA (Preferred Reporting Items of Systematic Review and Meta-Analysis) guidelines, as in previous systematic reviews (Grasser et al., 2013; Labib, Lindley, & Huck, 2020). Following the study selection phase, papers were screened according to their titles and abstracts in the first stage and to their full texts in the second stage. In total, 146 papers were included in the content analysis which involved five main categories; general study characteristics, characteristics of the study design, characteristics of walkability measures, spatial extent and unit, and associations found between walkability and walking-related outcomes. Then, the total sample of papers was stratified into two groups according to their sample as older adults (n=24) and the general population (n=122). See Chapter 4.1.2 and Supplementary Material in Chapter 9.2 for detailed explanations. This review facilitated a comprehensive understanding of how engagement in outdoor activities, beyond walking alone, may differ based on individual's unique needs and their interaction with urban environments. Furthermore, it assisted in refining the research questions posed in this dissertation's empirical studies.

Understanding the relationship between the characteristics of urban environments and human outdoor activities has drawn the attention of scholars from different research fields for decades (Gehl, 2006). To explore this relationship, studies have used methods, including but not limited to, activity monitoring, spatial analysis, and surveys and questionnaires. Activity monitoring involves tracking individuals' activities using wearable or portable devices such as Global Positioning System (GPS) and/or accelerometer devices. This method enables detailed analysis of outdoor human activities. The use of objective methods, such as tracking, is essential especially in urban aging studies since it helps overcome some of the limitations of self-reported data due to recall bias, such as individuals' cognitive or memory problems that could affect accurate recall of activities when asked in a survey, not considering some types of activities like dancing or gardening as physical activity, or incorrect answers due to social desirability. GPS and accelerometer devices are widely used to measure the location and/or duration of routine activities (Cornwell & Cagney, 2017) such as PA (Vorlíček et al., 2019) or resting (Owen, Healy, Matthews, & Dunstan, 2010). The most important advantage of this method is that it provides accurate results (with the median positional error during walking as 3.9 meters, the variation in the median error as 0.7 meters in open areas, 2.6 meters in half-open areas, and 5.2 meters in urban canyons as in Qstarz BT-Q1000X GPS devices) (Schipperijn et al., 2014), which are particularly essential for studying human outdoor behavior and certain characteristics of POS (Delclòs-Alió, Marquet, et al., 2020; Marquet et al., 2020; Vich et al., 2021).

Another method called spatial analysis is used to examine the spatial distribution and patterns of urban environments and outdoor activities by utilizing geographic information systems (GIS). This method offers the opportunity to explore and understand the intricate relationships between human activity patterns and urban environments from a geographic perspective, aiding in prediction and decision-making processes in planning and design. The drawback of spatial analysis is that it can be processing intensive.

Finally, surveys and questionnaires, provide valuable insights into human behavior and perceptions regarding outdoor activities and urban environments, along with detailed information about individuals such as age, gender, or socioeconomic status. These methods play a crucial role in understanding the variations in individual differences and the characteristics of urban environments and outdoor activities. By collecting and analyzing demographic data through questionnaires and surveys, differences between age or gender groups can be understood, while individuals' perception of their environment and how it influences their outdoor activities can provide a deeper understanding of the complex relationship between the environment and outdoor activities from the perspective of those experiencing it. It is worth noting that questionnaires are subject to recall bias (as mentioned before), particularly concerning perceived duration, types, patterns, or location of activities, which can be misleading especially among certain population groups, like children or older adults.

These methods were employed in empirical studies conducted as part of this dissertation which aiming to comprehend the relationship between urban environments and older adults' outdoor activities. Following this introductory section that explains the overall research design of the thesis and the systematic literature review, the subsequent sections will focus on two empirical studies. They will provide information on the study setting, sample, data collection methods, measures, and key definitions, as well as spatial and statistical analyses utilized in conducting these studies.

3.2. Setting of empirical studies

Two empirical studies conducted in Barcelona form a significant part of this dissertation. This chapter's objective is to furnish information regarding the city's geography, climate, demography, scale, and urban texture. This information will enhance the comprehension of the context and analyses conducted in the studies, ultimately leading to a more accurate interpretation of the results.

Geography, climate, and demography of Barcelona

Barcelona is situated in the northeast of the Iberian Peninsula (Figure 5). It is a coastal city in Catalonia bordered by the Mediterranean Sea in the southeast and the Collserola mountain range in the northwest. As a result, the city has evolved within the confines of these natural boundaries.

The city experiences a hot-summer Mediterranean climate, characterized by generally mild temperatures year-round (with a maximum of 35 °C and minimum of 5 °C). Annual precipitation in the area is moderate, ranging between 600mm and 650mm, with the majority occurring during fall and spring (European Environment Agency, 2012). However, with the impacts of global warming, the weather conditions in Barcelona is also altering (Gessner, Fischer, Beyerle, & Knutti, 2021). Nevertheless, these conditions create a mostly favorable environment for outdoor activities, as there are no frequent extreme weather events throughout the year. This aspect is particularly significant for studying the impact of characteristics of urban environments on outdoor activities among older adults in Barcelona.

Barcelona City has a population of 1,628,936 as of 2018, with over one-fifth of the population (349,433) consisting of older adults (≥65 years old) (Ajuntament de Barcelona, 2018). The number of older adults in Barcelona is on the rise, and it is projected that by the year 2030, one in every three residents will be in this age group (Barcelona Estadistica, 2018).

Figure 5 Location and boundaries of Barcelona city

Source: own production

Scale

Selection of appropriate scales in urban studies related to outdoor activities is crucial due to its direct impacts on the analyses. This is particularly important in urban aging research. Numerous studies indicate that older adults tend to spend more time in their residential neighborhoods compared to younger adults, who often leave for school or work (Aneshensel, Harig, & Wight, 2015). Moreover, older adults often face mobility challenges, making it more difficult for them to engage in outdoor activities in wider areas compared to their younger counterparts (Aneshensel et al., 2015; Lawton & Simon, 1968). Consequently, several studies have focused on residential neighborhoods to analyze the influence of the built environment on outdoor activities among older adults (Cao et al., 2019; Chang, 2020; Chaudhury, Campo, Michael, & Mahmood, 2016; Glass & Balfour, 2003; Gong, Gallacher, Palmer, & Fone, 2014; Mollenkopf et al., 2004). However, there are also publications that criticize this approach for generalizing or stereotyping the older adult population, as well as for overlooking some types of outdoor activities such as recreational activities that mostly take place outside of residential neighborhoods (Kwan, 2018), possibly due to a lack of natural areas, especially in dense urban cities (Fuller & Gaston, 2009; Haaland & van den Bosch, 2015).

At the macroscale, planning decisions can shape the distribution and characteristics of public open spaces, while at the microscale, the presence and design of public open spaces and urban microelements can influence how people use them and the amount of time they spend in these spaces. Thus, scale selection should be carefully considered for each research question.

In light of these considerations, the first empirical study in this dissertation (Chapter 5.1) focuses on the neighborhood scale to examine the impacts of neighborhood public open spaces and urban microelements on older adults' outdoor activities within their residential neighborhoods. The second empirical study (Chapter 5.2), on the other hand, takes a city-scale approach to explore the relationship between urban vitality and its impacts on outdoor resting. Due to the availability of data on public open spaces and urban microelements provided by the City Hall (Ajuntament de Barcelona, 2016), as well as urban vitality data

(Delclòs-Alió & Miralles-Guasch, 2018), the empirical studies were limited with the outdoor activities took place within the boundaries of Barcelona city (Figure 5).

Urban texture

Barcelona City, covering an area of 102 km^2, is commonly described as a compact, walkable, and vital city (Delclòs-Alió & Miralles-Guasch, 2018; Delclòs-Alió, Vich, & Miralles-Guasch, 2020; Marquet & Miralles-Guasch, 2015). It possesses unique characteristics related to its density, urban morphology, geography, climate, urban planning, and design, among others. Therefore, the study of public open spaces and microelements is particularly relevant to study Barcelona in understanding the relationship between characteristics of urban spaces and outdoor activities among older adults.

In terms of greenspace per inhabitant, Barcelona has a lower ratio compared to other European cities, with approximately 18 m^2 (including the peri-urban forest of Collserola Natural Park) (Figure 6). While there are not many large urban parks in the city, small parks (Figure 6), ramblas (mostly former waterways transformed into broad, mainly pedestrian boulevards) and plazas (Figure 7) can compensate for the need for open spaces for outdoor activities (Baró et al., 2014; Miralles-Guasch et al., 2019). Barcelona boasts a dense and evenly distributed number of street trees (98.4/1,000 inhabitants) (Figure 8) as well as public benches in various places (16.9/1,000 inhabitants) (Ajuntament de Barcelona, 2016; Baró et al., 2014) (Figure 9). Therefore, despite the relatively low ratio of urban greenspaces, Barcelona offers a high provision of public open spaces and urban microelements. Combined with the city's climate and the cultural inclination to spend time outdoors, like in other Mediterranean cities, Barcelona fosters a citywide engagement in outdoor activities throughout the year.

3.3. Recercaixa project

The main data for the empirical studies was collected as part of the RecerCaixa Project ("Ciudad, calidad de vida y movilidad activa en la tercera edad. Un análisis multi-metodológico a través de Tracking LivingLabs") (Delclòs-Alió, Marquet, et al., 2020; Marquet et al., 2020; Miralles-Guasch et al., 2019; Vich et al., 2021). The project (2016ACUP30 – Programa RecerCaixa 2016) was conducted by Xavier Delclòs-Alió, Guillem Vich, and Oriol Marquet and other members of the research group GEMOTT under the supervision of Carme Miralles-Guasch. Since the author of this dissertation was not directly involved in the data collection process, this data is categorized as secondary data.

Sample

The project was conducted during 2017-2018 and data was collected from 269 participants residing in the Barcelona Metropolitan Area. Participants were recruited through 39 senior day centers located across the metropolitan area. A snowball/chain-referral sampling technique was employed to include voluntary older adults from participants' social circles. Eligible participants were required to be 65 years old or older and without specific mobility impairments.

Prior to participation, participants were provided with written and oral information about the study, including the research protocol and instructions, and they provided informed consent. Confidentiality was maintained by using random identification numbers. The study received approval from the Ethics Committee on Animal and Human Experimentation at Universitat Autònoma de Barcelona (UAB; CEEAH-3656).

In the analyses, the total sample of the RecerCaixa Project was categorized by gender (woman/man), and age groups, distinguishing between the youngest-older (<75 years old) and the oldest-older adults (≥75 years old), as the outdoor behavior of older adults in relation to the built environment exhibits significant variations based on individual differences (Notthoff et al., 2017). Women comprised 56.9% (n=153) of the 269 participants, while youngest-older adults accounted for 50.5% (n=136) of the total (Table 1). Thus, a relatively balanced representation of both genders and age groups was ensured.

Table 1 Descriptive of the Sample

Variable	**Count (percentage)**	**Cross-group counts (percentages within the primary group)**
n (%)	269 (100%)	
Gender		
Women (W)	153 (56.9%)	76 Yoe (49.7%) – 77 Ooe (50.3%) 101 GH (66%) – 47 RH (30.7%) – 5 BH (3.3%)
Men (M)	116 (43.1%)	60 Yoe (51.7%) – 56 Ooe (48.3%) 90 GH (77.6%) – 24 RH (20.7%) – 2 BH (1.7 %)
Age		
Youngest older adults (Yoe)	136 (50.5%)	76 W (55.9%) – 60 M (44.1%) 105 GH (77.2%) – 30 RH (22.1%) – 1 BH (0.7%)
Oldest older adults (Ooe)	133 (49.5%)	77 W (57.9%) – 56 M (42.1%) 86 GH (64.7%) – 41 RH (30.8%) – 6 BH (4.5%)
Perception of health		
Good (GH)	191 (71%)	101 W (52.9%) – 90 M (47.1%) 105 Yoe (55%) – 86 Ooe (45%)
Regular (RH)	71 (26%)	47 W (66.2%) – 24 M (33.8%) 30 Yoe (42.3%) – 41 Ooe (57.7%)
Bad (BH)	7 (3%)	5 W (71.4%) – 2 M (28.6%) 1 Yoe (14.3%) – 6 Ooe (85.7%)

Source: own production

Data collection and management

GPS and accelerometer data

Participants within the RecerCaixa Project were requested to wear a GPS device (QStarz BT-Q1000X; QStarz International Co., Ltd., Taipei, Taiwan) and an accelerometer device (Actigraph GT3X+; ActiGraph LLC, Pensacola, Florida USA) on their wrists for seven days. Geolocated points captured by the GPS and accelerometer devices (total n=12,165,103) were aggregated into 15-second intervals using the Physical Activity Location Measurement System – PALMS (Center for Wireless and Population Health Systems) (University of California, San Diego, CA) (Jankowska, Schipperijn, & Kerr, 2015) (Figure 10).

Figure 6 Greenspaces in Barcelona city

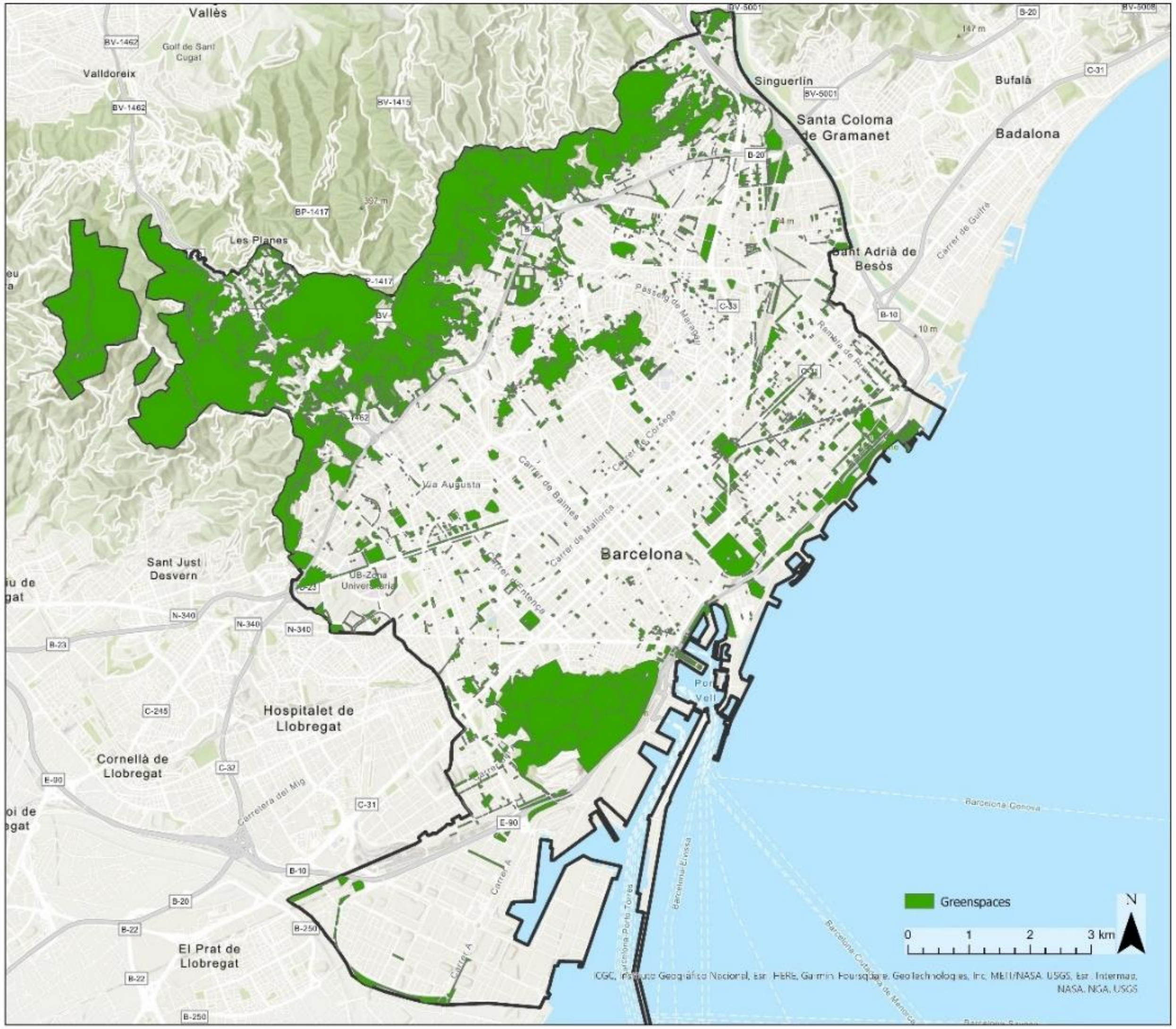


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Figure 7 Boulevards (Ramblas) and Plazas in Barcelona city

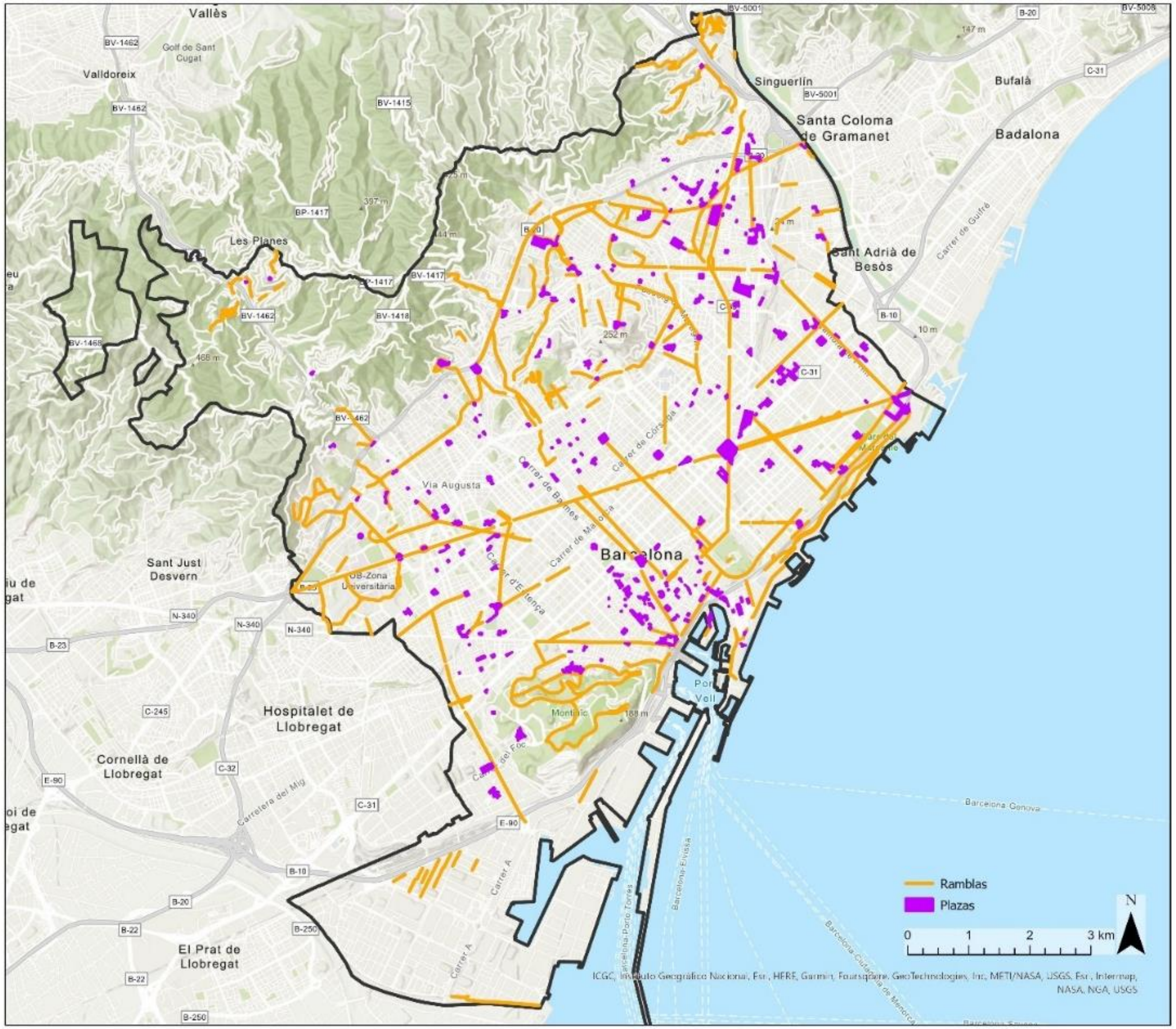

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Figure 8 Street trees in Barcelona city

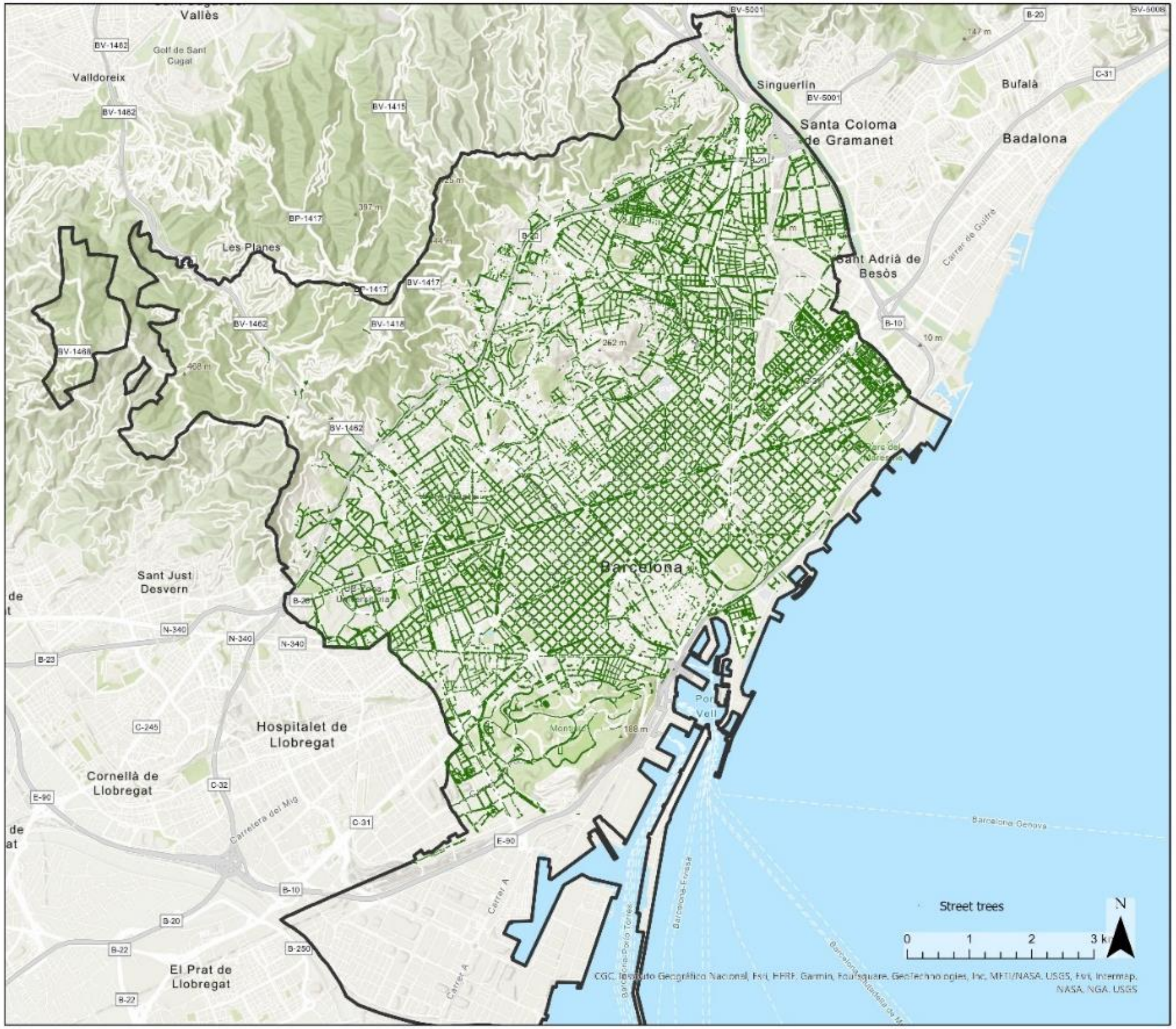

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Figure 9 Benches in Barcelona city

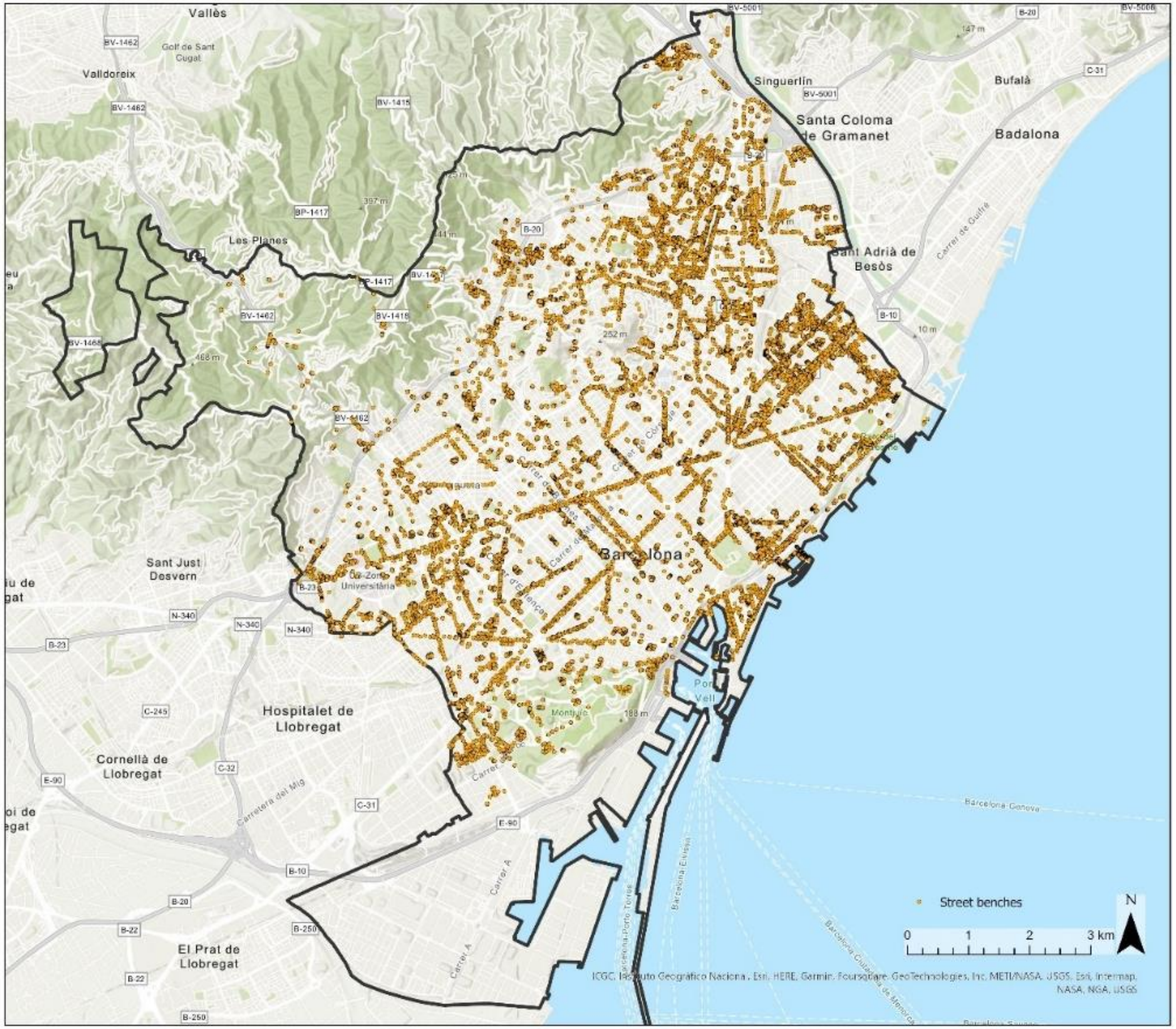

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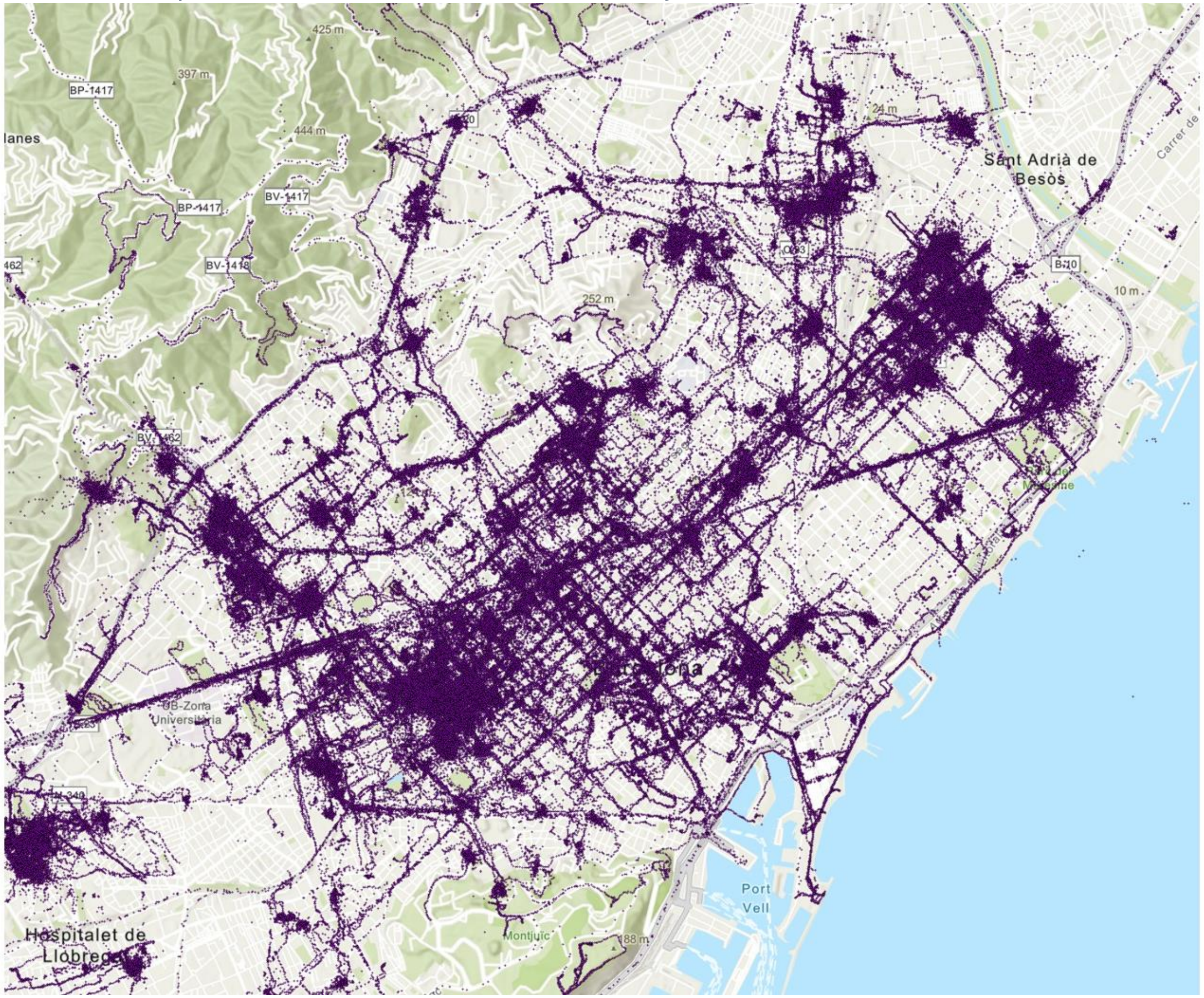
Figure 10 Geolocated datapoints collected within the RecerCaixa Project



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All collected points were then transformed into trips and these were analyzed to determine valid days which, according to previous studies (Rundle et al., 2016; Trost, Mciver, & Pate, 2005), included at least ten hours of device-wearing time during at least four days — including weekend days — within the study period. Then with the option that PALMS offers, valid pedestrian trips were selected for the empirical analyses (Figure 11).

By employing PALMS, detailed information about each participant's itineraries could be obtained. This information included, but not limited to, the mode of transport (vehicle, cycling, and walking, determined based on the assumptions of average speed), whether the participant was physically active or resting at each point, the intensity level of physical activity, the number of trips conducted in a day, and whether the activity took place indoors, outdoors, or in a vehicle. This information was derived from accelerometers and GPS devices depending on the Signal to Noise Ratio.

Consequently, the availability of this information allowed for a detailed exploration of the characteristics of participants' itineraries in the analyses (Figure 12).

Figure 11 Participants' valid pedestrian trips within Barcelona city

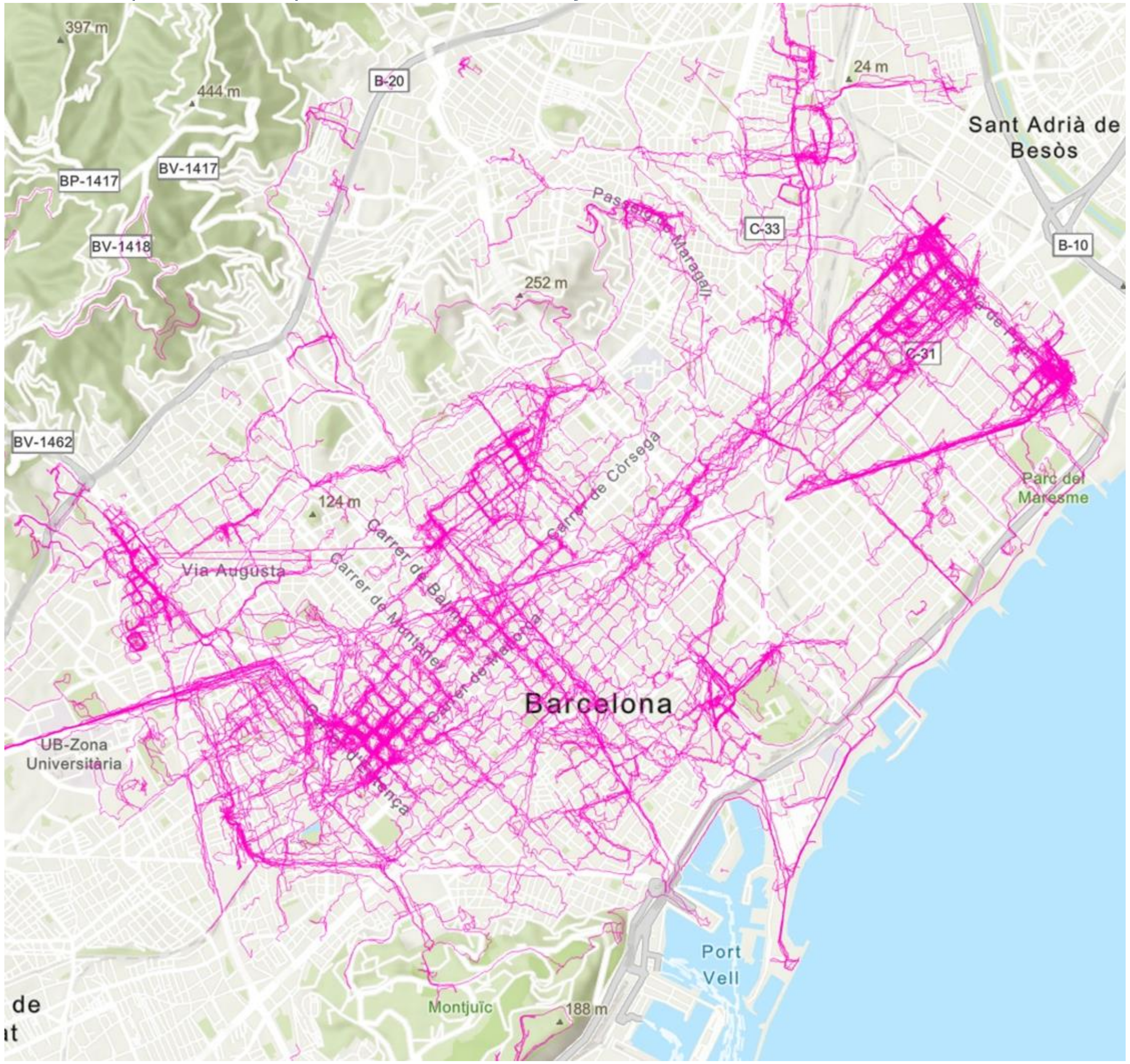

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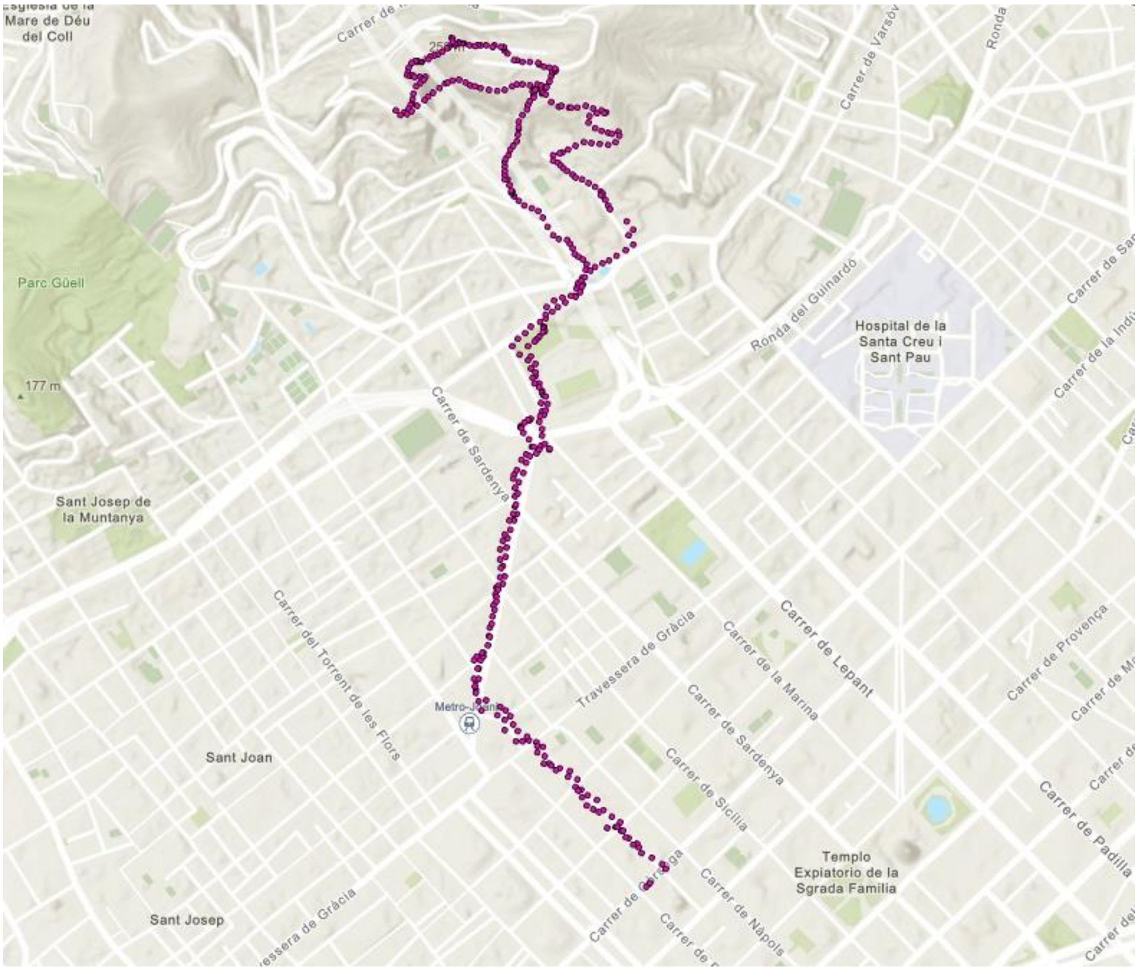
Figure 12 Example of daily tracking datapoints from one trip of a participant[3]



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Questionnaire

Besides GPS tracking, participants were also requested to complete a questionnaire as part of the RecerCaixa Project. The questionnaire consisted of 18 main questions (with sub-questions) pertaining to participants' primary mode of transportation, perceived daily physical activity time, perceived health status, availability of services in their neighborhoods, and perceived time spent walking to access these services (See Chapter 9.4). Additionally, the questionnaire included inquiries about participants' perceptions of the built environment in their neighborhoods, such as the presence of benches, trees, sidewalks, their maintenance, street characteristics (including noise, traffic, and safety), and

[3] Trackpoints around participant's residence were omitted to ensure privacy

overall neighborhood satisfaction. Although the questionnaire primarily provides nominal data (e.g., yes-no answers), it still serves as a valuable source for this study, facilitating a deeper understanding of how individual characteristics (e.g., perceived health status), as well as perceived neighborhood characteristics can influence older adults' outdoor activities in relation to objectively measured urban design and planning features.

Public open spaces and urban microelements data

The data regarding public open spaces (POS) and urban microelements were obtained from the City's Land Use Map (Ajuntament de Barcelona, 2016) in the form of shapefile layers (Table 2). The information in the shapefiles were used as they were obtained from the source. However, for the bench layer, any overlapping data were meticulously removed and excluded from the dataset prior to the analysis.

Table 2 Description of greenspaces, POS and microelement layers used in the first empirical study

Layer	Definition	Unit	Unit used in analyses	Source
Greenspaces	All parks and gardens in the city	area (km^2)	percentage (greenspace area in neighborhood area)	City's Land Use Map
Plazas and Ramblas (boulevards) as POS	All plazas and ramblas (boulevards) in the city	area (km^2)	percentage (plaza and rambla area in neighborhood area)	
Benches	Benches on the streets, boulevards, and plazas in the city, excluding the ones in parks	Count/area (km^2)	ratio (bench count in neighborhood area)	
Trees	Trees on the streets, boulevards, and plazas in the city, excluding the ones in parks	count/area (km^2)	ratio (tree count in neighborhood area)	

Source: own production

3.4. Measures, key definitions and analyses

This section is devoted to providing a description of the measures and key definitions utilized in the empirical studies presented in this dissertation.

Public open spaces and microelements

In one of the empirical studies (Chapter 5.1), the analysis focused on specific POS and urban microelements within participants' neighborhoods. The POS considered in this study included greenspaces encompassing all parks and gardens in the city, boulevards (ramblas), and plazas. Urban microelements examined included street trees and benches, referring to those located on the streets, boulevards, and plazas in the city (excluding the ones in parks, due to data limitations) (Table 2).

Neighborhood

Neighborhood definitions vary in the literature, with some studies using administrative units (Lotfi & Koohsari, 2011; Yi, Samat, & Wan Muda, 2017) and others using buffers around residential address (Arvidsson, Eriksson, Lonn, & Sundquist, 2013; Nyunt et al., 2015). In the empirical studies presented in this dissertation, neighborhoods were defined using street network buffers around residential addresses. These buffers were established based on a 10-to-15-minute walking distance for older adults, as suggested by previous research (Adams et al., 2014; Carlson et al., 2012; Marquet & Miralles-Guasch, 2014; Prins et al., 2014). These buffers were used in the main analyses of the first empirical study (Chapter 5.1) to calculate key variables within neighborhoods, as well as in the neighborhood vitality calculations in the second empirical study (Chapter 5.2). Additionally, they were employed in walkability calculations which were used as covariates in both analyses.

Outdoor activities

One of the main focuses of this dissertation is studying outdoor activities among older adults. However, since the existing research emphasizes physical activity as the main outdoor activity, it is important to clearly define the outdoor activities considered in this thesis.

- *Outdoor physical activity* encompassed all pedestrian activities that occur outdoors and involve physical activity (PA) (Activity intensity > 0). Tracking data was used to identify outdoor pedestrian points where participants were active. As the data points were gathered every 15 seconds, the variable representing PA time was analyzed as the cumulative number of points (4 data points = 1 minute of PA).

- *Outdoor resting* included pedestrian data points that occurred outdoors without any PA involvement. These points were selected from the same dataset mentioned above. For the second empirical study (Chapter 5.2), each data point was coded as resting = 1 and active = 0 based on the activity intensity variable in PALMS, where Activity intensity = 0 indicated resting, and Activity intensity > 0 indicated activity engagement.
- *Total outdoor time (TOT)* or *Time out-of-home (TOH)* encompassed the overall time spent in any activity that took place outdoors, regardless of the activity levels. Therefore, TOT or TOH included the time spent in both outdoor PA and outdoor resting activities in the first empirical study (Chapter 5.1).

<u>Walkability and vitality</u>

In both empirical studies neighborhood walkability was considered as a covariate that could potentially act as a confounder in the analyses. Walkability was assessed using the walkability index developed by (Frank, Sallis, et al., 2010), which incorporates variables such as intersection density, residential density, retail floor area ratio, and land use mix. The formula used to calculate the neighborhood walkability was as follows:

> *Neighborhood walkability = [(2×z - intersection density) + (z – net residential density) + (z – retail floor area ratio) + (z – land use mix)]*

Although this walkability index was originally created for the general population and was based on the data from two cities in the United States, it was used in this dissertation due to practical constraints such as time and energy resources. Developing a new walkability index specifically for older adults in Barcelona was beyond the scope of this study.

Urban vitality, as a complex phenomenon, has been theorized by various researchers (Jacobs, 1961; Maas, 1984; Mehta, 2009; Montgomery, 1998) and has been analyzed for different cities based on these theories (Delclòs-Alió & Miralles-Guasch, 2018; Sung, Go, & Choi, 2013). The urban vitality index for Barcelona was created by Delclòs-Alió and Miralles-Guasch (2018) considering six urban conditions outlined in Jane Jacobs' book (1961). These conditions included diversity, contact opportunity, need for aged buildings, concentration, accessibility, and distance from border vacuums.

The diversity condition was calculated based on the building-use mix and the ratio of residential to non-residential uses. Contact opportunity referred to the opportunities created by the built environment for pedestrians to interact and was calculated using block size and street width. The need for aged buildings, included the mean construction year of the buildings and its standard deviation. Concentration, meaning the number of people or possible users of a space, was calculated with population density, housing density, and building density. Accessibility was measured by the distance to the nearest public transportation stop, including bus, metro, or train. Border vacuums, defined by Jacobs as large infrastructures, such as railways, or buildings acting as barriers, and the last condition was calculated as the distance from these border vacuums.

These variables were calculated for 100m x 100m cells within Barcelona city, and z-scores were used to standardize the indicators for comparison. For variables that had a negative impact on vitality, such as distance to border vacuums, the values were included as negative. Conversely, for variables like population density that had positive influences on urban vitality, the values were included as positive. All these values were integrated into an index called the JANE index, as described in the aforementioned study (Delclòs-Alió & Miralles-Guasch, 2018). This data was used in the analysis of the second empirical study presented in this dissertation (Chapter 5.2).

<u>Spatial and Statistical Analyses</u>

Spatial Analyses

In the first empirical study, a spatial analysis was performed to examine the relationship between PA and TOH and the presence of POS such as greenspaces, plazas, and boulevards (ramblas), and urban microelements including benches and street trees within neighborhoods. Neighborhoods were defined as 500-meter street network buffer from participants' residential addresses, corresponding to approximately 10-minutes walking for older adults. The percentage of POS and the density of microelements in each neighborhood were calculated using official land-use data (Table 2). Additionally, participants' PA time and TOH within their neighborhoods were calculated from GPS-tracking data.

In the second empirical study (Chapter 5.2), the analysis focused on the relationship between urban vitality and outdoor resting. Urban vitality using JANE vitality index (Delclòs-Alió & Miralles-Guasch, 2018), was assessed at two levels:

1) Track-based vitality, which involved overlaying participants' outdoor points from GPS-tracking data with the JANE vitality index (Delclòs-Alió & Miralles-Guasch, 2018),

2) Residence-based vitality, which involved averaging the vitality values around participants' neighborhoods.

Both studies utilized ArcMAP (version 10.5; Esri Inc., Redlands, CA) for the analyses.

Statistical Analyses

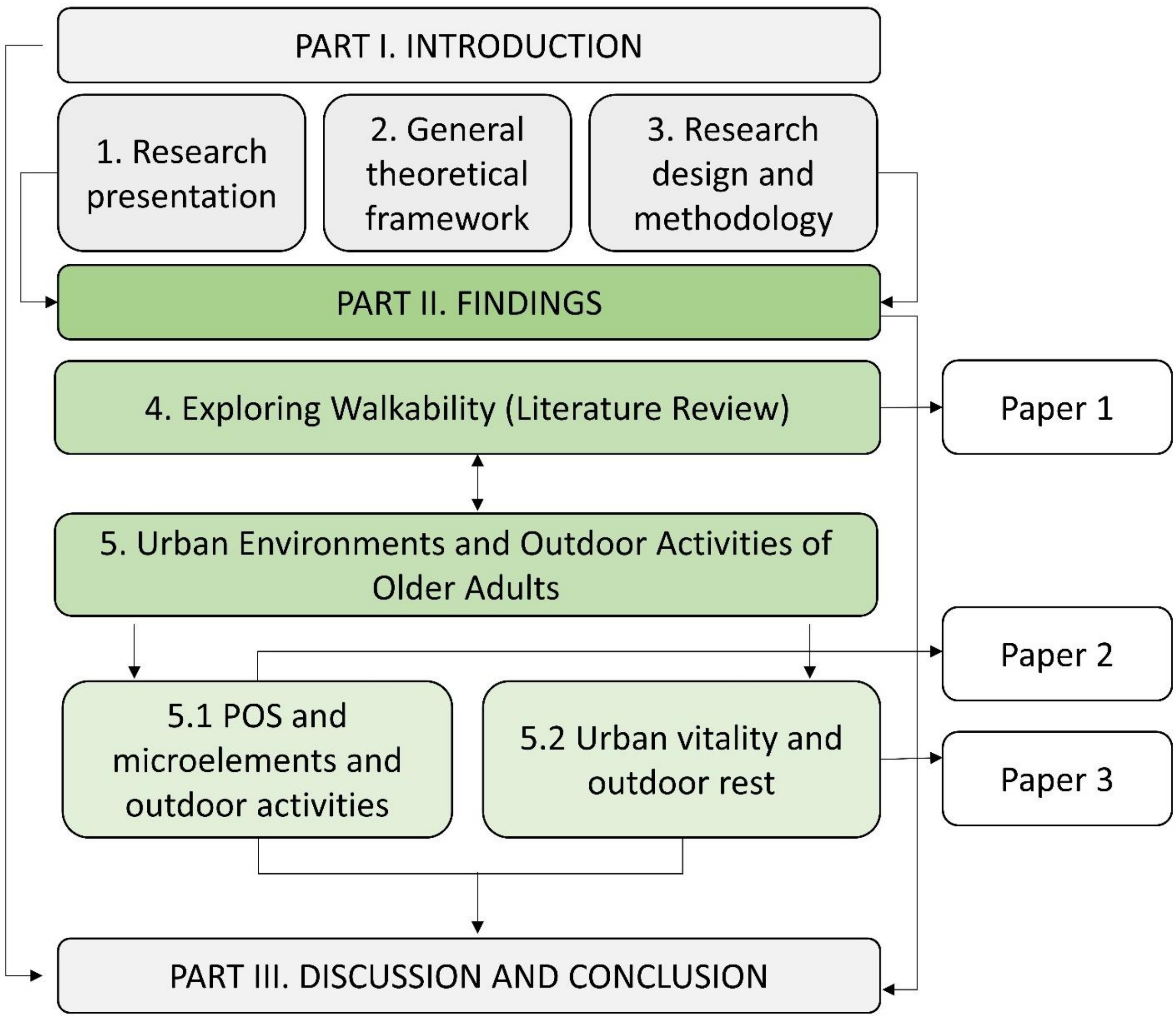
In both empirical studies, bivariate analysis and descriptive statistics were initially employed to understand the relationship between the variables and outcomes. Since the variables used in the first empirical study were not normally distributed, nonparametric tests such as the Mann-Whitney U test for two-category variables and the Kruskal-Wallis test for variables with three or more categories were used. Additionally, one-way ANOVA tests were conducted to identify statistically significant associations in both studies.

In the first case study (Chapter 5.1), multilevel linear regression analyses were conducted to examine the relationship between the variables and outcomes while accounting for covariates such as neighborhood walkability and main daily mode of transport. Initially, a model was run for all participants considering both PA and

TOH within their neighborhoods. Subsequently, the models were stratified by gender and age groups to further explore the impacts of individual differences. IBM SPSS (version 21, IBM Corp, Armonk, NY) was used for the statistical analyses in this empirical study.

In the second empirical study (Chapter 5.2), mixed effects logistic regression models were employed to investigate the relationship between urban vitality and the probability of resting outdoors. Additionally, three interaction terms were created: age and track-based vitality, age and gender, and age, gender, and track-based vitality. These interaction terms were used to calculate the adjusted predictive probabilities of outdoor rest at representative values of age, gender, and track-based vitality. The statistical analyses in this study were performed using Stata (version 15; StataCorp LLC, Texas, USA).

PART II. FINDINGS



4. Exploring walkability

4.1. How different are objective operationalizations of walkability for older adults compared to the general population? A systematic review

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BMC Geriatrics

RESEARCH Open Access

How different are objective operationalizations of walkability for older adults compared to the general population? A systematic review

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Abstract

Background: Walking is an essential activity for everyone and for older adults in particular, given that it is the most accessible form of physical activity and one of the healthiest transportation modes. Understanding how walkability (the potential of the environment to enable and/or encourage walking) has been objectively measured and analyzed for older adults is critical to create more inclusive, healthy, and sustainable environments and to promote healthy aging. Despite the numerous reviews on physical activity among older adults and its relationship with the built environment, the literature still lacks comparison reviews focusing specifically on objective operationalizations of walkability for older adults vs. the general population.

Methods: We conducted a systematic review of 146 empirical studies that measured walkability objectively in relation to walking-related outcomes. We compared studies focused on older adults ($n = 24$) and the general population ($n = 122$). Content analysis included the characteristics of the study design, walkability measures, spatial extent, and associations found between walkability and walking-related outcomes.

Results: In both groups of publications, the majority of studies were conducted in the US, Canada, and Europe, and largely in high-income countries. They were mostly published in health-related journals and used cross-sectional designs, operationalized walkability by using indexes, employed self-reported measures for walking-related outcomes, and found positive associations between walkability and walking outcomes. However, we observed some differences among studies focusing on older adults. Compared to studies focusing on the general population, a larger proportion of studies on older adults was conducted in the Middle East and Asia, and they used longitudinal designs, mixed methods to measure walking-related outcomes, variables related with land-use characteristics, safety from traffic and crime, and greenery, and a larger proportion found positive, as well as no associations between walkability and walking-related outcomes.

Conclusion: Although there is a promising increase in interest in older adults-focused walkability studies in the last decade, there is still a need for more studies focusing on different settings, using wider spatial extents, longitudinal

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JCR (2022): Impact Factor = 4.1, Journal Rank (JCI)= Q1 (Gerontology), Q2 (Geriatricas & Gerontology)

4.1.1. Introduction

Walking is one of the most accessible, economically viable, democratic, communal, sustainable, environmentally friendly, and healthiest forms of transportation (Gunnarsson, 1996; Le, Buehler, & Hankey, 2018; Litman, 2004; Pucher & Buehler, 2010). It is also the easiest way of including physical activity (PA) into daily life routines while helping to achieve recommendations for a physically and mentally healthy life (i.e., 150–300 minutes/ week of moderate-intensity activity for adults aged 18–64 years, and a minimum of 150 minutes/ week for persons ≥65 years) (World Health Organization, 2021, 2011). Additionally, for specific population groups, such as older adults (≥65 years), walking is the most common, if not the only, type of PA (DiPietro, 2001). Yet, engaging in this activity is related to various factors. Among many other factors, walking depends on who is undertaking this activity (i.e., the characteristics of individuals). Some population groups, for instance, older adults, are less involved in this activity due to factors such as increased physical limitations compared to other age groups. Walking also depends on where it takes place, since the characteristics of an environment could encourage or limit this activity. Some environmental features, such as dimly lit streets, steps, steep hills, or broken pavements might become a barrier for walking among some groups such as older adults more than others (Garvin, Nykiforuk, & Johnson, 2012), due to the decrease in the level of "individual competence" (Nahemow & Lawton, 1973, p. 25) to cope with the "environmental press" (Murray, 2008, pp. 385–396; Nahemow & Lawton, 1973). Thus, some environments could be more "walking-friendly" or walkable than others, for different types of individuals.

The definition of walkability varies vastly in the literature, and depends on "who is asking" (Lo, 2009, p. 148) or personal perspective. The most common definition has been the walking/ pedestrian friendliness of a given place (Moura, Cambra, & Gonçalves, 2017). However, more detailed definitions such as how traversable, compact, safe, lively and sociable, physically enticing, or exercise-inducing an environment is, have also been used (Forsyth, 2015). Walkability has also been defined as a complex and multidimensional concept, whose dimensions are measurable "individually or combined into an index" (Forsyth, 2015, p. 11). Studies measuring walkability of a place have received greater scholarly attention in the last decades in different countries, under the scope of various research fields, and using a wide array of variables and operationalization methods (Shields, Gomes da Silva, Lima e Lima, & Osorio, 2021). Many studies have associated walkability with PA outcomes, and while the results generally show a positive association between the two, variations for different pedestrian groups, such as children, adults, older adults, or impaired pedestrians, are also highlighted (Moura et al., 2017; Ubiali, Gori, Rochira, Raguzzoni, & Fantini, 2021). Some studies have employed subjective measures (e.g., perceptions), while others have preferred measuring walkability objectively (e.g., by using Geographic Information Systems - GIS). Although some studies on adults presented partial agreement between subjective and objective measures of walkability (Gebel, Bauman, & Owen, 2009), high misperception levels were also highlighted in other studies (Gebel, Bauman, Sugiyama, & Owen, 2011). Studies on older adults that used objective measures in their analysis generally presented stronger associations (Lin & Moudon, 2010; Moura et al., 2017).

Various reviews on walkability studies have to date focused on how differently walkability is defined in the literature (Forsyth, 2015; Lo, 2009), how it is operationalized, and how it could contribute to more PA engagement (Ariffin, Abd Rahman, & Zahari, 2021; Ewing & Handy, 2009; Hall & Ram, 2018; Talen & Koschinsky, 2013; Wang & Yang, 2019), or on the trends that walkability research has followed throughout the years (Shields et al., 2021). Some reviews narrowed down their scope to specific groups such as adults (Grasser et al., 2013) or children (Ubiali et al., 2021). Despite the high importance of walking among older adults and theirs being the most sedentary group (with about 60 to 80% of their daily time spent physically inactive), to the best of our knowledge, none of the systematic reviews on the PA of older adults (Barnett, Barnett, Nathan, Van Cauwenberg, & Cerin, 2017; Van Cauwenberg et al., 2011; Van Cauwenberg, Nathan, Barnett, Barnett, & Cerin, 2018; Cerin, Nathan, van Cauwenberg, Barnett, & Barnett, 2017; Moran et al., 2014) focused specifically on walkability, but rather included various built environment characteristics in their studies. Only one systematic review focused on the relationship between walkability and the PA of older adults (Edwards & Dulai, 2018); however, their specific aim was to examine the impacts of stairs on this relationship. Thus, we believe that there is a need for a systematic review which summarizes how objective walkability has been operationalized to date, its relationship with walking outcomes, and how these differed for older adults, for whom walking is particularly essential. By detecting the gaps in the literature, and summarizing the methodologies of previous studies, this review could help to inform future literature reviews and empirical analyses that share similar aims. Additionally, by highlighting how objective walkability measures differ for older adults compared to the general population, this review could also offer insight for urban designers, planners, and/or local governments.

Following this introduction, the next section provides a description of the methodology employed for this systematic literature review. Then in the results section, we first present the pattern of demographic groups included in all reviewed publications, and then we compare the descriptive results from papers focusing only on older adults and those exploring the general population. Finally, we discuss these results, and end the paper with concluding remarks.

4.1.2. Methods

4.1.2.1. Search Strategy

This systematic review followed the PRISMA (Preferred Reporting Items of Systematic Review and Meta-Analysis) guidelines (Page et al., 2021). First, we defined a query logic based on keywords related to walkability and walking-related PA. Second, we ran initial tests in different databases, and conducted the final search on June 25, 2019, in three electronic databases: PubMed, Scopus, and Web of Science (WoS) (Figure 13). In order to include the seminal publications meeting our criteria, we did not set a start date for the search.

4.1.2.2. Inclusion and exclusion criteria

Papers were included only if they were, 1) focusing on measuring walkability (i.e., only those with an explicit mention of walkability in their titles or abstracts, methods, and results sections, excluding those using walkability only for sample recruitment, for instance); 2) measuring walkability objectively (with GIS, or environmental/ street audits conducted by trained people); 3) having subjectively or objectively measured (e.g., by using self-reports or accelerometers) walking-related outcomes (excluding those combining different types of PA, such as cycling, gardening, skating, etc., under one category such as total PA or active commuting); 4) relating these walking-related outcomes with walkability; 5) original empirical research published in peer-reviewed journals; and 6) written in English.

4.1.2.3. *Study selection*

Study selection was conducted in four phases for the first part of the review (Figure 13). After removing the duplicates from the total records retrieved from the database search (n = 3279), we first included 2008 manuscripts in the phase of title screening and then abstract screening for relevance. According to the selection criteria, a total of 1625 papers were excluded at these phases. Then full texts of the remaining papers (n = 383) were reviewed. Given the detailed information gathered at this stage, a further 237 papers were excluded. Finally, the remaining 146 papers were included in the content analysis. For consistency, all phases were completed by the first author (ZSA). After each phase, the second and third authors (XDA and GV, respectively) individually screened a random selection of 20% of the publications to eliminate the risk of bias and confirm the correctness of the selection. In case of doubt or disagreement, discussions of the papers among the authors took place until a joint decision was made.

4.1.2.4. *Data extraction and content analysis*

For all included publications (n = 146) data were extracted and assessed under five main categories. The reasons and details of the categorization and coding used in these categories are explained briefly below, and in detail in Supplementary Material in Chapter 9.2.

1) General study characteristics: Publication year, Journal field, Geographical context (study setting), Demographic group under study.

2) Characteristics of the study design: Research design (cross-sectional, longitudinal, or mixed), Spatial data collection method (GIS or audit), Outcome data collection method (objective, subjective, or mixed methods).

3) Characteristics of walkability measures: Operationalization of walkability (indexes or separate variables), Walkability variables used.

4) Spatial extent and unit: Spatial extent (residential area, school site, etc.), Spatial unit (administrative units, statistical units, buffers, etc.), Buffer type (circular, street network, or sausage buffer), and buffer size.

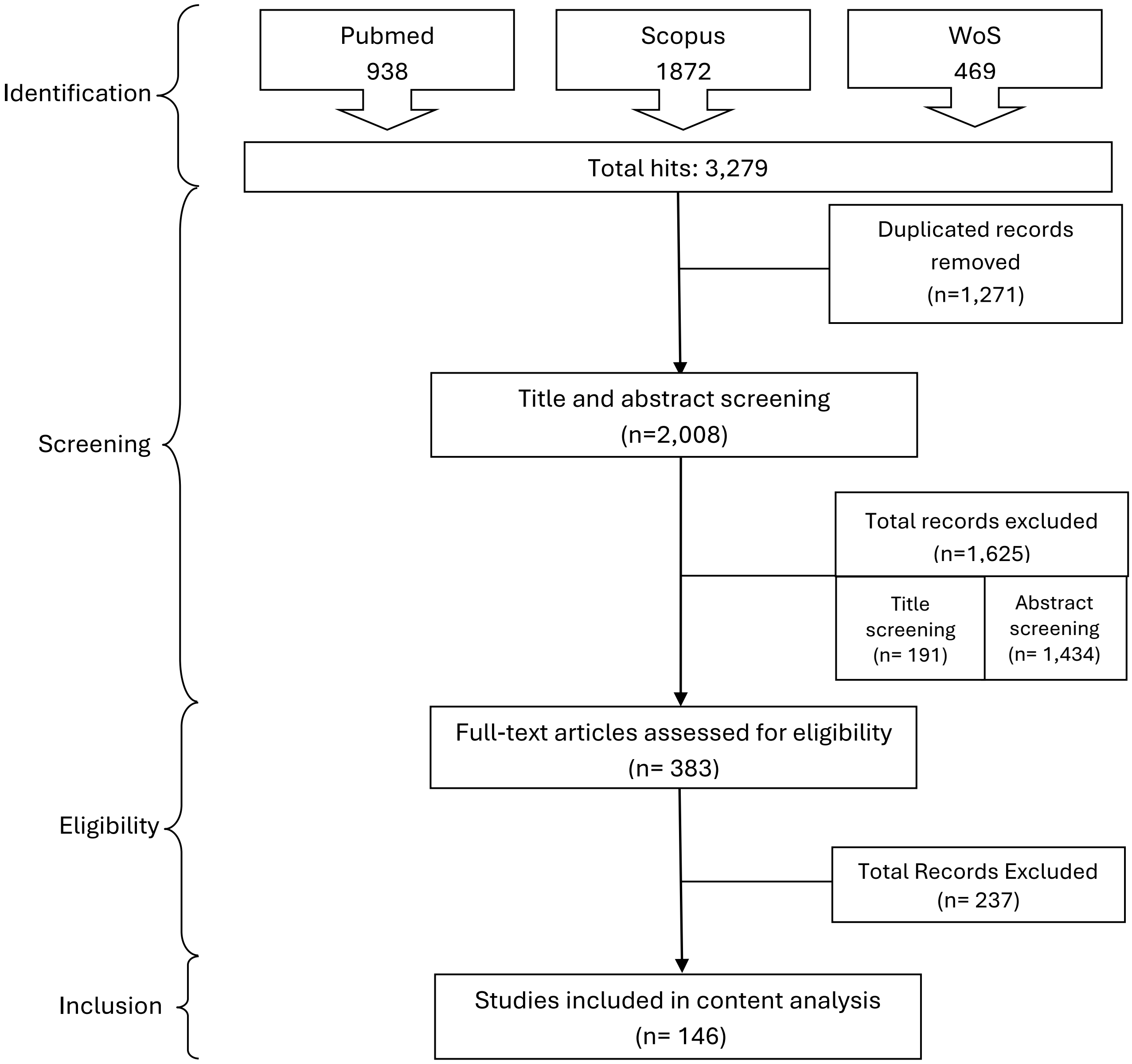
5) Associations found between walkability and walking-related outcomes (coded as positive, negative, no association, mixed —for studies providing results for different population groups or settings— or partial —for studies providing results for different buffer sizes or different walking-related outcomes and/or, studies providing different associations for each walkability variable used, and when this difference is not acute, e.g., two no associations, two positive, and three negative associations).

After analyzing the contents of all publications meeting our criteria (n = 146) according to the abovementioned fields, we stratified the analysis to compare publications focusing only on older adults (n = 24), and the general population (n = 122).

4.1.3. Results

Among all publications included in the content analysis (n = 146), 50.7% (n = 74) focused on adults, although the definition of this group varied vastly across studies (See Supplementary Material in Chapter 9.2 for further information). 17.8% (n = 26) focused on “all population” in their analysis while 15.1% focused on young people (n = 22). Finally, publications focusing on older adults formed 16.4% of the analyzed studies, with 24 publications.

Figure 13 PRISMA flow chart for systematic literature search and search terms used in the three databases



Search terms used in databases:

WoS: ((((((TI=((walk* OR pedestrian OR mobil* OR "physical activity" OR "physically active" OR "active transport*" OR "active transit" OR "active travel") AND walkab* NOT walkabout)))))))

Scopus: (TITLE-ABS-KEY (walk*) OR TITLE-ABS-KEY (pedestrian) OR TITLE-ABS-KEY (mobil*) OR TITLE-ABS-KEY ("physical activity") OR TITLE-ABS-KEY ("physically active") OR TITLE-ABS-KEY ("active transport*") OR TITLE-ABS-KEY ("active transit") OR TITLE-ABS-KEY ("active travel") AND TITLE-ABS-KEY (walkab*) AND NOT TITLE-ABS-KEY (walkabout))

PubMed: ((((((((walk*[Title/Abstract]) OR pedestrian[Title/Abstract]) OR mobil*[Title/Abstract]) OR "physical activity"[Title/Abstract]) OR "physically active"[Title/Abstract]) OR "active transport*"[Title/Abstract]) OR "active transit"[Title/Abstract]) OR "active travel"[Title/Abstract]) AND walkab*[Title/Abstract]) NOT walkabout[Title/Abstract]

We applied filters in each database: *Language: English*, and *Publication type: article*. *(Source: own production)*

The results of the content analysis are presented in Table 3, Table 4, and Table 5. In addition, Table 6 presents detailed list of publications in relation to all variables included in the content analysis.

General study characteristics

Publication year

Most of the studies focusing on both older adults and the general population were published in the last decade, and the number of publications in both groups increased remarkably in this period (Table 3). The oldest publications meeting our criteria dated from 2007 among studies focusing on older adults, and from 2005 among general population-focused studies.

Journal field

More than half of the studies in both literature groups were published in health-related journals (Table 3), followed by inter- or multi-disciplinary journals, transportation or urban studies, and environment- or geography-related journals.

Table 3 Proportion of different variables included in the analysis among papers focusing on older adults vs. general population

General study characteristics **Publication year**		Older adults n= 24 (100%)	General population n= 122 (%)
	2016-2019	11 (45.8)	57 (46.7)
	2011-2015	10 (41.7)	53 (43.4)
	2005-2010	3 (12.5)	12 (9.8)
Journal field			
	Health	13 (54.2)	77 (63.1)
	Inter- or multi-disciplinary	9 (37.5)	38 (31.1)
	Transportation or urban studies	1 (4.2)	4 (3.3)
	Environment or geography	1 (4.2)	3 (2.5)
Geographical context			
	US and Canada	12 (50.0)	68 (55.7)
	Europe	7 (29.2)	25 (20.5)
	Middle East and Asia	4 (16.7)	4 (3.3)
	Oceania	1 (4.2)	21 (17.2)
	Latin America	0 (0.0)	2 (1.6)
	Multiple country	0 (0.0)	2 (1.6)

Characteristics of the study design			
Research design			
	Cross-sectional	18 (75.0)	105 (86.1)
	Longitudinal	5 (20.8)	16 (13.1)
	Mixed	1 (4.2)	1 (0.8)
Spatial data collection method			
	GIS	22 (91.7)	114 (93.4)
	Audits	2 (8.3)	8 (6.6)
Outcome data collection method			
	Self-reported	14 (58.3)	70 (57.4)
	Device	3 (12.5)	31 (25.4)
	Mixed	7 (29.2)	21 (17.2)
Characteristics of the walkability measures			
Operationalization of walkability			
	Index	19 (79.2)	112 (91.8)
	Separate variables	5 (20.8)	10 (8.2)
Spatial extent and unit			
Spatial extent			
	Residential	24 (100.0)	107 (87.7)
	School site	0 (0.0)	5 (4.1)
	Residential + Workplace	0 (0.0)	4 (3.3)
	Residential + School site	0 (0.0)	3 (2.5)
	Other	0 (0.0)	3 (2.5)
Spatial unit			
	Buffer	17 (70.8)	82 (67.2)
	Statistical units	4 (16.7)	25 (20.5)
	Administrative units	3 (12.5)	9 (7.4)
	Combination	0 (0.0)	3 (2.5)
	Other	0 (0.0)	3 (2.5)
Associations found between walkability and walking-related outcomes			
	Positive	15 (62.5)	74 (60.7)
	No association	5 (20.8)	18 (14.8)
	Partial	3 (12.5)	20 (16.4)
	Mixed	1 (4.2)	5 (4.1)
	Negative	0 (0.0)	5 (4.1)

Source: own production

Table 4 Proportion of walkability variables used among papers focusing on older adults vs. the general population

Walkability variables used	**Older adults (n=167 variables used in 24 studies) n (%)**	**General population (n=518 variables used in 122 studies) n (%)**
Land use characteristics	56 (33.5)	85 (16.4)
Safety from traffic	20 (12)	26 (5)
Street connectivity	19 (11.4)	116 (22.4)
Street design	19 (11.4)	55 (10.6)
Activity and destination density and access to services	18 (10.8)	92 (17.8)
Population density	15 (9)	86 (16.6)
Safety from crime	8 (4.8)	14 (2.7)
Greenery	8 (4.8)	20 (3.9)
Transportation accessibility	3 (1.8)	16 (3.1)
Topographic characteristics	1 (0.6)	6 (1.2)
Socioeconomic characteristics	0 (0)	2 (0.4)

Source: own production

Geographical context

The most used settings in walkability studies among both older adults- and general population-focused publications were the US and Canada (50 and 55.7% respectively) (Table 3). This was followed by Europe in both groups (29.2 and 20.5% respectively). However, among publications focusing on older adults, 16.7% were conducted in the Middle East and Asia, while the share among general population-focused literature was only 3.3%. The third most used setting among studies focusing on the general population was Oceania with 17.2% of the studies included in this group, while only one study focusing on older adults was conducted in this geographical context with a share of 4.2%.

Characteristics of the study design

Research design

Most studies in both groups of literature were designed as cross-sectional (75% among older adults- and 86.1% among general population-focused studies) (Table 3). Among publications focusing on older adults the share of longitudinal studies showed a higher percentage (20.8%) compared to that among general population-focused publications (13.1%).

Spatial data collection method

The vast majority of studies focusing on both older adults (91.7%) and the general population (93.4%) used GIS to collect their spatial data (Table 3). The share of audit usage among older adults-focused studies (8.3%) was slightly higher compared to the share among studies focusing on the general population (6.6%).

Outcome data collection method

Most of the outcome data was collected by self-reports in both literature groups (Table 3). Among studies focusing on the general population, device usage showed a higher share (25.4%) compared to the share among publications focusing on older adults (12.5%). However, using mixed methods to collect walking-related outcome data presented a higher share among older adults-focused studies (29.2%).

Characteristics of the walkability measures

Operationalization of walkability

Studies mostly used indexes to operationalize walkability among older adults and the general population, with a higher share among the latter (79.2 and 91.8%, respectively) (Table 3). The share of using separate variables, however, was higher among studies focusing on older adults (20.8%) compared to the share among the general population literature (8.2%). The most used indexes among older adults-focused publications were the walkability index of Frank et al. (2010), the WalkScore index, and the walkability index of Frank et al. (2005), respectively (data not shown). Among studies focusing on the general population the most preferred index was WalkScore. This was followed by the walkability index of Frank et al. (2010), and new indexes created by the publications.

Table 5 Proportion of buffer types and sizes used among studies focusing on older adults vs. general population

Buffer type	**Older adults (n=17 buffer types used in 17 studies using buffers) n (%)**	**General population (n=91 buffer types used in 82 studies using buffers) n (%)**
Street network buffer	9 (53)	47 (51.6)
Circular buffer	8 (47)	42 (46.2)
Sausage buffer	0 (0)	2 (2.2)

Buffer size	**Older adults (n=20 buffer sizes used in 17 studies using buffers) n (%)**	**General population (n=125 buffer sizes used in 82 studies using buffers) n (%)**
50 m	0 (0)	1 (1)
200 m	1 (5)	1 (1)
250 m	0 (0)	1 (1)
400 m	3 (15)	9 (7)
500 m	3 (15)	9 (7)
600 m	0 (0)	1 (1)
800 m	1 (5)	11 (9)
1000 m	5 (25)	31 (25)
1200 m	0 (0)	1 (1)
1500 m	0 (0)	2 (2)
1600 m	0 (0)	14 (11)
1700 m	0 (0)	1 (1)
2000 m	1 (5)	4 (3)
3000 m	1 (5)	1 (1)
2500 m	5 (25)	37 (30)
4830 m	0 (0)	1 (1)

Buffer size ≤ 1000 m or > 1000 m n (%)		
≤ 1000 m	13 (65)	64 (51)
> 1000 m	7 (35)	61 (49)

Source: own production

Walkability variables used

In 24 publications focusing on older adults, a total of 167 walkability variables were used. Most of the variables in this group of publications (33.5%) related to land use characteristics (Table 4). This was followed by safety from traffic category with 12%. Following this, street connectivity (11.4%), street design (11.4%), and activity and destination density (10.8%) were the next most used categories of walkability variables among publications focusing on older adults. Population density presented a share of 9%, while greenery and safety from crime each formed 4.8%, respectively, of the publications in this group. Variables related with transportation accessibility and topographic characteristics were the least preferred, while no variables related to socioeconomic characteristics were used among older adults-focused publications. Among publications focusing on the general population (n = 122), a total of 518 variables were used to measure walkability. The most common variables were related to street connectivity (22.4%), and activity and destination density (17.8%). Following these, 16.6% of the walkability variables used in this literature group were related to population density, and 16.4% to land use characteristics. Variables related to street design formed 10.6%, while safety from traffic had 5% share. Greenery (3.9%), transportation accessibility (3.1%), safety from crime (2.7%), topographic (1.2%) and socio-economic characteristics (0.4%) were also used but to a lower extent compared to other categories among this group of publications. See Table S2 in Supplementary Material in Chapter 9.2 for walkability variables used in each study.

<u>Spatial extent and unit</u>

Spatial extent

All publications on older adults focused on residential areas to measure walkability (Table 3). Among publications on the general population, residential areas were also the most preferred spatial extent with 87.7%. Notwithstanding, 4.1% of the publications in this group used school sites, while some had more than one spatial extent in their studies such as residential and workplace or residential and school site. Lastly, other spatial extents such as daily walking itineraries or routes to parks were also used among studies on the general population.

Spatial unit

Most of the publications in both groups used buffers to measure walkability in their studies (Table 3). This was followed by statistical units (e.g., census block groups, statistical areas/sectors/tracts, etc.) (16.7% among older adults-focused publications and 20.5% among the general population literature) and administrative units (e.g., zip/postal codes, neighborhood boundaries, etc.) (12.5% and 7.4%, respectively).

Buffer type and size

Among 17 older adults-focused studies using buffers, 53% used street network buffers while the rest used circular buffers (Table 5). Some studies used more than one buffer size in this group of publications. Among the 20 buffer sizes used, the most common were 1000 m and 2500 m (25% each) (Table 5). This was followed by 400 m- and 500 m-buffers, each presenting 15% of the total. Buffers equal to or less than 1000 m were preferred more (65%) than those greater than 1000 m in this group (35%) (See Supplementary Material in Chapter 9.2 for detailed information on the selection of 1000 m as a threshold). Among 82 papers using buffers in publications focusing on the general population, a total of 91 buffer types were used. Among these, 51.6% were street network buffers, 46.2% were circular buffers, and 2.2% were sausage buffers. Similar to older adults-focused publications, some of the papers focusing on the general population used more than one buffer size in their studies. Among the total of 125 buffer sizes used, buffers less or greater than 1000 m were almost equally preferred among the publications in this group. Due to the high usage of the WalkScore index among the publications focusing on the general population, the most common buffer size was 2500 m (≈1.5 miles) (30%) (See Supplementary Material in Chapter 9.2 for buffer sizes of WalkScore indexes). This was followed by 1000 m (25%), 1600 m (≈1 mile) (11%,) and 800 m (≈0.5 mile) (9%).

Table 6 Content analysis of the reviewed publications

Demographic group under study	# of articles	Reference
All population	26	(Adams et al., 2015; Althoff et al., 2017; Arvidsson et al., 2013; Arvidsson, Kawakami, Ohlsson, & Sundquist, 2012; Badland et al., 2016; Boisjoly, Wasfi, & El-Geneidy, 2018; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Curl et al., 2018; Eriksson, Arvidsson, Gebel, Ohlsson, & Sundquist, 2012; Hajna, Ross, Joseph, Harper, & Dasgupta, 2015; Learnihan, Van Niel, Giles-Corti, & Knuiman, 2011; Lee et al., 2015; X. Li, Santi, Courtney, Verma, & Ratti, 2018; Y. Li et al., 2018; McGowan, Fuller, Cutumisu, North, & Courneya, 2017; Reyer, Fina, Siedentop, & Schlicht, 2014; Rundle et al., 2016; Sallis et al., 2016; Shay & Khattak, 2012; Thielman, Manson, Chiu, Copes, & Rosella, 2016; Villanueva et al., 2014; Wasfi, Dasgupta, Eluru, & Ross, 2015; Wei, Xiao, Wen, & Wei, 2016; Yang & Diez-Roux, 2017)
Adults	74	(Barnes, Winters, Ste-Marie, McKay, & Ashe, 2016; Brown et al., 2013; Carter et al., 2017; Cerin et al., 2011; Christiansen, Madsen, Schipperijn, Ersboll, & Troelsen, 2014; Chum, Atkinson, & O'Campo, 2019; Cole, Dunn, Hunter, Owen, & Sugiyama, 2015; Cruise et al., 2017; Dills, Rutt, & Mumford, 2012; Doyle, Kelly-Schwartz, Schlossberg, & Stockard, 2006; Duncan et al., 2016; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn, Mitas, & Stelzer, 2010; Eom & Cho, 2015; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank, Kershaw, Chapman, Campbell, & Swinkels, 2015; Frank, Saelens, Powell, & Chapman, 2007; Frank, Schmid, Sallis, Chapman, & Saelens, 2005; Gell, Rosenberg, Carlson, Kerr, & Belza, 2015; Grasser, van Dyck, Titze, & Stronegger, 2016; Hajna, Kestens, et al., 2016; Hajna, Ross, Joseph, Harper, & Dasgupta, 2016; Han et al., 2018; Hirsch, Moore, Evenson, Rodriguez, & Roux, 2013; Hirsch, Winters, Clarke, Ste-Marie, & McKay, 2017; J A Hirsch, Roux, Moore, Evenson, & Rodriguez, 2014; Hosler, Gallant, Riley-Jacome, & Rajulu, 2014; Huang, Moudon, Zhou, & Saelens, 2019; Hwang, Hurvitz, & Duncan, 2016; Jack & McCormack, 2014; James et al., 2017; Jensen et al., 2017; Kelley, Kandula, Kanaya, & Yen, 2016; Kelly, Lian, Struthers, & Kammrath, 2015; Kerr et al., 2010, 2014; Koohsari, Owen, Cerin, Giles-Corti, & Sugiyama, 2016; Lo et al., 2019; Marquet & Hipp, 2019; Mayne et al., 2013; Mayne, Morgan, Jalaludin, & Bauman, 2017; McCormack et al., 2012; McCormack, McLaren, Salvo, & Blackstaffe, 2017; McCormack, Shiell, Doyle-Baker,

		Friedenreich, & Sandalack, 2014; Méline et al., 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Reid et al., 2017; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Riley, Mark, Kristjansson, Sawada, & Reid, 2013; Rundle et al., 2019; Sallis et al., 2009; Salvo et al., 2014; Salvo, Lashewicz, Doyle-Baker, & McCormack, 2018; Shimura, Sugiyama, Winkler, & Owen, 2012; Shimura, Winkler, & Owen, 2014; Siqueira Reis, Hino, Rech, Kerr, & Hallal, 2013; Smith, Panter, & Ogilvie, 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Tamura et al., 2019; Towne et al., 2016, 2018; Tuckel, Milczarski, & Peter Tuckel, PhD; William Milczarski, 2015; Twardzik et al., 2019; Wasfi, Steinmetz-Wood, & Kestens, 2017; Witten et al., 2012; Yi et al., 2017)	
Young people	22	(Buck et al., 2014; D'Haese et al., 2016; D'Haese, Van Dyck, De Bourdeaudhuij, Deforche, & Cardon, 2014; Giles-Corti et al., 2011; Graziose et al., 2016; Hinckson et al., 2017; Hobin et al., 2012; Hunter et al., 2019; Janssen & King, 2015; Kligerman, Sallis, Ryan, Frank, & Nader, 2007; Lovasi et al., 2011; Maddison et al., 2009; McCormack, Giles-Corti, Timperio, Wood, & Villanueva, 2011; McGrath et al., 2016; De Meester et al., 2012; De Meester, Van Dyck, De Bourdeaudhuij, Deforche, & Cardon, 2013; Molina-García & Queralt, 2017; Molina-Garcia, Queralt, Adams, Conway, & Sallis, 2017; Oliver et al., 2015; Perez et al., 2017; Ross et al., 2018; Wang et al., 2017)	
Older adults	24		
Publication period	**# of articles**	**Reference**	
		Older adults	**General population**
2005-2010	Older adults: 3 General population: 12	(Berke, Koepsell, Moudon, Hoskins, & Larson, 2007; Frank, Kerr, Rosenberg, & King, 2010; Michael & Carlson, 2009)	(Doyle et al., 2006; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Frank, Sallis, et al., 2010; Frank et al., 2007, 2005; Kerr et al., 2010; Kligerman et al., 2007; Maddison et al., 2009; Owen et al., 2007; Sallis et al., 2009)
2011-2015	Older adults: 10 General population: 53	(Carlson et al., 2012; Van Holle et al., 2014, 2015; King et al., 2011; Lotfi & Koohsari, 2011; Michael, Gold, Perrin, & Hillier,	(Adams et al., 2015; Arvidsson et al., 2013, 2012; Brown et al., 2013; Buck et al., 2014; Cerin et al., 2011; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Cole et al., 2015; D'Haese et al., 2014; Dills et al., 2012; Van Dyck et al., 2011; Eom & Cho, 2015; Eriksson et al.,

		2011; Nyunt et al., 2015; Strath et al., 2012; Takahashi, Baker, Cha, & Targonski, 2012; Winters et al., 2015)	2012; Frank et al., 2015; Gell et al., 2015; Giles-Corti et al., 2011; Hajna et al., 2015; Hirsch et al., 2013; J A Hirsch et al., 2014; Hobin et al., 2012; Hosler et al., 2014; Jack & McCormack, 2014; Janssen & King, 2015; Kelly et al., 2015; Kerr et al., 2014; Learnihan et al., 2011; Lee et al., 2015; Lovasi et al., 2011; Mayne et al., 2013; McCormack et al., 2012, 2011, 2014; De Meester et al., 2012, 2013; Norman et al., 2013; Oliver et al., 2015; Oluyomi et al., 2014; Reyer et al., 2014; Riley et al., 2013; Salvo et al., 2014; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Sugiyama et al., 2015; Sundquist et al., 2011; Tuckel et al., 2015; Villanueva et al., 2014; Wasfi et al., 2015; Witten et al., 2012)
2016-2019	Older adults: 11 General population: 57	(Bodeker, 2018; Chudyk, McKay, Winters, Sims-Gould, & Ashe, 2017; Clarke et al., 2017; Van Holle et al., 2016; Kikuchi et al., 2018; Liao et al., 2019; Marquet, Hipp, & Miralles-Guasch, 2017; Portegijs, Keskinen, Tsai, Rantanen, & Rantakokko, 2017; Todd et al., 2016; Travers et al., 2018; Zandieh, Flacke, Martinez, Jones, & van Maarseveen, 2017)	(Althoff et al., 2017; Badland et al., 2016; Barnes et al., 2016; Boisjoly et al., 2018; Carter et al., 2017; Chum et al., 2019; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016; Duncan et al., 2016; Forjuoh et al., 2017; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna, Ross, et al., 2016; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2017; Huang et al., 2019; Hunter et al., 2019; Hwang et al., 2016; James et al., 2017; Jensen et al., 2017; Kelley et al., 2016; Koohsari et al., 2016; X. Li et al., 2018; Y. Li et al., 2018; Lo et al., 2019; Marquet & Hipp, 2019; Mayne et al., 2017; McCormack et al., 2017; McGowan et al., 2017; McGrath et al., 2016; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Perez et al., 2017; Reid et al., 2017; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2016; Salvo et al., 2018; Smith et al., 2019; Sugiyama et al., 2019; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Twardzik et al., 2019; Wang et al., 2017; Wasfi et al., 2017; Wei et al., 2016; Yang & Diez-Roux, 2017; Yi et al., 2017)

Journal field	# of articles	Reference	
		Older adults	General population
Health	Older adults: 13 General population: 77	(Berke et al., 2007; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2014; Michael & Carlson, 2009; Michael et al., 2011; Nyunt et al., 2015; Strath et al., 2012; Takahashi et al., 2012; Todd et al., 2016; Winters et al., 2015)	(Adams et al., 2015; Brown et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Christian et al., 2011; Chum et al., 2019; D'Haese et al., 2016, 2014; Van Dyck, Cardon, et al., 2010; Eriksson et al., 2012; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2005; Gell et al., 2015; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hobin et al., 2012; Hosler et al., 2014; Hunter et al., 2019; Jack & McCormack, 2014; James et al., 2017; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2014; Kligerman et al., 2007; Koohsari et al., 2016; Lee et al., 2015; Y. Li et al., 2018; Lovasi et al., 2011; Maddison et al., 2009; Marquet & Hipp, 2019; Mayne et al., 2017; McCormack et al., 2012, 2011; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reid et al., 2017; Richardson et al., 2017; Rundle et al., 2016, 2019; Sallis et al., 2016; Salvo et al., 2014, 2018; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Wang et al., 2017; Witten et al., 2012; Yang & Diez-Roux, 2017; Yi et al., 2017)
Inter- or multi-disciplinary	Older adults: 9 General population: 38	(Bodeker, 2018; Van Holle et al., 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Liao et al., 2019;	(Althoff et al., 2017; Arvidsson et al., 2013, 2012; Badland et al., 2016; Barnes et al., 2016; Cho & Rodríguez, 2015; Christiansen et al., 2014; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; Duncan et al., 2016; Van Dyck et al., 2011;

		Marquet et al., 2017; Portegijs et al., 2017; Zandieh et al., 2017)	Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Frank et al., 2007; Giles-Corti et al., 2011; Hajna, Ross, et al., 2016; Huang et al., 2019; Hwang et al., 2016; Janssen & King, 2015; Jensen et al., 2017; Kerr et al., 2010; Lo et al., 2019; Mayne et al., 2013; McCormack et al., 2017, 2014; De Meester et al., 2013; Oliver et al., 2015; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Riley et al., 2013; Ross et al., 2018; Sallis et al., 2009; Sundquist et al., 2011; Villanueva et al., 2014; Wasfi et al., 2015, 2017; Wei et al., 2016)
Transportation or urban studies	Older adults: 1 General population: 4	(Lotfi & Koohsari, 2011)	(Boisjoly et al., 2018; Doyle et al., 2006; Eom & Cho, 2015; Shay & Khattak, 2012)
Environment or geography	Older adults:1 General population: 3	(Travers et al., 2018)	(Dills et al., 2012; Learnihan et al., 2011; X. Li et al., 2018)
Geographical context	**# of articles**	**Reference**	
		Older adults	**General population**
US and Canada			
US	Older adults: 9 General population: 46	(Berke et al., 2007; Carlson et al., 2012; Frank, Kerr, et al., 2010; King et al., 2011; Michael & Carlson, 2009; Michael et al., 2011; Strath et al., 2012; Takahashi et al., 2012; Todd et al., 2016)	(Adams et al., 2015; Brown et al., 2013; Cerin et al., 2011; Cho & Rodríguez, 2015; Dills et al., 2012; Doyle et al., 2006; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2007, 2005; Gell et al., 2015; Graziose et al., 2016; Han et al., 2018; Hirsch et al., 2013; J A Hirsch et al., 2014; Hosler et al., 2014; Huang et al., 2019; Hwang et al., 2016; James et al., 2017; Jensen et al., 2017; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; X. Li et al., 2018; Lo et al., 2019; Lovasi et al., 2011; Marquet & Hipp, 2019; Norman et al., 2013; Oluyomi et al., 2014; Perez et al., 2017; Richardson et al., 2017; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2009; Shay & Khattak, 2012; Tamura et al., 2019; Towne et al.,

			2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Wang et al., 2017; Wei et al., 2016; Yang & Diez-Roux, 2017)
Canada	Older adults: 3 General population: 22	(Chudyk et al., 2017; Clarke et al., 2017; Winters et al., 2015)	(Barnes et al., 2016; Boisjoly et al., 2018; Chiu et al., 2015; Chum et al., 2019; Frank et al., 2015; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Hirsch et al., 2017; Hobin et al., 2012; Hunter et al., 2019; Jack & McCormack, 2014; Janssen & King, 2015; McCormack et al., 2017, 2014; McGowan et al., 2017; Reid et al., 2017; Riley et al., 2013; Salvo et al., 2018; Thielman et al., 2016; Wasfi et al., 2015, 2017)
Europe			
Austria	General population: 1	--	(Grasser et al., 2016)
Belgium	Older adults: 3 General population: 7	(Van Holle et al., 2014, 2015, 2016)	(D'Haese et al., 2016, 2014; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; De Meester et al., 2012, 2013)
Czech Republic	General population: 1	--	(Dygryn et al., 2010)
Denmark	General population: 1	--	(Christiansen et al., 2014)
Finland	Older adults: 1	(Portegijs et al., 2017)	--
France	General population: 2	--	(Duncan et al., 2016; Méline et al., 2017)
Germany	Older adults: 1 General population: 2	(Bodeker, 2018)	(Buck et al., 2014; Reyer et al., 2014)
Ireland	General population: 1	--	(Cruise et al., 2017)
Portugal	General population: 1	--	(Ribeiro & Hoffimann, 2018)

Spain	Older adults: 1 General population: 2	(Marquet et al., 2017)	(Molina-García & Queralt, 2017; Molina-Garcia et al., 2017)
Sweden	General population: 4	--	(Arvidsson et al., 2013, 2012; Eriksson et al., 2012; Sundquist et al., 2011)
United Kingdom	Older adults: 1 General population: 3	(Zandieh et al., 2017)	(Carter et al., 2017; Curl et al., 2018; Smith et al., 2019)
Middle East and Asia			
Iran	Older adults: 1	(Lotfi & Koohsari, 2011)	--
Japan	Older adults: 1 General population: 1	(Kikuchi et al., 2018)	(Y. Li et al., 2018)
Malaysia	General population: 1	--	(Yi et al., 2017)
Singapore	Older adults: 1	(Nyunt et al., 2015)	--
South Korea	General population: 2	--	(Eom & Cho, 2015; Lee et al., 2015)
Taiwan	Older adults: 1	(Liao et al., 2019)	--
Oceania			
Australia	Older adults: 1 General population: 16	(Travers et al., 2018)	(Badland et al., 2016; Christian et al., 2011; Cole et al., 2015; Giles-Corti et al., 2011; Koohsari et al., 2016; Learnihan et al., 2011; Mayne et al., 2013, 2017; McCormack et al., 2012, 2011; Owen et al., 2007; Shimura et al., 2012, 2014; Sugiyama et al., 2015, 2019; Villanueva et al., 2014)
New Zealand	General population: 5	--	(Hinckson et al., 2017; Maddison et al., 2009; McGrath et al., 2016; Oliver et al., 2015; Witten et al., 2012)
Latin America			
Brazil	General population: 1	--	(Siqueira Reis et al., 2013)

Mexico	General population: 1	--	(Salvo et al., 2014)
Multiple country	General population: 2	--	(Althoff et al., 2017; Sallis et al., 2016)
		Reference	
Research design	**# of articles**	**Older adults**	**General population**
Cross-sectional	Older adults: 18 General population: 105	(Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Liao et al., 2019; Lotfi & Koohsari, 2011; Marquet et al., 2017; Nyunt et al., 2015; Strath et al., 2012; Takahashi et al., 2012; Todd et al., 2016; Travers et al., 2018; Winters et al., 2015; Zandieh et al., 2017)	(Althoff et al., 2017; Arvidsson et al., 2013, 2012; Badland et al., 2016; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Buck et al., 2014; Cerin et al., 2011; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; D'Haese et al., 2016, 2014; Dills et al., 2012; Doyle et al., 2006; Duncan et al., 2016; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Gell et al., 2015; Giles-Corti et al., 2011; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; Hobin et al., 2012; Hosler et al., 2014; Huang et al., 2019; Hunter et al., 2019; Hwang et al., 2016; Jack & McCormack, 2014; James et al., 2017; Janssen & King, 2015; Jensen et al., 2017; Kelley et al., 2016; Kelly et al., 2015; Kligerman et al., 2007; Koohsari et al., 2016; Lee et al., 2015; X. Li et al., 2018; Y. Li et al., 2018; Lovasi et al., 2011; Maddison et al., 2009; Marquet & Hipp, 2019; Mayne et al., 2013, 2017; McCormack et al., 2012, 2011, 2014; McGrath et al., 2016; De Meester et al., 2012, 2013; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oliver et al., 2015; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reid et al., 2017; Reyer et al., 2014; Ribeiro

			& Hoffimann, 2018; Richardson et al., 2017; Riley et al., 2013; Rundle et al., 2016; Sallis et al., 2009, 2016; Salvo et al., 2014; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Villanueva et al., 2014; Wang et al., 2017; Wei et al., 2016; Witten et al., 2012; Yang & Diez-Roux, 2017; Yi et al., 2017)
Longitudinal	Older adults: 5 General population: 16	(Berke et al., 2007; Kikuchi et al., 2018; King et al., 2011; Michael & Carlson, 2009; Michael et al., 2011)	(Adams et al., 2015; Curl et al., 2018; Hajna, Ross, et al., 2016; J A Hirsch et al., 2014; Kerr et al., 2010, 2014; Learnihan et al., 2011; Lo et al., 2019; McCormack et al., 2017; McGowan et al., 2017; Ross et al., 2018; Rundle et al., 2019; Salvo et al., 2018; Twardzik et al., 2019; Wasfi et al., 2015, 2017)
Mixed	Older adults: 1 General population: 1	(Portegijs et al., 2017)	(Carter et al., 2017)
Spatial data collection method	**# of articles**	**Reference**	
		Older adults	**General population**
GIS	Older adults: 22 General population: 114	(Berke et al., 2007; Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Liao et al., 2019; Lotfi & Koohsari, 2011; Marquet et al., 2017; Michael &	(Adams et al., 2015; Althoff et al., 2017; Arvidsson et al., 2013, 2012; Badland et al., 2016; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016, 2014; Dills et al., 2012; Doyle et al., 2006; Duncan et al., 2016; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007,

		Carlson, 2009; Michael et al., 2011; Nyunt et al., 2015; Portegijs et al., 2017; Takahashi et al., 2012; Todd et al., 2016; Winters et al., 2015; Zandieh et al., 2017)	2005; Gell et al., 2015; Giles-Corti et al., 2011; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hobin et al., 2012; Huang et al., 2019; Hunter et al., 2019; Hwang et al., 2016; Jack & McCormack, 2014; James et al., 2017; Janssen & King, 2015; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Lee et al., 2015; X. Li et al., 2018; Y. Li et al., 2018; Lo et al., 2019; Lovasi et al., 2011; Maddison et al., 2009; Marquet & Hipp, 2019; Mayne et al., 2013, 2017; McCormack et al., 2012, 2011, 2017, 2014; McGowan et al., 2017; De Meester et al., 2012, 2013; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reid et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2009, 2016; Salvo et al., 2014, 2018; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2018, 2016; Tuckel et al., 2015; Twardzik et al., 2019; Villanueva et al., 2014; Wasfi et al., 2015, 2017; Wei et al., 2016; Yang & Diez-Roux, 2017; Yi et al., 2017)
Audits	Older adults: 2 General population: 8	(Strath et al., 2012; Travers et al., 2018)	(Hajna, Ross, et al., 2016; Hosler et al., 2014; Jensen et al., 2017; McGrath et al., 2016; Oliver et al., 2015; Richardson et al., 2017; Wang et al., 2017; Witten et al., 2012)
Outcome data collection method	**# of articles**	**Reference**	

		Older adults	General population
Self-reported	Older adults: 14 General population: 70	(Berke et al., 2007; Bodeker, 2018; Clarke et al., 2017; Frank, Kerr, et al., 2010; Kikuchi et al., 2018; Liao et al., 2019; Lotfi & Koohsari, 2011; Marquet et al., 2017; Michael & Carlson, 2009; Michael et al., 2011; Nyunt et al., 2015; Takahashi et al., 2012; Travers et al., 2018; Winters et al., 2015)	(Badland et al., 2016; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Cerin et al., 2011; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; Dills et al., 2012; Doyle et al., 2006; Van Dyck et al., 2011; Eom & Cho, 2015; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007; Giles-Corti et al., 2011; Grasser et al., 2016; Graziose et al., 2016; Hajna et al., 2015; Hirsch et al., 2013, 2017; Hobin et al., 2012; Hosler et al., 2014; Jack & McCormack, 2014; Janssen & King, 2015; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2010, 2014; Koohsari et al., 2016; Lee et al., 2015; Y. Li et al., 2018; Mayne et al., 2013, 2017; McCormack et al., 2012, 2017, 2014; McGowan et al., 2017; Méline et al., 2017; Molina-García & Queralt, 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Riley et al., 2013; Ross et al., 2018; Salvo et al., 2018; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Sugiyama et al., 2015, 2019; Towne et al., 2016, 2018; Tuckel et al., 2015; Villanueva et al., 2014; Wang et al., 2017; Wasfi et al., 2015, 2017; Wei et al., 2016; Witten et al., 2012; Yang & Diez-Roux, 2017)
Mixed	Older adults: 7 General population: 21	(Chudyk et al., 2017; Van Holle et al., 2014, 2015, 2016; King et al., 2011; Portegijs et al., 2017; Todd et al., 2016)	(Arvidsson et al., 2012; D'Haese et al., 2016, 2014; Duncan et al., 2016; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Eriksson et al., 2012; Frank et al., 2005; Gell et al., 2015; Hunter et al., 2019; Learnihan et al., 2011; Lo et al., 2019; Maddison et al., 2009; Marquet & Hipp, 2019; Molina-Garcia et al., 2017; Oliver et al., 2015; Perez et al., 2017; Rundle et al., 2019; Sallis et al., 2009; Smith et al., 2019; Sundquist et al., 2011)

Device	Older adults: 3 General population: 31	(Carlson et al., 2012; Strath et al., 2012; Zandieh et al., 2017)	(Adams et al., 2015; Althoff et al., 2017; Arvidsson et al., 2013; Buck et al., 2014; Carter et al., 2017; Dygryn et al., 2010; Hajna, Kestens, et al., 2016; Hajna, Ross, et al., 2016; Han et al., 2018; Hinckson et al., 2017; J A Hirsch et al., 2014; Huang et al., 2019; Hwang et al., 2016; James et al., 2017; Jensen et al., 2017; Kligerman et al., 2007; X. Li et al., 2018; Lovasi et al., 2011; McCormack et al., 2011; McGrath et al., 2016; De Meester et al., 2012, 2013; Reid et al., 2017; Richardson et al., 2017; Rundle et al., 2016; Sallis et al., 2016; Salvo et al., 2014; Tamura et al., 2019; Thielman et al., 2016; Twardzik et al., 2019; Yi et al., 2017)
Operationalization of walkability	**# of articles**	**Reference**	
		Older adults	**General population**
Index	Older adults: 19 General population: 112	(Berke et al., 2007; Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Liao et al., 2019; Lotfi & Koohsari, 2011; Marquet et al., 2017; Michael & Carlson, 2009; Nyunt et al., 2015; Portegijs et al., 2017; Takahashi et al., 2012; Winters et al., 2015)	(Althoff et al., 2017; Arvidsson et al., 2013, 2012; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016, 2014; Doyle et al., 2006; Duncan et al., 2016; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Van Dyck et al., 2011; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Giles-Corti et al., 2011; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hobin et al., 2012; Hosler et al., 2014; Hunter et al., 2019; Hwang et al., 2016; James et al., 2017; Janssen & King, 2015; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari

			et al., 2016; Learnihan et al., 2011; X. Li et al., 2018; Y. Li et al., 2018; Lo et al., 2019; Maddison et al., 2009; Marquet & Hipp, 2019; Mayne et al., 2013, 2017; McCormack et al., 2012, 2011, 2017, 2014; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012, 2013; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oliver et al., 2015; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reid et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2009, 2016; Salvo et al., 2014, 2018; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Villanueva et al., 2014; Wang et al., 2017; Wasfi et al., 2015, 2017; Wei et al., 2016; Witten et al., 2012; Yang & Diez-Roux, 2017; Yi et al., 2017)
Separate variables	Older adults: 5 General population: 10	(Michael et al., 2011; Strath et al., 2012; Todd et al., 2016; Travers et al., 2018; Zandieh et al., 2017)	(Adams et al., 2015; Badland et al., 2016; Cho & Rodríguez, 2015; Dills et al., 2012; Gell et al., 2015; Huang et al., 2019; Jack & McCormack, 2014; Jensen et al., 2017; Lee et al., 2015; Lovasi et al., 2011)
Spatial domain	**# of articles**	**Reference**	
		Older adults	**General population**
Residential	Older adults: 24 General population: 107	(Berke et al., 2007; Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2014,	(Adams et al., 2015; Arvidsson et al., 2013, 2012; Badland et al., 2016; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016,

		2015, 2016; Kikuchi et al., 2018; King et al., 2011; Liao et al., 2019; Lotfi & Koohsari, 2011; Marquet et al., 2017; Michael & Carlson, 2009; Michael et al., 2011; Nyunt et al., 2015; Portegijs et al., 2017; Strath et al., 2012; Takahashi et al., 2012; Todd et al., 2016; Travers et al., 2018; Winters et al., 2015; Zandieh et al., 2017)	2014; Duncan et al., 2016; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Forjuoh et al., 2017; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Gell et al., 2015; Grasser et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hosler et al., 2014; Huang et al., 2019; Hunter et al., 2019; Hwang et al., 2016; Jack & McCormack, 2014; James et al., 2017; Jensen et al., 2017; Kelley et al., 2016; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Lee et al., 2015; Lo et al., 2019; Mayne et al., 2017; McCormack et al., 2012, 2011, 2017, 2014; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012, 2013; Méline et al., 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reid et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2009, 2016; Salvo et al., 2014, 2018; Shay & Khattak, 2012; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Villanueva et al., 2014; Wang et al., 2017; Wasfi et al., 2015, 2017; Wei et al., 2016; Witten et al., 2012; Yang & Diez-Roux, 2017; Yi et al., 2017)
School site	General population: 5	--	(Giles-Corti et al., 2011; Graziose et al., 2016; Hobin et al., 2012; Janssen & King, 2015; Maddison et al., 2009)
Residential + Workplace	General population: 4	--	(Doyle et al., 2006; Y. Li et al., 2018; Marquet & Hipp, 2019; Mayne et al., 2013)

Residential + School site	General population: 3	--	(Lovasi et al., 2011; Molina-García & Queralt, 2017; Oliver et al., 2015)
Other (whole city, routes to parks, daily walking itineraries)	General population: 3	--	(Althoff et al., 2017; Dills et al., 2012; X. Li et al., 2018)
Spatial extent	**# of articles**	**Reference**	
		Older adults	**General population**
Buffer	Older adults: 17 General population: 82	(Berke et al., 2007; Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Kikuchi et al., 2018; Liao et al., 2019; Michael & Carlson, 2009; Nyunt et al., 2015; Portegijs et al., 2017; Strath et al., 2012; Takahashi et al., 2012; Todd et al., 2016; Travers et al., 2018; Winters et al., 2015; Zandieh et al., 2017)	(Adams et al., 2015; Althoff et al., 2017; Arvidsson et al., 2013, 2012; Badland et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Christian et al., 2011; Cole et al., 2015; Cruise et al., 2017; Curl et al., 2018; Duncan et al., 2016; Dygryn et al., 2010; Eriksson et al., 2012; Forjuoh et al., 2017; Frank et al., 2015, 2007, 2005; Gell et al., 2015; Giles-Corti et al., 2011; Grasser et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Han et al., 2018; Hinckson et al., 2017; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hobin et al., 2012; Huang et al., 2019; Hwang et al., 2016; Jack & McCormack, 2014; Janssen & King, 2015; Jensen et al., 2017; Kelley et al., 2016; Kerr et al., 2010, 2014; Kligerman et al., 2007; Lee et al., 2015; Y. Li et al., 2018; Lo et al., 2019; Lovasi et al., 2011; McCormack et al., 2012, 2011, 2017, 2014; McGowan et al., 2017; Méline et al., 2017; Norman et al., 2013; Oliver et al., 2015; Perez et al., 2017; Reid et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2016, 2019; Sallis et al., 2016; Salvo et al., 2014, 2018; Smith et al., 2019; Sugiyama et al., 2015, 2019; Tamura et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Villanueva et al.,

			2014; Wang et al., 2017; Wasfi et al., 2015, 2017; Wei et al., 2016; Yang & Diez-Roux, 2017)
Statistical units	Older adults: 4 General population: 25	(Van Holle et al., 2014, 2015, 2016; Michael et al., 2011)	(Cho & Rodríguez, 2015; Christiansen et al., 2014; Chum et al., 2019; D'Haese et al., 2016, 2014; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Eom & Cho, 2015; Frank, Sallis, et al., 2010; James et al., 2017; Kelly et al., 2015; Koohsari et al., 2016; Maddison et al., 2009; Mayne et al., 2013; McGrath et al., 2016; De Meester et al., 2012, 2013; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Owen et al., 2007; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Witten et al., 2012)
Administrative units	Older adults: 3 General population: 9	(King et al., 2011; Lotfi & Koohsari, 2011; Marquet et al., 2017)	(Barnes et al., 2016; Hosler et al., 2014; Hunter et al., 2019; Mayne et al., 2017; Oluyomi et al., 2014; Sallis et al., 2009; Shay & Khattak, 2012; Sundquist et al., 2011; Yi et al., 2017)
Combination	General population: 3	--	(Learnihan et al., 2011; X. Li et al., 2018; Marquet & Hipp, 2019)
Other (street segments, country level, enrollment zones)	General population: 3	--	(Dills et al., 2012; Doyle et al., 2006; Graziose et al., 2016)
		Reference	
Buffer type	**# of articles**	**Older adults**	**General population**
Street network buffer	Older adults: 9 General population: 47	(Bodeker, 2018; Carlson et al., 2012; Chudyk et al., 2017; Clarke et al., 2017; Frank, Kerr, et al., 2010; Kikuchi et al., 2018; Strath et al., 2012; Todd et al., 2016; Winters et al., 2015)	(Adams et al., 2015; Arvidsson et al., 2013; Buck et al., 2014; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; Christian et al., 2011; Cruise et al., 2017; Curl et al., 2018; Dygryn et al., 2010; Eriksson et al., 2012; Frank et al., 2015, 2007, 2005; Grasser et al., 2016; Hajna, Kestens, et al., 2016; Hirsch et al., 2013, 2017; Hwang et al., 2016; Jack & McCormack, 2014; Jensen et al., 2017; Kerr et al., 2010, 2014; Kligerman et al., 2007; Learnihan et al., 2011; Lee et al., 2015; Y. Li et al., 2018; McCormack et al., 2012, 2011, 2014;

			McGowan et al., 2017; Norman et al., 2013; Oliver et al., 2015; Perez et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Rundle et al., 2016; Sallis et al., 2016; Salvo et al., 2014; Smith et al., 2019; Sugiyama et al., 2015; Thielman et al., 2016; Villanueva et al., 2014; Wang et al., 2017; Wei et al., 2016; Yang & Diez-Roux, 2017)
Circular buffer	Older adults: 8 General population: 42	(Berke et al., 2007; Liao et al., 2019; Michael & Carlson, 2009; Nyunt et al., 2015; Portegijs et al., 2017; Takahashi et al., 2012; Travers et al., 2018; Zandieh et al., 2017)	(Althoff et al., 2017; Arvidsson et al., 2012; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Cole et al., 2015; Duncan et al., 2016; Forjuoh et al., 2017; Gell et al., 2015; Giles-Corti et al., 2011; Grasser et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Han et al., 2018; Hirsch et al., 2013; J A Hirsch et al., 2014; Hobin et al., 2012; Huang et al., 2019; Hwang et al., 2016; Janssen & King, 2015; Kelley et al., 2016; X. Li et al., 2018; Lo et al., 2019; Lovasi et al., 2011; Marquet & Hipp, 2019; McCormack et al., 2017; Méline et al., 2017; Reid et al., 2017; Reyer et al., 2014; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2016, 2019; Salvo et al., 2018; Sugiyama et al., 2019; Tamura et al., 2019; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Wasfi et al., 2015, 2017)
Sausage buffer	General population: 2	--	(Badland et al., 2016; Hinckson et al., 2017)
Combination*	General population: 4	--	(Grasser et al., 2016; Hirsch et al., 2013; Reyer et al., 2014; Rundle et al., 2016) *References are also included in related categories above
Buffer size	**# of articles**	**Reference**	
		Older adults	**General population**
50 m	General population: 1	--	(Tamura et al., 2019)
200 m	Older adults: 1 General population: 1	(Strath et al., 2012)	(Villanueva et al., 2014)

250 m	General population: 1	--	(Hinckson et al., 2017)
400 m	Older adults: 3 General population: 9	(Bodeker, 2018; Michael & Carlson, 2009; Travers et al., 2018)	(Badland et al., 2016; Carter et al., 2017; Han et al., 2018; Jensen et al., 2017; Kligerman et al., 2007; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Villanueva et al., 2014; Wei et al., 2016)
500 m	Older adults: 3 General population: 9	(Carlson et al., 2012; Kikuchi et al., 2018; Nyunt et al., 2015)	(Cruise et al., 2017; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Hinckson et al., 2017; Lovasi et al., 2011; McGowan et al., 2017; Sallis et al., 2016; Salvo et al., 2014)
600 m	General population: 1	--	(Wei et al., 2016)
800 m	Older adults: 1 General population: 11	(Michael & Carlson, 2009)	(Badland et al., 2016; Carter et al., 2017; Curl et al., 2018; Huang et al., 2019; Kerr et al., 2014; Kligerman et al., 2007; Marquet & Hipp, 2019; Oliver et al., 2015; Ribeiro & Hoffimann, 2018; Villanueva et al., 2014; Wei et al., 2016)
1000 m	Older adults: 5 General population: 31	(Berke et al., 2007; Frank, Kerr, et al., 2010; Kikuchi et al., 2018; Portegijs et al., 2017; Todd et al., 2016)	(Adams et al., 2015; Arvidsson et al., 2013, 2012; Buck et al., 2014; Cerin et al., 2011; Cruise et al., 2017; Dygryn et al., 2010; Eriksson et al., 2012; Frank et al., 2005, 2015, 2007; Gell et al., 2015; Grasser et al., 2016; Hinckson et al., 2017; Hobin et al., 2012; Hwang et al., 2016; Janssen & King, 2015; Lee et al., 2015; Y. Li et al., 2018; McGowan et al., 2017; Oliver et al., 2015; Perez et al., 2017; Rundle et al., 2016, 2019; Sallis et al., 2016; Salvo et al., 2014; Smith et al., 2019; Sugiyama et al., 2015, 2019; Wang et al., 2017; Wei et al., 2016)
1200 m	General population: 1	--	(Wei et al., 2016)
1500 m	General population: 2	--	(Grasser et al., 2016; Wei et al., 2016)
1600 m	General population: 14	--	(Badland et al., 2016; Carter et al., 2017; Christian et al., 2011; Hirsch et al., 2017; Jack & McCormack, 2014; Kerr et al., 2010,

			2014; Kligerman et al., 2007; McCormack et al., 2012, 2014; Norman et al., 2013; Reyer et al., 2014; Villanueva et al., 2014; Wei et al., 2016)
1700 m	General population: 1	--	(Wei et al., 2016)
2000 m	Older adults: 1 General population: 4	(Zandieh et al., 2017)	(Giles-Corti et al., 2011; Hinckson et al., 2017; Hwang et al., 2016; McCormack et al., 2011)
2500 m	Older adults: 5 General population: 37	(Chudyk et al., 2017; Clarke et al., 2017; Liao et al., 2019; Takahashi et al., 2012; Winters et al., 2015)	(Althoff et al., 2017; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Chiu et al., 2015; Cole et al., 2015; Duncan et al., 2016; Forjuoh et al., 2017; Gell et al., 2015; Hajna, Ross, et al., 2016; Hajna et al., 2015; Han et al., 2018; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Hwang et al., 2016; Kelley et al., 2016; X. Li et al., 2018; Lo et al., 2019; Marquet & Hipp, 2019; McCormack et al., 2017; Méline et al., 2017; Reid et al., 2017; Reyer et al., 2014; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2019; Salvo et al., 2018; Sugiyama et al., 2019; Thielman et al., 2016; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Wasfi et al., 2015, 2017; Yang & Diez-Roux, 2017)
3000 m	Older adults: 1 General population: 1	(Berke et al., 2007)	(Hwang et al., 2016)
4830 m	General population: 1	--	(Kerr et al., 2014)
Associations found between walkability and walking-related outcomes	**# of articles**	**Reference**	
		Older adults	**General population**

Positive	Older adults: 15 General population: 74	(Bodeker, 2018; Carlson et al., 2012; Clarke et al., 2017; Frank, Kerr, et al., 2010; Van Holle et al., 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Lotfi & Koohsari, 2011; Marquet et al., 2017; Michael et al., 2011; Portegijs et al., 2017; Strath et al., 2012; Todd et al., 2016; Winters et al., 2015)	(Althoff et al., 2017; Arvidsson et al., 2013, 2012; Badland et al., 2016; Barnes et al., 2016; Brown et al., 2013; Buck et al., 2014; Cho & Rodríguez, 2015; Christiansen et al., 2014; Chum et al., 2019; Cole et al., 2015; Cruise et al., 2017; D'Haese et al., 2016; Dills et al., 2012; Doyle et al., 2006; Duncan et al., 2016; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Gell et al., 2015; Giles-Corti et al., 2011; Grasser et al., 2016; Han et al., 2018; Hirsch et al., 2013, 2017; J A Hirsch et al., 2014; Huang et al., 2019; Hwang et al., 2016; Jack & McCormack, 2014; James et al., 2017; Kelley et al., 2016; Kelly et al., 2015; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Lee et al., 2015; X. Li et al., 2018; Mayne et al., 2013, 2017; McCormack et al., 2017, 2014; Méline et al., 2017; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Oliver et al., 2015; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Rundle et al., 2016, 2019; Sallis et al., 2009, 2016; Shay & Khattak, 2012; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Thielman et al., 2016; Towne et al., 2016, 2018; Villanueva et al., 2014; Wang et al., 2017; Wasfi et al., 2015, 2017; Wei et al., 2016; Witten et al., 2012; Yi et al., 2017)
No association	Older adults: 5 General population: 18	(Liao et al., 2019; Michael & Carlson, 2009; Nyunt et al., 2015; Takahashi et al., 2012; Travers et al., 2018)	(Christian et al., 2011; Curl et al., 2018; Forjuoh et al., 2017; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Hunter et al., 2019; Jensen et al., 2017; Y. Li et al., 2018; Lo et al., 2019; Maddison et al., 2009; McCormack et al., 2011; McGowan et al., 2017; Oluyomi et al., 2014; Reid et al., 2017; Riley et al., 2013; Ross et al., 2018)

Partial	Older adults: 3 General population: 20	(Chudyk et al., 2017; Van Holle et al., 2014; Zandieh et al., 2017)	(Boisjoly et al., 2018; Carter et al., 2017; Cerin et al., 2011; Chiu et al., 2015; D'Haese et al., 2014; Hinckson et al., 2017; Hosler et al., 2014; Kerr et al., 2014; Lovasi et al., 2011; Marquet & Hipp, 2019; McCormack et al., 2012; De Meester et al., 2012, 2013; Norman et al., 2013; Owen et al., 2007; Shimura et al., 2012, 2014; Tuckel et al., 2015; Twardzik et al., 2019; Yang & Diez-Roux, 2017)
Mixed	Older adults: 1 General population: 5	(Berke et al., 2007)	(Adams et al., 2015; Kerr et al., 2010; Perez et al., 2017; Richardson et al., 2017; Salvo et al., 2018)
Negative	General population: 5	--	(Hobin et al., 2012; Janssen & King, 2015; McGrath et al., 2016; Salvo et al., 2014; Tamura et al., 2019)

Source: own production

Associations found between walkability and walking-related outcomes

Most of the publications focusing on both older adults (62.5%) and the general population (60.7%) found positive associations between walkability and walking-related outcomes (Table 3). One fifth of the publications on older adults found no association while the share was lower among papers focusing on the general population (14.8%). There was no paper with a negative association in the literature on older adults, whereas 4.1% of the publications on the general population found negative associations between walkability and walking-related outcomes. Partial associations were found among 12.5% of studies focusing on older adults, while this proportion was 16.4% among studies on the general population.

4.1.4. Discussion

Understanding, defining and/or measuring walkability is essential for creating more democratic, sustainable, and healthy environments. These benefits are particularly important for older adults, for whom walking is one of the easiest ways to achieve the recommended daily physical activity levels. Therefore, a review of the operationalization of objective walkability, how it related to walking outcomes, and how this relationship differed for older adults compared to the general population, could shed light to the gaps in the literature and thus be useful for academics interested in this field of research, as well as being insightful for urban designers, planners, and decision makers to create more inclusive places that consider the differences of individuals and settings.

In our results, the increase in the number of walkability studies in the last decade is promising. This applies for studies focusing on older adults but also the general population, as mentioned in previous reviews (Barnett et al., 2017; Cerin et al., 2017; Wang & Yang, 2019). However, the fact that in our review many walkability studies in both groups focused on similar geographic settings (the US, Canada, and Europe) is of concern in terms of generalization of the results, despite the higher proportion observed in the number of studies focusing on older adults conducted in the Middle East and Asia. As it was also highlighted in previous studies, translating findings from these most common settings could be misleading, considering the differences in morphologies and land-use configuration between urban contexts across the globe, and the high proportion of studies conducted in high-income countries (Van Cauwenberg et al., 2011; Moura et al., 2017; Wang & Yang, 2019). For this reason, the literature also lacks examples from middle- and low- income countries or cities, where walking is not only an important and a low-cost type of PA for a healthier life, but also one of the most accessible ways of transportation (Litman, 2004). To this end, instead of following a one-size-fits-all approach, more studies conducted in different countries and even different cities of the same country, would bring new perspectives to walkability studies by highlighting the differences among settings, and their relationship with walking behavior of the general population and older adults in particular.

In terms of research design, cross-sectional studies were the most common among both groups of literature, as was also previously pointed out by other reviews (Barnett et al., 2017; Van Cauwenberg et al., 2018; Cerin et al., 2017; Sun, Norman, & While, 2013). However, compared to studies focusing on the general population, it is promising that we observed a higher ratio of longitudinal studies among older adults-focused publications in our review. As is suggested in studies of aging, longitudinal designs are essential to understand complicated relationships among events or risks and outcomes, as well as to reduce possible biases, such as selection bias in sampling (García-Peña, Espinel-Bermúdez, Tella-Vega, Pérez-Zepeda, & Gutiérrez-Robledo, 2018, p. 100). Thus, more longitudinal studies focusing on older adults would bring a more comprehensive understanding of walkability for this age group in the future, besides providing more reliable results.

In terms of data collection, most of the analyzed studies focusing on older adults used self-report measures to obtain walking-related outcomes. The ratio of use of technological devices for outcome data collection among older adults-focused studies presented a lower proportion than that of studies focusing on the general population, as was also mentioned in previous reviews (Cerin et al., 2017; Sun et al., 2013). This could be due to the methodological challenges of these devices to capture older adults' mobility, such as low battery life, underestimation of PA due to body-placement of the device, or difficulties encountered by participants when using these devices (Pires, Garcia, Pombo, & Flórez-Revuelta, 2018). However, self-report measures have various disadvantages, especially among studies focusing on older adults, such as not capturing all daily activity patterns since individuals may not consider some activities, like dancing, as a type of PA, possibility of changes in older adults' health status and/ or mood, or problems with memory and cognition that could affect accurate recall of PA on a survey (Garatachea, Luque, & Gallego, 2010). Thus, as previous studies suggested, the optimal reliability of results, especially in older adults' mobility research, could be gathered from the use of objective or mixed methods (Jana A. Hirsch, Winters, Clarke, & McKay, 2014; Meijering & Weitkamp, 2016), which promisingly presented a higher proportion among older adults-focused papers included in our review.

Regarding the operationalization of walkability, most studies in both groups used indexes. The most preferred index in studies focusing on the general population was WalkScore, as it was also mentioned (Hall & Ram, 2018), and criticized previously for being an "insufficient metric for population health studies", and for not capturing "the experiential nature of walking nor walkability" since it excludes recreational walking (Shields et al., 2021, p. 3,8), as well as the lack of consideration of attributes that would contribute to walking (Wang & Yang, 2019), such as measures related with safety (Forsyth, 2015). Also, this index is only validated in the US and Canada, as stated on their website. Thus, its use in other settings could be highly misleading. Among studies focusing on older adults, the most common index was the walkability index of Frank et al. (2010) (Frank, Sallis, et al., 2010). Although the variables used in this index (net residential density, retail floor area ratio, land use mix, and intersection density) could be meaningful to some extent to measure walkability in some other settings, this study was based on the data from two US cities and was not created specifically for older adults. Thus, although the values assigned for each variable in the formula were modified for adaptation in some of the reviewed papers (Bodeker, 2018; Van Holle et al., 2016), its use to study this age group and in different settings could also be misleading. Although walkability differed widely for older adults compared to other pedestrians, as highlighted in an empirical research (Moura et al., 2017) as well as in a recent study proposing a "walkability index for elderly health" (Alves et al., 2020), in our review, the proportion of publications among older adults-focused studies creating their own indexes was lower than that among publications focusing on the general population. However, the ratio of the usage of separate variables was higher among older adults-focused studies. Depending on the selection of variables, this measure could provide more meaningful results for walkability and its relationship with older adults' walking, rather than using an index which was not designed specifically for this age group. We believe that by using more specific variables or indexes, not only for the age groups under study but also for the settings, walkability measures could become more precise, and this would help create more walkable areas and promote walking for all.

The most used category of walkability variables among studies focusing on older adults were those related to land use characteristics in our review. This was followed by variables related to safety from traffic, which are intuitively believed to be specifically relevant to older adults' walking and used widely, as stated in a previous review (Van Cauwenberg et al., 2011). The ratio of the usage of variables related with street design was similar for publications focusing on older adults and the general population. Although this category included variables found by previous studies to be specifically essential for older adults' walking, such as sidewalk availability/ width/ material (Rosso, Harding, Clarke, Studenski, & Rosano, 2021), presence of benches (Akinci, Delclòs-Alió, Vich, & Miralles-Guasch, 2021; Ståhl et al., 2008) or restrooms (Cerin et al., 2017) plus many other examples, usage of these variables did not present considerably higher proportions among publications focusing on older adults. The ratio of using greenery-related variables was slightly higher among studies focusing on older adults compared to the general population. This is perhaps due to the numerous studies in the literature highlighting the positive relationship found between the presence of green areas (including parks or street trees) and older adults' walking (Jackson, 2003; Miralles-Guasch et al., 2019; Vich et al., 2021). However, the proportion of using these variables among older adults-focused studies was still low compared to the importance of this variable for their PA. Regarding the spatial extent for measuring walkability, different from publications on the general population, studies on older adults focused only on residential areas in their research. Similarly, the most used spatial units among studies on older adults were buffers which are equal to or smaller than 1000m, and administrative units (e.g., neighborhood boundaries/ units, zip/postal codes, etc,) presented a higher share among this group of literature. These results were expected considering that the range of activity among older adults mostly decreases to the immediate vicinity of their residences (Cao et al., 2019), and doubtless this sheds more importance on the characteristics of the built environment in the neighborhoods. However, this also limits the range of walkability studies by underestimating individual differences, since not all older adults' activity range or levels are the same. Additionally, different types of walking, such as recreational walking, could take place farther than the residential areas, and limiting studies with these extents could easily exclude these types of walking (Kwan, 2018). Thus, more studies using wider spatial extents and units in the future would provide more detailed information on walkability and its relationship with different types of walking, settings, and individuals.

Finally, most of the papers included in our review found a positive association between walkability and walking-related outcomes in both groups of publications. Among studies focusing on older adults, publications which found a positive association, as well as those which did not find any associations showed a higher proportion compared to publications focusing on the general population. The higher proportion of the latter could be explained by the lack of age-specific index usage among publications focusing on older adults (Alves et al., 2020). Using indexes which are not created while considering specific needs of this age group could be limited or even misleading in understanding the relationship between walkability and walking. Regarding the high percentage of positive associations found between walking and walkability, previous reviews also presented similar results (Van Cauwenberg et al., 2018; Cerin et al., 2017). A review on the general population explained the reason for this as the high number of studies conducted in high-income countries, since these settings are less likely to have deficiencies in the built environment, such as poor sidewalk infrastructures, or safety issues, such as high crime rates, compared to middle- or low-income settings (Adkins, Makarewicz, Scanze, Ingram, & Luhr, 2017; Wang & Yang, 2019). Thus, more studies conducted in different countries and even in different cities of a country, especially taking into consideration the possible socio-economic differences between cities, would bring a wider perspective to the research on walkability, be helpful to overcome the uncertainties in the literature, as well as inform governments to create solutions for creating more walkable places for various population groups, and promoting walking in settings with different characteristics.

Strengths and limitations

The first strength of our systematic review is that it focuses particularly on walkability studies. Second, it provides results for older adults and the general population separately, which highlights the differences more and helps to find solutions for creating better environments for everyone. Third, this review includes only objective operationalization of walkability. Considering the main focus on older adults, this is accepted as one of the most precise methods (Jana A. Hirsch et al., 2014; Lin & Moudon, 2010; Moura et al., 2017); thus we believe that the studies included in this review provided high reliability results. Finally, this review provided comprehensive information about not only how objective walkability has been defined and measured, which could be insightful for governments, but also scrutinized the methodologies used in walkability studies, which could be useful for researchers interested in conducting both literature reviews and empirical analyses on walkability. However, this systematic review is not exempt from limitations. First, although we included numerous characteristics of the studies in the content analysis, we did not cover other characteristics, such as sample size, which could provide different insights. Future research could consider including this variable in their reviews to enrich the body of literature. Second, selecting papers published only in English could have resulted in a language-based bias. However, we believe that the reviewed studies and the analysis presented here are representative, since the majority of empirical studies worldwide are published in English (Rao, 2018). Finally, as mentioned in other reviews (Elshahat, O'Rorke, & Adlakha, 2020; Forsyth, 2015) other types of biases, such as spatial selection bias (e.g., residential selection bias, whether people who walk more choose to live in highly walkable areas), or recall bias (e.g., studies using self-reported PA) among the included studies could have impacted their results and thus the results of our review and our interpretations, even indirectly.

4.1.5. Conclusion

This review draws attention to how objective walkability has been operationalized, how it is related to walking outcomes, and how these differed among studies focusing on older adults and the general population. Despite the promising increase in the last decade in the number of publications focusing on walkability for all sorts of population groups, the literature still lacks studies 1) focusing on different settings, especially low- and middle-income settings, 2) using wider spatial extents rather than only neighborhood scale, 3) using longitudinal designs, 4) using objective or mixed methods to collect their outcome data related with walking, and 5) creating indexes or using separate variables which are specific for settings and population groups, such as older adults. With future studies aiming to address these points, walkability studies could become more comprehensive and provide better answers to urban design and planning problems.

The methodologies used and the gaps found in the walkability literature highlighted in this review could be useful for researchers to conduct future reviews, as well as empirical analyses on walkability. Additionally, the differences in the definition and operationalization of objective walkability for older adults versus the general population summarized in this study could be insightful for not only researchers interested in the field, but also urban designers, planners, or local governments aiming to create more walkable places that would meet the needs of most population groups, but specifically older adults', in different settings. These would enrich the walkability literature and contribute to more democratic, sustainable, and healthy environments, as well as the societies in general.

5. The relationship between urban environments and outdoor activities among older adults

5.1. Neighborhood urban design and outdoor later life: An objective assessment of out-of-home time and physical activity among older adults in Barcelona

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Human Kinetics
ORIGINAL RESEARCH

Neighborhood Urban Design and Outdoor Later Life: An Objective Assessment of Out-of-Home Time and Physical Activity Among Older Adults in Barcelona

Zeynep S. Akinci, Xavier Delclòs-Alió, Guillem Vich, and Carme Miralles-Guasch

This study explores how older adults' time out-of-home and physical activity (PA) are associated with the provision of urban open spaces (green spaces, plazas, and boulevards) and microelements (street trees and benches) in their neighborhoods. The authors used data from 103 residents in Barcelona and matched it to official geospatial data. The authors adjusted a set of mixed-effects linear regressions, both for the entire sample and also stratified by age and gender. For the entire sample, the percentage of green spaces showed a positive association with neighborhood time out-of-home and PA, while participants' PA also showed a positive association with the presence of benches. Outdoor time among older women was not associated with any of the measured exposures. For men, the provision of green spaces and benches was positively associated with time out-of-home and PA. These results could inform the design of urban spaces that aim to encourage outdoor activity among older adults.

Keywords: accelerometer, compact cities, elders, GPS, green spaces, outdoor activity

Numerous studies and organizations highlight the importance of daily physical activity (PA) for older adults (≥65 years old). The World Health Organization (WHO) recommends that older adults engage in moderate to vigorous physical activity for at least 150 min every week in order to maintain overall well-being and prevent various physical and mental illnesses (Chang, Lu, Hu, Wu, & Hu, 2017; WHO, 2011; Yigitcanlar, Teimouri, & Degirmenci, 2020) and the prevalence of chronic illnesses (Ribeiro et al., 2018). Being involved in daily PA has proven to prevent falls (Sherrington, Lord, & Finch, 2004), risk of depression (Davis et al., 2020), cardiovascular diseases (Haennel & Lemire, 2002), diabetes (Colberg et al., 2016), obesity (Gamble, 2016), and some types of cancer (Batty & Thune, 2000).

However, not all older adults are able to meet such recommendations, especially considering certain individual factors, including poor health conditions; lack of company (Moschny et al., 2011); or psychological barriers, such as lack of confidence or fear of falling (Lee et al., 2008), which can hinder consistent involvement in PA (Joseph, Zimring, Kiefer, & Harris-Kojetin, 2006). In these cases, the WHO suggests that older adults be as active as possible throughout the day to maintain a healthy life, both physically and mentally. In this regard, spending time out-of-home (TOH) has also been associated with good overall health status (Petersen, Austin, Mattek, & Kaye, 2015). Older adults spending TOH for 30 min or more are more likely to present fewer depressive symptoms than those engaging in PA for the same amount of time (Kerr et al., 2012). Moreover, TOH also provides the opportunity to socialize or interact with other individuals (Cao, Heng, & Fung, 2019), instead of staying at home in isolation (Glass & Balfour, 2003) and probably in front of screens (Sugiyama, Salmon, Dunstan, Bauman, & Owen, 2007; Veitch et al., 2016). Thus, outdoor activity, whether in active or sedentary forms, can help older adults to achieve a healthy later life.

Beyond individual characteristics, built environment features such as the provision of open spaces and even certain urban microelements can also impact, encourage, or hinder elders' PA and TOH (Kato, Arai, Morita, & Fujita, 2020; Ottoni, Sims-Gould, Winters, Heijnen, & McKay, 2016; Stathi, Carlsson, Hovbrandt, & Iwarsson, 2008). There are a number of both qualitative and quantitative studies exploring the relationship of urban spaces and elders' outdoor activities; however, most of them focus on green spaces and only analyze elders' PA time, but not TOH (Levy-Storms, Chen, & Loukaitou-Sideris, 2018). In addition, and to the best of our knowledge, most studies focusing on microelements use qualitative data exploring perceptions of users, with only limited exceptions (Van Cauwenberg et al., 2014).

The aim of this paper was to explore the combined association between the provision of urban open spaces and certain microelements with elders' outdoor time and physical activity in their neighborhoods. Furthermore, we explored how these associations may present specific nuances in terms of age and gender, considering that the association between built environment features and older adults' outdoor behavior is likely to vary based on these individual characteristics (Lizárraga Mollinedo, 2013). We used high-resolution data from GPS devices and accelerometers from older adults residing in Barcelona. While the provision of green spaces in Barcelona is lower compared with other European cities (Baró et al., 2014), plazas and boulevards and certain urban microelements such as street trees and benches may encourage older adults to be active outdoors.

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Literature Review

From a socioecological perspective (Bronfenbrenner, 1977), the characteristics of physical environments can strongly influence

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5.2. Urban vitality and seniors' outdoor rest time in Barcelona

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Urban vitality and seniors' outdoor rest time in Barcelona

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ABSTRACT

Immobility and lack of physical activity (PA) are global problems among seniors (≥65 years old). While being active is preferable to not doing physical activity, not leaving the house for long periods might increase mortality risk, lead to social isolation, depression, cognitive impairment, besides other health problems. However, going out of home, even to spend rest time outdoors could improve mental health, increase vitamin D intake, or provide opportunities in involvement in various experiences such as psychosocial, emotional, cultural, therapeutic, leisure or even PA, since resting forms an essential part of PA for some seniors. Previous studies show that the characteristics of individuals as well as the physical environment and how seniors perceive it affect their outdoor behavior. Aiming to contribute to the literature which mostly focuses on the relationship between characteristics of the physical environment and seniors' PA, this study explores how a specific urban characteristic: urban vitality impacts seniors' outdoor rest while considering age and gender. To do so we used GPS-tracking and accelerometer data belonging to 253 seniors residing in Barcelona, in combination with a GIS-based urban vitality index and a questionnaire for sociodemographic data and neighborhood perceptions. Results show that seniors in Barcelona tend to rest rather than being active in more vital areas. However, results differ among age and gender groups. The probability of using vital areas for outdoor rest was especially higher among older senior men (≥75 years old). This study furthers our understanding of seniors' outdoor behavior, its relationship with the built environment and how this relationship varies among individual characteristics. Results might provide valuable insights for the design of vital urban spaces that can have positive contributions to seniors' lives while strengthening the community life by promoting social inclusion of all age and gender groups in urban life.

1. Introduction

Immobility and lack of physical activity (PA) are common issues for seniors (≥65 years old) around the globe (Azagba and Sharaf, 2014; Cunningham et al., 2020; Gomes et al., 2016; Schwanen and Páez, 2010). Older age, besides a series of causes, is often found to form a barrier to leave the home and this results in long hours spent indoors, often in front of screens, isolated (Jacobs et al., 2018; Rundek and Bennet, 2006). While the lack of PA is behind several noncommunicable diseases and a stark decrease in basic functions of everyday life (Knight, 2012), not leaving the home for extended periods of time might increase mortality risk (Jacobs et al., 2018), lead to social isolation, depression, cognitive impairment, besides other health problems (Petersen et al., 2015). Although being active is preferable to not doing physical activity, going out of home even if it is to rest, provides numerous opportunities to individuals such as being involved in social life (Antoninetti and Garrett, 2012; Cao et al., 2019), improving mental health (Kerr et al., 2012a), increasing vitamin D intake (Bouillon, 2017), and facilitating engagement in experiences including "psychosocial, emotional, cognitive, cultural, leisure, therapeutic, recreational, volunteer" and even PA (Jacobs et al., 2018: p.106), since outdoor rest forms an essential part of PA for some seniors (Stahl et al., 2008). However, since most of the research to date has focused on PA, still not much is known about the drivers of outdoor rest among seniors.

According to socioecological model, characteristics of individuals and physical environment are among the factors that affect individuals'

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5.2.1. Introduction

Immobility and lack of physical activity (PA) are common issues for seniors (≥65 years old) around the globe (Azagba & Sharaf, 2014; Cunningham et al., 2020; Gomes et al., 2017; Schwanen & Páez, 2010). Older age, besides a series of causes, is often found to form a barrier to leave the home and this results in long hours spent indoors, often in front of screens, isolated (Jacobs et al., 2018; Rundek & Bennet, 2006). While the lack of PA is behind several noncommunicable diseases and a stark decrease in basic functions of everyday life (Knight, 2012), not leaving the home for extended periods of time might increase mortality risk (Jacobs et al., 2018), lead to social isolation, depression, cognitive impairment, besides other health problems (Petersen et al., 2015). Although being active is preferable to not doing physical activity, going out of home even if it is to rest, provides numerous opportunities to individuals such as being involved in social life (Antoninetti & Garrett, 2012; Cao et al., 2019), improving mental health (Jacqueline Kerr et al., 2012), increasing vitamin D intake (Bouillon, 2017), and facilitating engagement in experiences including "psychosocial, emotional, cognitive, cultural, leisure, therapeutic, recreational, volunteer" and even PA (Jacobs et al., 2018, p. 106), since outdoor rest forms an essential part of PA for some seniors (Ståhl et al., 2008). However, since most of the research to date has focused on PA, still not much is known about the drivers of outdoor rest among seniors.

According to socioecological model, characteristics of individuals and physical environment are among the factors that affect individuals' behavior (Bronfenbrenner, 1977). Gender and age are two individual characteristics that mostly show different associations with seniors' outdoor behavior (Notthoff et al., 2017). Physical environment and how it is perceived also influence seniors' outdoor behavior (Akinci et al., 2021; Barnett et al., 2015; Joseph et al., 2006; Moniruzzaman, Páez, Nurul Habib, & Morency, 2013). Certain characteristics of urban environments, such as vitality, is found to have positive associations with seniors' outdoor activity involvement (Marquet et al., 2015). As Jacobs (1961) stated, no one enjoys watching an empty street but rather, "people entertain themselves (...) by watching street activity (p.35), watching the traffic, watching the people on the busy sidewalks, watching each other" (p.37) or, by watching urban vitality as its finest. In this regard, characteristics of urban built environments, especially the areas used for rest time, whether to sit and watch others pass by, or to have a break while doing PA, become even more important for seniors, as they have the capacity of promoting and extending outdoor active or rest time. Based on these perspectives, this study aims to examine whether urban vitality is associated with outdoor rest among seniors, while considering individual characteristics.

5.2.2. Background

Urban vitality (Jacobs, 1961) or liveliness (Mehta, 2009), is a complex concept that has been defined in various ways in previous studies; "the synergism of a sizeable number of varied and somewhat unique, commercial and experiential opportunities, and a relatively dense and socially heterogeneous pedestrian population, which animates certain city areas, almost continuously" (Maas, 1984, p. 19), "the extent to which a place feels alive or lively" (Montgomery, 1998, p. 97), "the capacity of an urban built environment to boost lively social activities" (Yue, Chen, Zhang, & Liu, 2019, p. 11:638) or "24h a day street life" (Sung et al., 2013, p. 165). These definitions were used in studies to spatially understand, assess, or optimize the functioning of complex urban systems. Among the multiple ways that vitality has been defined, one of the most insightful ones was that of Jane Jacobs (1961). According to her, the vitality of a place depends on various conditions including but not limited to, a diverse land-use pattern; contact opportunity granted by human-scaled blocks and sufficient street intersections that reduce walking distances and decrease traffic speed; need for aged buildings that enables diverse population groups to be present; concentration of people from all over the city; accessibility that enables places to be used actively 24h, and properly controlled border vacuums, defined as infrastructures with a large footprint which reduce walking activity by preventing connections between places (Delclòs-Alió & Miralles-Guasch, 2018; Jacobs, 1961; Sung et al., 2013).

Numerous studies have focused on the relationship between built environment and seniors' outdoor behavior. Different types of urban spaces and micro-elements are found to increase seniors' PA at different scales, such as greenspaces (Carlson et al., 2012; Miralles-Guasch et al., 2019), or benches (Akinci et al., 2021; Ottoni et al., 2016) as some seniors find it difficult to walk more than 200 meters without resting (Ståhl et al., 2008). Only a few studies have explored seniors' PA in relation to vitality (Marquet et al., 2015). In many studies, these relationships presented significant differences in terms of individual characteristics. Gender, for instance, was found to have significant associations with seniors' outdoor behavior in relation to built environment, as women being less involved in most outdoor activities (Notthoff et al., 2017; Rapp et al., 2018) and their activities are found less related with the characteristics of the built environment than their counterparts' (Akinci et al., 2021; Ottoni et al., 2016). Seniors' age also presented differences in their outdoor behavior, since their physical possibilities or moving capacity (European Union, 2019; J Kerr, Rosenberg, & Frank, 2012) as well as the loneliness levels (Luhmann & Hawkley, 2016) change considerably among younger (<75 years old) and older seniors (≥75 years old). These in turn could result in a higher need of social interaction or imply different relationships with the built environment.

Besides notable exceptions (Barnett et al., 2015; Cerin et al., 2016), most studies so far have explored built environment in relation to seniors' PA. While there are recent studies focusing on total outdoor time, some explored it regardless of PA levels in relation to seniors' driving status (Spinney, Newbold, Scott, Vrkljan, & Grenier, 2020), or some explored outdoor rest time (ORT) in relation to built environment characteristics but in middle-aged adults (Koohsari et al., 2020), and did not include urban vitality. There are few studies focused on seniors' outdoor rest but only explored space optimization or design (Peng, 2019; Peng, Shen, & Tao, 2020; Qingfen, 2018) and none of them focused on the vitality of the environment. Thus, to the best of our knowledge, this is the first study on the relationship between vital places and seniors' outdoor rest.

5.2.3. Methods

5.2.3.1. *Setting*

This study was set in Barcelona Metropolitan Region, with a population of 1,620,343 (2018). More than one fifth of its population consists of seniors (Barcelona Estadistica, 2018). Barcelona is located in the North-East coast of the Iberian Peninsula, and it is influenced by hot-summer Mediterranean climate, which mostly has mild temperatures during the year (maximum 35 °C and minimum -5 °C). The annual precipitation in the area is average and mainly takes place during fall and spring (European Environment Agency, 2012) which configures a friendly environment for outdoor activities with no frequent extreme climate events.

Barcelona is usually defined as a compact, walkable, and vital city (Delclòs-Alió & Miralles-Guasch, 2018; Delclòs-Alió, Vich, et al., 2020; Marquet & Miralles-Guasch, 2015). Despite having a low ratio of greenspace per inhabitant compared to other European cities (18m^2 including peri-urban forest of Collserola), small parks, streets, boulevards, and plazas with trees often compensate the need of spaces for outdoor activities (Baró et al., 2014; Vich, Marquet, & Miralles-Guasch, 2019). Not only Barcelona has a dense and homogeneous distribution of street trees (98.4 /1,000 inhabitants), but also of resting places such as public benches (16.9 /1,000 inhabitants). Thus, both in terms of climate conditions and the provision of urban spaces and micro-elements, Barcelona is a city where people can enjoy outdoor activities throughout the year.

5.2.3.2. *Sample*

Participants were recruited within the RecerCaixa Project ("Ciudad, calidad de vida y movilidad activa en la tercera edad. Un análisis multimetodológico a través de Tracking Living Labs") during June.2016 and June.2017. They were contacted through 39 senior day-centers located across the metropolitan area, which was then followed by snowball (chain-referral) sampling technique with voluntary seniors from participants' social circles. Participants were required to be 65 years old or above and not to have specific mobility impairments. After being informed written and orally about the study, and provided with research protocol and instructions, 269 participants provided informed consent. Confidentiality was ensured by using random identification numbers.

Considering that seniors' outdoor behavior in relation to the built environment present differences according to their individual characteristics, we classified our sample by age [younger (<75 years old), and older (≥75 years old) seniors] and gender.

This study was approved by the Ethics Committee on Animal and Human Experimentation at Universitat Aut` onoma de Barcelona (UAB; CEEAH-3656).

5.2.3.3. *Data collection*

Participants were asked to wear a GPS device (QStarz BT-Q1000X; QStarz International Co., Ltd., Taiwan, R.O.C.) and a wrist-worn accelerometer (Actigraph GT3X+; ActiGraph LLC, Pensacola, Florida USA) to collect data regarding their outdoor behavior for seven days. Data extracted from both devices were aggregated into 15 seconds intervals using the Physical Activity Location Measurement System (PALMS) v.R4 (Jankowska et al., 2015). Additionally, participants were asked to fill in a questionnaire with data regarding their age, gender, self-reported health, and the characteristics of their residential neighborhood. As such, they could state their perception on the presence and quality of sidewalks, benches, trees, along with their assessments on cleanliness, noise, and traffic conditions in their neighborhoods (See Chapter 9.4 for survey questions about neighborhood perception).

5.2.3.4. *Measurements and key definitions*

In order to characterize urban vitality, we used the previously validated "JANE vitality index" (Delclòs-Alió & Miralles-Guasch, 2018). The JANE index considers vitality as the combination of six urban conditions mentioned by Jane Jacobs (1961); diversity, contact opportunity, need for aged buildings, concentration, accessibility, and distance from border vacuums (Delclòs-Alió & Miralles-Guasch, 2018). When calculating JANE index, building-use mix and residential-nonresidential ratio was considered for the diversity condition. Contact opportunity included block size and street width. Need for aged buildings consisted of mean year of construction and its standard deviation. Concentration consisted of population density, housing density, and building density. Accessibility was calculated as the distance to the closest public transport stop. Finally, distance from border vacuums considered the distance from large infrastructures and large single-use buildings. The index was calculated for 100x100 m cells across the city, and we used z-scores of each value to obtain comparable indicators. We considered that some variables such as housing density or land-use mix could have positive effects, while some others such as large blocks or proximity to border vacuums, could negatively affect urban vitality. The scores either with negative or positive values derived from six urban variables were integrated into the final JANE index (See (Delclòs-Alió & Miralles-Guasch, 2018) for more information about the calculation).

We defined total outdoor time (TOT) as the time spent in any activity that takes place outdoors (excluding in-vehicle ones), regardless of PA levels. However, ORT only includes the time spent resting outdoors, with no PA involvement. Thus, TOT includes both ORT and time spent in outdoor activities with PA engagement.

We calculated participants' exposure to urban vitality based on (1) their daily trips using their GPS-tracks and (2) their residential neighborhood. Calculating the vitality that participants encountered in their daily trips provides a better account of their exposure to urban vitality than just using a fixed residential-based buffer. Furthermore, combining a track-based exposure with a residential-based one can help overcome the neighborhood averaging effect as described by Kim & Kwan (2021) (Kim & Kwan, 2021). Thus, *track-based vitality* was calculated by juxtaposing participants' outdoor GPS points to the vitality index calculated at 100 x 100 m cells. Each outdoor point was assigned the vitality value from the corresponding cell. *Residence-based vitality* expresses the average vitality values around the residence and was calculated by averaging the vitality index of cells intersecting a 650m network-buffer around participants' home addresses. We settled on a 650m network-buffer (approximately 10-15 min walk for seniors) based on previous research (Marquet & Miralles-Guasch, 2014; Prins et al., 2014). In addition, we also calculated neighborhood walkability for the 650m residential network-buffer, as follows (Frank, Sallis, et al., 2010):

Neighborhood walkability= [(2×z-intersection density) + (z-net residential density) + (z-retail floor area ratio) + (z-land-use mix)]

All calculations were conducted with ArcGIS 10.5 (ESRI, Redlands, CA).

5.2.3.5. *Data management*

Participants provided a total of 2,368 days of data and over 12 million GPS and accelerometer datapoints. Considering that the focus of the study was on outdoor rest, we eliminated in-vehicle and indoor datapoints based on Signal to Noise Ratio provided by the GPS receiver, while keeping only outdoor pedestrian datapoints belonging to valid days of participation (n=1,309,888 datapoints, corresponding to 942 valid user-days, recorded by 253 participants). Valid days included at least four wearing days and ten hours of device wear-time. Then we coded datapoints as Active=0 and Resting=1 and created a database with all the available data based on user-days.

5.2.3.6. *Statistical analysis*

First, we used descriptive statistics and bivariate analysis at user-day level to explore the association between average outdoor time (minutes) -total outdoor time (TOT) and outdoor rest time (ORT)- and vitality levels, individual and neighborhood characteristics, and neighborhood perceptions. For a better interpretation of the results and comparison between groups, we categorized both vitality variables in tertiles for descriptive analysis. One-way ANOVA tests were used to flag significant associations.

Second, we used a mixed effects logistic regression model with user ID as a random effect to fully examine the relationship between vitality and probability of resting rather than being active when spending time outdoors. We have tested the multicollinearity of explanatory variables before the model specifications. The model was adjusted by age, gender, perceived health, and self-reported neighborhood perceptions. In order to account for the residential effect fallacy (Chaix et al., 2017), we also included the residence-based vitality and walkability in the models. We included two vitality variables as continuous variables in the model.

Finally, considering the individual differences in seniors' outdoor behavior, we created three interaction terms between age and track-based vitality, age and gender, and age, gender and track-based vitality. By using these, we calculated the adjusted predictive probabilities of outdoor rest at each representative value of age, gender and track-based vitality, using the Stata 15 (StataCorp LLC, Texas, USA) margins command. These actions allowed us to estimate the odds of finding a resting datapoint at different levels of vitality and stratifying by age and gender, while controlling for the rest of the covariates.

5.2.4. Results

5.2.4.1. Descriptive results

Descriptive statistics of the study sample, perception of neighborhood characteristics, total outdoor time (TOT) and outdoor rest time (ORT) are presented in Table 13. Participants presented an average of 279.9 min of TOT out of which 201 min were ORT. Overall, they spent 72% of their daily outdoor time resting. We observed statistically significant differences in all variables (p-value <0.05). Average TOT and ORT among younger seniors (<75) (287.4 min and 203.7min, respectively) and women (292.6min and 219.2min, respectively) were higher than their counterparts. In terms of the ratio of ORT/TOT, older seniors (≥75) (73%) and women (75%) devoted a larger share of their outdoor time resting than their counterparts (p<0.01). Participants who reported bad health status showed a larger share of ORT (80%), although they had the lowest TOT (205.7 min) and ORT (164.6 min). Regarding track-based and residence-based vitality, TOT and ORT was higher in low vital areas and neighborhoods, however, the ratio of ORT/TOT was higher in high vitality areas.

Table 7 Descriptive statistics of the study sample, neighborhood characteristics, neighborhood perceptions, vitality and outdoor time

Variables		# of userdays with ORT	Average ORT (minutes)	# of userdays with TOT	Average TOT (minutes)	ORT/TOT ratio (%)	p value	
TOTAL		942	201.0	949	279.9	72%		
Age								
	<75	454	203.7	460	287.4	71%	0,000	**
	≥75	488	198.5	489	272.7	73%	0,001	**
Gender								
	Men	427	179.1	430	264.4	68%	0,000	**
	Women	515	219.2	519	292.6	75%	0,001	**
Health								
	Bad	27	164.6	27	205.7	80%	0,000	**
	Regular	233	209.1	235	278.0	75%	0,001	**
	Good	682	199.7	687	283.4	70%	0,005	**
Track-based Vitality								
	Low	259	237.1	260	332.2	71%	0,001	**
	Moderate	248	172.2	250	241.0	71%	0,000	**
	High	246	178.5	249	245.3	73%	0,002	**
Residence-based Vitality								
	Low	257	257.5	257	337.3	76%	0,001	**
	Moderate	254	184.1	255	268.9	68%	0,001	**
	High	242	145.1	247	212.3	68%	0,000	**
Neighborhood Walkability								
	Low	326	269.4	326	349.8	77%	0,001	**
	Moderate	316	153.9	322	226.5	68%	0,001	**
	High	300	176.3	301	261.2	67%	0,001	**
Neighborhood Perceptions								
Presence of enough sidewalks	Yes (Y)	839	189.8	846	268.2	71%	0,000	**
	No (N)	103	292.1	103	375.2	78%	0,001	**
Sidewalks with good conditions	(Y)	615	183.7	622	259.6	71%	0,000	**
	(N)	292	240.8	292	327.4	74%	0,001	**

Presence of elements on sidewalks which prevent walking	(Y)	387	225.9	389	308.8	73%	0,001	**
	(N)	538	183.8	543	257.3	71%	0,000	**
Presence of enough benches	(Y)	590	189.7	596	269.4	70%	0,000	**
	(N)	336	223.9	337	299.0	75%	0,001	**
Presence of steep streets which make walking difficult	(Y)	210	215.4	210	284.6	76%	0,001	**
	(N)	691	186.9	698	268.4	70%	0,000	**
Presence of different paths reaching the same destination	(Y)	672	183.1	679	256.3	71%	0,000	**
	(N)	235	227.8	235	316.2	72%	0,001	**
Presence of enough trees	(Y)	747	188.5	752	266.7	71%	0,000	**
	(N)	188	253.8	190	337.3	75%	0,001	**
Presence of good conditioned buildings	(Y)	857	205.1	864	283.6	72%	0,000	**
	(N)	54	197.4	54	300.4	66%	0,003	**
Clean neighborhood	(Y)	620	198.0	622	268.3	74%	0,000	**
	(N)	299	215.3	304	311.8	69%	0,001	**
Noisy neighborhood	(Y)	336	172.2	342	248.4	69%	0,001	**
	(N)	565	225.0	566	304.9	74%	0,000	**
Presence of traffic on streets	(Y)	687	178.5	694	252.2	71%	0,000	**
	(N)	255	261.8	255	355.0	74%	0,001	**

**Significant p value<0,01

Source: own production

Participants' outdoor behavior also differed based on how they perceived their neighborhoods. ORT was higher among those who considered their neighborhoods to lack sufficient and well-preserved sidewalks, not having enough trees and benches, that there were barriers on the sidewalks which prevent walking, and that streets were steep around their residences. ORT was also higher among those who considered their neighborhoods to be quiet, that they lack different paths to reach the same destination and that there was no traffic on the streets.

5.2.4.2. *Regressions and Adjusted Predictive Probabilities*

In logistic regression we observed statistically significant associations with the probability of resting rather than being active when outdoors, and most of the independent variables (Table 14). Compared with younger participants, older participants (b=0.453; p<0.01) were more likely to rest rather than being active while they were outdoors. Similarly, men were more likely to spend their outdoor time resting rather than being active compared with women (b=-0.292; p <0.01). Perceived regular health was related with higher possibility of resting rather than being active when outdoors (b=0.365; p<0.01). When moving through the city, participants were more likely to rest rather than being active in those areas that scored higher in the vitality index (b=0,135; p<0.01). In contrast, residence-based vitality and walkability did not show statistically significant relationship with the probability of resting rather than being active when outdoors (p= 0.066 and 0.150 respectively).

Table 8 Mixed effect logistic regression relating vitality, individual and neighborhood characteristics and neighborhood perceptions, and probability of resting vs. being active when outdoors

Fixed effects	B	p		CI (95%)	
Age					
<75.	=ref				
≥75	0,453	0.000	**	0,250	0,655
Gender					
Men	=ref				
Women	-0,292	0.003	**	-0,482	-0,103
Perceived Health					
Good	=ref				
Regular	0,365	0.000	**	0,194	0,535
Bad	0,350	0.162		-0,140	0,840
Track-based vitality	0,135	0.000	**	0,109	0,161
Residence-based vitality	-0,312	0.066		-0,645	0,020
Neighborhood Walkability	-0,028	0.150		-0,067	0,010
Neighborhood Perceptions					
Presence of enough sidewalks	0,324	0.012	*	0,073	0,575
Sidewalks with good conditions	0,201	0.025	*	0,025	0,377

Presence of elements on sidewalks which prevent walking	-0,211	0.010	*	-0,371	-0,051
Presence of enough benches	-0,013	0.874		-0,173	0,147
Presence of steep streets which make walking difficult	-0,142	0.145		-0,334	0,049
Presence of different paths reaching the same destination	-0,185	0.031	*	-0,353	-0,017
Presence of enough trees	0,006	0.946		-0,180	0,192
Presence of good conditioned buildings	-0,146	0.473		-0,543	0,252
Clean neighborhood	-0,673	0.000	**	-0,832	-0,513
Noisy neighborhood	0,218	0.004	**	0,068	0,369
Presence of traffic on streets	0,089	0.328		-0,089	0,266
Age (>=75) x Track-based vitality	-0,086	0.000	**	-0,128	-0,045
Age (>=75) x Gender (Men)	0,188	0.198		-0,098	0,474
Age (>=75) x Gender (Men) x Track-based vitality	0,431	0.000	**	0,371	0,491

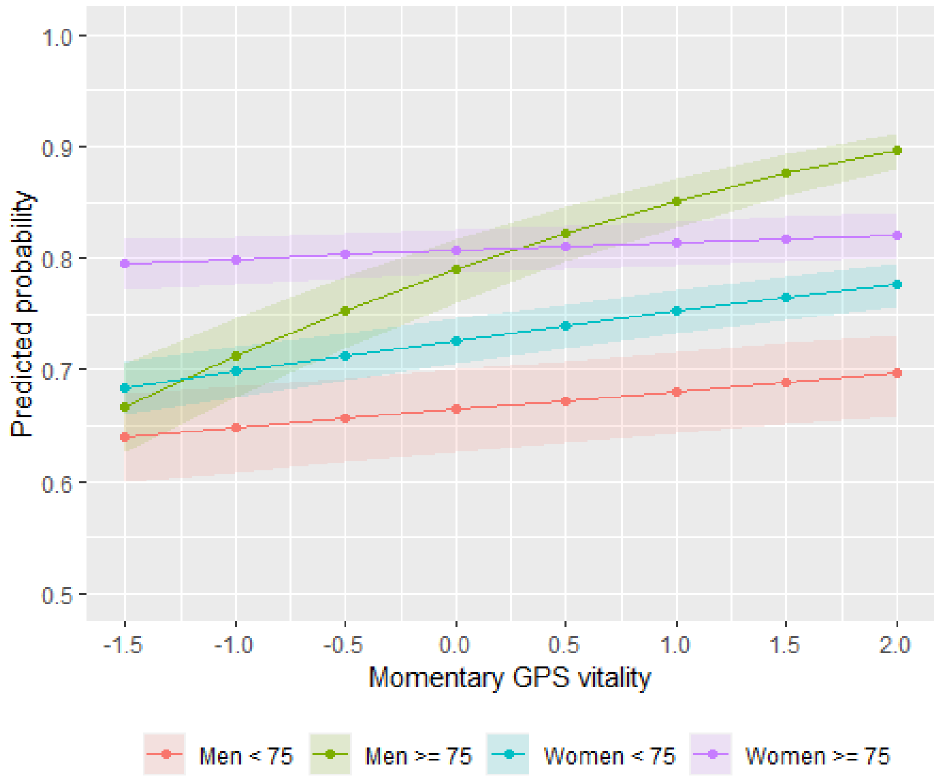
Outdoor points are labelled as Active= 0 Resting=1
B: Coefficient estimate, p: p-value, CI: Confidence Interval
*Significant p-value<0.05 ** Significant p-value<0.01

Source: own production

Regarding neighborhood characteristics, participants' probability of resting rather than being active when outdoors was higher when they perceived having enough ($b=0.324$; $p<0.05$) and well-conditioned sidewalks ($b=0.201$; $p<0.05$) and presence of noise in their neighborhoods ($b=0.218$; $p<0.01$). While perceived presence of elements which prevent walking on the sidewalks ($b=-0.211$; $p<0.05$), presence of different ways to reach the same destination in the neighborhood ($b=-0.185$; $p<0.05$) or perceiving the neighborhood to be clean ($b=-0.673$; $p<0.01$) were related with lower probabilities of resting rather than being active when outdoors.

Next, we used post-estimated adjusted predictive probabilities to observe the effect of the interactions between gender and age at predicting the possibility of resting rather than being active when outdoors (Figure 14). The difference between age groups' tendencies to rest rather than being active when outdoors and its relations with vital environments was even more visible. In general, for all participants, being exposed to more vital environments entailed a higher probability of resting rather than being active when outdoors. This trend, however, was not homogenic across age and gender groups. When the environment was more vital, older men's probability of resting rather than being active while they were outdoors was much higher than their younger and women counterparts. This was especially acute when compared to older women. Among younger seniors alone, the vitality of the environment had a slightly stronger effect on women's tendency to rest rather than being active when outdoors.

Figure 14 Predictive probabilities of the interactions between vitality, gender and age at predicting outdoor rest



Source: own production

5.2.5. Discussion and conclusion

In this paper we explored the relationship between seniors' outdoor rest and vitality of urban places using tracking data. Urban vitality was measured with the previously validated JANE vitality index. Outdoor rest data was collected by accelerometers and GPS devices, and sociodemographic data and neighborhood perceptions were obtained from a questionnaire. Results validated the hypothesis that seniors in Barcelona had a higher tendency to rest rather than being active in vital areas when they were outdoors. There are two plausible explanations for this result, although the motives of seniors' outdoor resting behavior are unknown. On the one hand, urban vitality itself could have attracted seniors, as Jacobs (1961) and Mehta (2009) suggest, and they might have chosen specifically these high vital areas to rest in order to watch more people and things happening around them. Since more people on the streets could mean more opportunities for social contact, this could also be correlated with the increased loneliness levels among seniors, especially after the age of 75 (Luhmann & Hawkley, 2016). On the other hand, our sample of seniors might have wanted to walk when they were outdoors, but due to the presence of many people or things happening around (urban vitality), they perhaps felt “unsafe” and needed to sit down somewhere to rest. Considering the increased levels of fear-of-fall among this age group especially after the age of 75 (Todd & Skelton, 2004), vitality or the presence of many other pedestrians around, might have negatively impacted seniors’ walking and compelled them to take a necessary rest somewhere.

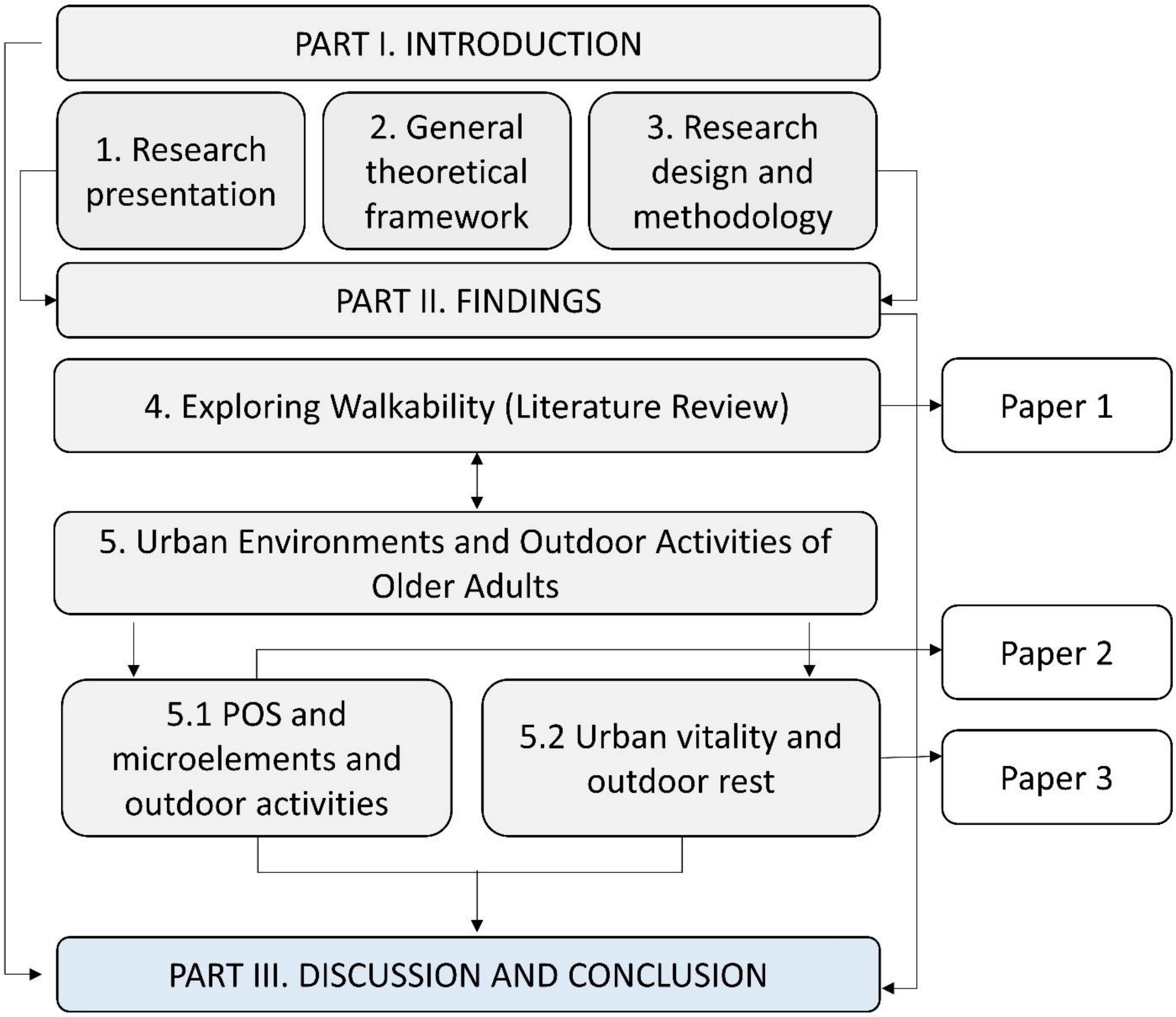
These two ideas could also be used to explain the differences in our results among two age groups, that older seniors’ probability of resting rather than being active when outdoors was much higher compared to their younger counterparts. Additionally, compared to the rest of the participants, the probability of resting rather than being active when outdoors had a much stronger association with vitality for older men. From a gender and age perspective this could be related to the fact that even in older ages, due to traditional work division, women are mostly in charge of house-errands or taking care of their spouses and/or grandchildren (Azevedo et al., 2007; Maciejewska, Marquet, & Miralles-Guasch, 2019; Rapp et al., 2018; Tarrant, 2010). As previous studies also found, characteristics and conditions of the built environment is more determinant in men’s outdoor behavior (Marquet et al., 2015) -except non-leisure trips which are mostly taken by women even in older ages (Boschmann & Brady, 2013; Mercado & Páez, 2009; Notthoff et al., 2017). Thus, senior women in our sample perhaps continued conducting these outdoor house-errands or caring tasks and rested wherever possible, regardless of the characteristics of the environment. Our results are in line with previous literature regarding the existence of a gender gap and the resulting gendered influence of the built environment in outdoor behaviors. For the first time, we were also able to show that the vitality of urban spaces also has a gender and age effect on outdoor rest.

Regarding neighborhood characteristics, perceiving sufficient and well-conditioned sidewalks, lack of obstacles when walking, and lack of different paths to reach the same destination were associated with higher probability of resting rather than being active when outdoors. Previous studies demonstrated that better sidewalk conditions would result in a higher volume of pedestrians (Rosso et al., 2021). However, this relationship was less significant for people between 65-75 years old, and it was no longer significant for people over 75 years old (Shigematsu et al., 2009). Thus, a plausible explanation could be that due to the presence of enough and good-conditioned sidewalks, or the lack of obstacles on the sidewalks in the analyzed neighborhoods, streets were used by many people (perhaps relatively younger people) and seniors either specifically preferred these vital areas to rest to be able to watch more people, or they took a necessary rest due to the "overcrowded" environment. Additionally, presence of more people might also bring along some "noise" to the neighborhood, which explains another result in our study that perceived noisy neighborhoods were related with higher possibility of resting rather than being active when outdoors. However, contrary to Jacobs (1961), traffic was not significantly associated with the probability of resting rather than being active when outdoors among this group of seniors. This could be due to the differences between the traffic volume in different neighborhoods of Barcelona, or how participants perceive it. Watching a large avenue with lots of cars passing at a time may not be as pleasant as watching the traffic on a one-way street. The perception of cleanliness at the neighborhood level was found associated with a lower possibility of resting rather than being active when outdoors, contrary to our expectations and also contrary to results from previous studies (Day, 2008) showing that clean environments are perceived as "safer" and thus, preferred more for outdoor activities. Finally, and again unexpectedly, the results did not show a significant association with the perception of enough benches in seniors' neighborhoods and the probability of resting rather than being active when outdoors. This could be explained by the gender gap or the domination of men in the use of urban micro-elements, as mentioned in a previous study in Barcelona that women do not prefer sitting on a bench if it is already occupied by a man (Ortiz et al., 2016). This gender gap was also demonstrated in a previous quantitative study which found positive relationship between the presence of benches in the neighborhood with only senior men's total outdoor time (Akinci et al., 2021).

To the best of our knowledge this is the first study to examine the relationship between seniors' outdoor rest and vitality of urban spaces. However, our study is not exempt from limitations. Neighborhood buffer selection might have caused bias in results and their interpretation, since not all seniors' outdoor spatial behavior and range are the same. Our results could be biased by different types of self-selection issues (Koohsari et al., 2015; O'Brien Cousins, 1997). First, the sample consists of people who are willing to take part in this study, so, they might have better health conditions and be more active than the "average" seniors in Barcelona. Second, related with residential self-selection issue, perhaps seniors in our sample who showed a higher probability to rest in vital areas may have chosen to live in vital neighborhoods and thus recorded more outdoor rest points coinciding with vital areas in their neighborhoods. Besides, the limitations of wrist-worn accelerometers could also be misleading due to their lower sensitivity in sedentary behavior compared to the hip-worn ones, although they are still considered trustable (>93-97%) in sedentary behavior studies (Montoye, Pivarnik, Mudd, Biswas, & Pfeiffer, 2016). While GPS provides high resolution spatiotemporal data, these devices also present technical limitations in terms of location accuracy as well as indoor-outdoor distinction (Duncan et al., 2013). However, GPS devices have been found to be more accurate when combined with accelerometer data (Jankowska et al., 2015). Finally, in our study we focused on the probability of resting when being outdoors, regardless of the activity purpose. Future studies that combine device data with qualitative information could explore motivations and types of outdoor rest activities, and their relationship with urban vitality.

This study aimed to contribute to the literature by providing in depth information on seniors' outdoor rest and its relationship with vitality of urban spaces. With no doubt seniors should aim to have an active lifestyle and meet daily recommended PA levels for a healthier later life. However, it should also be considered that seniors' involvement in PA is significantly related with the possibility to rest (Akinci et al., 2021; Ståhl et al., 2008). Thus, planning or designing outdoor rest areas may be of high importance for this demographic group. Our study showed that seniors in Barcelona tended to rest rather than being active when outdoors in high vital places. Urban designers and/or planners should consider placing public seats in these vital areas, which should be sufficient in number and appropriate in design for the usage of seniors whenever they want to have a rest, whether it be a necessary or a leisure rest.

PART III. DISCUSSION & CONCLUSION



6. Discussion

6.1. Discussion of the main findings

This section was designed to summarize and discuss the main results gathered from the studies included in this dissertation, a systematic literature review, and two empirical analyses. The section aims to present an overall understanding of the results in light of research questions and corresponding hypotheses.

In response to the general hypothesis regarding the impacts of urban environments on older adults' outdoor activities (H0)

The main hypothesis of this doctoral thesis posits that characteristics of urban environments have significant impacts on outdoor activities of older adults and this can influence their physical and mental health. This hypothesis finds support in the majority of studies conducted within this dissertation. The systematic literature review, while not by its results, but by the range of variables related to the built environment used in examined walkability studies, highlights the importance of environmental characteristics on walking —a prevalent outdoor activity among older adults. The research design and methods employed in the empirical studies were instrumental in exploring and comprehending the influence of the built environment and individual differences on outdoor activities of older adults. The findings of these studies reinforce the main hypothesis by providing examples of the relationship between characteristics of urban environments and outdoor activities among older adults at different scales. The first empirical study (Chapter 5.1) revealed that at neighborhood scale, the availability of POS and urban microelements were associated with higher levels of physical activity and time out-of-home. The second study (Chapter 5.2) demonstrated that older adults preferred vital areas for resting outdoors. The findings also underscored the influence of individual characteristics, such as age and gender, on the relationship between outdoor activities of older adults and the features of urban environments.

These results align with the theoretical framework of the thesis. According to the press-competence theory, the press from the environment is perceived differently depending on the competence level of individuals —which mainly based on individual characteristics— and this impacts engagement in outdoor activities. Similarly, the social-ecological framework emphasizes that both the characteristics of the built environment, such as the presence of POS and urban microelements, and individual characteristics, including gender and age, alongside other factors, play crucial roles in the likelihood of outdoor activity engagement among older adults. Given that increased activity engagement leads to improved overall health and wellbeing, as posited by the socioecological model for health promotion, the characteristics of the built environment can encourage individuals to participate in outdoor activities, thereby enhancing their physical and mental health. Thus, the characteristics of individuals and the features of the environment both play significant roles in facilitating outdoor activity involvement and healthy aging.

The following paragraphs aim to provide in-depth explanations for each hypothesis within this dissertation.

Regarding how operationalization of walkability differs between older adults and the general population (H1 and H4)

Contrary to the hypotheses, the results of the systematic literature review (Chapter 4) revealed striking similarities in the objective operationalization of walkability between studies focusing on older adults and the general population (Akinci, Delclòs-Alió, et al., 2022). As suggested by the press-competence theory, age has a significant impact on outdoor activity engagement, with the possible decrease in competence levels to cope with the environmental press as individuals age. However, the results of the review revealed that age was not consistently regarded as an influential factor among examined walkability studies since most of them used similar operationalizations of walkability for older adults and the general population, overlooking the specific needs of older adults in outdoor activity engagement. Furthermore, many studies included in the review concentrated on similar settings, such as the United States, Canada, and Europe, utilizing identical walkability variables or indexes to measure this phenomenon across different contexts. This generalizing approach ignores the impact of the factors influencing outdoor activities (e.g., characteristics of individuals, natural, built, and social environments), as mentioned in social-ecological frameworks. The following paragraphs provide detailed discussions on the observed similarities or challenges among the included walkability studies.

Walking stands out as the most common form, if not the only type, of physical activity (PA) among older adults. It serves as an accessible, sustainable, and health-enhancing mode of transportation, enabling individuals to incorporate PA into their daily routines for healthy aging. Nonetheless, the physical limitations that often accompany aging make walking, like other outdoor activities, more challenging for older adults. Coupled with barriers presented by the physical environment, such as inadequate pedestrian infrastructure or lack of public open spaces, engaging in walking becomes even more difficult for this population group. Thus, it is imperative that studies adopt different definitions and operationalizations of walkability tailored to older adults and other population groups in diverse settings.

Although there has been a promising increase in the number of walkability studies focusing on both population groups in the past decade, these studies have largely focused on similar contexts. While a one-size-fits-all approach may allow for generalization of results, it raises concerns on multiple fronts. Firstly, most of the settings were relatively high socioeconomic status (SES) areas, overlooking low- and middle-SES contexts where walking serves not only as a low-cost PA option but also an accessible mode of transportation. Secondly, this approach risks underestimating regional and local nuances, such as climate, geography, morphology, or urban fabric, which hold significant importance. Future studies should prioritize investigating underrepresented areas to comprehend and delineate the differences in walkability across diverse settings. This approach would enrich the field with diversity and enhance our understanding of this phenomenon.

Another notable similarity observed in walkability studies focusing on older adults and the general population is the selection of walkability variables and/or indexes. Some variable categories did not exhibit significant differences between the two population groups, despite many studies emphasizing their high importance for older adults, such as street design (including quantity and quality of pedestrian infrastructure and the presence of urban microelements) or the presence of greenery, as they contribute to older adults' engagement in walking (Levy-Storms et al., 2018). While it is understandable that these categories hold relevance for all population groups (Chang, 2020), studies targeting older adults were expected to place a greater emphasis on them. To enhance our understanding of diverse population groups and settings and to create environments that effectively address their unique needs, it is essential to adopt a more tailored approach in selecting walkability variables or creating specialized indexes. By considering these factors, walkability measures can become more precise, contributing to the creation of truly walkable environments that promote walking for all.

Another challenge to consider is the spatial extent used to operationalize walkability. Residential neighborhoods emerged as the most common spatial extent in studies focusing on older adults. Many studies suggested that older adults primarily spend their outdoor time within their residential neighborhoods, underscoring the neighborhood's particular significance for older adults compared to younger individuals (Cao et al., 2019; Chang, 2020; Chaudhury et al., 2016). However, this approach may overlook or underestimate different types of physical activities taking place beyond residential neighborhoods and fail to account for variations among individuals' range of activities. While this common approach is valuable for understanding the importance of neighborhoods in older adults' outdoor activities, it may also result in misleading conclusions.

Lastly, the results of the review demonstrated a positive relationship between walkability and higher levels of walking. Walkability undoubtedly serves as a crucial indicator in PA studies targeting both older adults and the general population. However, this positive association could be attributed to the high number of studies conducted in high-SES areas, which generally have better pedestrian infrastructure and, consequently, higher walkability levels (Wang & Yang, 2019).

In conclusion, employing more setting- and individual-specific variables or indexes, applied to different spatial extents, can lead to a better understanding of walkability and aid in the creation of more walkable areas that benefit everyone.

Although the systematic literature review did not directly support the hypotheses by its results (H1and H4), it provided evidence that the characteristics of the built environment play essential roles in walking as an outdoor activity, thereby supporting the main hypothesis (H0).

Regarding the impact of urban design on older adults' outdoor activities at the residential neighborhood level (H2) and how this impact differs according to individual characteristics (H4)

Features of urban design, such as the presence of POS, especially greenspaces, in residential neighborhoods were found associated with higher physical activity (PA) levels among older adults (Levy-Storms et al., 2018). However, the existing literature mostly consists of qualitative studies that focus on greenspaces and do not consider time out-of-home (TOH) regardless of PA levels. Therefore, the first empirical study presented in this dissertation (Chapter 5.1) aimed to deepen the understanding of the relationship between neighborhood urban design and outdoor activities by utilizing high-resolution quantitative data. This study examined not only various types of POS, including greenspaces, plazas and boulevards (or ramblas), but also urban microelements such as benches and street trees. Additionally, it included TOH besides the PA time.

The results showed that, for all participants, a greater presence of greenspaces in residential neighborhoods was associated with increased PA time and TOH within the neighborhood (Akinci et al., 2021). Furthermore, the availability of benches was found to be related to increased PA time. This finding is particularly important as it highlights the need for rest among some older adults during outdoor activities (Barron, 2015; Ottoni et al., 2016; Ståhl et al., 2008). When benches are available in POS, individuals can take breaks and continue to be active, leading to higher levels of daily PA. This can have great impacts on the health and well-being of older adults, as well as the society, as mentioned in ecological model for health promotion theory (McLeroy et al., 1988; Stokols, 1992, 1996).

Another notable finding of this study pertains to the gender differences in the impact of neighborhood urban design on older adults' outdoor activities. As stated in the social-ecological theories adopted for physical activity and active living

(Bornstein & Davis, 2014), gender and age are among the individual determinants that impact involvement in physical activity and thus living a healthier life. The results of the first empirical study show that while greenspaces and benches had a significant impact on PA and/or TOH among the total sample, further analysis stratified by gender revealed that the impact was only significant for older men. Older men were more physically active and spent more TOH when there were higher ratios of greenspaces and benches in their residential neighborhoods. A similar relationship was observed in a study by Marquet and Miralles-Guasch (Marquet & Miralles-Guasch, 2015), who explained these findings as men's outdoor activities being more influenced by the characteristics of the physical environment compared to women's activities. Several factors may contribute to this difference. Firstly, there may be variations in the types of activities undertaken by men and women, with leisure trips being more prevalent among men. The second factor is the disparity in the amount of time that men and women may allocate to recreational activities. These activities tend to be more influenced by the characteristics of the built environment compared to utilitarian trips —which include tasks, like household responsibilities or care-related tasks, that are often perceived as women's responsibilities, even in older age groups, and do not leave much time for leisure activities (Azevedo et al., 2007). Lastly, gendered differences in the use of POS and microelements may play a role, as women may be less inclined to use benches that are already occupied by men (Ortiz et al., 2016).

The first empirical study confirmed both hypotheses, demonstrating a strong relationship between neighborhood urban design and older adults' outdoor activities within their residential areas. Additionally, a significant gender difference was observed in this relationship.

<u>Regarding the impact of urban vitality on older adults' outdoor rest (H3) and how this impact differs according to individual differences (H4)</u>

Vitality plays a crucial role in fostering vibrant and engaging urban environments. It encompasses active street life and a sense of community, which can have great influences on outdoor activities (Jacobs, 1961). The second empirical study (Chapter 5.2) aimed to explore the relationship between vitality and outdoor activities further by focusing on outdoor resting specifically. The findings of the study supported the hypothesis that older adults in Barcelona tend to rest in areas with higher urban vitality levels (Akinci, Marquet, Delclòs-Alió, & Miralles-Guasch, 2022). One possible explanation for this behavior is rooted in Jane Jacobs' hypothesis (Jacobs, 1961) that people enjoy observing others, and since vitality entails a greater presence of people and events in POS, older adults may have preferred resting in more vital areas in Barcelona (Delclòs-Alió, Gutiérrez, & Miralles-Guasch, 2019; Delclòs-Alió & Miralles-Guasch, 2018). Another explanation could be that the perception of "unsafety" arises due to the bustling atmosphere in vital areas, leading older adults to seek respite by sitting down and resting instead of being active in these areas.

Similar to the first empirical study, this research also revealed significant differences when considering individual characteristics such as age and gender. Older men over 75 years old exhibited a higher probability of resting in high-vitality areas compared to their younger counterparts and women. This can be attributed, once again, to gender disparities in outdoor activities and division of labor, which often leave little time for resting outdoors among women. Additionally, the higher levels of feeling of loneliness, particularly among men over the age of 75, may explain why the oldest-older adults seek out more vital areas to rest outdoors, as increased chances of being engaged in social life.

These findings confirm the hypotheses proposed in this second empirical study, demonstrating that both the characteristics of the environment, as well as individual characteristics, significantly impact outdoor activities among older adults, such as outdoor resting.

6.2. Strengths and limitations of the study

This dissertation consists of three studies, and they have both strengths and limitations. This section aims to emphasize these that may have influenced the results and their interpretations. The limitations of the study could help to identify future research directions.

Strengths of the study

This sub-section highlights the strengths of the study and how the research design and methodology contribute to a comprehensive understanding of the relationship between urban environments and outdoor activities among older adults.

The study commenced with a systematic literature review, following the PRISMA guidelines. This rigorous approach ensured a thorough understanding of the research topic by reviewing previous studies and identify existing knowledge gaps in the field of walkability and thus outdoor activities among older adults in urban environments. The comprehensive literature review serves as a solid foundation for the study, allowing to build upon previous findings and contribute to new insights.

The study's strong focus on older adults is another strength due to the specific challenges and considerations associated with this age group. Older adults often face a higher prevalence of health problems compared to other population groups. Engaging in outdoor activities plays a vital role in preventing or mitigating these health issues. Moreover, designing urban environments that are adjusted to the needs of older adults can also benefit other population groups, such as children and people with disabilities. By prioritizing the creation of age-friendly urban spaces, environments that promote accessibility, safety, sustainability, and inclusivity for everyone would be created. Therefore, focusing on older adults in research would inform urban planners and designers not only to address this age group's specific needs but also to create urban spaces that cater to the diverse requirements of all individuals throughout their lifespan.

To comprehensively explore the relationship between urban environments and older adults' outdoor activities, the study employed a combination of research methods. These methods included activity monitoring, spatial analysis, and a questionnaire. By utilizing a multi-method approach, the study achieved a more robust analysis and interpretation of the findings. The integration of GIS is particularly noteworthy, as it minimizes certain biases that are commonly associated with self-report methods. The availability of high-resolution tracking data further enhanced the exploration of spatial correlations with optimal precision.

The study acknowledged the significance of various types of urban microelements and public open spaces, including those that are ubiquitous in Mediterranean cities (e.g., plazas) or unique to cities within Spanish borders (e.g., ramblas). By including different types of public open spaces and urban microelements in the analyses, the study gained a deeper understanding of the impacts that these urban design elements have on older adults' outdoor activities. This comprehensive approach provides valuable insights into the relationship between specific elements of urban environments and older adults' engagement in outdoor activities.

This study benefited from its setting in Barcelona, a walkable, vital, and compact city with a mild climate and an active street life that promotes outdoor activities. Barcelona's characteristics make it an ideal laboratory for studying human outdoor behavior in relation to urban environments. The favorable environmental conditions and the city's reputation as a desirable place to live and be outdoors contribute to the study's strength in capturing the nuanced dynamics between the characteristics of urban environments and older adults' outdoor activities.

Another strength of the study is that it involved a sample of 269 participants, with an equitable representation of both gender and age groups. This sample enhances the generalizability and applicability of the findings to the broader population of older adults. By ensuring a relatively representative sample, the study strengthens its ability to draw valid conclusions and make informed recommendations that can be applicable to older adults in other Mediterranean urban contexts.

Finally, the study maximized efficiency by utilizing data collected within the RecerCaixa Project prior to this thesis. By leveraging existing data, it was possible to conduct a comprehensive analysis while minimizing the costs and time required for data collection, especially considering the confinements during COVID-19 pandemic.

Limitations of the study

This sub-section addresses the limitations of the study, such as potential biases, methodological constraints, or data availability. Understanding these limitations is essential for interpreting the findings accurately and identifying areas for future research and improvement.

The study focused specifically on the context of Barcelona, considering its unique geography, demography, urban texture, and vibrant street culture. Thus, the results of the empirical studies may not be directly applicable to other cities or regions with different characteristics. However, they can still provide insights for future studies, particularly when replicating the studies in different settings and using different variables specific to those contexts. Additionally, the results of the systematic literature review can be useful for future reviews or studies on walkability.

GPS and accelerometer devices are widely used in measuring outdoor activities (Cornwell & Cagney, 2017), however, there are inherent limitations. These devices have a margin of error in accurately measuring the precise locations of outdoor activities (Schipperijn et al., 2014), especially in certain parts of the city, such as on narrow streets. This limitation should be considered when interpreting the spatial correlations between outdoor activities and urban spaces. While activity monitoring using wearable devices provides detailed analysis of outdoor activities, it does not capture the underlying motivation behind these activities. Understanding the reasons and intentions behind older adults' engagement in specific outdoor activities is essential but may not be fully addressed by this method alone. Complementary qualitative research approaches (e.g., interviews) could provide deeper insights into the motivations and subject experiences associated with outdoor activities.

The use of questionnaires as well as GPS tracking data introduces the possibility of certain biases. Recall bias and social desirability may affect the accuracy of participants' perceptions and responses in questionnaires. Additionally, since participants are aware of wearing devices that would track their activities, they might have been more active or spent more time outdoors than usual, leading to measurement reactivity (Ullrich, Baumann, Voigt, John, & Ulbricht, 2021). Even though 7-day-accelerometer monitoring time has been accepted as sufficient for reproducible measures of outdoor activities (Ullrich et al., 2021) the risk of bias remains, and it is important to acknowledge its potential impact on the results.

The study primarily focused on neighborhood and city scales when analyzing the relationship between urban environment characteristics and older adults' outdoor activities. However, smaller or bigger scales, such as regional scale or street scale, was not explicitly considered. This limitation may restrict a comprehensive analysis of how different scales impact older adults' outdoor activities. Additionally, the analyses were limited only with Barcelona city due to data availability.

While the study had a relatively diverse sample, the sample size may still be considered small for certain analyses and subgroup comparisons. A larger sample size would enhance the statistical power of the study and provide more accurate estimations of the relationship under investigation. Furthermore, the available secondary data mandated a binary classification —women and men—within the "gender" section. The limitation of the dataset's binary categorization has caused the exclusion of LGBTQIA+ people and their potential contributions to this research.

The cross-sectional data used in this study provides a snapshot of outdoor activities among older adults in Barcelona, enabling a general understanding of the spatial correlations. However, using longitudinal data, especially in urban aging studies, could provide a deeper understanding of how changes in urban spaces or aging process itself impact outdoor activities over time. Longitudinal data would offer valuable information for decision-making processes in urban planning and design. Additionally, the availability of more comprehensive data regarding individual characteristic, would provide a different perspective in understanding of the relationship between urban environments and outdoor activities among older adults.

Finally, another limitation of this study arises from the author's proficiency in only English and Turkish languages. As a result, the literature reviewed or consulted throughout the research process was primarily limited to publications written in these languages, which may have led to potential gaps, as relevant studies or findings published in other languages could have been inadvertently overlooked.

Acknowledging these limitations enables a more precise understanding of the findings and offers valuable insights for future research and improvements.

6.3. Future research

By recognizing and addressing the strengths and limitations, the study has laid the groundwork for further research. Researchers can use these insights to develop more rigorous investigations, enhance the generalizability of findings, minimize biases, employ more diverse research methods, explore different scales, diversify their samples, increase sample sizes, or include other individual factors such as SES. These steps will contribute to a more comprehensive understanding of the relationship between urban environments and outdoor activities among older adults, while also uncovering their implications for urban planning and design. Several potential areas for future research are outlined below.

1. Comparative Analysis: Future studies can conduct comparative analyses in different cities or regions characterized by diverse urban textures, climate conditions, and other relevant factors. Such research endeavors would enable the identification of shared patterns as well as context-specific influences. By embracing this approach, a more comprehensive understanding of the topic can be achieved.
2. Longitudinal studies: Future research can conduct longitudinal studies to capture the changes in outdoor activities among older adults and the built environment over time. By examining longitudinal data, valuable insights can be gained into the dynamic relationship between these variables, revealing how behavior and preferences are influenced as individuals age, and as urban spaces undergo transformations.
3. Qualitative Exploration: Future studies can complement quantitative methods with qualitative approaches, such as walk-along or sit-along interviews or focus group meetings, to delve into the motivations, barriers,

and experiences of older adults in outdoor activities and their interaction with urban environments. By incorporating qualitative research, a more comprehensive and nuanced understanding can be achieved.

4. Fine-grained Spatial Analysis: Future research can expand the analysis to include more refined spatial scales, such as individual streets, or plazas. Additionally, incorporating alternative methods, such as observations with video cameras "could reduce the time, labor and cost" (Benton et al., 2023, p. 3). This would also be a good option to eliminate possible measurement reactivity or social desirability biases. By adopting these approaches, a more detailed examination of the relationship between specific elements of the built environment and older adults' outdoor activities can be achieved, ultimately providing practical insights for urban design and planning interventions. The integration of technology into research further facilitates the acquisition of accurate and intricate insights into behavior patterns and preferences, without being limited with the available data.
5. Cross-Disciplinary Collaboration: Future studies can foster collaboration between researchers from various disciplines ranging from natural to social sciences, such as urban planning, physics, gerontology, public health, and environmental psychology. Embracing cross-disciplinary approaches (Nadal et al., 2009) can enhance the understanding of the intricate relationship between urban environments and older adults' outdoor activities, ultimately leading to more comprehensive and impactful interventions.
6. Inclusion and Representation: Future research should prioritize the inclusion of diverse individuals within research samples, encompassing older adults from varied genders, socioeconomic backgrounds, ethnicities, and cultural contexts. This approach would foster a more inclusive and representative understanding of the experiences and needs of older adults concerning outdoor activities and the built environment.
7. Interventions, Policy Evaluation and Practice Implementation: Future studies can encompass both the evaluation of interventions and policies aimed at enhancing outdoor activity opportunities for older adults, as well

as the exploration of practical implementations of research findings in real-world contexts, such as the Superblocks (Superilles) or the Green hubs (Eixos verds) projects in Barcelona, aiming to increase pedestrian activity spaces, and create healthier, greener, fairer and safer public spaces that enhance social connections (Ajuntament de Barcelona, 2021). This comprehensive approach would provide evidence-based insights to guide urban planners, designers, and policymakers in developing age-friendly environments, implementing effective interventions, and bridging the gap between academia and practice. By facilitating evidence-based decision-making and promoting the translation of research into meaningful policy and practice outcomes, these studies can contribute to develop better urban environments and implement interventions that promote physically and mentally healthy lifestyles for all.

7. Final reflections

This dissertation has provided evidence to support the proposition that the characteristics of urban environments significantly influence outdoor activities of older adults and their health, with variations based on individual differences such as age and gender. The main hypothesis has been supported by three studies, examining the differences in the operationalizations of walkability for older adults compared to the general population, the impacts of neighborhood urban design on older adults' outdoor activities within their residential neighborhoods, and the relationship between urban vitality and outdoor rest among older adults.

The planning and design of public open spaces and their components play a crucial role in shaping people's behaviors in cities (Gehl, 2011; Whyte, 2020). Two aspects: context and users, are particularly important in the process of urban planning and design. The context serves as the foundation for the urban planning and design projects, and a comprehensive understanding of the natural, physical, social, and economic characteristics of a setting is at high importance. Each city possesses a unique story with its history, culture, geography, climate, and socioeconomic dynamics. All these different characteristics require varying approaches in planning and design. Only by carefully studying the existing fabric of a city, its exclusive features, strengths, and weaknesses, it is possible to gain deeper understanding of the most appropriate planning and design solutions for that specific setting (Cooper Marcus & Francis, 1998).

Undoubtedly, urban spaces find their true essence through the people, the users. Therefore, urban planning and design must always center around individuals who exhibit diversity in needs, preferences, and characteristics (Gehl, 2010). This is especially critical for older adults as they predominantly constitute the primary users of public open spaces during the day, especially following retirement, when they have more personal time at their disposal. Moreover, the aging process can exert additional influence on an individual's health, potentially affecting both their utilization of public open spaces and their engagement in outdoor activities. As a result, understanding and integrating the needs and preferences of older adults concerning their involvement in outdoor activities into the planning and design becomes imperative for fostering autonomous and healthy aging within urban environments that are inclusive and responsive (Musselwhite & Haddad, 2010).

It is critical for researchers to put these two fundamental aspects, the context and people, at the center of their studies. By considering the characteristics of settings and users, researchers can develop context-specific and user-based solutions that are tailored to the unique challenges and needs of locations and individuals. With this approach, research can provide valuable insights for urban planners, designers, and decision-makers to create urban environments that serve for the diverse needs, preferences, and behaviors of different user groups. This would foster a sense of belonging, facilitate social cohesion, promote outdoor activities, and improve individuals’ overall health and wellbeing.

Well-designed urban environments, or more specifically public open spaces equipped with urban microelements can yield multiple benefits for individuals and society (Gehl, 2011). The adequate provision of context- and user-specific greenspaces, plazas, streets, or boulevards can create enjoyable environments for both leisure and utilitarian outdoor activities. This enables older adults to be involved in physical activity or outdoor resting and provide them with more opportunities for being socially and physically active while spending more time out-of-home. Ensuring sufficient provision of public open spaces with various urban microelements, including tables, chairs, sun/rain/wind protection elements, and public toilets in all neighborhoods can also foster more equitable urban environments, offering quality outdoor spaces that people of all ages, genders, and socioeconomic statuses can utilize without incurring additional costs, unlike paid services in cafes and restaurants. In addition, the availability of well-designed and well-maintained POS can facilitate social interactions among older adults and other age groups, enhancing their wellbeing and fostering a sense of community, rather than being isolated and confined to screens within their homes (Grindlay, Ochoa-Covarrubias, & Lizárraga, 2020; Sugiyama & Thompson, 2007).

A city's unique context, whether it be its climate or available resources, also plays a crucial role in shaping sustainable practices (Lizárraga Mollinedo, 2006). The integration of natural infrastructure within POS —by using appropriate vegetation for that setting— can contribute to mitigating the effects of climate change by reducing the impact of urban heat island (Shishegar, 2014). This natural infrastructure, in the form of street vegetation, planting beds, waterbodies, urban gardens or parks, can also provide protection from adverse weather conditions, particularly crucial for vulnerable populations such as children and older adults (Leyk et al., 2019), especially as heat extremes become more common in European cities (Gessner et al., 2021). Increasing the amount of POS with natural infrastructure expands the pedestrian activity spaces in cities and reduce the surface area designated for motorized vehicles, including roads and parking spots (Faiz, 1993; Litman, 2017; Rye & Hrelja, 2020; Rye & Koglin, 2014), ultimately improving air quality (von Schneidemesser et al., 2019). By aligning urban planning and design with the local context and considering the characteristics of individuals, we can create cities that are not only livable but also environmentally conscious and resilient.

It is imperative for researchers to meticulously address and include these aspects in their research, and for urban planners and designers to ground their projects in research findings. Giving priority to the distinct attributes of settings and users in design of urban open spaces would significantly contribute to the creation of sustainable and livable cities for all age groups. These combined efforts would collectively promote outdoor activities, and thus physically and mentally healthy aging for all individuals, while simultaneously promoting healthier societies and environments (Cooper Marcus & Francis, 1998; Gehl, 2010).

PART IV. REFERENCES & ANNEXES

8. References

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9. Annexes

9.1. Letters of coauthors

GEMOTT
Grup d'Estudis de Mobilitat Transport i Territori

Estimats membres de la Comissió Acadèmica del Programa (CAP) de doctorat en Geografia de la UAB,

Ens adrecem a vosaltres per a certificar formalment la nostra participació com a co-autors en els materials presentats com part de la tesi per compendi de publicacions titulada *ACTIVE AGING THROUGH URBAN ENVIRONMENTS: EXPLORING WALKABILITY, PUBLIC SPACES, AND URBAN VITALITY IN SUPPORTING OLDER ADULTS' OUTDOOR ACTIVITIES* i realitzada per la doctoranda Zeynep Sila Akinci.

Per la present constatem que cap dels materials, resultats o conclusions presentats en aquesta tesi no s'han utilitzat en cap altre treball acadèmic o tesi fins a la data. Ens adherim a les polítiques acadèmiques de l'escola de doctorat de la Universitat Autònoma de Barcelona i comprenem la importància de mantenir la integritat i l'autenticitat del treball de recerca.

A més a més, ens comprometem a no utilitzar cap dels materials o resultats presentats en aquesta tesi en qualsevol futur treball acadèmic o tesi sense la corresponent citació i reconeixement.

Moltes gràcies,

Signat, a 18 de juliol de 2023,

Maria Carme Miralles Guasch - DNI 39851421B (TCAT) Signat digitalment per Maria Carme Miralles Guasch - DNI 39851421B (TCAT) Data: 2023.07.18 17:41:09 +02'00'

XAVIER DELCLÒS ALIÓ - DNI 48009057F Digitally signed by XAVIER DELCLÒS ALIÓ - DNI 48009057F Date: 2023.07.18 17:29:28 +02'00'

ORIOL MARQUET SARDA - DNI 46145311C Digitally signed by ORIOL MARQUET SARDA - DNI 46145311C Date: 2023.07.18 17:42:41 +02'00'

Prof. Carme Miralles Guasch	Dr. Xavier Delclòs Alió	Dr. Oriol Marquet Sardà
Dpt. Geografia UAB	Dpt. Geografia URV	Dpt. Geografia UAB

The University of Texas at Austin
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July 19, 2023
Austin, TX, USA
Via email

To whom it may concern,

I, Dr. Deborah Salvo, associate professor at Department of Kinesiology and Health Education at The University of Texas at Austin,

STATE THAT

the following article

> Akinci, Zeynep S., Xavier Delclòs-Alió, Guillem Vich, Deborah Salvo, Jesús Ibarluzea, and Carme Miralles Guasch. 2022. "How Different Are Objective Operationalizations of Walkability for Older Adults Compared to the General Population? A Systematic Review." BMC Geriatrics 22(673):1–22. doi: 10.1186/s12877-022-03233-x.

has not previously been part of any other doctoral thesis, and I RENOUNCE to present it as such in the future.

Deborah Salvo, PhD
Associate Professor
Director, People, Health & Place Lab
Department of Kinesiology & Health Education
The University of Texas at Austin
dsalvo@austin.utexas.edu

biodonostia
osasun ikerketa institutua
instituto de investigación sanitaria

To whom it may concern,

I, Dr. Jesús Ibarluzea Maurolagoitia, Head of Envrionmental Epidemiology and Child Development Group at Biodonostia Institute, with the ID number 14948426J

STATE THAT

the following article

> Akinci, Zeynep S., Xavier Delclòs-Alió, Guillem Vich, Deborah Salvo, Jesús Ibarluzea, and Carme Miralles Guasch. 2022. "How Different Are Objective Operationalizations of Walkability for Older Adults Compared to the General Population? A Systematic Review." BMC Geriatrics 22(673):1–22. doi: 10.1186/s12877-022-03233-x.

has not previously been part of any other doctoral thesis, and I RENOUNCE to present it as such in the future.

En Donostia-San Sebastián, a 18 de Julio de 2023

Jesús Mª Ibarluzea Maurolagoitia

IBARLUZEA MAUROLAGOITIA, JESUS MARIA (AUTENTICACIÓN)

Firmado digitalmente por IBARLUZEA MAUROLAGOITIA, JESUS MARIA (AUTENTICACIÓN)
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9.2. Supplementary Material

Categorizations and codings in Systematic Literature Review

General study characteristics

Publication year

Publication years were grouped under 5-year periods (2005-2010, 2011-2015), except the last period (2016-2019) which consisted of 4 years.

See Table 6 in the manuscript for publication period of each publication included in the analysis.

Journal fields

Journals were categorized depending on the focus field mentioned in their own websites as: health-related, inter- or multi-disciplinary studies, transportation or urban studies, and environment- or geography-related journals **(Table S1)**.

See Table 6 in the manuscript for journal field of each publication included in the analysis.

Table S1. List of journals under each journal field

Journal field and name of the journals	# of publications
Health	90
The International Journal of Behavioral Nutrition and Physical Activity	14
Preventive Medicine	9
American Journal of Preventive Medicine	7
Journal of Physical Activity & Health	7
BMC Public Health	5
Journal of Urban Health : Bulletin of the New York Academy of Medicine	4

Journal field and name of the journals	# of publications
Environment or Geography	4
Environment and Behavior	2
Geographical Research	1
Transactions in GIS	1

Journal field and name of the journals	# of publications
Transportation or Urban Studies	5

American Journal of Health Behavior	2
American Journal of Health Promotion : AJHP	2
American Journal of Public Health	2
BMJ Open	2
Journal of Environmental and Public Health	2
Journal of Immigrant and Minority Health	2
Preventing Chronic Disease	2
Appetite	1
Blood Purification	1
BMC Geriatrics	1
British Journal of Sports Medicine	1
Canadian Journal of Public Health	1
Canadian Journal on Aging = La Revue Canadienne Du Vieillissement	1
Cancer Epidemiology, Biomarkers & Prevention	1
CMAJ Open	1
Disability and Health Journal	1
Environmental Health Perspectives	1
European Journal of Public Health	1
Health Reports	1
International Journal of Public Health	1
Journal of Aging and Health	1

International Journal of Sustainable Transportation	1
Journal of the American Planning Association	1
Journal of Transport and Land Use	1
Journal of Urban Planning and Development - ASCE	1
Transportation Research Part D: Transport and Environment	1

Journal field and name of the journals	**# of publications**
Inter- or Multi-disciplinary Studies	47
International Journal of Environmental Research and Public Health	13
Health & Place	11
Journal of Transport and Health	8
Social Science & Medicine	5
PloS One	3
Medicine and Science in Sports and Exercise	2
Environment and Planning B: Urban Analytics and City Science	1
Nature	1
Sustainability	1
International Journal of Health Geographics	1
Journal of Human Kinetics	1

Journal of Community Health	1
Journal of Environmental Health	1
Journal of Epidemiology and Community Health	1
Journal of Obesity	1
Journal of Public Health	1
Lancet (London, England)	1
Malaysian Journal of Nutrition	1
Obesity Surgery	1
Pediatric Exercise Science	1
Population Health Metrics	1
Preventive Medicine Reports	1
Public Health	1
Research Quarterly for Exercise and Sport	1
Risk Management and Healthcare Policy	1
Sports Medicine (Auckland, N.Z.)	1
Supportive Care Cancer	1

Source: own production

Geographical context (study setting)

Study settings were sorted under five groups: 1) Europe (including Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Ireland, Portugal, Spain, Sweden, and the UK), 2) Middle East and Asia (including Iran, Japan, Malaysia, Singapore, South Korea, and Taiwan), 3) Oceania (including Australia and New Zealand), 4) Latin America (including Brazil and Mexico), and 5) the United States and Canada. Besides, there were two studies (Althoff et al., 2017; Sallis et al., 2016) conducted their analyses on multiple countries.

See Table 6 in the manuscript for study setting of each publication included in the analysis.

Demographic groups under study

We created four categories for demographic groups under study according to how they were defined in the original study as: all population, adults, young people, and older adults. The definition of adults varied vastly across studies as being older than a specific age without defining a maximum limit (e.g., older than 16, 18, 20, 25 or 45 years) or being within specific age intervals (e.g., 20-64, 20-70, 37-73, or 18-90 years). Under the young people group we included studies focusing on students (e.g., (Giles-Corti et al., 2011; Hobin et al., 2012)), adolescents (e.g., (De Meester et al., 2013; Wang et al., 2017)), children (e.g., (Buck et al., 2014; D'Haese et al., 2016)), and toddlers (Hunter et al., 2019). Most of the included studies defined older adults as people ≥ 65 years (besides a few that put the age limit at 70 or 75 years). There was one study that defined older adults as being over 55 years (Nyunt et al., 2015), and it was included under the older adults group in our analysis.

In cases when the papers focused on specific groups (SG) without any information on age, like "cancer survivors" (McGowan et al., 2017) or "anonymous participants from activity-oriented mobile phone application" (X. Li et al., 2018), then we included them under the "all population" category. However, when they defined an age group among the SG, such as "female adults with Body Mass Index between 21-39.9" (Hajna, Ross, et al., 2016), "healthy recent Cuban immigrants between 30-45 years" (Brown et al., 2013), or "employed adults" (Marquet & Hipp, 2019) then we included these in the related age group categories (in these cases in the adults group).

See Table 6 in the manuscript for demographic groups under study in each publication included in the analysis.

<u>Characteristics of the study design</u>

Research design

Studies providing results from both cross-sectional and longitudinal data were coded as "mixed". See Table 6 in the manuscript for research design of each publication included in the analysis.

Spatial data collection method

We have only included publications using objective methods to operationalize walkability in this review. Studies using Geographic Information Systems (GIS) or environmental/ street audits for spatial data collection were coded accordingly either as “GIS” or “audit”.

See Table 6 in the manuscript for spatial data collection method of each publication included in the analysis.

Outcome data collection method

Studies using objective methods to collect their outcome data (e.g., accelerometer, GPS devices) were coded as “device” and the ones using subjective methods (e.g., interviews, travel diaries) were coded as “self-reported”. Those using both methods were coded as “mixed”.

See Table 6 in the manuscript for outcome data collection method of each publication included in the analysis.

Characteristics of walkability measures

Operationalization of walkability

Publications were coded under “index” category when they 1) used one existing index or a combination of many (e.g., the walkability index of Frank et al. (2010) (Frank, Sallis, et al., 2010), WalkScore...), 2) created their own indexes, or 3) used separate variables and presented their results as a score. If a study used separate variables or an environmental audit, and provided results separately for each variable, then it was coded under the “separate variables” category.

See Table 6 in the manuscript for the operationalization of walkability in each publication included in the analysis.

Walkability variables used

Mostly, studies used more than one variable to measure walkability and each variable was grouped under the relevant category. All variables used in indexes or environmental/street audits (sometimes more than 80 variables in a single audit) were coded one by one under each corresponding category for a detailed understanding of operationalization of walkability.

Variables used in studies were grouped under eleven categories as 1) Population density, 2) Activity and destination density/ access to services, 3) Socioeconomic characteristics, 4) Land use characteristics, 5) Street connectivity, 6) Topographic characteristics, 7) Street design, 8) Safety from traffic, 9) Safety from crime, 10) Transportation accessibility, and 11) Greenery.

Variables were included in the abovementioned categories as they were used in the original study or according to their relevance. When the original study included a variable under a category which is similar to ours, then the categorization was done accordingly. However, this was not the case all the time. For instance, variables such as presence of shopping mall, schools, restaurant, fitness center, religious institution, post office, etc. used in the Pedestrian Environment Data Scan (PEDS) audit would have been included under “activity and destination density/access to services” category in our analysis, however in the original study (Travers et al., 2018) these were related to and included under the land use category, so we also have included them under “land use characteristics” category in our study. Similarly in the same audit, cul-de-sac or permanent street closing was included under “safety from crime” category in the original study and thus in our analysis, although other variables related to cul-de-sac/ dead-end streets from other studies were included under “street connectivity” category.

Lastly, WalkScore and StreetSmart WalkScore indexes were coded under “activity and destination density/ access to services” category since both of them were mainly based on the distance to destinations/ amenities, while TransitScore index was coded under “transportation accessibility” category due to its specific focus.

See Table S2. for walkability variables included under each category and used in each publication included in the analysis.

Spatial extent and unit

Spatial extent

Spatial extents used in studies were coded as they were mentioned in the original publication (e.g., residential, school site or workplace). Studies using other spatial extents such as daily walking itineraries, entire cities, or routes to parks were coded under “other” category.

See Table 6 in the manuscript for spatial extent used in each publication included in the analysis.

Spatial unit

For spatial units, studies used buffers, administrative units (e.g., postal codes, municipal levels, neighborhood boundaries/units, etc.) and statistical units (e.g., census groups, statistical areas/ districts/ sectors, etc.). Studies using units such as street segments, country level, or enrollment zones were coded as “others”. Finally, studies using more than one spatial unit (e.g., buffer+ census block group) were coded as “combination”.

See Table 6 in the manuscript for spatial extent and unit used in each publication included in the analysis.

Buffer type and size

When studies used more than one buffer type or size (e.g., for sensitivity analysis), each was coded separately under the corresponding group. Buffer distances provided in studies as miles were converted to meters (1 mile=1,609.34 m) and included in the closest group (e.g., studies using 0.5 miles were included in the group of 800 m). Unless otherwise specified, studies using WalkScore (including Street Smart and Transit WalkScore) were accepted to be using 2,500 m (≈1.5 miles) buffers as it was stated in the methodological information provided in their official website (https://www.walkscore.com/methodology.shtml). Regarding their buffer types, unless otherwise specified, those using WalkScore and TransitScore were coded as circular buffers, and those using StreetSmart WalkScore were coded as street network buffers depending on the information provided in their aforementioned website.

For a better interpretation of the results, we also grouped buffer sizes into two groups as: 1) equal to and less than 1,000 m, and 2) greater than 1,000 m, depending on the findings of previous studies stating that older adults' physical activity (PA) was related to walkability within 1,000 m buffers (Berke et al., 2007; Frank, Kerr, et al., 2010) and to other built environment features in smaller buffer sizes (Portegijs, Keskinen, Eronen, & Saajanaho, 2020).

See Table 6 in the manuscript for buffer types and sizes used in each publication included in the analysis.

Associations found between walkability and walking

For studies using indexes/scores, the associations were mostly clear and coded accordingly as positive, negative, or no association. When studies provided results for each walkability variable separately and when the difference between the number of associations found between walkability variables and outcomes was greater than one (e.g., three positive, and one negative association), then the majority defined the final decision for that paper as either positive, negative, or no association (in this case it was positive). In the cases where the difference is not clear (e.g., three positive, three negative, and two no association) then they were coded as partial. Additionally, studies providing different results for different buffer sizes (e.g., for sensitivity analysis) or different walking-related outcomes (e.g., transportation walking, leisure walking…) were also coded as "partial". Finally, studies presenting results for different population subgroups (e.g., female vs. male) or for different settings in the study (e.g., different cities in a country) were coded as "mixed".

See Table 6 in the manuscript for associations found between walkability and walking-related outcomes in each publication included in the analysis.

Table S2. Walkability variables used in analyzed publications focusing on older adults vs. general population

Walkability variables	Reference
POPULATION DENSITY	
Population density	Older adults (Marquet et al., 2017; Portegijs et al., 2017) General population (Cho & Rodríguez, 2015; Eom & Cho, 2015; Gell et al., 2015; Grasser et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Jack & McCormack, 2014; James et al., 2017; Janssen & King, 2015; Y. Li et al., 2018; Lovasi et al., 2011; Marquet & Hipp, 2019; McCormack et al., 2014; Rundle et al., 2019; Sugiyama et al., 2019; Tamura et al., 2019)
Residential density	Older adults (Carlson et al., 2012; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Lotfi & Koohsari, 2011; Nyunt et al., 2015; Todd et al., 2016; Zandieh et al., 2017) General population (Adams et al., 2015; Arvidsson et al., 2013, 2012; Badland et al., 2016; Buck et al., 2014; Cerin et al., 2011; Cho & Rodríguez, 2015; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016, 2014; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eriksson et al., 2012; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Graziose et al., 2016; Hajna, Ross, et al., 2016; Hinckson et al., 2017; Hobin et al., 2012; Huang et al., 2019; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Maddison et al., 2009; McCormack et al., 2012; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012, 2013; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oliver et al., 2015; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Ribeiro & Hoffimann, 2018; Riley et al., 2013; Rundle et al., 2016; Sallis et al., 2009, 2016; Salvo et al., 2014; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015; Sundquist et al., 2011; Villanueva et al., 2014; Wang et al., 2017; Wei et al., 2016; Witten et al., 2012; Yi et al., 2017)
Household density	Older adults (Bodeker, 2018) General population

	(Reyer et al., 2014)
Residential dwelling density	General population (Grasser et al., 2016; Mayne et al., 2013, 2017)
More dwelling units per acre of the parcel	Older adults (Berke et al., 2007)
Single family residential (SFR) parcel count	General population (Shay & Khattak, 2012)
Acres of SFR land	General population (Shay & Khattak, 2012)
ACTIVITY AND DESTINATION DENSITY/ ACCESS TO SERVICES	
Job/ business density	General population (Huang et al., 2019; Jack & McCormack, 2014; McCormack et al., 2014)
SFR parcels less than 4 miles to commercial use	General population (Shay & Khattak, 2012)
Fast food outlets	General population (Hobin et al., 2012)
More grocery store restaurant or retail clusters in 1km buffer	Older adults (Berke et al., 2007)
Fewer grocery stores or markets in 1km buffer	Older adults (Berke et al., 2007)
Local destinations	General population (McGrath et al., 2016)
Neighborhood destinations	General population (Witten et al., 2012)
Destination accessibility	General population (Oliver et al., 2015; Rundle et al., 2019)
Retail floor area ratio	Older adults (Bodeker, 2018; Carlson et al., 2012; Frank, Kerr, et al., 2010; King et al., 2011; Lotfi & Koohsari, 2011; Todd et al., 2016; Zandieh et al., 2017)

	General population (Adams et al., 2015; Cerin et al., 2011; Christiansen et al., 2014; Cruise et al., 2017; Dygryn et al., 2010; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007; Graziose et al., 2016; Janssen & King, 2015; Kerr et al., 2010; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Mayne et al., 2013; McGrath et al., 2016; Norman et al., 2013; Owen et al., 2007; Perez et al., 2017; Reyer et al., 2014; Riley et al., 2013; Rundle et al., 2016; Sallis et al., 2009; Salvo et al., 2014; Shimura et al., 2012, 2014; Sugiyama et al., 2015; Wang et al., 2017; Wei et al., 2016)
Access to retail areas	General population (Y. Li et al., 2018)
Shopping malls	General population (Hobin et al., 2012)
Acres of commercial land	General population (Shay & Khattak, 2012)
Number of shopping malls in 1km buffer	General population (Lee et al., 2015)
Total floor area of shopping mall in 1km buffer	General population (Lee et al., 2015)
Recreation facilities	General population (Hobin et al., 2012)
Private recreation density	Older adults (Carlson et al., 2012)
Number of private recreational facilities	General population (Wang et al., 2017)
Density of mix of recreational facilities /km2	General population (Jack & McCormack, 2014)
Mix of recreational facilities	General population (McCormack et al., 2014)
Fitness facility density	General population (Huang et al., 2019)
Distance to school	General population (Oliver et al., 2015)

Smaller size of closest office complex	Older adults (Berke et al., 2007)
Longer distance to closest office mixed use complex	Older adults (Berke et al., 2007)
Fewer educational parcels in 1km buffer	Older adults (Berke et al., 2007)
WalkScore	Older adults (Liao et al., 2019; Takahashi et al., 2012) General population (Althoff et al., 2017; Barnes et al., 2016; Boisjoly et al., 2018; Brown et al., 2013; Cole et al., 2015; Duncan et al., 2016; Forjuoh et al., 2017; Gell et al., 2015; Hajna et al., 2015; Hajna, Ross, et al., 2016; Han et al., 2018; Hirsch et al., 2013; J A Hirsch et al., 2014; Hwang et al., 2016; Kelley et al., 2016; X. Li et al., 2018; Lo et al., 2019; Marquet & Hipp, 2019; McCormack et al., 2017; Méline et al., 2017; Reid et al., 2017; Reyer et al., 2014; Riley et al., 2013; Ross et al., 2018; Rundle et al., 2019; Salvo et al., 2018; Sugiyama et al., 2019; Towne et al., 2016, 2018; Tuckel et al., 2015; Twardzik et al., 2019; Wasfi et al., 2015, 2017)
StreetSmart Walkscore	Older adults (Chudyk et al., 2017; Clarke et al., 2017; Winters et al., 2015) General population (Chiu et al., 2015; Hirsch et al., 2013, 2017; Thielman et al., 2016; Yang & Diez-Roux, 2017)
Market concentration/ market monopoly	General population (Eom & Cho, 2015)
Stores within easy walking distance from home – Irvine-Minnesota Inventory (IMI audit)	General population (Jensen et al., 2017)
Many places to go within easy walking distance from home- IMI audit	General population (Jensen et al., 2017)
Employment density	General population (Cho & Rodríguez, 2015)
Retail service / job density	General population

	(Cho & Rodríguez, 2015)
SOCIOECONOMIC CHARACTERISTICS	
Residential property values	General population (Huang et al., 2019)
Socioeconomic status	General population (Oliver et al., 2015)
LAND USE CHARACTERISTICS	
Residential percentage	General population (Hunter et al., 2019)
Land use mix	Older adults (Bodeker, 2018; Carlson et al., 2012; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Lotfi & Koohsari, 2011; Marquet et al., 2017; Nyunt et al., 2015; Portegijs et al., 2017; Todd et al., 2016; Travers et al., 2018; Zandieh et al., 2017) General population (Adams et al., 2015; Arvidsson et al., 2013, 2012; Badland et al., 2016; Buck et al., 2014; Cerin et al., 2011; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cruise et al., 2017; D'Haese et al., 2014; Dills et al., 2012; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eriksson et al., 2012; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Grasser et al., 2016; Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Hinckson et al., 2017; Hobin et al., 2012; James et al., 2017; Janssen & King, 2015; Jensen et al., 2017; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Lovasi et al., 2011; Maddison et al., 2009; Marquet & Hipp, 2019; Mayne et al., 2013, 2017; McCormack et al., 2012; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012, 2013; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Richardson et al., 2017; Riley et al., 2013; Rundle et al., 2016; Sallis et al., 2009, 2016; Salvo et al., 2014; Shimura et al., 2012, 2014; Siqueira Reis et al., 2013; Smith et al., 2019; Sugiyama et al., 2015; Sundquist et al., 2011; Tamura et al., 2019; Villanueva et al., 2014; Wang et al., 2017; Wei et al., 2016; Witten et al., 2012; Yi et al., 2017)
Land use intensity	Older adults

	(Zandieh et al., 2017)
Walkable land use mix	Older adults (Marquet et al., 2017)
Number and variety of land uses	Older adults (Strath et al., 2012)
Proportion of mixed land use	General population (Grasser et al., 2016)
Land use mix and diversity	General population (Badland et al., 2016; D'Haese et al., 2016)
Single family home detached - Pedestrian Environment Data Scan (PEDS audit)	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)
Single family home duplex semidetached -PEDS audit	Older adults (Travers et al., 2018)
Town house terrace row house- PEDS audit	Older adults (Travers et al., 2018)
Flat apartments more than 3 stories- PEDS audit	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)
Mobile homes caravan parks cabins- PEDS audit	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)
Post office police station courthouse- PEDS audit	Older adults (Travers et al., 2018)
Hospital medical facility- PEDS audit	Older adults (Travers et al., 2018)
Retail shops restaurants- PEDS audit	Older adults (Travers et al., 2018)

	General population (Hajna, Ross, et al., 2016)
Office institutional- PEDS audit	General population (Hajna, Ross, et al., 2016)
Hotel hospitality- PEDS audit	Older adults (Travers et al., 2018)
Industrial area- PEDS audit	General population (Hajna, Ross, et al., 2016)
Vacant undeveloped areas- PEDS audit	General population (Hajna, Ross, et al., 2016)
Gas service station- PEDS audit	Older adults (Travers et al., 2018)
Big box shop- PEDS audit	Older adults (Travers et al., 2018)
Shopping mall- PEDS audit	Older adults (Travers et al., 2018)
Strip mall row of shops- PEDS audit	Older adults (Travers et al., 2018)
Plaza square park playground landscaped open space- PEDS audit	Older adults (Travers et al., 2018)
Public space other- PEDS audit	Older adults (Travers et al., 2018)
Gym Fitness center- PEDS audit	Older adults (Travers et al., 2018)
Movie theatre- PEDS audit	Older adults (Travers et al., 2018)
Recreational other- PEDS audit	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)

Harbor marina- PEDS audit	Older adults (Travers et al., 2018)
Nature feature- PEDS audit	Older adults (Travers et al., 2018)
Open field golf course- PEDS audit	Older adults (Travers et al., 2018)
Lake pond- PEDS audit	Older adults (Travers et al., 2018)
Stream river canal creek- PEDS audit	Older adults (Travers et al., 2018)
Ocean beach- PEDS audit	Older adults (Travers et al., 2018)
Mountain Hills- PEDS audit	Older adults (Travers et al., 2018)
Community center library- PEDS audit	Older adults (Travers et al., 2018)
Museum auditorium concert hall theater- PEDS audit	Older adults (Travers et al., 2018)
Religious institution- PEDS audit	Older adults (Travers et al., 2018)
Art or craft galleries- PEDS audit	Older adults (Travers et al., 2018)
Restaurants- PEDS audit	Older adults (Travers et al., 2018)
Coffee shops- PEDS audit	Older adults (Travers et al., 2018)
Corner store- PEDS audit	Older adults (Travers et al., 2018)
Primary middle or junior high school- PEDS audit	Older adults (Travers et al., 2018)

Highschool- PEDS audit	Older adults (Travers et al., 2018)
School other- PEDS audit	Older adults (Travers et al., 2018)
Day care center- PEDS audit	Older adults (Travers et al., 2018)
Vertical mixed use- PEDS audit	Older adults (Travers et al., 2018)
Parking structure- PEDS audit	Older adults (Travers et al., 2018)
STREET CONNECTIVITY	
Three way intersection density	General population Grasser et al., 2016)
Four way intersection density	General population Grasser et al., 2016)
Intersection count	General population (Shay & Khattak, 2012; Siqueira Reis et al., 2013)
Street density	Older adults (Michael et al., 2011) General population (Cho & Rodríguez, 2015; Tamura et al., 2019)
Street connectivity /intersection density	Older adults (Bodeker, 2018; Carlson et al., 2012; Frank, Kerr, et al., 2010; Van Holle et al., 2014, 2015, 2016; Kikuchi et al., 2018; King et al., 2011; Lotfi & Koohsari, 2011; Michael et al., 2011; Nyunt et al., 2015; Portegijs et al., 2017; Todd et al., 2016; Zandieh et al., 2017) General population (Adams et al., 2015; Arvidsson et al., 2013, 2012; Badland et al., 2016; Buck et al., 2014; Cerin et al., 2011; Christian et al., 2011; Christiansen et al., 2014; Chum et al., 2019; Cruise et al., 2017; Curl et al., 2018; D'Haese et al., 2016, 2014; Doyle et al., 2006; Van Dyck et al., 2011; Van Dyck, Cardon, et al., 2010; Van Dyck, Cerin, et al., 2010; Dygryn et al., 2010; Eom & Cho, 2015; Eriksson et al., 2012; Frank, Sallis, et al., 2010; Frank et al., 2015, 2007, 2005; Gell et al., 2015; Grasser et al., 2016;

	Graziose et al., 2016; Hajna, Kestens, et al., 2016; Hajna et al., 2015; Hajna, Ross, et al., 2016; Hobin et al., 2012; Hunter et al., 2019; James et al., 2017; Janssen & King, 2015; Kelly et al., 2015; Kerr et al., 2010, 2014; Kligerman et al., 2007; Koohsari et al., 2016; Learnihan et al., 2011; Lovasi et al., 2011; Maddison et al., 2009; Mayne et al., 2013, 2017; McCormack et al., 2012, 2011; McGowan et al., 2017; McGrath et al., 2016; De Meester et al., 2012; Molina-García & Queralt, 2017; Molina-Garcia et al., 2017; Norman et al., 2013; Oliver et al., 2015; Oluyomi et al., 2014; Owen et al., 2007; Perez et al., 2017; Reyer et al., 2014; Ribeiro & Hoffimann, 2018; Riley et al., 2013; Rundle et al., 2016, 2019; Sallis et al., 2009, 2016; Salvo et al., 2014; Shimura et al., 2012, 2014; Smith et al., 2019; Sugiyama et al., 2015, 2019; Sundquist et al., 2011; Villanueva et al., 2014; Wang et al., 2017; Wei et al., 2016; Witten et al., 2012; Yi et al., 2017)
Road-based intersection density	General population (Cruise et al., 2017)
Connectivity	Older adults (Michael & Carlson, 2009) General population (Doyle et al., 2006)
Street intersection	General population (Hinckson et al., 2017; Huang et al., 2019; Marquet & Hipp, 2019)
Connected node ratio	General population (Carter et al., 2017; Hunter et al., 2019; Janssen & King, 2015)
Miles of roads	General population (Shay & Khattak, 2012)
Average block area	General population (Badland et al., 2016)
Average block length	General population (Hunter et al., 2019; Janssen & King, 2015)
Block length	General population (Doyle et al., 2006)
Smaller size of block where residence is located	Older adults (Berke et al., 2007)
Path cycleway length	General population

	(Jack & McCormack, 2014; McCormack et al., 2014)
Road density	General population (Carter et al., 2017; Y. Li et al., 2018)
Number of cul-de-sacs	General population (Carter et al., 2017)
Cul-de-sac density	General population (Hinckson et al., 2017)
Number of junctions	General population (Carter et al., 2017)
Segment has dead-end- PEDS audit	General population (Hajna, Ross, et al., 2016)
Segment continues- PEDS audit	General population (Hajna, Ross, et al., 2016)
Road dead-ends but path continue- PEDS audit	General population (Hajna, Ross, et al., 2016)
Footpath based intersection density	General population Cruise et al., 2017)
Path continuity- SPACES audit	General population (Witten et al., 2012)
Sidewalk completeness continuity- PEDS audit	General population (Hajna, Ross, et al., 2016)
Sidewalks continuity to other sidewalks crosswalks- PEDS audit	General population (Hajna, Ross, et al., 2016)
Direct route- SPACES audit	General population (Witten et al., 2012)
Short distance between intersections- IMI audit	General population (Jensen et al., 2017)
Presence of many alternative routes for getting from place to place -IMI audit	General population (Jensen et al., 2017)

Few or no cul-de-sacs streets- IMI audit	General population (Jensen et al., 2017)
Area of neighborhood including in 1km buffer	General population (Lee et al., 2015)
Ratio of three or four way intersections	General population (Cho & Rodríguez, 2015)
Total length of retaining wall of apartment complex	General population (Lee et al., 2015)
Presence of alley- IMI audit	Older adults (Travers et al., 2018)
Pedestrian access point through cul-de-sac- IMI audit	Older adults (Travers et al., 2018)
TOPOGRAPHICAL CHARACTERISTICS	
Land slope sloping streets	General population (Gell et al., 2015)
Hills	General population (Dills et al., 2012)
Flat area- PEDS audit	General population (Hajna, Ross, et al., 2016)
Slight hill- PEDS audit	General population (Hajna, Ross, et al., 2016)
Steep hill- PEDS audit	General population (Hajna, Ross, et al., 2016)
Gradient steepness- SPACES audit	General population (Witten et al., 2012)
Steep slope- PEDS audit	Older adults (Travers et al., 2018)
STREET DESIGN	
Road conditions materials uniformity- PEDS audit	General population (Hajna, Ross, et al., 2016)

Path obstructions- PEDS audit	General population (Hajna, Ross, et al., 2016)
Parking on and off street- PEDS audit	General population (Hajna, Ross, et al., 2016)
Pedestrian amenities	General population (Hajna, Ross, et al., 2016; McGrath et al., 2016)
Way finding aids- PEDS audit	General population (Hajna, Ross, et al., 2016)
Sidewalk density	General population (Huang et al., 2019; Hunter et al., 2019; Janssen & King, 2015)
Sidewalk length	General population (Lee et al., 2015; McCormack et al., 2014)
Sidewalk availability	General population (Richardson et al., 2017)
Presence and width of sidewalks	Older adults (Strath et al., 2012)
Sidewalk length density in meters/ km2	General population (Jack & McCormack, 2014)
Informal pedestrian network PEDSHED	General population (Giles-Corti et al., 2011; McCormack et al., 2011)
Walkshed area	General population (Jack & McCormack, 2014; McCormack et al., 2014)
Paved trail- PEDS audit	General population (Hajna, Ross, et al., 2016)
Sidewalk coverage	Older adults (Michael & Carlson, 2009)
Footpath density	General population (Carter et al., 2017)
Effective walkable area	General population (Carter et al., 2017)
Sidewalk coverage design material	General population

	(Dills et al., 2012; Hosler et al., 2014)
Street amenity shady trees streetlamps shops	General population (Hajna, Ross, et al., 2016; Hosler et al., 2014)
Total length of trails in 1km buffer	General population (Lee et al., 2015)
Total length of streets with pedestrian sidewalks (m)	General population (Lee et al., 2015)
Ratio of pedestrian sidewalks	General population (Lee et al., 2015)
Total length of pedestrian zones	General population (Lee et al., 2015)
Geometry of street canyons	General population (X. Li et al., 2018)
Footpath- PEDS audit	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)
Footpaths complete on both sides- PEDS audit	Older adults (Travers et al., 2018)
Benches chairs- PEDS audit	Older adults (Travers et al., 2018)
Public restroom- PEDS audit	Older adults (Travers et al., 2018)
Footpath shade- PEDS audit	Older adults (Travers et al., 2018)
Bus stop with seating- PEDS audit	Older adults (Travers et al., 2018)
Bus stop without seating- PEDS audit	Older adults (Travers et al., 2018)
Path type- SPACES audit	General population (Witten et al., 2012)

Path surface type- SPACES audit	General population (Witten et al., 2012)
Width/ number of path lane- PEDS audit	General population (Hajna, Ross, et al., 2016; Witten et al., 2012)
Width of the street- SPACES audit	General population (Witten et al., 2012)
Vehicle parking- SPACES audit	General population (Witten et al., 2012)
Curb type- SPACES audit	General population (Witten et al., 2012)
Street maintenance	General population (Dills et al., 2012)
Cleanliness litter - PEDS audit	General population (Hajna, Ross, et al., 2016)
Articulation in building designs- PEDS audit	General population (Hajna, Ross, et al., 2016)
Neighborhood maintenance	General population (Dills et al., 2012)
Interesting sights	General population (Dills et al., 2012)
Beauty aesthetics	Older adults (Strath et al., 2012) General population (Dills et al., 2012; McGrath et al., 2016)
Upkeep	General population (Hosler et al., 2014)
General maintenance- PEDS audit	Older adults (Travers et al., 2018)
Attractiveness of segment- PEDS audit	Older adults (Travers et al., 2018)
Interesting urban design- PEDS audit	Older adults

	(Travers et al., 2018)
Open view- PEDS audit	Older adults (Travers et al., 2018)
Attractiveness of the view- PEDS audit	Older adults (Travers et al., 2018)
Path maintenance- SPACES audit	General population (Hajna, Ross, et al., 2016; Witten et al., 2012)
Many interesting things to look at while walking- IMI audit	General population (Jensen et al., 2017)
Many attractive natural sights- IMI audit	General population (Jensen et al., 2017)
Attractive buildings homes- IMI audit	General population (Jensen et al., 2017)
Enclosure- PEDS audit	General population (Hajna, Ross, et al., 2016)
Pleasantness	Older adults (Travers et al., 2018)
Available street parking, parking availability	Older adults (Strath et al., 2012)
Other sidewalks greenbelt trails paths- PEDS audit	Older adults (Hajna, Ross, et al., 2016) General population (Travers et al., 2018)
Access to public space- PEDS audit	Older adults (Travers et al., 2018)
Pedestrian street closed to cars- PEDS audit	General population (Hajna, Ross, et al., 2016)
Powerlines along segment- PEDS audit	General population (Hajna, Ross, et al., 2016)
Bicycle lane- PEDS audit	General population (Hajna, Ross, et al., 2016)

SAFETY FROM TRAFFIC	
Traffic volume	Older adults (Michael & Carlson, 2009) General population Hajna, Ross, et al., 2016; Witten et al., 2012)
Bike or Pedestrian path- PEDS audit	General population (Hajna, Ross, et al., 2016)
Vehicular traffic exposure	General population (Giles-Corti et al., 2011; McCormack et al., 2011)
Low road speed distance to roads with speed limit	General population (Janssen & King, 2015)
Traffic circle roundabout- PEDS audit	Older adults (Travers et al., 2018)
Median strip- PEDS audit	Older adults (Travers et al., 2018)
So much traffic along nearby streets	General population (Jensen et al., 2017)
Usually slow speed of traffic on most nearby streets- IMI audit	General population (Jensen et al., 2017)
Speed limits- PEDS audit	General population (Hajna, Ross, et al., 2016)
Ratio of high speed roads around schools	General population (Oliver et al., 2015)
Traffic speed- SPACES audit	General population (Witten et al., 2012)
Traffic safety	Older adults (Travers et al., 2018) General population (Dills et al., 2012; Hosler et al., 2014; Jensen et al., 2017)
Traffic control devices- SPACES audit	General population (Hajna, Ross, et al., 2016; Witten et al., 2012)

Presence of crosswalks and pedestrian signals help walkers cross	General population (Jensen et al., 2017)
Most drivers exceed the posted speed while driving- IMI audit	General population (Jensen et al., 2017)
Street crossing- PEDS audit	Older adults (Travers et al., 2018) General population (Hajna, Ross, et al., 2016)
White line- PEDS audit	Older adults (Travers et al., 2018)
Colored line- PEDS audit	Older adults (Travers et al., 2018)
Pedestrian crossing zebra- PEDS audit	Older adults (Travers et al., 2018)
Different road surface- PEDS audit	Older adults (Travers et al., 2018)
Refuge island- PEDS audit	Older adults (Travers et al., 2018)
Vehicle lanes- PEDS audit	Older adults (Travers et al., 2018)
Marked midblock crossing- PEDS audit	Older adults (Travers et al., 2018)
Posted speed limit- PEDS audit	Older adults (Travers et al., 2018)
Speed bump hump raised crosswalk- PEDS audit	Older adults (Travers et al., 2018)
Curb bulb out curb extension- PEDS audit	Older adults (Travers et al., 2018)
Curb cuts in segment- PEDS audit	General population (Hajna, Ross, et al., 2016)

Traffic signal- PEDS audit	Older adults (Travers et al., 2018)
Stop sign- PEDS audit	Older adults (Travers et al., 2018)
Give way sign- PEDS audit	Older adults (Travers et al., 2018)
Pedestrian activated signal- PEDS audit	Older adults (Travers et al., 2018)
Pedestrian overpass underpass bridge- PEDS audit	Older adults (Travers et al., 2018)
Traffic signs at the intersection	General population (Richardson et al., 2017)
Crossings	General population (Dills et al., 2012; Richardson et al., 2017)
Hard buffer between road and path- PEDS audit	General population (Hajna, Ross, et al., 2016)
Soft buffer between road and path- PEDS audit	General population (Hajna, Ross, et al., 2016)
Pedestrian safety	General population (McGrath et al., 2016)
Presence of driveways in the segment- PEDS audit	General population (Hajna, Ross, et al., 2016)
SAFETY FROM CRIME	
Bars nightclubs- PEDS audit	Older adults (Travers et al., 2018)
Front porch- PEDS audit	Older adults (Travers et al., 2018)
Prominence of garages- PEDS audit	Older adults (Travers et al., 2018)
Graffiti- PEDS audit	Older adults (Travers et al., 2018)

Litter- PEDS audit	Older adults (Travers et al., 2018)
Well lit streets at night- IMI audit	General population (Jensen et al., 2017)
Pedestrians, bikers easily seen by people in their homes- IMI audit	General population (Jensen et al., 2017)
Presence of high crime rate- IMI audit	General population (Jensen et al., 2017)
Crime rate makes it unsafe to walk at night- IMI audit	General population (Jensen et al., 2017)
Gang activity- IMI audit	General population (Jensen et al., 2017)
Groups of teenagers or adults hanging out causing trouble- IMI audit	General population (Jensen et al., 2017)
House or place you suspect drug dealing occurs- IMI audit	General population (Jensen et al., 2017)
Activity level visible persons from age groups in the segment	Older adults (Strath et al., 2012)
Other pedestrians	General population (Dills et al., 2012)
Personal safety	General population (Dills et al., 2012)
Safety from crime	Older adults (Travers et al., 2018)
Total crime	General population (Gell et al., 2015)
Cul-de-sac or permanent street closing- PEDS audit	Older adults (Travers et al., 2018)
Lighting	General population

	(Hajna, Ross, et al., 2016; Richardson et al., 2017)
Must you walk through a parking lot to get to most buildings- PEDS audit	General population (Hajna, Ross, et al., 2016)
TRANSPORTATION ACCESSIBILITY	
Transit access	General population (Richardson et al., 2017)
Number of public transit bus routes	General population (Salvo et al., 2014)
Subway stop density	General population (Lovasi et al., 2011; Rundle et al., 2016)
Density of rail transit stops	General population (Rundle et al., 2019)
Public transportation access	Older adults (Michael & Carlson, 2009)
Density of public transit stations	General population (Buck et al., 2014; Hinckson et al., 2017; Jack & McCormack, 2014)
Bus stop density	General population (Lovasi et al., 2011; McCormack et al., 2014)
Public transportation density	General population (Sallis et al., 2016)
Distance to the nearest transit stop	General population (Sallis et al., 2016)
Transportation infrastructure quality	Older adults (Strath et al., 2012)
TransitScore	General population (Barnes et al., 2016; Hirsch et al., 2013)
Transit stops within easy walking distance from home- IMI audit	General population (Jensen et al., 2017)
Accessibility	Older adults (Travers et al., 2018)

Transit facilities- PEDS audit	General population (Hajna, Ross, et al., 2016)
GREENERY	
Amount of street greenery	General population (X. Li et al., 2018)
Acres of tree canopy	General population (Shay & Khattak, 2012)
Greenness Normalized difference vegetation index (NDVI)	General population (Marquet & Hipp, 2019; Tamura et al., 2019)
Number/count of parks	Older adults (Carlson et al., 2012) General population (Hinckson et al., 2017; Hobin et al., 2012; Huang et al., 2019; Sallis et al., 2016; Salvo et al., 2014; Wang et al., 2017)
Park access	General population (Y. Li et al., 2018)
Trees and greenery	General population (Dills et al., 2012)
Distribution of parks greenspaces	Older adults (Michael & Carlson, 2009)
Proportion of greenspace	General population (Jack & McCormack, 2014; McCormack et al., 2014)
Public park density	General population (Cho & Rodríguez, 2015) Older adults (Nyunt et al., 2015)
Park type mix	General population (McCormack et al., 2014)
Density of mix of park types/ km2	General population (Jack & McCormack, 2014)
Area of parks in neighborhood/ km2	General population

	(Lee et al., 2015)
Ratio of area of parks in neighborhood	General population (Lee et al., 2015)
Ratio of area of parks in neighborhood including 1 km buffer/ km2	General population (Lee et al., 2015)
Park playground- PEDS audit	Older adults (Travers et al., 2018)
Playing or sport field- PEDS audit	Older adults (Travers et al., 2018)
Public garden- PEDS audit	Older adults (Travers et al., 2018)
Forest bush- PEDS audit	Older adults (Travers et al., 2018)
Street trees- PEDS audit	Older adults (Travers et al., 2018)

Source: own production

9.3. Examples of tracking raw database

	ID	date	Age	Gender_R	Perceived_health	Daily_PA_m	Daily_rest_m	N_walkability	Mode_Transport
22	GR0138S	17-Jun-2017	68	Mujer	Buena	484.00	742.75	Low walkability	Caminar
23	GR0157A	17-Jun-2017	71	Hombres	Buena	143.25	1132.00	Low walkability	Caminar
24	GR015BB	24-Jun-2017	84	Hombres	Buena	50.00	856.00	High walkability	Caminar
25	GR025N3	12-Jul-2017	76	Mujer	Regular	.50	67.75	High walkability	T. público
26	GR027FY	12-Jul-2017	67	Hombres	Buena	159.75	631.50	Low walkability	T. privado
27	GR0135V	08-Jul-2017	69	Hombres	Buena	.00	.00	Low walkability	T. privado
28	GR0138S	21-Jun-2017	68	Mujer	Buena	223.00	1044.75	Low walkability	Caminar
29	GR0157A	21-Jun-2017	71	Hombres	Buena	244.00	1196.00	Low walkability	Caminar
30	GR0264D	12-Jul-2017	70	Mujer	Buena	90.25	98.00	Low walkability	Caminar
31	GR027FY	13-Jul-2017	67	Hombres	Buena	162.25	476.50	Low walkability	T. privado
32	GR027FY	15-Jul-2017	67	Hombres	Buena	84.25	592.75	Low walkability	T. privado
33	GR027FY	16-Jul-2017	67	Hombres	Buena	220.75	307.75	Low walkability	T. privado
34	GR012BE	14-Jun-2017	79	Mujer	Buena	46.75	152.50	High walkability	Caminar
35	GR0138S	26-Jun-2017	68	Mujer	Buena	26.00	270.25	Low walkability	Caminar
36	GR013U5	22-Jun-2017	73	Hombres	Buena	289.00	1151.00	High walkability	Caminar
37	GR013U5	23-Jun-2017	73	Hombres	Buena	397.25	1042.75	High walkability	Caminar
38	GR0153F	22-Jun-2017	66	Hombres	Buena	193.75	625.75	High walkability	Caminar
39	GR0153F	23-Jun-2017	66	Hombres	Buena	199.00	693.50	High walkability	Caminar
40	GR0157A	26-Jun-2017	71	Hombres	Buena	42.00	235.00	Low walkability	Caminar

	ID	date	time	dateTime	lat	lon	iov
3311796	GR07NBY	2017-11-12	02:42:45	2017-11-12 02:42:45.0	41.32587733	2.09026319	1
3311797	GR07PNJ	2017-11-12	02:42:45	2017-11-12 02:42:45.0	41.32697542	2.09886550	1
3311798	GR07JUR	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.42381021	2.20113633	0
3311799	GR07JWC	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.42172689	2.20081321	0
3311800	GR07JXY	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.42002046	2.20336530	1
3311801	GR07K45	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.42428047	2.20268914	1
3311802	GR07KDV	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.42304209	2.20450488	0
3311803	GR07KU3	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.41815325	2.20769547	1
3311804	GR07NBY	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.32587733	2.09026319	1
3311805	GR07PNJ	2017-11-12	02:43:00	2017-11-12 02:43:00.0	41.32698558	2.09885970	1
3311806	GR07JUR	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.42381042	2.20113601	0
3311807	GR07JWC	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.42172662	2.20081279	0
3311808	GR07JXY	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.41988407	2.20335925	1
3311809	GR07K45	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.42428605	2.20270184	1
3311810	GR07KDV	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.42304291	2.20450548	0
3311811	GR07KU3	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.41813802	2.20768112	1
3311812	GR07NBY	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.32587733	2.09026319	1
3311813	GR07PNJ	2017-11-12	02:43:15	2017-11-12 02:43:15.0	41.32703672	2.09877330	1
3311814	GR07JUR	2017-11-12	02:43:30	2017-11-12 02:43:30.0	41.42381042	2.20113554	0
3311815	GR07JWC	2017-11-12	02:43:30	2017-11-12 02:43:30.0	41.42172672	2.20081265	0

9.4. Questionnaire

Questionnaire within RecerCaixa Project, used in Paper 5.1 and 5.2.

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Codi usuari: ______________ **Data:** ____________

BLOC 1. CARACTERÍSTIQUES GENERALS I HÀBITS DE MOBILITAT

1. Acostuma vostè a sortir de casa cada dia de la setmana?
Sí .... ☐
No .... ☐
NS/NC .... ☐

2. Disposa de carnet de cotxe o moto?
Sí .... ☐
No .... ☐
NS/NC .... ☐

3. Té accés habitual a un cotxe o moto?
Sí .... ☐
No .... ☐
NS/NC .... ☐

4. Quin mitjà de transport utilitza <u>principalment</u> en el seu dia a dia?

Caminant		Cotxe conductor + altres persones	
Bicicleta		Cotxe acompanyant	
Autobús		Moto conductor	
Metro		Moto acompanyant	
FGC		Altres (especificar)	
RENFE/Rodalies		NS/NC	
Cotxe conductor sol			

5. Quin és el <u>principal motiu</u> pel qual utilitza aquest mitjà de transport?

Combinació d'horaris més bona .... ☐
Més proximitat al lloc de residència.. ☐
Més barat .... ☐
Més ràpid .... ☐
Més puntual o regular .... ☐
Més còmode o agradable .... ☐
Poca oferta de transport públic des del lloc de residència o origen .... ☐
No tenir carnet de conduir .... ☐
No disposar de vehicle privat .... ☐

6. Per quin motiu es desplaça amb cadascun dels següents mitjans de transport?

Caminant	
Bicicleta	
Autobús	
Metro	
FGC	

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RENFE/Rodalies	
Cotxe	
Moto	

BLOC 2. SALUT I ACTIVITAT FÍSICA

7. Com diria que és la seva salut en general?

☐ Excel·lent
☐ Molt bona
☐ Bona
☐ Regular
☐ Dolenta

Pensi en activitats que requereixen un esforç físic que faci de forma habitual.
Les activitats físiques comporten respirar una mica més fort del normal i poden incloure aixecar pesos baixos, anar en bicicleta a un ritme regular, o activitats suaus com el pilates o similars. NO INCLOGUIS CAMINAR. (Duració mínima de 10 minuts)

8. Quants dies a la setmana realitza activitat física? *(Duració mínima de 10 minuts)*

_____ dies/setmana
NS/NC................☐

9. En aquests casos, quant temps hi dedica? *(Duració mínima de 10 minuts)*

Hores: _ _ Minuts: _ _
NS/NC................☐

Pensi en el que camina de forma habitual.
Això inclou a casa, viatjar d'un lloc a un altre, i qualsevol altra activitat a peu que hagi fet exclusivament per passejar, esport, exercici o oci.

10.Quants dies a la setmana camina com a mínim 10 minuts?

_____ dies/setmana
NS/NC................☐

11.En aquests casos, durant quant temps camina?

Hores: _ _ Minuts: _ _
NS/NC................☐

Pensi en el temps que passa assegut/da de forma habitual.
Això pot incloure el temps assegut en un escriptori, visitant amics, llegint o veient la televisió.

12.Quant temps passa assegut/da en un dia habitual?

Hores: _ _ Minuts: _ _
NS/NC................☐

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BLOC 3. PERCEPCIÓ DEL BARRI

13. Botigues, equipaments i d'altres elements al teu barri

¿Quant de temps es triga en arribar des de casa als establiments més properes o instal·lacions que figuren a continuació, si hi va caminant?

	Minuts caminant a la destinació					NS/NC
	1-5	6-10	11-20	21-30	+30	
Mercat						
Supermercat						
Ferreteria						
Verduleria / fruiteria						
Banc / Caixer automàtic						
Bar/Restaurant						
Oficina de correus						
Parada o estació de transport públic						
Biblioteca pública						
Escola - Institut						
Llibreria						
Centre Cívic						
Centre Atenció Primària (CAP) - Hospital						
Farmàcia						
Parc						
Gimnàs						
Perruqueria						
Cinema o teatre						
Centre Comercial						
Casal d'avis						

14. Accés a serveis

Marqui la resposta que millor s'aplica al seu barri. Tant "local" com "a poca distància" o "a prop" vol dir en menys de 10 minuts a peu des de casa.

Al meu barri....	Si	No	NS/NC
Puc fer la majoria de les meves compres quotidianes a botigues locals.			
Hi ha botigues a poca distància de casa meva.			
És difícil aparcar a prop de casa meva.			
Hi ha molts llocs per anar en una distància raonable a peu.			
És fàcil caminar al transport públic des de casa.			

15. Elements als carrers del meu barri

Marqui la resposta que millor s'aplica al seu barri.

Al meu barri....	Si	No	NS/NC
Hi ha prou voreres per caminar-hi.			
Les voreres estan en bones condicions.			
Hi ha elements a la vorera que dificulten caminar-hi (motocicletes aparcades, contenidors mal posats, etc.).			
Hi ha prou bancs al meu barri			

Els carrers són costeruts i és difícil caminar-hi.			
Hi ha moltes cantonades, fent que les illes de cases siguin normalment curtes (80-100m).			
Hi ha prou arbres a la majoria de carrers.			
Els edificis del meu barri estan en bon estat.			
El meu barri està net.			
El meu barri és sorollós.			
Als carrers del barri hi ha trànsit.			

16.Percepció a l'anar a peu.
Marqui amb la resposta que millor s'aplica al seu barri.

Al meu barri....	**Si**	**No**	**NS/NC**
Considero que és segur caminar-hi.			
Considero que és agradable caminar-hi.			
Quan camino, canvio de carrer per tal d'evitar certes zones (per trànsit, soroll, poca llum, males olors, etc.)			

17.La gent que viu al meu barri

Al meu barri....	**Si**	**No**	**NS/NC**
Hi ha gent que camina pel meu barri.			
Conec a gent que viu al meu barri.			
Em sento identificat amb la gent que viu al meu barri.			

18.Satisfacció amb el meu barri

Com de satisfet/a està, en general, amb el barri en el que viu?

Satisfet/a ☐
Indiferent ☐
Insatisfet/a ☐

9.5. Thesis outreach

To improve the content and the dissemination of the publications, the studies included in this thesis was presented in national and international conferences, seminars, and workshops:

1) **XXVII Congreso de la Asociación Española de Geografía (AGE)**. Ciudad de La Laguna,Tenerife. 14-17 December 2021. Communication. Authors: Zeynep S. Akinci, Xavier Delclòs-Alió, Guillem Vich, Carme Miralles-Guasch. Title: Neighborhood Urban Design and Outdoor Later Life: An Objective Assessment Of Out-Of-Home Time And Physical Activity Among Older Adults In Barcelona
2) **51st Annual Conference of the British Society of Gerontology (BSG2022**). Bristol (Online) 6-8 July 2022. Oral presentation. Authors: Zeynep S. Akinci, Xavier Delclòs-Alió, Guillem Vich, Deborah Salvo Dominguez, Jesús Ibarluzea and Carme Miralles-Guasch. Title: How different are objective operationalizations of walkability for older persons compared to the general population? A systematic review.
3) **Urban Transitions 2022**. Integrating Urban and Transport Planning, Environment and Health for Healthier Urban Living. Sitges, Barcelona. 8-10 November 2022. Oral presentation. Authors: Zeynep S. Akinci, Oriol Marquet, Xavier Delclòs-Alió, Carme Miralles-Guasch. Title: Urban vitality and seniors' outdoor rest time in Barcelona
4) **Webinar Género y Movilidad.** GEMOTT. 16 December 2020. Oral presentation. Authors: Zeynep S. Akinci, Xavier Delclòs-Alió, Guillem Vich, and Carme Miralles-Guasch. Title: A gender perspective in neighborhood urban design and outdoor later life
5) **Urban mobility in Barcelona: moving towards sustainable and age-inclusive urban transitions Workshop** – ENTOURAGE – The Research Group on Territorial Analysis and Tourism Studies (GRATET) of the Universitat Rovira i Virgili (URV). 8 September 2023 Barcelona. Oral presentation of the thesis in Research Highlights Session.

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