Journal of Transport & Health 42 (2025) 102032

Contents lists available at ScienceDirect

Journal of Transport & Health

journal homepage: www.elsevier.com/locate/jth

Understanding leisure walking behaviour among recently retired older adults in Tehran: Gender-specific influences and regional implications

Amirhossein Abdi [a,b], Steve O'Hern [c,*]

[a] Faculty of Civil and Environmental Engineering, Tarbiat Modares University, P.O. Box, 14115-397, Tehran, Iran
[b] Institute of Transport Studies, Monash University, 23 College Walk, Clayton Campus, Victoria, 3800, Australia
[c] Travel Behaviour and Analysis, Institute for Transport Studies, University of Leeds, UK

A R T I C L E I N F O

Keywords:
Older adults
Low– and middle-income country (LMIC)
Leisure walking
Retirement

A B S T R A C T

Introduction: The pace of population ageing is increasing worldwide. Ageing is often associated with declining mobility and a potential decrease in one's quality of life. However, walking can play a vital role in maintaining physical and mental well-being as individuals age.
Immediately after retirement, older adults, now with more free time, can shape their post-retirement habits. Nurturing a habit of regular walking can effectively reduce both physical and mental health risks in the long term, thereby alleviating some burden on healthcare systems.
Methods: This study explores the influential factors affecting leisure walking frequency among older adults. We conducted a survey of individuals who are within the first years of retirement in Tehran Province, the capital city of Iran. In total, 3692 complete responses were received, including 2064 males and 1628 females. Participants were surveyed about their weekly leisure walking frequency and provided information on demographics, socioeconomic attributes, lifestyle, personal preferences, and perceived environmental factors, with additional environmental features extracted using OpenStreetMap. A Random Thresholds Random Parameters Hierarchical Ordered Probit (RTRP-HOPIT) model was constructed to examine walking frequency, with a particular focus on gender-specific models.
Results: Analysis revealed that common influencing factors for leisure walking among both genders included pet ownership, vehicle ownership, marital status, education level, social support for walking, exercising as a favourite hobby, presence of slopes or steps within the neighbourhood, distance to green spaces, and the number of green spaces nearby, as well as the prevalence of major roads and intersections. For male retirees, being divorced or widowed emerged as the most influential factor contributing to low walking levels. For females, proximity to shopping areas had the highest impact on walking levels.
Conclusion: The research provides unique insight into how leisure walking can be promoted amongst older adults in low- and middle-income countries, and the findings can be utilised to encourage increased physical activity and better health both within the study region of Tehran and more broadly in other low- and middle-income countries that are experiencing an ageing population.

This article is part of a special issue entitled: Planning,Transport,Ageing published in Journal of Transport & Health.

* Corresponding author.
E-mail addresses: amirhosseinabdi96@gmail.com (A. Abdi), s.ohern@leeds.ac.uk (S. O'Hern).

https://doi.org/10.1016/j.jth.2025.102032
Received 12 April 2024; Received in revised form 7 March 2025; Accepted 10 March 2025
Available online 17 March 2025

1. Introduction

The global population is ageing at an accelerating pace, with the proportion of people aged 60 years and older expected to double from 12 % to 22 % between 2015 and 2050 (World Health Organization (WHO), 2023). This trend is particularly pronounced in low- and middle-income countries, with estimates that 80 % of older individuals will reside in these countries by 2050 (World Health Organization (WHO), 2023). Iran is currently experiencing a pronounced increase in its ageing population. In 2022, the proportion of individuals aged over 60 in Iran exceeded 10 % of the population (Bizaer, 2022). At the same time, Iran's population growth rate has reached a historic low (Doshmangir et al., 2023). This demographic shift poses important challenges for the nation's future.

The connection between mobility and health is complex. While ageing is often associated with declining mobility and a potential decrease in one's quality of life (Musselwhite et al., 2015), this connection is not absolute. It is possible to leverage everyday mobility to improve well-being, particularly during the transition from work to retirement (Berg, 2016). Although the car remains the predominant mode of transportation for most older adults, centring a mobility strategy solely around it may not be advisable (Musselwhite and Shergold, 2013). Private vehicles may initially seem like the most convenient option for older individuals, offering mobility over longer distances with less physical effort compared to more active alternatives. However, a notable number of older adults choose to limit or cease driving entirely when health issues arise (Musselwhite and Shergold, 2013), demonstrating the distinct travel behaviours exhibited by older adults and the need for non-motorised alternatives for travel.

Older adults are likely to have fewer and shorter trips in comparison to other age groups (Moniruzzaman et al., 2013). Notably, about a third of the elderly population indicates unsatisfied travel requirements, mainly in regards to recreational trips (Luiu et al., 2017). Unsatisfied travel demands can produce twofold effects, not only influencing physical health but also reducing social incorporation (Corran et al., 2018), which is one of the determinants of overall well-being. Furthermore, isolation is connected to an increased risk of all-cause mortality (Holt-Lunstad et al., 2010), compromised immune system function (Corran et al., 2018), and a higher likelihood of cardiovascular disease among older adults (Steptoe et al., 2013). In this respect, walking plays a vital role in maintaining physical and mental well-being as individuals age (Hatamzadeh and Hosseinzadeh, 2020).

Walking can be divided into different domains, which are characterized in terms of their respective motivations and determinant factors. Transportation walking, which includes walking for commuting and to engage in activities, has been thoroughly studied (Thielman et al., 2015; Zang et al., 2022). These studies highlight the importance of neighbourhood characteristics, such as walkability and population density, in shaping patterns of transportation walking. Leisure walking, which includes recreational walks and exercise, has garnered less interest in scholarly literature (Cheng et al., 2019; Wasfi et al., 2017). Although some recent research has addressed environmental influences on leisure walking, including the availability of recreational facilities, the evidence has been less consistent than that relating to transportation walking. For example, Cheng et al. (2019) found variations in walking accessibility to recreational amenities for older adults, suggesting disparities in leisure walking opportunities. Additionally, Wasfi et al. (2017) investigated the impact of walkability on walking behaviour and found inconsistent associations between walkability and leisure walking compared to transportation walking. This discrepancy underscores the need for further research into the factors influencing leisure walking behaviour, including the role of neighbourhood amenities and social factors.

Following retirement, older adults, who now have greater amounts of leisure time, can effectively manage their post-retirement lives, for example by choosing to either develop healthy leisure walking routines (Van Dyck et al., 2017). Nurturing a habit of regular walking can reduce both physical and mental health risks, thereby alleviating some burden on healthcare systems. Therefore, it is essential to ascertain how changes in life, such as retirement, influence walking behaviour. Transitioning into retirement is accompanied by major changes in day-to-day patterns, as individuals adjust to a life without work-time constraints (Barnes et al., 2016). For instance, daily commuting ceases upon retirement, this transition gives individuals more leisure time in which to take recreational walks and pursue other forms of physical activity (Barnes et al., 2016). Research indicates that, at this point in life, walking is a favoured exercise practice, and numerous retirees replace previously vigorous activity with frequent walking that becomes incorporated into their emerging routines (Searle et al., 2022). Retirement also reshapes transportation options; with no workplace to commute to, travel habits undergo considerable revision, leading some older adults to incorporate more walking into their errands and recreation (Berg et al., 2014). These revisions in walking behaviour are shaped by a number of determinants, such as the built environment, personal motivation, and social support. For instance, retirees who live in areas near accessible facilities will walk (Nathan et al., 2014). Moreover, newly retired individuals form everyday mobility routines based on personal preference and resources in negotiation with family members, highlighting how individual goals and social circumstances shape their lifestyle change (Travers et al., 2018).

Gender distinction plays a notable role in shaping leisure walking habit development among older adults. Men and women tend to have dissimilar walking patterns during this phase of life, due to variations in sociodemographic circumstances, residential area attributes, and individual lifestyle behaviours. A systematic review, for instance, observed that women tend to undertake more leisure walking than men, however this gender distinction tends to decrease with advancing age and in some instances reverses in the oldest populations (Pollard and Wagnild, 2017). Moreover, there are considerable differences in how men and women react to certain determinants of walking behaviour; for instance, walking activity in older men is more likely to be influenced by their access to other mobility options, i.e., automobiles (Hatamzadeh and Hosseinzadeh, 2020), whereas older women tend to pair leisure walking with socializing (Socci et al., 2021) and have a greater reaction to neighbourhood environmental characteristics (Li et al., 2022). Such trends highlight the necessity for gendered models of walking behaviour in older age, and the current study plays a role in filling this gap as it investigates frequency levels of walking for men and women separately.

When considering the specific context of Iran, previous research has demonstrated that walking behaviour is shaped by a combination of built environment characteristics, urban planning policies, and cultural practices. In Tehran, the high residential and commercial density, mixed land use, and good proximity to public transportation stops were identified as factors contributing to increased walking behaviour (Ahmadipour et al., 2021). Nevertheless, obstacles like high dependency on private vehicles, insufficient walking infrastructure, and safety issues prevent the uptake of walking as a significant mode of transport (Hatamzadeh and Hosseinzadeh, 2020). In other major Iranian cities, such as Shiraz and Isfahan, challenges such as inadequate sidewalk infrastructure, incomplete street connections, and significant traffic-related risks have been noted as barriers to increased walking (Panahi et al., 2022; Shaer and Haghshenas, 2021). Notwithstanding the identification of these challenges, there is scarce research on active transportation in Iran, especially on walking behaviour across different demographic groups and various urban environments (Hatamzadeh and Hosseinzadeh, 2020).

In summary, several recent studies have investigated the walking behaviours of older adults, highlighting the importance of factors such as walkability and environmental aspects (Hatamzadeh and Hosseinzadeh, 2020; Zang et al., 2021, 2022), infrastructure, and environmental deficiencies (Zandieh et al., 2017). Studies have also delved into age stratification (Shigematsu et al., 2009; Wasfi et al., 2017), gender differences (Hatamzadeh and Hosseinzadeh, 2020; Mosallanezhad et al., 2014), and neighbourhood inequalities (Zandieh et al., 2017). Nevertheless, there's a notable research gap in understanding the leisure walking behaviour of older adults. Of the research that has been conducted, it tends to focus on high-income countries, with limited research considering low- and middle-income countries. Furthermore, to our knowledge, no previous studies have investigated recently retired older adults walking behaviours in Iran.

2. Methodology

2.1. Participants and procedure

We conducted a survey of individuals in their early years of retirement in Tehran Province, the capital of Iran. To target individuals within this age cohort, we focused on a large organization in Tehran, namely the Tehran Municipality. This organization has a significant number of employees and civil servants, representing diverse demographics and socioeconomic statuses. The human resources department of the Tehran Municipality maintains contact with retirees and provides them with health services and retirement pensions. With the assistance of the human resources department, we distributed a questionnaire to all recent retirees. In total, 3692 complete responses were received, including 2064 males and 1628 females. Ethics approval for the study was obtained from the lead author's university, and all participants provided informed consent.

Participants were asked about the frequency of leisure walking sessions of at least 30 min in duration per week. According to a study by Mosallanezhad et al. (2014), older adults who walk for at least 30 min in a session show better results in health and fitness measures. Recognising the challenges associated with precisely determining the exact number of walks individuals undertake each week, particularly considering variations across different weeks, we opted for a categorical approach. Participants were presented with three distinct frequency levels to choose from: low frequency (less than 2 times per week), moderate frequency (2–4 times per week), and high frequency (5 or more times per week). This methodological decision aimed to simplify the data collection process for participants while mitigating potential inaccuracies resulting from the variability in reported walking frequencies.

Recent research has emphasised the importance of considering a wider array of variables beyond demographics and socioeconomic factors (Cerin et al., 2014; Zandieh et al., 2017). Our questionnaire aligns with this guidance by including additional variables covering a variety of aspects to provide a better understanding of behaviours, including demographic and socioeconomic attributes, lifestyle,

Table 1
Descriptive statistics of OSM-derived variables [M (SD)].

Variables	Male retired (n = 2064)			Female retired (n = 1628)		
	Low frequency (n = 316)	Moderate frequency (n = 1598)	High frequency (n = 150)	Low frequency (n = 178)	Moderate frequency (n = 1223)	High frequency (n = 227)
Distance to the nearest shopping mall (km)	2.98 (2.96)	2.74 (2.97)	2.85 (2.62)	3.29 (3.28)	3.04 (2.83)	2.65 (2.31)
Distance to the nearest green space (km)	2.17 (2.43)	2.05 (2.29)	1.89 (1.88)	2.31 (2.41)	1.84 (2.00)	1.72 (1.46)
Number of green spaces within the neighbourhood	1.47 (1.24)	1.76 (1.25)	1.74 (1.05)	1.32 (1.18)	1.74 (1.32)	1.79 (1.03)
Number of shopping malls within the neighbourhood	2.21 (1.47)	2.23 (1.83)	2.44 (1.51)	2.13 (1.64)	1.98 (1.10)	2.76 (1.95)
Number of intersections within 1000m radius of residence	170.75 (55.20)	149.32 (62.26)	145.98 (54.48)	166.24 (58.32)	151.86 (66.75)	140.41 (61.43)
Number of major roads within 1000m radius of residence	16.57 (10.89)	13.68 (9.61)	13.14 (9.24)	17.83 (10.15)	14.70 (8.71)	12.63 (8.32)

personal preferences, and their perceived environmental attributes. Furthermore, the location of residence was obtained to extract additional environmental attributes using OpenStreetMap (OSM). Tables 1 and B1 (Appendix B) summarise variables extracted from the questionnaire and OSM, respectively, cross-tabulated by frequency level outcomes.

2.2. Statistical analysis

In the context of categorical ordinal data, which is used as the target variable in this study, ordered probit models emerge as powerful modelling tools (Fountas and Anastasopoulos, 2017; Rahimi et al., 2020). These models have attracted significant attention from researchers due to several advantages over other approaches. By assuming a normal distribution for error terms and estimating thresholds for ordered categorical outcomes, ordered probit models effectively address the estimation challenges associated with multinomial probit models while capturing the ordinal nature of the dependent variable (Fountas and Anastasopoulos, 2017). This characteristic enhances their flexibility and robustness in handling ordinal data with a natural ordering of categories. Consequently, they provide a more accurate depiction of the relationship between predictors and the dependent variable categories, thereby improving the quality of analysis and the insights derived from the study (Washington et al., 2020).

Furthermore, incorporating randomness into the parameters and thresholds enhances the model's ability to account for unobserved heterogeneity. This approach not only results in better model fit but also captures variation across individuals, as varying parameters are considered among them. Such approaches have been less frequently utilised in analysing the walking behaviour of older adults, as previous modelling studies primarily focused on fixed parameter models (Hatamzadeh and Hosseinzadeh, 2020; Thielman et al., 2015; Zang et al., 2021). To address this gap, our research aims to employ a Random Thresholds Random Parameters Hierarchical Ordered Probit (RTRP-HOPIT) model to analyse the walking behaviour of recently retired males and females.

Appendix A provides an overview of the mathematical formulations for the model, the estimation of marginal effects, and the log-likelihood ratio test used to differentiate modelling based on gender.

Table 2
Results of RTRP-HOPIT model for male retirees.

Variable	Coefficient	t-statistics	Marginal effects		
			Low	Moderate	High
Demographic and Socioeconomic factors					
Age: 65 years and older	−0.219*	−1.73	0.025	−0.004	−0.021
Education: high school degree or less	−0.484***	−4.34	0.102	−0.023	−0.079
Marital status: divorced or widowed (standard deviation of parameter distribution)	−0.716*** (1.455**)	−4.58 (2.26)	0.163	−0.115	−0.048
Lifestyle Factors and Personal Preferences					
Pet dog ownership	0.576***	2.61	−0.112	0.094	0.018
Social support: never (standard deviation of parameter distribution)	−0.703*** (0.981**)	−4.16 (2.11)	0.155	−0.097	−0.058
Activities during walks: exercising	0.478**	2.00	−0.100	0.061	0.039
Perceived Environmental Attributes					
Presence of significant slopes or steps (standard deviation of parameter distribution)	−0.267** (0.384**)	−2.42 (2.08)	0.035	−0.022	−0.013
OSM-Derived Factors					
Distance to the nearest green space, used in increments of 0.1 km (standard deviation of parameter distribution)	−0.911*** (1.388**)	−4.53 (2.35)	0.147	−0.066	−0.081
Number of green spaces within the neighbourhood (standard deviation of parameter distribution)	0.472*** (0.824**)	3.90 (2.06)	−0.069	0.047	0.022
Number of intersections within 1000m radius of residence (standard deviation of parameter distribution)	−0.518*** (1.395*)	−2.79 (1.66)	0.016	−0.009	−0.007
Number of major roads within 1000m radius of residence (standard deviation of parameter distribution)	−0.847*** (0.511**)	−5.69 (2.45)	0.138	−0.096	−0.042
Threshold Parameters					
μ_0 (standard deviation of parameter distribution)	0.457** (0.248***)	2.37 (3.98)			
μ_1 (standard deviation of parameter distribution)	0.992** (0.752***)	2.54 (4.26)			
Threshold Covariates					
HH size: three or more individuals	0.143**	2.37	0.007	−0.003	−0.004
Vehicle ownership: none	−0.915***	−6.30	−0.123	0.082	0.041
Model Statistics					
Number of observations	2064				
LL at the null, $LL(\mathbf{0})$	−7860.95				
LL at the model, $LL(\boldsymbol{\beta})$	−5398.57				
ρ^2	0.313				

***, ** and * indicate 99%, 95%, and 90% confidence level, respectively.

3. Results

A Random Thresholds Random Parameters Hierarchical Ordered Probit (RTRP-HOPIT) model was constructed using the R programming language to examine walking frequency among recently retired individuals, with a particular focus on gender-specific models. To demonstrate the statistical validity of the gender-specific models, we conducted a log-likelihood ratio test, yielding a statistic of 32.27 with 14 degrees of freedom, which exceeds the critical value of 29.14 at a 99 % confidence level. This confirms that gender-specific modelling is statistically justified. Additionally, the presence of significant factors in both models and the overall good model fit further support the use of separate models.

As detailed in the preceding section, estimation was conducted using a simulated maximum likelihood estimator with 500 Halton sequences (Halton, 1960). Given the inclusion of random parameters in this model, several distributions—Normal, Lognormal, Uniform, and Triangular—were tested to determine the most suitable fit. The findings suggest that the Normal distribution emerged as the best choice for the random parameters, consistent with previous research utilising similar models (Fountas and Anastasopoulos, 2017; Rahimi et al., 2020; Yan et al., 2021).

The dependent variable in each model categorised walking frequency into three levels: low (less than 2 times per week), moderate (2–4 times per week), and high (5 or more times per week). Given the three categories, two threshold parameters (μ_0 *and* μ_1) were incorporated into the model specifications. During the modelling process, variables were added based on their t-statistics corresponding to a 90 % confidence level or higher on a two-tailed *t*-test. Additionally, random parameters exhibiting significant standard deviations, indicative of a 90 % confidence level or higher, were retained in the specifications.

Tables 2 and 3 present the estimated parameters alongside the computed marginal effects for male and female models, respectively, with ρ^2 values of 0.313 for the male model and 0.298 for the female model, indicating very good overall model fit. Also, Figures B1 and B2 (Appendix B) display the calculated marginal effects of the model for recently retired males and females, with variables ordered by their impact on the probability of low walking activity for better representation. It is worth noting that marginal effects represent the

Table 3
Results of RTRP-HOPIT model for female retirees.

Variable	Coefficient	t-statistics	Marginal effects		
			Low	Moderate	High
Demographic and Socioeconomic					
Education: high school degree or less	−0.517***	−5.66	0.128	−0.045	−0.083
Marital status: divorced or widowed (standard deviation of parameter distribution)	−0.621*** (1.145*)	−4.58 (1.68)	0.143	−0.109	−0.034
Retirement occupation: Executive/Professional	0.205*	1.86	−0.012	0.011	0.001
Lifestyle Factors and Personal Preferences					
Screen exposure: more than 4 h (standard deviation of parameter distribution)	−0.467*** (0.800*)	−4.63 (1.89)	0.113	−0.062	−0.051
Pet dog ownership	0.651***	3.34	−0.137	0.104	0.033
Social support: never (standard deviation of parameter distribution)	−0.715*** (1.358***)	−4.32 (3.11)	0.174	−0.119	−0.055
Activities during walks: exercising	0.330**	2.15	−0.061	0.048	0.013
Activities during walks: browsing shops	0.921***	3.47	−0.160	0.123	0.037
Perceived Environmental Attributes					
Presence of significant slopes or steps (standard deviation of parameter distribution)	−0.404** (0.519*)	−2.46 (1.70)	0.099	−0.065	−0.034
OSM-Derived Factors					
Distance to the nearest shopping mall, used in increments of 0.1 km (standard deviation of parameter distribution)	−1.279*** (2.012***)	−6.09 (2.75)	0.191	−0.094	−0.097
Distance to the nearest green space, used in increments of 0.1 km (standard deviation of parameter distribution)	−0.895*** (1.403**)	−5.18 (2.06)	0.145	−0.059	−0.086
Number of green spaces within the neighbourhood (standard deviation of parameter distribution)	0.455** (0.737**)	2.19 (2.44)	−0.072	0.051	0.021
Number of intersections within 1000m radius of residence (standard deviation of parameter distribution)	−0.843** (1.120***)	−2.03 (2.78)	0.017	−0.009	−0.008
Number of major roads within 1000m radius of residence (standard deviation of parameter distribution)	−0.792** (0.612**)	−2.46 (2.17)	0.152	−0.130	−0.022
Threshold Parameters					
μ_0 (standard deviation of parameter distribution)	0.397**(0.252**)	2.06 (2.14)			
μ_1 (standard deviation of parameter distribution)	0.740***(0.525**)	3.18 (2.27)			
Threshold Covariates					
Vehicle ownership: none	−0.969***	−5.85	−0.128	0.090	0.038
Perceived safety: unsafe	0.302**	2.55	0.026	−0.015	−0.011
Model Statistics					
Number of observations	1628				
LL at the null, $LL(\mathbf{0})$	−6643.79				
LL at the model, $LL(\boldsymbol{\beta})$	−4661.21				
ρ^2	0.298				

***, ** and * indicate 99%, 95%, and 90% confidence level, respectively.

change in the probability of each level of leisure walking, measured on a 0–1 scale, when a binary (indicator) variable changes from 0 to 1 or when a continuous variable increases by one unit.

The following subsections in this section objectively present the findings, while the discussion section focuses more on the implications and the rationale behind these findings.

3.1. Demographic and socioeconomic factors

The education level, marital status, and vehicle ownership were common significant factor among both gender models. The findings indicate that education level plays a crucial role in influencing walking frequency for both genders. Specifically, males with a high school degree or less exhibit a decrease in the likelihood of engaging in moderate and high-frequency walking by 0.023 and 0.079, respectively. Females with lower education levels experience a similar decline, with reductions of 0.045 for moderate-frequency walking and 0.083 for high-frequency walking. Marital status also emerges as a significant factor. For males, being divorced or widowed leads to a 0.115 decrease in the likelihood of moderate-frequency walking and a 0.048 decrease for high-frequency walking. Females in similar marital situations face reductions of 0.109 and 0.034 for moderate and high-frequency walking, respectively. The variability in how marital status impacts individuals is reflected in its designation as a random parameter in the model. The indicator variable for individuals with no vehicle ownership was found to be significant in the threshold functions. This indicator variable has a negative coefficient, indicating that when a retiree lives without a vehicle in their household, the probabilities of moderate and high walking frequency increase. Marginal effects demonstrate that not owning a vehicle increases the odds of choosing moderate and high walking levels by 0.082 and 0.041 for males, and by 0.090 and 0.038 for females, respectively.

Gender-specific significant variables reveal further nuances. In the male model, retirement at age 65 or older is associated with a substantial decrease in the probability of moderate and high-frequency walking, by 0.004 and 0.021, respectively, when compared to younger retirees. For females, occupational status plays a significant role; those retiring from executive or professional positions are more likely to engage in both moderate and high-frequency walking than those retiring from other types of positions. The indicator variable for a household size of three or more was found to be significant as a threshold covariate in the model for male retirees. This variable has a positive coefficient, suggesting that when male retirees live in households with three or more people, their likelihood of having moderate or high walking frequency is reduced by 0.003 and 0.004, respectively.

3.2. Lifestyle factors and personal preferences

Owning a pet dog in the household and social support were identified as significant variables affecting walking levels across both genders. Specifically, the presence of a pet dog increased moderate walking levels by 0.094 for males and 0.104 for females. For high walking levels, marginal effects were 0.018 for males and 0.033 for females. Additionally, the peer support for walking was recognized as a random parameter. The marginal effect results show that retired males without peer support for walking reduce the probability of engaging in moderate and high levels of walking frequency by 0.097 and 0.058, respectively. Likewise, the probabilities are reduced by 0.119 and 0.055 for females.

The engagement in other activities in combination with walking was recognized as another significant variable in the models. In both genders, the incorporation of exercise in walking activities was linked with a higher walking rate, capturing a 0.061 and 0.039 rise in moderate and high walking levels in males, and a 0.048 and 0.013 rise in females. Activity of browsing shops was found to be a significant variable only for females, raising the likelihood of achieving moderate and high levels of walking by 0.123 and 0.037, respectively.

Screen time for female retirees was also observed to be a significant random parameter for the model. Women who spent more than 4 h on the screen daily are often associated with the lowest likelihood of undertaking moderate and high walking frequencies, with declines of 0.062 and 0.051, respectively. The significance of the random parameter indicates that the impact is different for various individuals.

3.3. Built environment

Two variables measuring perceived environmental attributes of neighbourhoods were significant. Firstly, the presence of significant slopes or steps was found to lead to a 0.022 and 0.013 reduction in the probability of moderate and high walking levels for males, and a 0.065 and 0.034 reduction for females. This variable exhibits a statistically significant standard deviation, indicating that it is a random parameter with varying effects across individuals. Secondly, specific to the female's model, the indicator variable representing unsafe neighbourhoods showed a positive threshold covariate, showing that when females perceive their neighbourhood as unsafe, the probabilities of them having moderate and high walking frequency are reduced by 0.015 and 0.011, respectively.

Five variables derived from the OSM database were identified as significant, all of which also exhibited statistically significant random parameters, indicating unobserved heterogeneity among individuals. Four of these variables were significant for both males and females, while one was unique to the female model. For the variables common to both genders, a 0.1 km increase in the distance from a retiree's home to the nearest green space was linked to a decrease in the probability of engaging in moderate and high levels of walking by 0.066 and 0.081 for males, and by 0.059 and 0.086 for females. In contrast, having more green spaces within a retiree's neighbourhood increased the likelihood of moderate and high walking levels by 0.047 and 0.022 for males, and by 0.051 and 0.021 for females. An increase in the number of intersections within a 1000 m radius of a retiree's home reduced the probability of moderate and high walking levels by 0.009 and 0.007 for males and by 0.009 and 0.008 for females. Similarly, a greater number of major roads within the same radius decreased the likelihood of moderate and high walking levels by 0.096 and 0.042 for males and by 0.130 and 0.022 for females. The distance to the nearest shopping mall was a significant variable specific to female retirees. A 0.1 km increase in this distance corresponded to a reduction of 0.094 and 0.097 in the likelihood of engaging in moderate and high levels of walking, respectively.

4. Discussion

The modelling results highlighted in Section 3 show that several factors are associated with the level of leisure walking, including education level, marital status, vehicle ownership, retirement age, occupational status before retirement, pet ownership, social support, activities during walks, screen time, perceived environmental attributes of the neighbourhood, accessibility to green space, urban network attributes, and access to shopping facilities. In addition, gender segmentation of the analysis reveals that these factors often exert differing effects on males and females walking behaviours. Some of them are found statistically significant for one gender and not for the other, while still others act commonly but with magnitudes differing between genders.

In light of this summary, Section 4.1 reports our main findings and elaborates on underlying reasons driving the significance of these factors; also, considerations are given to gender roles in differing findings as an external factor through which models are separated. In this section, we also discuss the relevance of our findings to the existing literature, along with contributions and new insights that emerge from our analyses. Next, in Section 4.2, we present policy recommendations arranged in order of priorities based on the magnitude of marginal effects of the identified factors and their potentialities.

4.1. Insights and contributions

Common among both males and females, significant demographic and socioeconomic factors include educational status, being widowed or divorced, and vehicle ownership in the household. The significant role of education on the walking level outcome likely stems from broader social and economic factors. Individuals with low educational backgrounds may be subjected to limited intake of health information, poor levels of health literacy, and poor understanding of how regular physical activity, such as walking, can benefit their well-being. Economic constraints further restrict their capability to engage in leisure activities or get access to safe walking environments. In addition, physically demanding jobs common among this demographic may result in the preference to rest during their free time rather than engage in any further physical activity. In contrast, individuals with more education tend to be much more aware of the health benefits of walking. They also may have more access to resources that support recreational leisure walking. These findings align with previous research linking education level to physical activity outcomes in older adults (Cerin et al., 2013; Dubuc et al., 2014).

Another demographic characteristic that influences the frequency of walking is marital status, primarily through the provision of support from spouses, which can encourage health-promoting behaviour. Spouses can serve as both motivators and partners in engaging in physical activity such as walking. The loss of this support, through divorce or widowhood, can lead to a decline in physical activity, affected by the loss of encouragement along with the emotional and psychological challenges that come with these life changes. This reduced physical activity could, in turn, accelerate health decline, creating a cycle of lower activity and poor health outcomes (Ding et al., 2021; Grundström et al., 2021). Specifying the indicator variable for divorce or being a widow, a random parameter emphasises its varying effect on the outcome and heterogeneity within this group. The explored heterogeneity contributes to the literature by highlighting how other unmeasured personal traits may moderate the influence of marital status on physical activity and cause variation among individuals. In addition, the vehicle ownership by the household is another common significant socioeconomic characteristic of recently retired, which indirectly reduces walking levels by raising the threshold value in the models. Previous work underlined car ownership as a discouraging factor for walking and fostering a more car-dependent lifestyle (Buehler et al., 2020).

Considering gender-specific contributing factors, the decrease in walking levels is associated with retirement at older ages (65 or older) among males and may be explained by several aspects. As individuals retire later, they often experience declines in physical health, energy levels, and mobility, making regular walking more difficult. This finding is consistent with conclusions from earlier studies (Mosallanezhad et al., 2014). Interestingly, this pattern was not observed among female retirees, contributing to the existing body of knowledge. This difference may be explained by the traditional view of men as the primary breadwinners in Iran, where men are likely to delay retirement to sustain their revenues, while women are more likely to retire earlier. Additionally, retired males from larger families (three or more individuals) are likely to be less active, possibly because they are preoccupied with ensuring their family's economic well-being after retirement and the associated reduction in income, rather than using this period to increase their activity levels.

Females, at retirement from professional or executive status, are most likely to be associated with higher levels of physical activity after retirement. This suggests that occupational status plays an important role in physical activity levels in retirement. Women in higher-status jobs are likely to have greater autonomy, less physically demanding work, and more flexibility in scheduling, e.g., being able to work from home. These may facilitate them in forming and sustaining a walking habit prior to retirement, which is continued afterward. Additionally, these women are probably more health-conscious and have greater access to facilities for physical activity, as again evidenced by their higher education and income levels. Conversely, and as the novel finding of this work, the occupation men retire from is insignificant, likely due to cultural factors in Iran. Men, regardless of job status, may be less inclined to prioritise recreational activities like leisure walking both during employment and post-retirement. This could be because they might seek additional work or have less time for leisure activities after retiring, resulting in a more consistent pattern of physical activity that is less dependent on their former working roles.

Having discussed the demographic and socioeconomic contributing factors in the previous paragraphs, the next category of significant factors includes lifestyle factors and personal preferences among retirees. In both genders, the presence of a pet dog in the household and social support for physical activity are associated with higher leisure walking levels. Although pet ownership rates in Iran are lower than in Western countries, our finding confirms the previously identified positive impact of dog ownership on increasing physical activity levels, particularly among older adults (Garcia et al., 2015; Wu et al., 2017). Also, Lindsay Smith et al. (2017) underscored the importance of support for physical activity and its association with higher levels of engagement. Our research further contributes to their finding by acknowledging social support for recreational walking as a random parameter, indicating that its impact varies with individuals. Such variation may be based on personal characteristics; for instance, more introverted or less social individuals may experience a lesser effect of support compared to extroverts.

The combination of walking with other activities as a lifestyle factor and personal preference influences walking levels. Activity multiplicity during walking time, such as incorporating exercise or shopping, contributes to the attractiveness and utility of walking by making it multifaceted and multipurpose, leading to increased frequency. In both men and women, the integration of exercise into walking activity is linked to an increased likelihood of walking at a moderate to high intensity. This indicates that exercise is a potent stimulus for walking in both genders. The necessity of adding exercise to the walking activities of elderly individuals, such as brisk walking, jogging, and stretching, has been highlighted in the past research (Bai et al., 2022; Ikenaga et al., 2017). Additionally, the study identified browsing shops as a female-specific significant variable. This activity increases the likelihood of moderate to high walking levels, indicating that combining walking with errands or leisure activities is a powerful motivator for female walkers. One earlier study by Farren et al. (2015) also suggests the role of walking to shopping centres and mall walking in enhancing the level of physical activity in older adults. Nevertheless, contrary to our result, their study does not reveal mall walking as a female-specific determinant.

The last lifestyle variable is daily screen time, which was found to be significant in the female retirees' model as a random parameter. This represents a sedentary behaviour and indicates that female retirees who have over 4 h of daily screen time are generally susceptible to lower physical activity levels. The significance of the random parameter suggests that this effect varies at the individual level, potentially reflecting heterogeneity in lifestyle habits, health, or individual-level habits that mediate physical activity and screen time. It could also reflect heterogeneity in how screen time is embedded in daily life such that some participants are replacing it with more active behaviour while others are not. Furthermore, the insignificance of screen time in the male retiree model may be due to fewer men in the dataset spending over 4 h a day on screen time, indicating that it plays a less central role in their sedentary behaviour compared to women.

Apart from demographic and socioeconomic factors, as well as lifestyle and personal preferences, built environment factors also play a role in predicting leisure walking levels. In our work, the built environment is measured in two ways: first, through the objective and perceived neighbourhood characteristics of retirees, and second, through the subjective measurement of spatial characteristics using OSM.

Regarding the perceived characteristics, the presence of significant slopes or steps in the neighbourhood reduces walking levels for both genders, with a more pronounced effect on females. This likely stems from the increased physical challenge and perceived effort required, making these areas less appealing for leisure walking. Additionally, the random nature of this variable suggests that its impact varies among retirees, potentially influenced by factors such as individual fitness levels and endurance. For some, these environmental barriers are more discouraging than for others. Furthermore, the finding that perceived safety is a significant variable for women implies that women are less likely to participate in leisure walking in unsafe neighbourhoods, which is a logical outcome. The reason why this variable only appears in the female model is due to the heightened sensitivity to safety issues that women have, as stated by Basu et al. (2021), and safety is more of an issue for women compared to men in these contexts.

The analyses also show a correlation of greater satisfaction with perceived environmental attributes and frequency of walking among the retirees. Even though these trends were not statistically significant in the models, they give useful insight into the dynamics at play. For instance, 77.73 % of male residents in areas with perceived broad sidewalk width recorded moderate frequency of walking in comparison to 75.44 % of male residents in areas with narrow sidewalks. Additionally, in safe and well-lit sidewalk spaces, 93.18 % of the women possessed moderate or high walking frequency, as opposed to fewer in unsafe spaces. Safety and perceived cleanliness were also positively related to walking frequency, with safety being particularly so. For instance, 86.38 % of the men who felt safe in their neighbourhood had moderate or high walking frequency, as opposed to 80.71 % in perceived unsafe spaces. While none of these subtle patterns were statistically significant, they inform on possible dynamics affecting walking behaviour among retirees. One plausible explanation is the subjective nature of perceived variables, which can vary among individuals in similar circumstances, making it challenging to establish statistically significant connections between perceived variables and outcomes (Uijtdewilligen et al., 2024). Furthermore, individuals' perceptions of these attributes might be influenced by various combinations of factors. For example, perceived neighbourhood safety could vary depending on illumination conditions and whether it is daytime or nighttime, while perceived sidewalk width might change based on the time of day and the flow of pedestrians. Exploring alternative statistical methods, particularly those incorporating latent constructs, would be beneficial for future research endeavours.

Regarding subjective measurement of environmental factors using OSM, distance to the green spaces, number of green spaces within the neighbourhood, number of intersections, and number of major roads within the buffer area of the residence of retirees were significantly linked to the walking levels of both genders as random parameters. Previously, and similar to our research, Hogendorf et al. (2020) reported that for every 0.1 km increase in distance to the nearest green area, individuals spent 22.76 fewer minutes walking for leisure per week. Zandieh et al. (2017) also mentioned the shortage of green spaces as a form of inequality and disparity in land use, particularly in deprived areas, which negatively affects outdoor walking levels among older adults. Zang et al. (2021) and

Hatamzadeh and Hosseinzadeh (2020) demonstrated a negative association between recreational walking and intersection density and a high ratio of major roads, respectively. Despite these similarities, the cited associations were limited to fixed parameters, and our study reveals the randomness of the effect of such environmental factors among retirees.

While earlier research has established positive relationships between proximity to shops and walking for transport extensively (Cerin et al., 2014; Shigematsu et al., 2009), the relationship between leisure walking and access to shopping centres, and especially through the lens of gender, is less studied. This research fills this gap by examining this association, with a significant correlation identified between lower distances to the nearest shopping mall and higher walking activity levels in female retirees. The gender-specific influence identified can be attributed to variation in shopping behaviour and recreational activities, with women having a greater inclination to include shopping trips in their leisure walking routine. On the other hand, men might emphasise other types of activities or might not view closeness to shopping complexes as a decisive factor in walking, in which case there would be no significant correlation discovered in the male retiree model.

4.2. Policy implications

Figures B1 and B2 (Appendix B) show the marginal effects of contributing factors for recently retired males and females, respectively. The variables in these diagrams are ranked by their influence on the likelihood of low walking activity to identify the most vulnerable groups and the most effective policies.

For male retirees, the divorced or widowed marital status appears to be the most influential determinant associated with decreased walking activity, indicating a greater probability of decline in physical engagement in this subgroup. It is therefore necessary for policies to focus on comprehending the specific barriers and needs of this subgroup to promote higher levels of physical activity. The second notable variable is the perceived lack of social support among males, thus highlighting the need to design leisure walking motivation according to peer group, friend, and family circumstances. Initiatives aimed at increasing family members' awareness could involve monitoring their loved ones walking frequency and providing encouragement or company during walks. Together with marital status, these emphasise the significance of social contacts, especially among male retirees, to maintain healthy lifestyles.

The proximity to green spaces emerged as the third most influential aspect for male retirees. Notably, although the quantity of green spaces is also significant in the models, its effect on probabilities is comparatively weaker than the proximity to the nearest green space. This demonstrates that it is critical for urban planners to design urban spaces with the objective of equitable distribution of greenery in neighbourhoods, rather than solely increasing the absolute number of green spaces.

The number of major roads is the fourth most important determinant of the likelihood of lower levels of walking activity. Major roads act as physical barriers to the movement of pedestrians and require the provision of infrastructural measures like underpasses, footbridges, and signalised crossings for safe crossing. Some of the policy recommendations include installing facilities like escalators or lifts in pedestrian overpasses and underpasses to better accommodate older individuals, conducting regular maintenance checks, and timing in signalised intersections based on the walking speed of older adults, as they might walk slower than the speed designed in signal phase timings to cross the road safely (Bollard and Fleming, 2013). Besides, promoting mixed-use development and pedestrianisation is suggested, this being a technique that has a positive influence on the built environment by bringing more vibrancy, improved accessibility, lower car dependency, and promoting walkability (Hatamzadeh and Hosseinzadeh, 2020). Not owning a car highly encourages medium and high walking frequencies, as individuals under this status favour walking even for their leisure trips. Considering this fact and its important effect on the frequency of walking, policy measures need to focus on promoting walking as an appealing mode of recreational travel, especially in areas with a high rate of vehicle ownership. As much as pet dog ownership has an important effect on the frequency of walking, one must consider the fact that the culture of pet dog ownership in Iran is considerably low compared to Western countries. This imbalance is due to a combination of various factors, ranging from religious and cultural constraints, along with the dominant apartment lifestyle in the capital. Any suggested policies thus must pay close attention to these asymmetries and the special socio-cultural environment.

For retired females, although certain variables suggest similarities with those for males, such as pet ownership, vehicle ownership, marital status, distance to green spaces, number of major roads, and support for walking, there are notable differences to consider. Firstly, the primary influencing factor for leisure walking levels among recently retired females is their proximity to shopping malls, followed by social support availability and a preference for shopping as a favourite hobby. This underscores the significance of retail areas, not only as commercial centres but also as catalysts for social interaction and leisure walking. It emphasises the importance of enhancing their accessibility and integrating them into the urban environment with equitable access for all residents. Additionally, among the common factors, some discrepancies can be observed. For instance, females' likelihood of low walking probabilities is more influenced by their perception of no support for walking compared to men, as shown by the larger marginal effect obtained. This indicates their higher requirement for social support regardless of socio-demographic groups.

In addition to the previously mentioned factors as top-priority interventions, female and male retirees with a high school diploma or less have lower walking frequencies. This result highlights the necessity to promote awareness of the advantages of walking and offer appropriate incentives. In addition to this demographic, men from families with three or more members have difficulty sustaining regular walking frequencies, perhaps because of their traditional role as breadwinners in the Iranian community. Even in post-retirement life, they may be more concerned about the financial security of their children, decreasing the likelihood of moderate or high levels of walking frequency, and therefore their well-being should be a focus of targeted interventions. Lastly, the presence of steps and slopes, while exhibiting lower marginal effects compared to higher priority factors, highlights the importance of designing environments that are more friendly to older adults. This can be achieved by incorporating shorter stairs and providing landing areas between stairs or slopes, which represents a considerate design to accommodate the needs of older adults.

5. Summary and conclusions

This study offers valuable insights into the diverse range of demographic, socioeconomic, lifestyle, personal preferences, and environmental factors that shape the leisure walking habits of recent retirees in Tehran. Despite the unique contributions of this research, it is important to acknowledge its limitations. The reliance on self-reported survey data, with participants recruited through their former employers and current pension providers, introduces potential biases, including self-report bias and selection bias, which may affect the generalisability of the findings. To address these issues, future research should aim to collect data from a more diverse and representative sample of older adults.

Additionally, the survey design, while informed by existing literature, may have omitted other relevant variables that influence walking behaviour. Future studies could benefit from incorporating qualitative methods, such as focus groups with recent retirees, to explore in greater depth the barriers and facilitators of leisure walking.

Nevertheless, this research provides important insights into how leisure walking can be effectively promoted among older adults in low- and middle-income countries. The findings have practical implications for encouraging increased physical activity and improving health outcomes, not only within the context of Tehran but also in other regions experiencing similar demographic shifts. By understanding the key factors that influence walking behaviour, policymakers and practitioners can develop targeted interventions to support active ageing and enhance the well-being of older populations.

CRediT authorship contribution statement

Amirhossein Abdi: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Steve O'Hern:** Writing – review & editing, Writing – original draft, Supervision.

Data availability

The dataset analysed and used in this study is available upon reasonable request.

Financial disclosure

The authors declare that they have no relevant financial relationships with ineligible companies or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors gratefully acknowledge the invaluable assistance of the Department of Human Resources, Tehran and the Retirement Organization of Tehran Municipality in facilitating the data collection process.

Appendix A. Random Thresholds Random Parameters Hierarchical Ordered Probit Model

The ordered probit model determines the probabilities of ordinal outcomes by considering a vector of latent variables, y^*, represented as a linear function for each instance, as indicated in Eq. (A.1) by Washington et al. (2020). Here, X represents a matrix where each row corresponds to an observation in the dataset and each column corresponds to an explanatory variable, β represents a column vector of estimated parameters, and ε denotes the error term column vector, which follows a standard normal distribution across observations with a mean of 0 and a variance of 1.

$$y^* = X\beta + \varepsilon \tag{A.1}$$

The observed dependent variable or ordinal category (y) in the dataset is defined according to Eq. (A.2), where the threshold parameters $\mu_0, \mu_1, \ldots, \mu_{N-1}$ are estimated together with β (Washington et al., 2020).

$$y = \begin{cases} 0 & if \quad y^* \le \mu_0 \\ 1 & if \quad \mu_0 < y^* \le \mu_1 \\ 2 & if \quad \mu_1 < y^* \le \mu_2 \\ \dots & \dots \quad \dots \\ n & if \quad \mu_{n-1} < y^* \le \mu_n \\ \dots & \dots \quad \dots \\ N & if \quad \mu_{N-1} < y^* \end{cases} \tag{A.2}$$

In Eq. (A.2), y represents an ordered sequence of integers, with N being the highest integer in the sequence. Given a standard normal distribution for the error terms, the task is to estimate the probability of $\{0, 1, 2, \dots, n, \dots, N\}$ occurring for observations, as demonstrated in Eq. (A.3) (Washington et al., 2020). Where, $F(.)$ is the standard normal cumulative density function.

$$\begin{array}{c} P(y=0|X) = P(y^* \le \mu_0|X) = F(\mu_0 - X\beta) \\ P(y=1|X) = P(\mu_0 < y^* \le \mu_1|X) = F(\mu_1 - X\beta) - F(\mu_0 - X\beta) \\ P(y=2|X) = P(\mu_1 < y^* \le \mu_2|X) = F(\mu_2 - X\beta) - F(\mu_1 - X\beta) \\ \dots \\ P(y=n|X) = P(\mu_{n-1} < y^* \le \mu_n|X) = F(\mu_n - X\beta) - F(\mu_{n-1} - X\beta) \\ \dots \\ P(y=N|X) = P(\mu_{N-1} < y^*|X) = 1 - F(\mu_{N-1} - X\beta) \end{array} \tag{A.3}$$

The conventional framework of ordered probit models, as described in Eq. (A.1) -(A.3), is characterized by several significant limitations. Most notably, both the estimated coefficients and threshold parameters are uniformly fixed across all observations, potentially leading to inconsistent parameter estimation (Mannering and Bhat, 2014). The Random Thresholds Random Parameters Hierarchical Ordered Probit (RTRP-HOPIT) model relaxes the assumption of fixed coefficients by allowing them to vary across observations. Additionally, it permits threshold parameters to be influenced by a unique set of explanatory variables, which may not directly affect the ordinal outcomes and can vary across observations (Fountas and Anastasopoulos, 2017; Rahimi et al., 2020). Also, conventional ordered models assume that a common set of explanatory variables influences all levels of ordinal outcomes (Fountas and Anastasopoulos, 2017). However, to address this issue, some researchers have introduced a generalized format of ordered models (Yasmin and Eluru, 2013). Nevertheless, the utilization of the generalized form might lead to negative probabilities for ordinal outcomes (Rahimi et al., 2020). In this regard, the RTRP-HOPIT model excels, as it not only allows for versatility in terms of threshold parameters but also ensures positive probabilities by imposing constraints to guarantee their positivity (Fountas et al., 2021).

As mentioned, the RTRP-HOPIT model captures unobserved heterogeneity by allowing parameters to be randomly distributed among observations. The amount of a random parameter distributed for each observation can be defined as Eq. (A.4):

$$\beta_i = \beta + \Gamma w_i \tag{A.4}$$

Where, β_i is the vector of random parameters for observation i, Γ represents the diagonal matrix of standard deviations, and w_i is a term that follows a normal distribution with a mean of zero and a variance of one.

In addition to random parameters, the RTRP-HOPIT model allows the threshold parameters to vary across observations. In this context, μ_{in} represents the threshold parameter for observation i at ordinal level n, as defined by Eq. (A.5) (Greene and Hensher, 2010):

$$\mu_{i,n} = \mu_{i,n-1} + \exp\,(t_n + \gamma_n u_{in} + d_n S_i) \tag{A.5}$$

Where, t_n represents an intercept for threshold n, which signifies the mean of the threshold intercept. S_i is the vector of explanatory variables affecting the thresholds, d_n is vector of estimable parameters, allowing thresholds vary across observations. Additionally, u_{in} is a normally distributed term with a mean of zero and a standard deviation of one, and γ_n represents the standard deviation of the threshold intercept term.

This research utilised a simulated maximum likelihood estimator with Halton sequences to achieve efficient estimation of model parameters (Halton, 1960). Based on the recommendation by previous literature, we used 500 Halton draws to ensure stability and precision of the estimated parameters (Fountas and Anastasopoulos, 2017; Rahimi et al., 2020; Yan et al., 2021).

The pseudo R-squared value is calculated to assess the overall fit of the models. A higher value indicates that the proposed model better predicts the outcome. Eq. (A.6) provides the definition of pseudo R-squared (ρ^2).

$$\rho^2 = 1 - {LL(\beta)}/{LL(0)} \tag{A.6}$$

Where $LL(0)$ represents the log-likelihood of the null model, while $LL(\beta)$ denotes the log-likelihood of the converged model.

Marginal Effects

Marginal effects refer to the measure of the change in the probability of a particular outcome resulting from a change in an independent variable, holding all other variables constant.

The marginal effect for indicator variables is described as the alteration in estimated probabilities when the indicator variable transitions from 0 to 1 (Washington et al., 2020). Eq. (A.7) illustrates how the marginal effect of an indicator variable is computed.

$$M_{x_{ik}}^{P_{in}} = P_{in}[when\ x_{ik} = 1] - P_{in}[when\ x_{ik} = 0] \tag{A.7}$$

P_{in} represents the probability of outcome category n for observation i, while x_{ik} denotes the k –th indicator variable associated with observation i.

The marginal effect for the k –th continuous variable of observation i (x_{ik}) is calculated as shown in Eq. (A.8). Since this study employs an ordered model with three levels of walking frequency ($y = \{0,1,2\}$), three sub-equations represent these sequences in Eq. (A.8).

$$\frac{\delta P_i(y=0)}{\delta x_{ik}} = -f(\mu_0 - x_{ik}\beta_{ik})\beta_{ik}\ \frac{\delta P_i(y=1)}{\delta x_{ik}} = [f(\mu_0 - x_{ik}\beta_{ik}) - f(\mu_1 - x_{ik}\beta_{ik})]\beta_{ik}\frac{\delta P_i(y=2)}{\delta x_{ik}} = f(\mu_1 - x_{ik}\beta_{ik})\beta_{ik} \tag{A.8}$$

Where, $f(.)$ is the standard normal probability density function. Eq. (A.7) and (A.8) calculate the change in probability for each observation individually. To derive an overall average marginal effect across the sample, aggregating these individual changes in probabilities is recommended. (Yan et al., 2021).

Model Separation

The log-likelihood ratio test was used to demonstrate that two separate gender-specific models are statistically valid. The equation for this test, as applied to our analysis, is provided in Eq. (A.9) (Washington et al., 2020).

$$LR = -2[LL(\beta^{combined}) - LL(\beta^{male}) - LL(\beta^{female})] \tag{A.9}$$

Where $LL(\beta^{combined})$, $LL(\beta^{male})$, and $LL(\beta^{female})$ represent the log-likelihood at convergence for the combined model (including both males and females), the male model, and the female model, respectively. The statistic calculated using Eq. (A.9) follows a chi-square distribution, with the degrees of freedom determined by subtracting the total number of estimated parameters in the gender-specific models from the number of parameters estimated in the combined model.

Appendix B. Additional Tables and Figures

Table B1
Descriptive statistics of questionnaire-derived variables

Variables	Question in the questionnaire	Male retired (n = 2064)			Female retired (n = 1628)		
		Low frequency (n = 316)	Moderate frequency (n = 1598)	High frequency (n = 150)	Low frequency (n = 178)	Moderate frequency (n = 1223)	High frequency (n = 227)
Demographic and Socioeconomic factors:							
Age	What is your age? Please select the range that best fits your age. (Options: 1.[50–55), 2.[55–60), 3.[60–65), 4.[65 and older])	1: 21 (6.65 %) 2: 119 (37.66 %) 3: 134 (42.41 %) 4: 42 (13.29 %)	1: 176 (11.01 %) 2: 573 (35.85 %) 3: 729 (45.63 %) 4: 120 (7.51 %)	1: 19 (12.67 %) 2: 68 (45.33 %) 3: 53 (35.33 %) 4: 10 (6.67 %)	1: 27 (15.17 %) 2: 57 (32.02 %) 3: 81 (45.51 %) 4: 13 (7.30 %)	1: 189 (15.46 %) 2: 376 (30.74 %) 3: 563 (46.04 %) 4: 95 (7.76 %)	1: 35 (15.42 %) 2: 80 (35.24 %) 3: 91 (40.09 %) 4: 21 (9.25 %)
Education	What is the highest level of education you have completed? (Options: 1.High school degree or less, 2.Bachelor's degree, 3.Master's degree or higher)	1: 122 (38.61 %) 2: 133 (42.09 %) 3: 61 (19.30 %)	1: 537 (33.67 %) 2: 669 (41.93 %) 3: 392 (24.54 %)	1: 42 (28.00 %) 2: 67 (44.67 %) 3: 41 (27.33 %)	1: 86 (48.31 %) 2: 69 (38.76 %) 3: 23 (12.92 %)	1: 327 (26.73 %) 2: 547 (44.72 %) 3: 349 (28.55 %)	1: 56 (24.67 %) 2: 109 (48.02 %) 3: 62 (27.31 %)
Household (HH) size	How many people live in your household? (Options: 1.One person, 2. Two people, 3.Three people, 4.Four or more people)	1: 23 (7.28 %) 2: 92 (29.11 %) 3: 146 (46.20 %) 4: 55 (17.41 %)	1: 131 (8.20 %) 2: 603 (37.68 %) 3: 649 (40.62 %) 4: 215 (13.50 %)	1: 18 (12 %) 2: 83 (55.33 %) 3: 42 (28 %) 4: 7 (4.67 %)	1: 20 (11.24 %) 2: 31 (17.42 %) 3: 106 (59.55 %) 4: 21 (11.80 %)	1: 127 (10.39 %) 2: 305 (24.92 %) 3: 553 (45.21 %) 4: 238 (19.48 %)	1: 28 (12.33 %) 2: 84 (36.97 %) 3: 104 (45.81 %) 4: 11 (4.84 %)
Marital status	What is your marital status? (Options: 1.Single, 2.Married, 3.Divorced, 4. Widowed)	1: 23 (7.28 %) 2: 195 (61.71 %) 3: 51 (16.14 %)	1: 136 (8.51 %) 2: 1195 (74.89 %) 3: 138 (8.64 %)	1: 13 (8.67 %) 2: 119 (79.33 %) 3: 7 (4.67 %)	1: 18 (10.11 %) 2: 96 (53.93 %) 3: 38 (21.35 %)	1: 103 (8.42 %) 2: 917 (75.00 %) 3: 105 (8.58 %)	1: 21 (9.25 %) 2: 186 (81.94 %) 3: 8 (3.52 %)

(continued on next page)

Table B1 (*continued*)

Variables	Question in the questionnaire	Male retired (n = 2064)			Female retired (n = 1628)		
		Low frequency (n = 316)	Moderate frequency (n = 1598)	High frequency (n = 150)	Low frequency (n = 178)	Moderate frequency (n = 1223)	High frequency (n = 227)
		4: 47 (14.87 %)	4: 129 (8.07 %)	4: 11 (7.33 %)	4: 26 (14.61 %)	4: 98 (8.00 %)	4: 12 (5.29 %)
Retirement occupation	What was your job position upon retirement? (Options: 1.Executive/Professional, 2.Administrative/Office Support, 3.Skilled Trades/Technical, 4. Labor/Manual Work)	1: 51 (16.14 %)	1: 382 (23.91 %)	1: 35 (23.33 %)	1: 21 (11.80 %)	1: 271 (22.15 %)	1: 84 (36.96 %)
		2: 74 (23.42 %)	2: 479 (29.96 %)	2: 44 (29.33 %)	2: 121 (68.03 %)	2: 761 (62.21 %)	2: 123 (54.18 %)
		3: 86 (27.22 %)	3: 363 (22.72 %)	3: 48 (32.00 %)	3: 12 (6.74 %)	3: 57 (4.66 %)	3: 9 (3.96 %)
		4: 105 (33.22 %)	4: 374 (23.41 %)	4: 23 (15.33 %)	4: 24 (13.48 %)	4: 134 (10.97 %)	4: 11 (4.85 %)
Vehicle ownership	How many vehicles does your household currently own? (Options: 1. One vehicle, 2.Two vehicles, 3.Three or more vehicles, 4.None)	1: 89 (28.16 %)	1: 719 (45.04 %)	1: 48 (32.00 %)	1: 53 (29.78 %)	1: 515 (42.11 %)	1: 74 (32.60 %)
		2: 153 (48.42 %)	2: 537 (33.62 %)	2: 22 (14.67 %)	2: 83 (46.63 %)	2: 437 (35.74 %)	2: 39 (17.18 %)
		3: 48 (15.19 %)	3: 125 (7.82 %)	3: 9 (6.00 %)	3: 27 (15.17 %)	3: 112 (9.16 %)	3: 18 (7.93 %)
		4: 26 (8.23 %)	4: 217 (13.53 %)	4: 71 (47.33 %)	4: 15 (8.43 %)	4: 159 (13.00 %)	4: 96 (42.29 %)
Lifestyle Factors and Personal Preferences:							
Daily screen exposure	How much time do you spend on screens daily? (Options: 1.Less than 1 h, 2.1–2 h, 3.2–4 h, 4.More than 4 h)	1: 54 (17.09 %)	1: 371 (23.20 %)	1: 35 (23.03 %)	1: 12 (6.74 %)	1: 204 (16.68 %)	1: 52 (22.91 %)
		2: 102 (32.28 %)	2: 531 (33.23 %)	2: 52 (34.21 %)	2: 38 (21.35 %)	2: 397 (32.47 %)	2: 78 (34.36 %)
		3: 91 (28.80 %)	3: 411 (25.75 %)	3: 33 (21.71 %)	3: 40 (22.47 %)	3: 371 (30.32 %)	3: 49 (21.59 %)
		4: 69 (21.84 %)	4: 285 (17.82 %)	4: 32 (21.05 %)	4: 88 (49.44 %)	4: 251 (20.53 %)	4: 48 (21.14 %)
Dog ownership	Do you own a pet dog in your household? (Options: 1.Yes, 2.No)	1: 11 (3.48 %)	1: 116 (7.26 %)	1: 6 (4.00 %)	1: 6 (3.37 %)	1: 108 (8.83 %)	1: 13 (5.73 %)
		2: 305 (96.52 %)	2: 1482 (92.74 %)	2: 144 (96.00 %)	2: 172 (96.63 %)	2: 1115 (91.17 %)	2: 214 (94.27 %)
Social support	How often do you receive accompaniment or motivation from your friends, peer communities, or family members for leisure walks on a weekly basis? (Options: 1.Frequently, 2.Occasionally, 3.Rarely, 4.Never)	1: 26 (8.23 %)	1: 139 (8.70 %)	1: 30 (20.00 %)	1: 17 (9.55 %)	1: 116 (9.49 %)	1: 45 (19.82 %)
		2: 64 (20.25 %)	2: 629 (39.38 %)	2: 68 (45.33 %)	2: 22 (12.36 %)	2: 491 (40.16 %)	2: 114 (50.22 %)
		3: 51 (16.14 %)	3: 443 (27.70 %)	3: 41 (27.33 %)	3: 41 (23.03 %)	3: 329 (26.89 %)	3: 52 (22.91 %)
		4: 175 (55.38 %)	4: 387 (24.22 %)	4: 11 (7.33 %)	4: 98 (55.06 %)	4: 287 (23.46 %)	4: 16 (7.05 %)
Activities during walks	What hobby do you enjoy most while walking? (Options: 1.Listening to podcasts or music, 2.Exercising, 3. Observing nature, 4.Browsing shops, 5. Other (Please specify), 6. I do not engage in hobbies while walking)	1: 23 (7.28 %)	1: 174 (10.89 %)	1: 13 (8.67 %)	1: 14 (7.87 %)	1: 110 (9.00 %)	1: 32 (14.10 %)
		2: 27 (8.54 %)	2: 439 (27.49 %)	2: 53 (35.33 %)	2: 21 (11.80 %)	2: 356 (29.10 %)	2: 50 (22.03 %)
		3: 51 (16.14 %)	3: 320 (20.05 %)	3: 34 (22.67 %)	3: 27 (15.17 %)	3: 162 (13.26 %)	3: 41 (18.06 %)
		4: 67 (21.20 %)	4: 285 (17.82 %)	4: 22 (14.67 %)	4: 37 (20.79 %)	4: 414 (33.85 %)	4: 63 (27.75 %)
		5: 36 (11.39 %)	5: 199 (12.45 %)	5: 16 (10.67 %)	5: 28 (15.73 %)	5: 85 (6.95 %)	5: 22 (9.69 %)
		6: 112 (35.45 %)	6: 181 (11.30 %)	6: 12 (8.00 %)	6: 51 (28.65 %)	6: 96 (7.84 %)	6: 19 (8.37 %)
Perceived Environmental Attributes:							
Shade presence on sidewalks	How would you describe the availability of shade along sidewalks in your area? (Options: 1.Sufficient, Adequate shade coverage for pedestrians, 2. Limited, Some areas have shade, but overall coverage is sparse, 3. Absent, No shade is present along the sidewalks)	1: 89 (28.16 %)	1: 452 (28.29 %)	1: 42 (28.00 %)	1: 50 (28.09 %)	1: 346 (28.29 %)	1: 64 (28.17 %)
		2: 155 (49.05 %)	2: 780 (48.91 %)	2: 74 (49.33 %)	2: 87 (48.88 %)	2: 599 (48.91 %)	2: 111 (48.90 %)
		3: 72 (22.79 %)	3: 366 (22.90 %)	3: 34 (22.67 %)	3: 41 (23.03 %)	3: 278 (22.80 %)	3: 52 (22.93 %)
Sufficient sidewalk width	How would you rate the width of sidewalks in your area? (Options: 1. Ample width, providing comfortable pedestrian movement, 2.Moderate width, occasionally causing	1: 65 (20.57 %)	1: 377 (23.60 %)	1: 43 (28.67 %)	1: 41 (23.03 %)	1: 287 (23.47 %)	1: 58 (25.55 %)
		2: 175 (55.38 %)	2: 923 (57.77 %)	2: 86 (57.33 %)	2: 94 (52.81 %)	2: 705 (57.59 %)	2: 130 (57.30 %)
		3: 76 (24.05 %)	3: 298 (18.63 %)	3: 21 (14.00 %)	3: 43 (24.16 %)	3: 231 (18.94 %)	3: 39 (17.15 %)

(*continued on next page*)

Table B1 (*continued*)

Variables	Question in the questionnaire	Male retired (n = 2064)			Female retired (n = 1628)		
		Low frequency (n = 316)	Moderate frequency (n = 1598)	High frequency (n = 150)	Low frequency (n = 178)	Moderate frequency (n = 1223)	High frequency (n = 227)
	congestion, 3.Narrow width, hindering pedestrian movement)						
Presence of adequate lighting	How would you describe the lighting in your area? (Options: 1.Well-lit, ensuring visibility, 2.Adequately lit, with occasional areas of dimness, 3. Poorly lit, hindering visibility.)	1: 51 (16.14 %) 2: 202 (63.92 %) 3: 63 (19.94 %)	1: 375 (23.48 %) 2: 929 (58.15 %) 3: 294 (18.37 %)	1: 46 (30.67 %) 2: 85 (56.67 %) 3: 19 (12.67 %)	1: 26 (14.61 %) 2: 117 (65.73 %) 3: 35 (19.66 %)	1: 288 (23.54 %) 2: 710 (58.03 %) 3: 225 (18.43 %)	1: 67 (29.52 %) 2: 139 (61.23 %) 3: 21 (9.25 %)
Presence of significant slopes or steps	Are there significant slopes or steps in your surroundings? (Options: 1.Yes, 2. No)	1: 202 (63.92 %) 2: 114 (36.08 %)	1: 696 (43.55 %) 2: 902 (56.45 %)	1: 48 (32.00 %) 2: 102 (68.00 %)	1: 133 (74.72 %) 2: 45 (25.28 %)	1: 528 (43.16 %) 2: 695 (56.84 %)	1: 75 (33.04 %) 2: 152 (66.96 %)
Perceived safety	How safe do you perceive your surroundings? (Options: 1.Safe, 2. Neutral, 3.Unsafe)	1: 38 (12.03 %) 2: 191 (60.44 %) 3: 87 (27.53 %)	1: 217 (13.58 %) 2: 1045 (65.47 %) 3: 336 (21.05 %)	1: 24 (16.00 %) 2: 98 (65.33 %) 3: 28 (18.67 %)	1: 10 (5.62 %) 2: 113 (63.48 %) 3: 55 (30.90 %)	1: 86 (7.03 %) 2: 820 (67.02 %) 3: 317 (25.95 %)	1: 33 (14.52 %) 2: 145 (63.88 %) 3: 49 (21.60 %)
Perceived cleanliness	How clean do you perceive your surroundings? (Options: 1.Clean, 2. Neutral, 3.Dirty)	1: 48 (15.19 %) 2: 209 (66.14 %) 3: 59 (18.67 %)	1: 232 (14.52 %) 2: 1095 (68.62 %) 3: 271 (16.96 %)	1: 33 (22.00 %) 2: 101 (67.33 %) 3: 16 (10.67 %)	1: 22 (12.36 %) 2: 110 (61.80 %) 3: 46 (25.84 %)	1: 151 (12.34 %) 2: 843 (68.91 %) 3: 229 (18.75 %)	1: 50 (22.03 %) 2: 147 (64.77 %) 3: 30 (13.20 %)

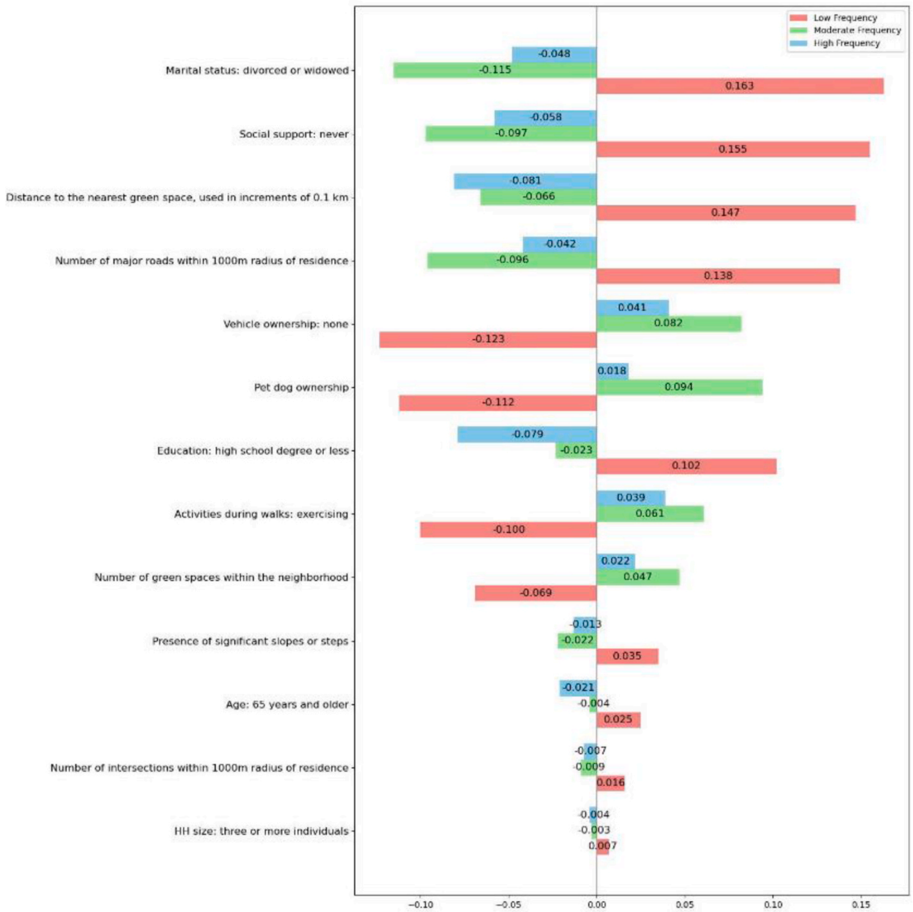

Fig. B1. Calculated marginal effects of variables for male retirees ordered by absolute impact on low walking frequency.

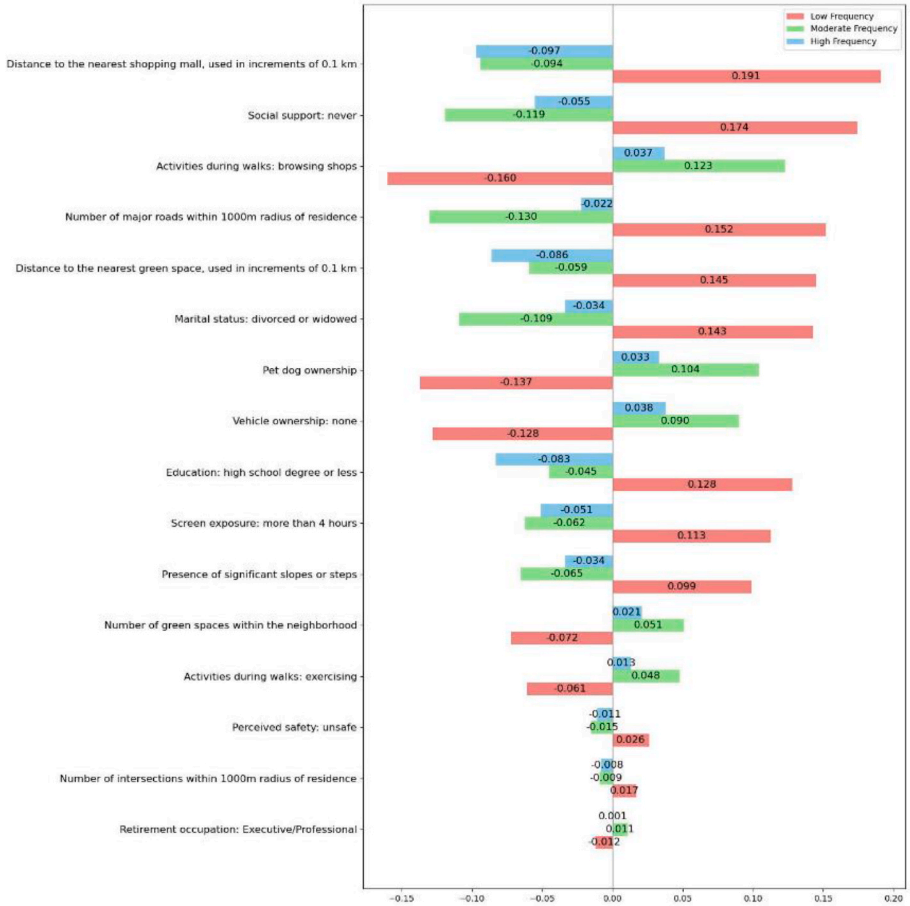

Fig. B2. Calculated marginal effects of variables for female retirees ordered by absolute impact on low walking frequency.

References

Ahmadipour, F., Mamdoohi, A.R., Wulf-Holger, A., 2021. Impact of built environment on walking in the case of Tehran, Iran. J. Transport Health 22, 101083. https://doi.org/10.1016/j.jth.2021.101083.

Bai, X., Soh, K.G., Omar Dev, R.D., Talib, O., Xiao, W., Cai, H., 2022. Effect of brisk walking on health-related physical fitness balance and life satisfaction among the elderly: a systematic review. Front. Public Health 9. https://doi.org/10.3389/fpubh.2021.829367.

Barnes, R., Winters, M., Ste-Marie, N., McKay, H., Ashe, M.C., 2016. Age and retirement status differences in associations between the built environment and active travel behaviour. J. Transport Health 3, 513–522. https://doi.org/10.1016/j.jth.2016.03.003.

Basu, N., Haque, M.M., King, M., Kamruzzaman, M., Oviedo-Trespalacios, O., 2021. The unequal gender effects of the suburban built environment on perceptions of security. J. Transport Health 23, 101243. https://doi.org/10.1016/j.jth.2021.101243.

Berg, J., 2016. Mobility changes during the first years of retirement. Qual. Ageing 17, 131–140. https://doi.org/10.1108/QAOA-11-2015-0052.

Berg, J., Levin, L., Abramsson, M., Hagberg, J.-E., 2014. Mobility in the transition to retirement – the intertwining of transportation and everyday projects. J. Transport Geogr. 38, 48–54. https://doi.org/10.1016/j.jtrangeo.2014.05.014.

Bizaer, M., 2022. What Iran's emerging demographic "tsunami" means for tehran [WWW Document]. Middle East Institute. URL. https://www.mei.edu/publications/what-irans-emerging-demographic-tsunami-means-tehran, 8.16.24.

Bollard, E., Fleming, H., 2013. A study to investigate the walking speed of elderly adults with relation to pedestrian crossings. Physiother. Theory Pract. 29, 142–149. https://doi.org/10.3109/09593985.2012.703760.

Buehler, R., Pucher, J., Bauman, A., 2020. Physical activity from walking and cycling for daily travel in the United States, 2001–2017: demographic, socioeconomic, and geographic variation. J. Transport Health 16, 100811. https://doi.org/10.1016/j.jth.2019.100811.

Cerin, E., Mellecker, R., Macfarlane, D.J., Barnett, A., Cheung, M., Sit, C.H.P., Chan, W., 2013. Socioeconomic status, neighborhood characteristics, and walking within the neighborhood among older Hong Kong Chinese. J. Aging Health 25, 1425–1444. https://doi.org/10.1177/0898264313510034.

Cerin, E., Sit, C.H., Barnett, A., Johnston, J.M., Cheung, M.-C., Chan, W.-M., 2014. Ageing in an ultra-dense metropolis: perceived neighbourhood characteristics and utilitarian walking in Hong Kong elders. Public Health Nutr. 17, 225–232. https://doi.org/10.1017/S1368980012003862.

Cheng, L., Caset, F., De Vos, J., Derudder, B., Witlox, F., 2019. Investigating walking accessibility to recreational amenities for elderly people in Nanjing, China. Transp Res D Transp Environ 76, 85–99. https://doi.org/10.1016/j.trd.2019.09.019.

Corran, P., Steinbach, R., Saunders, L., Green, J., 2018. Age, disability and everyday mobility in London: an analysis of the correlates of 'non-travel' in travel diary data. J. Transport Health 8, 129–136. https://doi.org/10.1016/j.jth.2017.12.008.

Ding, D., Gale, J., Bauman, A., Phongsavan, P., Nguyen, B., 2021. Effects of divorce and widowhood on subsequent health behaviours and outcomes in a sample of middle-aged and older Australian adults. Sci. Rep. 11, 15237. https://doi.org/10.1038/s41598-021-93210-y.

Doshmangir, L., Khabiri, R., Gordeev, V.S., 2023. Policies to address the impact of an ageing population in Iran. Lancet 401, 1078. https://doi.org/10.1016/S0140-6736(23)00179-4.

Dubuc, M.-M., Barbat-Artigas, S., Karelis, A.D., Aubertin-Leheudre, M., 2014. Relationship between the level of education and functional capacity in active elderly adults. J. Frailty; Aging 1–5. https://doi.org/10.14283/jfa.2014.16.

Farren, L., Belza, B., Allen, P., Brolliar, S., Brown, D.R., Cormier, M.L., Janicek, S., Jones, D.L., King, D.K., Marquez, D.X., Rosenberg, D.E., 2015. Mall walking program environments, features, and participants: a scoping review. Prev. Chronic Dis. 12, 150027. https://doi.org/10.5888/pcd12.150027.

Fountas, G., Anastasopoulos, P.Ch, 2017. A random thresholds random parameters hierarchical ordered probit analysis of highway accident injury-severities. Anal. Methods Accid. Res. 15, 1–16. https://doi.org/10.1016/j.amar.2017.03.002.

Fountas, G., Fonzone, A., Olowosegun, A., McTigue, C., 2021. Addressing unobserved heterogeneity in the analysis of bicycle crash injuries in Scotland: a correlated random parameters ordered probit approach with heterogeneity in means. Anal. Methods Accid. Res. 32, 100181. https://doi.org/10.1016/j.amar.2021.100181.

Garcia, D.O., Wertheim, B.C., Manson, J.E., Chlebowski, R.T., Volpe, S.L., Howard, B.V., Stefanick, M.L., Thomson, C.A., 2015. Relationships between dog ownership and physical activity in postmenopausal women. Prev. Med. (Baltim) 70, 33–38. https://doi.org/10.1016/j.ypmed.2014.10.030.

Greene, W.H., Hensher, D.A., 2010. Modeling Ordered Choices. Cambridge University Press. https://doi.org/10.1017/CBO9780511845062.

Grundström, J., Konttinen, H., Berg, N., Kiviruusu, O., 2021. Associations between relationship status and mental well-being in different life phases from young to middle adulthood. SSM Popul Health 14, 100774. https://doi.org/10.1016/j.ssmph.2021.100774.

Halton, J.H., 1960. On the efficiency of certain quasi-random sequences of points in evaluating multi-dimensional integrals. Numer. Math. (Heidelb) 2, 84–90. https://doi.org/10.1007/BF01386213.

Hatamzadeh, Y., Hosseinzadeh, A., 2020. Toward a deeper understanding of elderly walking for transport: an analysis across genders in a case study of Iran. J. Transport Health 19, 100949. https://doi.org/10.1016/j.jth.2020.100949.

Hogendorf, M., Oude Groeniger, J., Noordzij, J.M., Beenackers, M.A., van Lenthe, F.J., 2020. Longitudinal effects of urban green space on walking and cycling: a fixed effects analysis. Health Place 61, 102264. https://doi.org/10.1016/j.healthplace.2019.102264.

Holt-Lunstad, J., Smith, T.B., Layton, J.B., 2010. Social relationships and mortality risk: a meta-analytic review. PLoS Med. 7, e1000316. https://doi.org/10.1371/journal.pmed.1000316.

Ikenaga, M., Yamada, Y., Kose, Y., Morimura, K., Higaki, Y., Kiyonaga, A., Tanaka, H., 2017. Effects of a 12-week, short-interval, intermittent, low-intensity, slow-jogging program on skeletal muscle, fat infiltration, and fitness in older adults: randomized controlled trial. Eur. J. Appl. Physiol. 117, 7–15. https://doi.org/10.1007/s00421-016-3493-9.

Li, J., Tian, L., Ouyang, W., 2022. Exploring the relationship between neighborhood-built environment and elderly health: a research based on heterogeneity of age and gender groups in beijing. Front. Public Health 10. https://doi.org/10.3389/fpubh.2022.882361.

Lindsay Smith, G., Banting, L., Eime, R., O'Sullivan, G., van Uffelen, J.G.Z., 2017. The association between social support and physical activity in older adults: a systematic review. Int. J. Behav. Nutr. Phys. Activ. 14, 56. https://doi.org/10.1186/s12966-017-0509-8.

Luiu, C., Tight, M., Burrow, M., 2017. The unmet travel needs of the older population: a review of the literature. Transp. Rev. 37, 488–506. https://doi.org/10.1080/01441647.2016.1252447.

Mannering, F.L., Bhat, C.R., 2014. Analytic methods in accident research: methodological frontier and future directions. Anal. Methods Accid. Res. 1, 1–22. https://doi.org/10.1016/j.amar.2013.09.001.

Moniruzzaman, Md, Páez, A., Nurul Habib, K.M., Morency, C., 2013. Mode use and trip length of seniors in Montreal. J. Transport Geogr. 30, 89–99. https://doi.org/10.1016/j.jtrangeo.2013.03.007.

Mosallanezhad, Z., Salavati, M., Sotoudeh, G.R., Nilsson Wikmar, L., Frändin, K., 2014. Walking habits and health-related factors in 75-year-old Iranian women and men. Arch. Gerontol. Geriatr. 58, 320–326. https://doi.org/10.1016/j.archger.2013.11.008.

Musselwhite, C., Holland, C., Walker, I., 2015. The role of transport and mobility in the health of older people. J. Transport Health 2, 1–4. https://doi.org/10.1016/j.jth.2015.02.001.

Musselwhite, C.B.A., Shergold, I., 2013. Examining the process of driving cessation in later life. Eur. J. Ageing 10, 89–100. https://doi.org/10.1007/s10433-012-0252-6.

Nathan, A., Wood, L., Giles-Corti, B., 2014. Perceptions of the built environment and associations with walking among retirement village residents. Environ. Behav. 46, 46–69. https://doi.org/10.1177/0013916512450173.

Panahi, N., Pourjafar, M., Ranjbar, E., Soltani, A., 2022. Examining older adults' attitudes towards different mobility modes in Iran. J. Transport Health 26, 101413. https://doi.org/10.1016/j.jth.2022.101413.

Pollard, T.M., Wagnild, J.M., 2017. Gender differences in walking (for leisure, transport and in total) across adult life: a systematic review. BMC Public Health 17, 341. https://doi.org/10.1186/s12889-017-4253-4.

Rahimi, E., Shamshiripour, A., Samimi, A., Mohammadian, A.Kouros, 2020. Investigating the injury severity of single-vehicle truck crashes in a developing country. Accid. Anal. Prev. 137, 105444. https://doi.org/10.1016/j.aap.2020.105444.

Searle, A., Herbert, G., Ness, A., Foster, C., Waylen, A., Jago, R., 2022. A qualitative exploration of attitudes to walking in the retirement life change. BMC Public Health 22, 472. https://doi.org/10.1186/s12889-022-12853-2.

Shaer, A., Haghshenas, H., 2021. The impacts of COVID-19 on older adults' active transportation mode usage in Isfahan, Iran. J. Transport Health 23, 101244. https://doi.org/10.1016/j.jth.2021.101244.

Shigematsu, R., Sallis, J.F., Conway, T.L., Saelens, B.E., Frank, L.D., Cain, K.L., Chapman, J.E., King, A.C., 2009. Age differences in the relation of perceived neighborhood environment to walking. Med. Sci. Sports Exerc. 41, 314–321. https://doi.org/10.1249/MSS.0b013e318185496c.

Socci, M., Santini, S., Dury, S., Perek-Białas, J., D'Amen, B., Principi, A., 2021. Physical activity during the retirement transition of men and women: a qualitative longitudinal study. BioMed Res. Int. 2021. https://doi.org/10.1155/2021/2720885.

Steptoe, A., Shankar, A., Demakakos, P., Wardle, J., 2013. Social isolation, loneliness, and all-cause mortality in older men and women. Proc. Natl. Acad. Sci. USA 110, 5797–5801. https://doi.org/10.1073/pnas.1219686110.

Thielman, J., Rosella, L., Copes, R., Lebenbaum, M., Manson, H., 2015. Neighborhood walkability: differential associations with self-reported transport walking and leisure-time physical activity in Canadian towns and cities of all sizes. Prev. Med. (Baltim) 77, 174–180. https://doi.org/10.1016/j.ypmed.2015.05.011.

Travers, C., Dixon, A., Laurence, A., Niblett, S., King, K., Lewis, P., Owen, N., Veysey, M., 2018. Retirement health and lifestyle study: Australian neighborhood environments and physical activity in older adults. Environ. Behav. 50, 426–453. https://doi.org/10.1177/0013916517707294.

Uijtdewilligen, T., Baran Ulak, M., Jan Wijlhuizen, G., Geurs, K.T., 2024. Effects of crowding on route preferences and perceived safety of urban cyclists in The Netherlands. Transp. Res. Part A Policy Pract 183, 104030. https://doi.org/10.1016/j.tra.2024.104030.

Van Dyck, D., Mertens, L., Cardon, G., De Cocker, K., De Bourdeaudhuij, I., 2017. Opinions toward physical activity, sedentary behavior, and interventions to stimulate active living during early retirement: a qualitative study in recently retired adults. J. Aging Phys. Activ 25, 277–286. https://doi.org/10.1123/japa.2015-0295.

Wasfi, R., Steinmetz-Wood, M., Kestens, Y., 2017. Place matters: a longitudinal analysis measuring the association between neighbourhood walkability and walking by age group and population center size in Canada. PLoS One 12, e0189472. https://doi.org/10.1371/journal.pone.0189472.

Washington, S., Karlaftis, M., Mannering, F., Anastasopoulos, P., 2020. Statistical and Econometric Methods for Transportation Data Analysis. Chapman and Hall/CRC. https://doi.org/10.1201/9780429244018.

World Health Organization (WHO), 2023. Ageing and Health [WWW Document]. World Health Organization. URL. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health, 8.16.24.

Wu, Y.-T., Luben, R., Jones, A., 2017. Dog ownership supports the maintenance of physical activity during poor weather in older English adults: cross-sectional results from the EPIC Norfolk cohort. J. Epidemiol. Community Health 71, 905–911. https://doi.org/10.1136/jech-2017-208987.

Yan, X., He, J., Wu, G., Zhang, C., Liu, Z., Wang, C., 2021. Weekly variations and temporal instability of determinants influencing alcohol-impaired driving crashes: a random thresholds random parameters hierarchical ordered probit model. Anal. Methods Accid. Res. 32, 100189. https://doi.org/10.1016/j.amar.2021.100189.

Yasmin, S., Eluru, N., 2013. Evaluating alternate discrete outcome frameworks for modeling crash injury severity. Accid. Anal. Prev. 59, 506–521. https://doi.org/10.1016/j.aap.2013.06.040.

Zandieh, R., Flacke, J., Martinez, J., Jones, P., van Maarseveen, M., 2017. Do inequalities in neighborhood walkability drive disparities in older adults' outdoor walking? Int. J. Environ. Res. Publ. Health 14, 740. https://doi.org/10.3390/ijerph14070740.

Zang, P., Qiu, H., Xian, F., Zhou, X., Ma, S., Zhao, Y., 2021. Research on the difference between recreational walking and transport walking among the elderly in mega cities with different density zones: the case of guangzhou city. Front. Public Health 9. https://doi.org/10.3389/fpubh.2021.775103.

Zang, P., Xian, F., Qiu, H., Ma, S., Guo, H., Wang, M., Yang, L., 2022. Differences in the correlation between the built environment and walking, moderate, and vigorous physical activity among the elderly in low- and high-income areas. Int. J. Environ. Res. Publ. Health 19, 1894. https://doi.org/10.3390/ijerph19031894.