Journal of Physical Activity and Health, (Ahead of Print)
https://doi.org/10.1123/jpah.2025-0499
First Published Online: Nov. 12, 2025

Human Kinetics
ORIGINAL RESEARCH

Neighborhood Environment Attributes are Associated With Disparities in Walking by Exercise Preference

Misaki Takahashi,[1] Shiho Amagasa,[1,2] Noritoshi Fukushima,[2] Masataka Taguri,[3] Yoshiharu Fukuda,[1] Klaus Gebel,[4] Ding Ding,[5] and Shigeru Inoue[2]

[1]Teikyo University Graduate School of Public Health, Tokyo, Japan; [2]Department of Preventive Medicine and Public Health, Tokyo Medical University, Tokyo, Japan; [3]Department of Health Data Science, Tokyo Medical University, Tokyo, Japan; [4]School of Public Health, Faculty of Health, University of Technology Sydney, Ultimo, NSW, Australia; [5]Prevention Research Collaboration, School of Public Health, University of Sydney, Sydney, NSW, Australia

Background: We aimed to investigate the relationship between neighborhood environments and disparities in walking based on exercise preference. ***Methods:*** This nationwide cross-sectional study included 40,423 Japanese adults (aged 20–98 y, male 50.5%) who responded to a web-based survey with stratified sampling in 2021. Neighborhood environment characteristics were assessed using the Japanese version of the International Physical Activity Questionnaire Environmental Module. Weekly time spent walking for leisure and utilitarian purposes was assessed by questionnaire. The Slope Index of Inequality was calculated using a multivariable logistic regression model and was used to examine the relationship between neighborhood environments and walking disparities by exercise preference. ***Results:*** Almost half (45.2%) of the participants did not like exercise. Median total walking time was 180 minutes per week (utilitarian walking: 90 min/wk, leisure walking: 45 min/wk) for those who liked exercise and 100 minutes per week (utilitarian walking: 60 min/wk, leisure walking: 0 min/wk) for those who disliked it. Except for safety from traffic and crime, all walkability attributes were positively associated with walking, regardless of exercise preference. The association between access to shops and public transport and utilitarian walking was stronger among participants who disliked exercise, contributing to a disparity in walking by exercise preference. On the other hand, the presence of recreational facilities was more strongly associated with leisure walking among those who liked exercise, related to a greater disparity in leisure walking by exercise preference. ***Conclusions:*** Activity-friendly neighborhood environments may be associated with a smaller disparity in utilitarian walking between those who liked or disliked exercise.

Keywords: behavioral science, built environment, public health, walkability, epidemiology

Key Points

- Except for safety from traffic and crime, all walkability attributes were positively associated with walking, regardless of exercise preference.
- The association between access to shops and public transport and utilitarian walking was stronger among participants who disliked exercise, contributing to a disparity in walking by exercise preference.
- The presence of recreational facilities was more strongly associated with leisure walking among those who liked exercise, related to a greater disparity in leisure walking by exercise preference.

Physical activity (PA) plays a crucial role in preventing noncommunicable diseases and promoting health.[1–6] However, in 2022, 31.3% of adults worldwide did not meet the recommended levels of PA, and this prevalence has shown little improvement between 2000 and 2022.[7] In Japan, 50.6% of adults did not meet the recommended levels of PA in 2020.[7] Moreover, over the past 20 years, age-adjusted mean step counts among Japanese adults have decreased by approximately 600 to 800 steps per day.[8] Population-level improvement in PA is required for meeting the Global Action Plan on Physical Activity 2018–2030 target of "a 15% relative reduction in the global prevalence of physical inactivity in adults and in adolescents by 2030."[9]

To achieve population-level improvements in PA, it is essential to understand and apply ecological models.[10] These theoretical frameworks explain how health behaviors are influenced by multiple levels of factors—including intrapersonal, interpersonal, organizational, community, and policy—and emphasize the importance of multilevel interventions to achieve sustainable behavior change.[10,11] Given that PA is influenced by a wide range of factors, the application of ecological

Fukushima https://orcid.org/0000-0003-1819-554X
Taguri https://orcid.org/0000-0001-8902-0056
Fukuda https://orcid.org/0000-0003-2099-1924
Gebel https://orcid.org/0000-0003-0330-7756
Ding https://orcid.org/0000-0001-9850-9224
Inoue https://orcid.org/0000-0003-1931-2613
Amagasa (shiho.ama@gmail.com) is corresponding author, https://orcid.org/0000-0002-6047-0771

models is particularly relevant.[11] In addition to social and psychological factors, environmental and policy contexts matter and explain variations across PA domains such as leisure, transport, occupational, and household activities.[10] Ecological models thus provide a valuable framework for understanding how complex interactions across these levels can either promote or obstruct PA.[10,11]

Creating activity-friendly environments is an important strategy for improving population-level PA.[9,12,13] Many studies have demonstrated the association between neighborhood environment characteristics, such as access to shops and public transport, sidewalks, recreational facilities, aesthetics and safety, and PA, especially walking behavior.[14–16] Walking has been the most widely used indicator in epidemiological studies on environment and PA, as it is the most fundamental form of PA and conceptually aligned with environmental attributes.[14–16] Although these environmental attributes are generally recognized as conducive to walking, several studies have reported that their contributions can vary by psychological attributes of individuals, highlighting potential interactions between environmental and individual factors of walking.[17–20] However, previous research on the interaction between environmental and psychosocial attributes of walking has resulted in inconsistent findings.[17–20] Some studies have found the association between built environments and walking to be stronger in adults with less favorable attitudes toward walking,[17,19,20] whereas one study suggested the opposite.[18] Negative attitudes toward PA, such as dislike of exercise, have been identified as significant psychological factors influencing PA levels.[21,22] In addition, prior research has mainly tested the interactions, without explicitly examining how environmental conditions contribute to disparities in walking among individuals with different attitudes toward PA. Research using inequality indices to quantify such disparities remains limited. Therefore, this study aimed to examine how neighborhood environmental characteristics are associated with disparities in walking between those who like exercise versus those who do not.

Methods

Participants and Data Collection

This cross-sectional study used data from the Survey on Neighborhood Environment and Physical Activity and Health, a nationwide web-based survey conducted in Japan in December 2021. Participants were recruited from a large-scale survey panel managed by Rakuten Insight (formerly Rakuten Research), a major nationwide internet research agency in Japan, which had approximately 2.2 million registered panelists in 2022. We targeted participants in 95 cities, including 70 cities that participated in the Nationwide Person Trip Survey[23] conducted by the Ministry of Land, Infrastructure, Transport, and Tourism in 2015, 2 cities (Himeji and Yanagawa) that have participated in the Ministry of Land, Infrastructure, Transport, and Tourism's "City Walkability Promotion Program,"[24] and an additional 23 prefectural capital cities that were not included in the above categories.

A total of 62,400 adults residing in 95 cities with urban to rural areas were included in the study. In 94 of the 95 cities (except for Kobe City), 600 participants were selected per city using stratified sampling: 100 individuals from each age group (20–29, 30–39, 40–49, 50–59, 60–69, and 70+ years) with an equal gender ratio, resulting in a total of 56,400 participants. In Kobe City, for another research purpose, the target sample was 6000, using the same sampling method: 1000 individuals from each age group, also with an equal gender distribution.

For the analysis, the 95 cities were classified into 5 categories based on the Urban Classification Table of the Ministry of Land, Infrastructure, Transport, and Tourism: (1) 3 major metropolitan areas (major metro areas), (2) regional core urban areas (core urban areas), (3) regional central urban areas with a central city population of 400,000 or more (large central urban areas), (4) regional central urban areas with a central city population of less than 400,000, and (5) regional primary urban areas (small central urban areas).[25] Ethical approval for this study was obtained from the ethics committees of Tokyo Medical University (T2021-0211) and Teikyo University (23-004-2).

Assessment of the Neighborhood Environment (Independent Variables)

Perceived Neighborhood Environment

The International Physical Activity Questionnaire Environmental Module (IPAQ-E) Japanese version was used to assess participants' perceived neighborhood environment.[26–28] In previous studies, IPAQ-E showed good test–retest reliability (Spearman correlation coefficients: .79–.99, kappa statistics: .63–.97)[27] and moderate to strong construct validity (Spearman correlation coefficients: .27–.81) with corresponding subscales of the established Neighborhood Environment Walkability Scale–Abbreviated.[28] Several of the items from the IPAQ-E have been linked to PA in international research across 11 countries.[29] This questionnaire consists of 17 items, of which 9 core items were included in this study: (1) access to shops (a proxy for land use mix), (2) access to public transport, (3) sidewalks, (4) recreational facilities, (5) crime safety, (6) traffic safety, (7) seeing many people being physically active in my neighborhood (social environment), (8) aesthetics, and (9) bike lanes. The "bike lanes" was excluded because it did not conceptually match the outcome (walking), leaving a total of 8 items analyzed. Participants rated these items on a 4-point Likert scale ranging from "strongly disagree" to "strongly agree." In this questionnaire, "neighborhood" was defined as the area within a 10- to 15-minute walk from a participant's residence.

Objective Neighborhood Environment

We used the Japan postcode-level walkability index (JPWI) as an objective indicator of neighborhood walkability.[30] Briefly, the JPWI was derived from 3 elements—population density, intersection density, and the number of facility types (land use mix)—measured within a 1000-m road network buffer around the representative point of each postcode area.[30] Each component was square root transformed, standardized to obtain the index, with higher values indicating more walkable neighborhoods (mean: 0.00 [0.94], range: −1.85 to 2.59). Participants' self-reported residential postcodes were linked to the publicly available JPWI data set,[30] and the corresponding postcode-level JPWI value was assigned to each participant.

Assessment of PA (Dependent Variables)

A self-administered questionnaire was used to assess domain-specific walking. Participants were asked to report the frequency of walking (days per week) and the average duration of walking (minutes per day) for different purposes, including walking for leisure, commuting, shopping, and other purposes. A previous study has validated domain-specific walking assessments.[16] In this study, walking was divided into leisure walking and utilitarian walking (ie, commuting, shopping, and other purposes), as the

relationship between environmental characteristics and PA depends on the context of the PA.[31–33]

Exercise Preference

Exercise preference was assessed with a single item in the self-administered questionnaire, "Do you like exercise?" Those who responded "yes" were classified as "like exercise," whereas those who responded "no" were classified as "dislike exercise." In Japan, the concept of "exercise preference" is widely recognized, and "dislike of exercise" ("undō-girai") is generally understood as a broad term describing individuals with negative attitudes, emotions, or behaviors toward exercise or sport.

Sociodemographic Variables (Covariates)

Sociodemographic variables included age (<65 y and ≥65 y), gender, years of education (<13 y and ≥13 y), employment status (employed and unemployed), household income (<4,000,000, 4,000,000–7,999,999, and ≥8,000,000 yen), living arrangement (living alone/living with others), frequency of driving (<3 and ≥3 d/wk), body mass index (calculated as weight [in kilograms] divided by height squared [in meter squared] and categorized as <18.5, 18.5–24.9, and ≥25.0), self-rated health (good and poor), Kessler 6 Scale (a psychological distress scale consisting of 6 items, with scores ranging from 0 to 24, categorized as <5 and ≥5 points),[34,35] and smoking status (smoker and nonsmoker). We selected these variables as covariates based on previous studies examining the association between neighborhood environments and PA.[11,16,36]

Statistical Analysis

Differences in participants' characteristics between individuals who like and dislike exercise were examined using Fisher exact test for categorical variables and the Wilcoxon rank-sum test for continuous variables. The Slope Index of Inequality (SII) was employed to assess how environmental differences contribute to disparities in walking time by exercise preference. The SII is an absolute measure of inequality commonly used to evaluate health inequalities across different socioeconomic groups.[37] If a health outcome is completely equally distributed, the SII equals 0.[38] Higher values of SII indicate greater disparities.[38]

In this study, the SII was calculated using the environmental characteristics from the IPAQ-E, maintaining their original 4-point scale: "very poor," "somewhat poor," "somewhat good," and "very good." Each category was assigned a rank based on the cumulative distribution midpoint, ranging from 0 (most disadvantaged) to 1 (most advantaged). The dependent variables, walking time for leisure, respectively utilitarian purposes, were dichotomized as 0 minutes per week or more than 0 minutes per week. These dependent variables were regressed against the midpoint values using a logistic regression model adjusted for participant's characteristics. The SII was calculated as the absolute difference in predicted values between 2 extremes (rank = 1 and rank = 0).[37,39,40] The SIIs were calculated separately for individuals who liked or disliked exercise, and the differences between the groups were compared using *Z*-tests.[38] In addition, we conducted similar analyses using the JPWI as an objective measure. Participants' postcode-linked JPWI values were categorized into quartiles (Q1–Q4) based on the sample distribution, and SIIs were computed as above. All analyses were performed using R version 4.4.0. A p value of <.05 was regarded as statistically significant.

Results

A total of 48,128 participants responded to the survey. To ensure consistency across cities, 600 responses were randomly selected from the 5369 respondents in Kobe City and included in the present analysis. After data cleaning, 2936 participants who completed the survey in an unusually short time (<6 min) or provided outlier responses were excluded. Finally, data from 40,423 residents were included in the analysis (Figure 1).

Table 1 shows the characteristics of the study participants. The mean age of the participants was 49.4 (15.6) years and 49.5% were

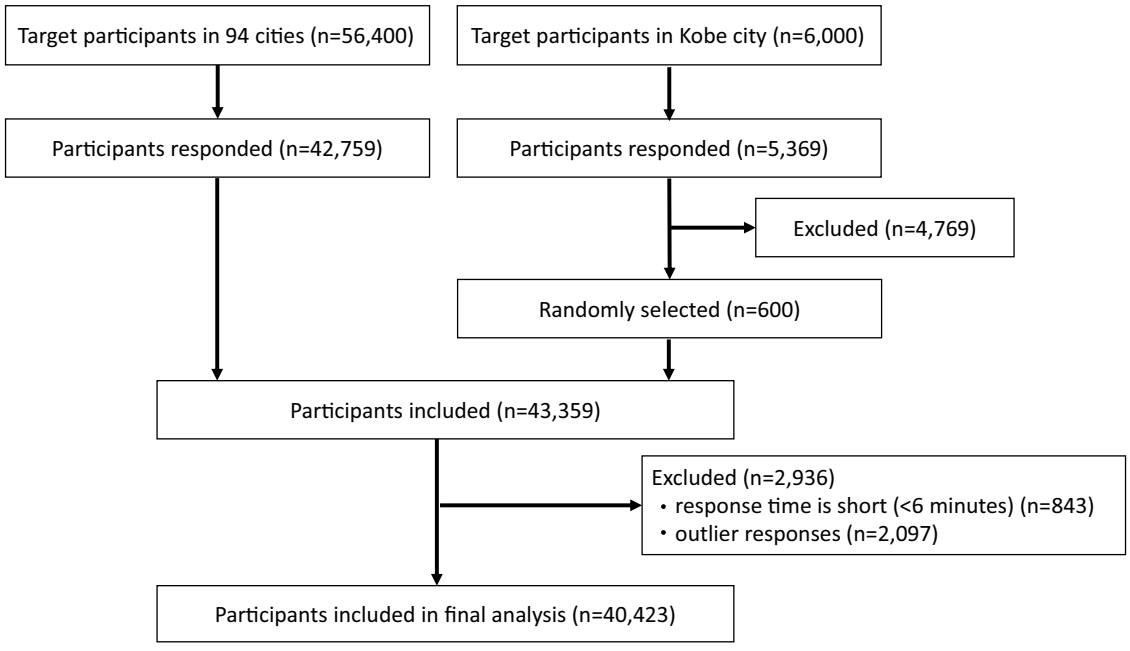

Figure 1 — Participant flow.

Table 1 Characteristics of Study Participants

	Overall N = 40,423 n (%)	Like exercise n = 22,161 n (%)	Dislike exercise n = 18,262 n (%)	*P*
Gender				<.001
Woman	20,016 (49.5%)	9261 (41.8%)	10,755 (58.9%)	
Age				<.001
≥65 y	7951 (19.7%)	4611 (20.8%)	3340 (18.3%)	
Residential area				.033
Major metro areas	14,548 (36.0%)	8089 (36.5%)	6459 (35.4%)	
Core urban areas	4656 (11.5%)	2577 (11.6%)	2079 (11.4%)	
Large central urban areas	8301 (20.5%)	4533 (20.5%)	3768 (20.6%)	
Small central urban areas	12,918 (32.0%)	6962 (31.4%)	5956 (32.6%)	
Education				<.001
≥13 y	27,610 (68.3%)	15,855 (71.5%)	11,755 (64.4%)	
Employment status				<.001
Employed	29,011 (71.8%)	16,551 (74.7%)	12,460 (68.2%)	
Household income				<.001
<4,000,000 yen	14,222 (35.2%)	6915 (31.2%)	7307 (40.0%)	
4,000,000–7,999,999 yen	17,213 (42.6%)	9716 (43.8%)	7497 (41.1%)	
≥8,000,000 yen	8988 (22.2%)	5530 (25.0%)	3458 (18.9%)	
Living arrangement				<.001
Living with others	33,940 (84.0%)	18,831 (85.0%)	15,109 (82.7%)	
Driving				<.001
≥3 d/wk	22,872 (56.6%)	13,272 (59.9%)	9600 (52.6%)	
BMI				<.001
<18.5 kg/m^2	4423 (10.9%)	2090 (9.4%)	2333 (12.8%)	
18.5–24.9 kg/m^2	27,856 (68.9%)	16,111 (72.7%)	11,745 (64.3%)	
≥25.0 kg/m^2	8144 (20.1%)	3960 (17.9%)	4184 (22.9%)	
Self-rated health				<.001
Good	33,127 (82%)	19,546 (88.2%)	13,581 (74.4%)	
K6				<.001
≥5 points	17,138 (42.4%)	8129 (36.7%)	9009 (49.3%)	
Smoking status				.009
Nonsmoker	33,646 (83.2%)	18,543 (83.7%)	15,103 (82.7%)	
Total walking time (min/wk)	140 (45, 300)	180 (65, 350)	100 (25, 230)	<.001
Utilitarian walking time (min/wk)	75 (20, 180)	90 (27, 200)	60 (5, 150)	<.001
Leisure walking time (min/wk)	20 (0, 120)	45 (0, 150)	0 (0,60)	<.001

Abbreviations: BMI, body mass index; K6, the 6-item Kessler psychological distress scale. Note: Walking time is presented as the median (interquartile range). Other variables are presented as n (%). Comparisons between those who like and dislike exercise were conducted using the Wilcoxon rank-sum test for walking time and Fisher exact test for categorical variables.

female. Almost half (45.2%) of the participants did not like exercise. There were significant differences in time spent walking between those who liked and disliked exercise. The median total walking time was 180 minutes per week (interquartile range: 65, 350) for those who liked exercise and 100 minutes per week (25, 230) for those who disliked it ($P < .001$). The median utilitarian walking time was 90 minutes per week (interquartile range: 27, 200) for those who liked exercise and 60 minutes per week (5, 150) for those who disliked it ($P < .001$). The median leisure walking time was 45 minutes per week (interquartile range: 0, 150) for those who liked exercise and 0 minutes per week (0, 60) for those who disliked it ($P < .001$). The JPWI values for the areas where the participants of this study resided range from −1.85 to 2.59, covering the entire areas across Japan.

The results for SII are presented in Figure 2. All neighborhood environmental characteristics, except for safety from crime and safety from traffic, exhibited significantly positive SII values, regardless of exercise preference.

For utilitarian walking, among all environmental characteristics, the highest SII was observed for access to shops in both those who like and dislike exercise, with values of 11.6 (95% CI, 10.1–13.0) and 14.4 (95% CI, 12.6–16.2), respectively. When comparing those who liked exercise with those who disliked it, the SII values for access to shops and access to public transport were

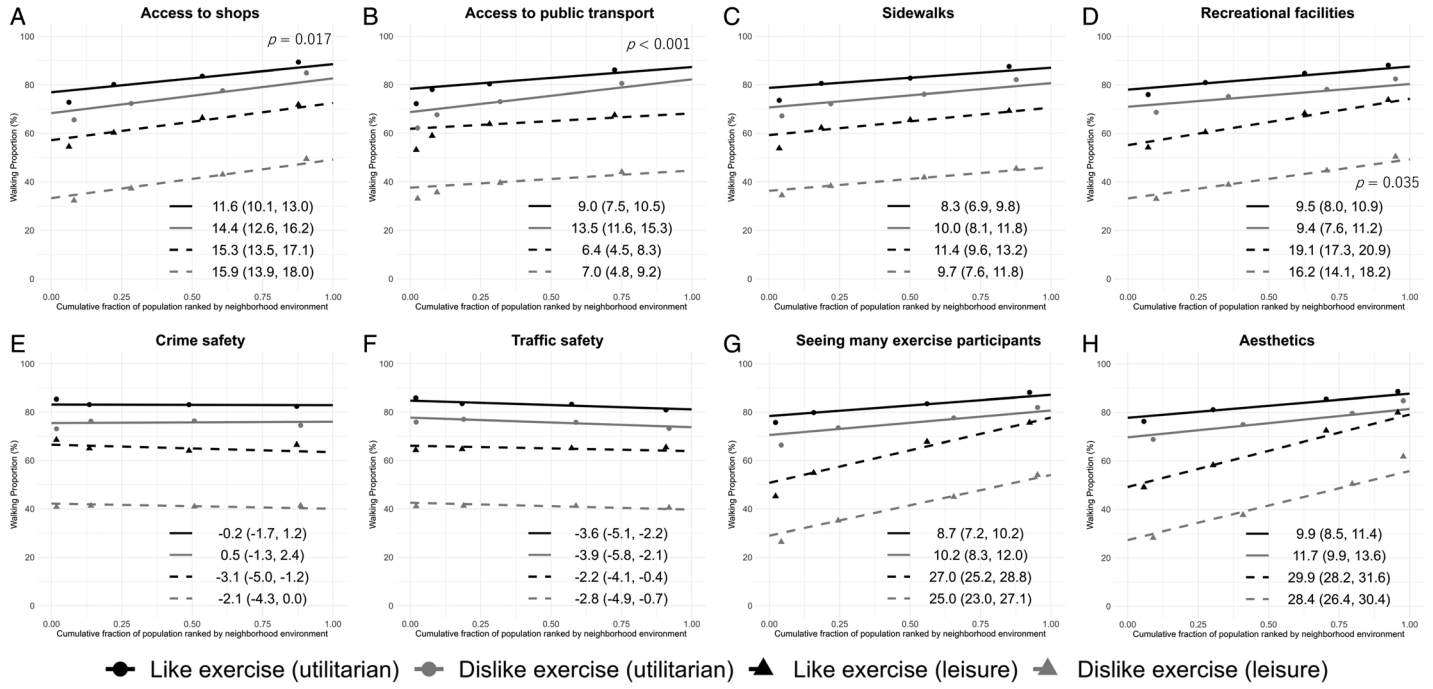

Figure 2 — Slope Index of Inequality (SII) for utilitarian and leisure walking by exercise preference across neighborhood environments. Dots represent observed values. Line slopes represent the SII. Values indicate SII (95% CIs). *P* values indicate differences in SII between exercise preference groups. Adjusted for gender, age, residential area, education, employment status, household income, living arrangement, driving status, BMI, self-rated health, K6, and smoking status. BMI indicates body mass index; K6, 6-item Kessler psychological distress scale.

significantly higher among those who disliked exercise ($P = .017$ and $P < .001$, respectively).

For leisure walking, aesthetics showed the highest SII in both groups, with values of 29.9 (95% CI, 28.2–31.6) for individuals who liked exercise and 28.4 (95% CI, 26.4–30.4) for those who disliked it. When comparing the 2 groups, the SII value for recreational facilities was significantly higher among those who liked exercise ($P = .035$).

The SII values for safety from crime were not significantly associated with utilitarian walking, regardless of exercise preference. For safety from traffic, negative SII values were observed for both utilitarian and leisure walking in both exercise preference groups.

In analyses using the JPWI, SII for utilitarian walking was 12.5 (95% CI, 11.0–13.9) among individuals who liked exercise and 14.4 (95% CI, 12.6–16.2) among those who disliked it (Supplementary Figure S1 [available online]). For leisure walking, the corresponding SII values were 10.6 (95% CI, 8.8–12.5) and 12.5 (95% CI, 10.4–14.6), respectively. Differences between exercise preference groups were not statistically significant (utilitarian: $P = .108$; leisure: $P = .190$).

Discussion

This study examined the association between neighborhood environmental characteristics and walking disparities between individuals who liked or disliked exercise in a Japanese adult population. We found that walking time for utilitarian purposes and particularly for leisure was shorter among those who disliked exercise than among those who liked it. For all of the environmental characteristics, except for safety from traffic and safety from crime, favorable environments were associated with walking, regardless of exercise preference. Associations of specific environmental attributes, such as good access to shops and public transport, with utilitarian walking were stronger among individuals who disliked exercise. This pattern may contribute to a smaller disparity in utilitarian walking by exercise preference. On the other hand, the presence of recreational facilities was more strongly associated with leisure walking among those who liked exercise, which may be related to a greater disparity in leisure walking by exercise preference.

Our finding that individuals who disliked exercise walk less than individuals who liked it is consistent with previous research reporting that the dislike of exercise was associated with leisure-time physical inactivity among adults.[21] In addition, a qualitative study using semistructured in-depth interviews identified disliking exercise as one of the major barriers to PA among undergraduates.[22] Furthermore, the median walking time for leisure was 0 minutes per week among individuals who disliked exercise, compared with 45 minutes per week among those who liked it. A large proportion of participants who disliked exercise did not engage in leisure walking, suggesting that it may be a particularly undesirable activity for them. This may be partly explained by the nature of leisure walking. Utilitarian walking, such as walking for commuting or shopping, is often driven by necessity and may be less influenced by exercise preference. By contrast, engaging in leisure walking may require a certain level of interest or enjoyment, which could make it more susceptible to differences in individuals' exercise preference.

Regarding utilitarian walking, the SII value for access to shops was the highest among all environmental characteristics in both exercise preference groups. When comparing individuals who liked exercise with those who disliked it, the SII values for access to shops and access to public transport were significantly higher among individuals who disliked exercise. These findings suggest

that good accessibility to shops and public transport may play a key role in promoting utilitarian walking, particularly among individuals who are otherwise less inclined to engage in PA, such as those who dislike exercise. Therefore, improving accessibility may contribute to a smaller disparity in walking and potentially increasing overall PA levels in the population.

For leisure walking, the SII values for aesthetics and the presence of many physically active people in the neighborhood were considerably higher than those for other environmental characteristics, regardless of exercise preference. Furthermore, there were no significant differences in SII values between those who liked or disliked exercise. By contrast, the SII value for recreational facilities was significantly higher among individuals who liked exercise. This suggests that certain environmental characteristics, such as aesthetics and the presence of many physically active people in the neighborhood, may be associated with higher levels of leisure walking without contributing to a greater disparity by exercise preference. By contrast, recreational facilities may be associated with a greater disparity in leisure walking. These findings highlight the importance of examining not only the general associations between environments and walking but also the potential variation in these associations across different population subgroups. Environmental characteristics that are perceived as favorable by a broad range of individuals, regardless of exercise preference, may be more likely to support equitable patterns of leisure walking. By contrast, environments that tend to align with exercise preference may be associated with a greater disparity in leisure walking. From a public health and urban planning perspective, it may be worthwhile to consider inclusive environmental improvements—such as enhancing neighborhood aesthetics and fostering socially supportive environments—that could encourage leisure walking among individuals who like or dislike exercise.

According to the SII results, safety from crime was not significantly associated with walking, except for leisure walking among individuals who liked exercise. For traffic safety, the SII showed significantly negative values for both utilitarian and leisure walking, regardless of exercise preference. This indicates that a higher proportion of walking was observed in areas with heavy traffic where individuals perceived walking as dangerous, irrespective of whether they liked or disliked exercise. Previous studies have reported inconsistent findings regarding the relationships between crime safety, traffic safety, and walking.[14,16,27] In addition, some studies have suggested that the relationship between these environmental factors and walking may vary by context.[41] With regard to traffic safety, areas with higher traffic volumes tend to have greater land use mix-diversity, which may, in turn, promote walking.[42]

This study has several limitations. First, walking was assessed using a self-reported questionnaire, which is prone to biases.[43,44] However, a strength of questionnaires is that they enable measuring domain-specific walking. Second, as this study was conducted through an internet-based survey targeting a specific panel of survey respondents, selection bias may have occurred among the participants. Third, based on previous studies,[16,42,45] walking during work was excluded from the analysis as it typically occurs outside the participant's neighborhood, which may have affected the results. We acknowledge that, given the large sample size, it is likely that some of the participants would live only a few minutes walking distance away from work. Fourth, as this was a cross-sectional study, reverse causation cannot be ruled out. Although several environmental attributes could be assessed with some degree of objectivity using the JPWI, others, particularly aesthetics and the presence of many physically active people in the neighborhood, were assessed by self-report and are susceptible to reverse causation. Fifth, although the study included participants from a wide range of regions across Japan, a relatively large proportion were from areas with high JPWI compared with the national population distribution. Therefore, caution should be paid when interpreting the results. Finally, the generalizability of our study's findings may be limited in countries with higher crime rates or differing environmental contexts.[46] For example, a previous review on promoting PA in low- and middle-income countries discussed how PA choices and needs vary in different contexts, suggesting that in regions with higher crime rates or less favorable environmental conditions, walking may be influenced more by necessity than personal preference, which may not align with our study's findings in Japan.[46] Further research in diverse contexts may be needed.

Conclusions

Our findings suggest that the association between access to shops and public transport and utilitarian walking was stronger among participants who disliked exercise, contributing to a smaller disparity in walking by exercise preference. On the other hand, the presence of recreational facilities was more strongly associated with leisure walking among those who liked exercise, which may be related to a greater disparity in leisure walking by exercise preference. Understanding the role that environmental attributes play in disparities in walking helps inform decision making in urban design and transportation to improve population-level PA more equitably.

Acknowledgments

We express our sincere thanks to all participants who responded to the questionnaire for this study. We are most grateful to the funding bodies that supported our research. **Funding Source:** This research was supported by AMED under grant number JP25ck0106004 and the Japanese Ministry of Health, Labor, and Welfare (grant number: 22FB0201 and 25FA2001).

References

1. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012;380(9838):219–229. PubMed ID: 22818936 doi:10.1016/S0140-6736(12)61031-9
2. Ammar A, Trabelsi K, Hermassi S, et al. Global disease burden attributed to low physical activity in 204 countries and territories from 1990 to 2019: Insights from the global burden of disease 2019 study. *Biol Sport*. 2023;40(3):835–855. PubMed ID: 37398951 doi:10.5114/biolsport.2023.121322
3. Schuch FB, Stubbs B, Meyer J, et al. Physical activity protects from incident anxiety: a meta-analysis of prospective cohort studies. *Depress Anxiety*. 2019;36(9):846–858. PubMed ID: 31209958 doi:10.1002/da.22915
4. Schuch FB, Vancampfort D, Firth J, et al. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry*. 2018;175(7):631–648. PubMed ID: 29690792 doi:10.1176/appi.ajp.2018.17111194
5. Northey JM, Cherbuin N, Pumpa KL, Smee DJ, Rattray B. Exercise interventions for cognitive function in adults older than 50: a systematic review with meta-analysis. *Br J Sports Med*. 2018;52(3):154–160. PubMed ID: 28438770 doi:10.1136/bjsports-2016-096587
6. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451–1462. doi:10.1136/bjsports-2020-102955

7. Strain T, Flaxman S, Guthold R, et al. National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5·7 million participants. *Lancet Glob Health*. 2024;12(8):e1232–e1243. PubMed ID: 38942042 doi:10.1016/S2214-109X(24)00150-5
8. Takamiya T, Inoue S. Trends in step-determined physical activity among Japanese adults from 1995 to 2016. *Med Sci Sports Exerc*. 2019;51(9):1852–1859. PubMed ID: 30933002 doi:10.1249/MSS.0000000000001994
9. World Health Organization. *Global Action Plan on physical Activity 2018–2030: More Active People for a Healthier World*. 2018:20–45.
10. Sallis JF, Owen N, Fisher E. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, eds. *Health Behavior: Theory, Research, and Practice*. 5th ed. John Wiley & Sons, Inc.; 2015:43–64.
11. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380(9838):258–271. PubMed ID: 22818938 doi:10.1016/S0140-6736(12)60735-1
12. Giles-Corti B, Gunn L, Hooper P, et al. Built environment and physical activity. In: Nieuwenhuijsen M, Khreis H, eds. *Integrating Human Health Into Urban and Transport Planning*. Springer International Publishing; 2019:347–381.
13. Gebel K, Bauman AE, Bull FC. Built environment: Walkability of neighbourhoods. In: Killoran A, Rayner M, eds. *Evidence-Based Public Health: Effectiveness and Efficiency*. Oxford University Press; 2010:298–312.
14. Barnett DW, Barnett A, Nathan A, Van Cauwenberg J, Cerin E. Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):103. doi:10.1186/s12966-017-0558-z
15. Cerin E, Nathan A, van Cauwenberg J, Barnett DW, Barnett A. The neighbourhood physical environment and active travel in older adults: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2017;14(1):15. doi:10.1186/s12966-017-0471-5
16. Inoue S, Ohya Y, Odagiri Y, et al. Association between perceived neighborhood environment and walking among adults in 4 cities in Japan. *J Epidemiol*. 2010;20(4):277–286. PubMed ID: 20472982 doi:10.2188/jea.JE20090120
17. Ding D, Sallis JF, Conway TL, et al. Interactive effects of built environment and psychosocial attributes on physical activity: a test of ecological models. *Ann Behav Med*. 2012;44(3):365–374. PubMed ID: 22899301 doi:10.1007/s12160-012-9394-1
18. Carlson JA, Sallis JF, Conway TL, et al. Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Prev Med*. 2012;54(1):68–73. PubMed ID: 22027402 doi:10.1016/j.ypmed.2011.10.004
19. Van Dyck D, Cerin E, Conway TL, et al. Interacting psychosocial and environmental correlates of leisure-time physical activity: a three-country study. *Health Psychol*. 2014;33(7):699–709. PubMed ID: 24245836 doi:10.1037/a0033516
20. Beenackers MA, Kamphuis CB, Prins RG, Mackenbach JP, Burdorf A, van Lenthe FJ. Urban form and psychosocial factors: do they interact for leisure-time walking? *Med Sci Sports Exerc*. 2014;46(2):293–301. PubMed ID: 24051658 doi:10.1249/MSS.0000000000000017
21. Reichert FF, Barros AJ, Domingues MR, Hallal PC. The role of perceived personal barriers to engagement in leisure-time physical activity. *Am J Public Health*. 2007;97(3):515–519. PubMed ID: 17267731 doi:10.2105/AJPH.2005.070144
22. Othman MS, Mat Ludin AF, Chen LL, et al. Motivations, barriers and exercise preferences among female undergraduates: a need assessment analysis. *PLoS One*. 2022;17(2):e0264158. doi:10.1371/journal.pone.0264158
23. Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Guidance for Urban Transport Surveys. 2024. Accessed September 18, 2025. https://www.mlit.go.jp/toshi/tosiko/toshi_tosiko_tk_000024.html
24. Ministry of Land, Infrastructure, Transport and Tourism (MLIT). City Walkability Promotion Program. 2020. Accessed September 18, 2025. https://www.mlit.go.jp/toshi/toshi_gairo_tk_000092.html
25. Ministry of Land I, Transport and Tourism (MLIT). Urban Classification Table. 2018. Accessed March 11, 2025. https://www.mlit.go.jp/common/001241794.pdf
26. Alexander A, Bergman P, Hagströmer M, Sjöström M. IPAQ environmental module; reliability testing. *J Public Health*. 2006;14(2):76–80. doi:10.1007/s10389-005-0016-2
27. Inoue S, Murase N, Shimomitsu T, et al. Association of physical activity and neighborhood environment among Japanese adults. *Prev Med*. 2009;48(4):321–325. PubMed ID: 19463488 doi:10.1016/j.ypmed.2009.01.014
28. Sallis JF, Kerr J, Carlson JA, et al. Evaluating a brief self-report measure of neighborhood environments for physical activity research and surveillance: Physical Activity Neighborhood Environment Scale (PANES). *J Phys Act Health*. 2010;7(4):533–540. PubMed ID: 20683096 doi:10.1123/jpah.7.4.533
29. Sallis JF, Bowles HR, Bauman A, et al. Neighborhood environments and physical activity among adults in 11 countries. *Am J Prev Med*. 2009;36(6):484–490. PubMed ID: 19460656 doi:10.1016/j.amepre.2009.01.031
30. Tanimoto R, Hanibuchi T, Nakaya T. Development of Japan post-code-level walkability index and examination of its usefulness. *Q J Geogr*. 2023;75(1):16–26. doi:10.5190/tga.75.1_16
31. Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. Understanding environmental influences on walking, review and research agenda. *Am J Prev Med*. 2004;27(1):67–76. PubMed ID: 15212778 doi:10.1016/j.amepre.2004.03.006
32. Van Holle V, Deforche B, Van Cauwenberg J, et al. Relationship between the physical environment and different domains of physical activity in European adults: a systematic review. *BMC Public Health*. 2012;12(1):807. doi:10.1186/1471-2458-12-807
33. Gebel K, Bauman AE, Owen N, Foster S, Giles-Corti B. *Position Statement: The Built Environment and Walking*. National Heart Foundation; 2009.
34. Kessler RC, Andrews G, Colpe LJ, et al. Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychol Med*. 2002;32(6):959–976. PubMed ID: 12214795 doi:10.1017/S0033291702006074
35. Sakurai K, Nishi A, Kondo K, Yanagida K, Kawakami N. Screening performance of K6/K10 and other screening instruments for mood and anxiety disorders in Japan. *Psychiatry Clin Neurosci*. 2011;65(5):434–441. PubMed ID: 21851452 doi:10.1111/j.1440-1819.2011.02236.x
36. Loyen A, Wendel-Vos GCW, Shekoh MI, Verschuren WMM, Picavet HSJ. 20-year individual physical activity patterns and related characteristics. *BMC Public Health*. 2022;22(1):437. doi:10.1186/s12889-022-12862-1
37. Hosseinpoor AR, Bergen N, Kunst A, et al. Socioeconomic inequalities in risk factors for non communicable diseases in low-income and middle-income countries: results from the World Health Survey. *BMC Public Health*. 2012;12:912. doi:10.1186/1471-2458-12-912
38. Hyldgård VB, Johnsen SP, Søgaard R. Index-based inequality in quality of care: an empirical comparison of apples and pears. *Clin Epidemiol*. 2021;13:791–800. PubMed ID: 34512032 doi:10.2147/CLEP.S311813
39. Regidor E. Measures of health inequalities: part 2. *J Epidemiol Community Health*. 2004;58(11):900–903. PubMed ID: 15483304 doi:10.1136/jech.2004.023036

40. World Health Organization. *Handbook on Health Inequality Monitoring: With a Special Focus on Low-and Middle-Income Countries*. World Health Organization; 2013.
41. Ding D, Adams MA, Sallis JF, et al. Perceived neighborhood environment and physical activity in 11 countries: do associations differ by country? *Int J Behav Nutr Phys Act*. 2013;10(1):57. doi:10.1186/1479-5868-10-57
42. Zhou R, Li Y, Umezaki M, et al. Association between physical activity and neighborhood environment among middle-aged adults in Shanghai. *J Environ Public Health*. 2013;2013:239595. doi:10.1155/2013/239595
43. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act*. 2008;5(1):56. doi:10.1186/1479-5868-5-56
44. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181–188. PubMed ID: 18091006 doi:10.1249/mss.0b013e31815a51b3
45. Sales D, Matsudo V, Fisberg M, Drenowatz C, Marques A, Ferrari G. Perception of the neighborhood environment, physical activity by domain and sitting time in Brazilian adults. *Int J Environ Res Public Health*. 2022;19(23):15744. doi:10.3390/ijerph192315744
46. Salvo D, Jáuregui A, Adlakha D, Sarmiento OL, Reis RS. When moving is the only option: the role of necessity versus choice for understanding and promoting physical activity in low- and middle-income countries. *Annu Rev Public Health*. 2023;44(1):151–169. doi:10.1146/annurev-publhealth-071321-042211