sustainability

Review

Green Space and Physical Activity in China: A Systematic Review

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Abstract: Green space may play an essential role in residents' physical activity (PA), but evidence remains scattered in China. This study systematically reviewed scientific evidence regarding the influence of green space on PA among residents in China. Keyword and reference searches were conducted in PubMed, Web of Science, Scopus, EBSCO, and CNKI from the inception of an electronic bibliographic database to May 2021. Eligibility criteria included the following: study designs—observational (e.g., longitudinal or cross-sectional studies) and experimental studies; study subjects—people of all ages; exposures—green space (e.g., parks, vegetation areas, open green fields); outcomes—leisure-time and work/school-related PA (e.g., active commuting); and country—China. All but two studies identified at least one measure of green space to be associated with PA. Street greenness was associated with increased odds of active commuting (e.g., cycling) and walking, and a reduced risk of physical inactivity. Access to green space was associated with increased PA levels and green space usage. Distance to green space was inversely associated with the odds of PA. By contrast, evidence linking overall greenness exposure to PA remains limited. Future studies adopting experimental study design are warranted to establish more robust scientific evidence of causality between green space and PA in China. Future studies are also warranted to examine the underlining mechanisms and the differential impacts of green space on population subgroups in China.

Keywords: green space; parks; exercise; physical activity; China; review

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1. Introduction

Physical inactivity is a leading risk factor for major non-communicable diseases such as type 2 diabetes, coronary heart disease, and cancer [1]. Based on the 2014 National Fitness Survey, only 15% of adults in China regularly engaged in 30 or more minutes per day of moderate-to-vigorous intensity physical activity (MVPA) on 3 days per week [2]. Based on the 2016 Physical Activity and Fitness: The Youth Study, less than 30% of children and adolescents met the recommendation of 60 or more minutes of daily MVPA made by the World Health Organization (WHO) [3,4].

Green space (e.g., parks, gardens, forests, and greenways) consists of land areas which are covered with grass, trees, shrubs, or other vegetation [5]. Green space exposure is linked to reduced risks of all-cause mortality, cardiovascular disease, respiratory disease, diabetes, stress, anxiety, and depression [6,7]. It may also contribute to long-term health benefits for residents through the creation of a free, low-cost environment for physical activity (PA) [8,9]. Green space has received increasing attention in public health research and has been recognized as an essential environmental factor for PA engagement [8,9]. People exercising in green space focus on environmental factors, such as natural surroundings, rather than individual factors such as body image or appearance-enhancement when compared with those participating in sports and gym-based exercises [10]. PA in an outdoor natural environment may provide greater health benefits than exercising indoors [11]. The unique benefits of nature-based exercise are centered on notions of the affordances and variability of nature [12]. Exposure to nature contributes to improving cognitive function, brain activity, blood pressure, mental health, and sleep [13].

A large body of literature has examined green space in relation to PA [14–16]. For example, people living in neighborhoods with higher levels of green space were found to engage in more PA [17]. The availability of green space was associated with an increased likelihood of achieving the PA level recommended by guidelines [18]. Improved access to urban parks and green spaces has been shown to increase PA [14,19,20]. However, conflicting evidence is also present. For example, Hillston et al. found that distance to green space was not associated with self-reported leisure-time PA in the U.K. [15]. Similarly, access to parks was not associated with PA in New Zealand [21]. Discrepancies across studies could be partially due to the heterogeneous populations and geographical locations under examination, as well as differences in research methods (e.g., cross-sectional vs. longitudinal study designs) and measurements (e.g., objective vs. self-perceived green space measures). The usage of green space for PA may be different among people from different socio-economic strata and cultural backgrounds [16,22]. Most previous studies on green space and PA focused exclusively on populations in developed countries (e.g., the USA, the U.K., New Zealand, or Australia), though research on people residing in China has increased gradually in recent years. China has experienced a rapid urbanization process, with the urbanization rate increasing from 49.7% in 2010 to nearly 64% in 2020 [23]. Although urbanization has inevitably affected green space, the government has taken measures to protect and improve green space. The forest coverage rate in China reached 23.04% in 2020 from only 8.6% in 1949 [24]. The green coverage rate increased to 41.15% in 2019 in urban areas [25]. Moreover, China possesses unique characteristics in terms of physical activity pattern and built environment, which may differ from those of other countries. However, evidence regarding the relationship between green space and physical activity is still scattered.

This study aimed to systematically review the existing literature regarding the impact of green space on PA among residents in China, and to contribute to the literature in the following three ways: First, it synthesized and contrasted studies conducted in different countries, which facilitated a multifaceted overview of the impact of green space on PA. Second, it assessed the potential mechanisms linking green space to PA, with pathways grounded in a conceptual framework that could inform behavioral interventions. Third, study findings could be valuable to policymakers and stakeholders such as urban planners in designing or modifying certain features of green space in order to promote a healthier lifestyle.

2. Methods

The systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [26].

2.1. Study Selection Criteria

Studies that met all of the following criteria were included in the review: (1) Study designs: observational studies (e.g., longitudinal or cross-sectional studies), or experimental studies; (2) Study subjects: people of all ages; (3) Exposures: various green space types and measures (e.g., parks, vegetation areas, or open green fields); (4) Outcomes: leisure-time or work/school-related PA (e.g., active commuting); (5) Type of outcomes measure: Objective and/or subjective PA measure; (6) Article type: peer-reviewed publications; (7) Time window of search: from the inception of an electronic bibliographic database to May 2021; (8) Country: China; and (9) Language: articles written in English or Chinese.

Studies that met any of the following criteria were excluded from the review: (1) studies that examined either green spaces or PA but not both; (2) articles not written in English and Chinese; and (3) letters, editorials, study/review protocols, case reports, or review articles.

2.2. Search Strategy

A keyword search was performed in five electronic bibliographic databases: PubMed, Web of Science, Scopus, EBSCO (including SPORTDiscus and GreenFILE), and CNKI (a central Chinese scientific literature database). The search algorithm included all possible combinations of keywords from the following two groups: (1) "greenspace", "greenspaces", "green-space", "green space", or "green spaces"; (2) "motor activity", "motor activities", "sport", "sports", "physical fitness", "physical exertion", or "physical activity." The complete list of keywords and search algorithms in PubMed is provided in Appendix A. Medical Subject Headings (MeSH) terms "exercise", "China", and "human" were used in the PubMed search. Potentially eligible articles were retrieved, and their full texts were evaluated. Two co-authors of this review independently performed title and abstract screening against the study selection criteria. Cohen's kappa (κ = 0.70) was used to assess inter-rater agreement. A third co-author resolved the discrepancies between the above two co-authors through discussion. Besides the keyword search, a manual search in Google Scholar was also performed.

2.3. Data Extraction and Synthesis

A standardized data extraction form was used to collect the following methodological and outcome variables from each included study: author(s), year of publication, city, study design, sample size, age range, proportion of females, sample characteristics, statistical model, non-response rate, geographical coverage, setting, type of green space measure, detailed measure of green space, type of PA measure, detailed measure of PA, estimated effects of green space on PA, and key findings on the relationship between green space and PA. The data extraction was independently conducted by two co-authors of this review. Discrepancies were resolved through discussion with a third co-author.

We summarized the common themes and findings of the included studies narratively. A meta-analysis proved infeasible due to the substantial heterogeneities in green space and PA measures across the included studies.

2.4. Study Quality Assessment

The National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was used to assess the quality of each included study [27]. There were 14 quality assessment questions for each included study. A score of one was assigned for the answer of "yes" for each question, whereas a score of zero was assigned for the answer of "no". An overall score of study quality is obtained by calculating scores for all criteria. We used study quality assessment to measure the strength of scientific evidence but not to determine the inclusion of studies.

3. Results

3.1. Study Selection

Figure 1 shows the study selection flowchart. We identified a total of 3017 articles through keyword and reference searches, including 441 articles from PubMed, 256 articles from Web of Science, 446 articles from Scopus, 870 articles from EBSCO, 1000 articles from CNKI, and four articles through a manual search in Google Scholar. After removing duplicates, 2870 unique articles underwent title and abstract screening, in which 2808 articles were excluded against the study selection criteria. The remaining 62 articles underwent full-text review. Of these, 21 articles were excluded—6 articles were not conducted in China, three reported no green space measure, four reported no PA-related outcome, and the remaining eight were reviews or commentaries instead of original studies. Therefore, 41 articles in total were included in the review [16,17,20,22,28–64].

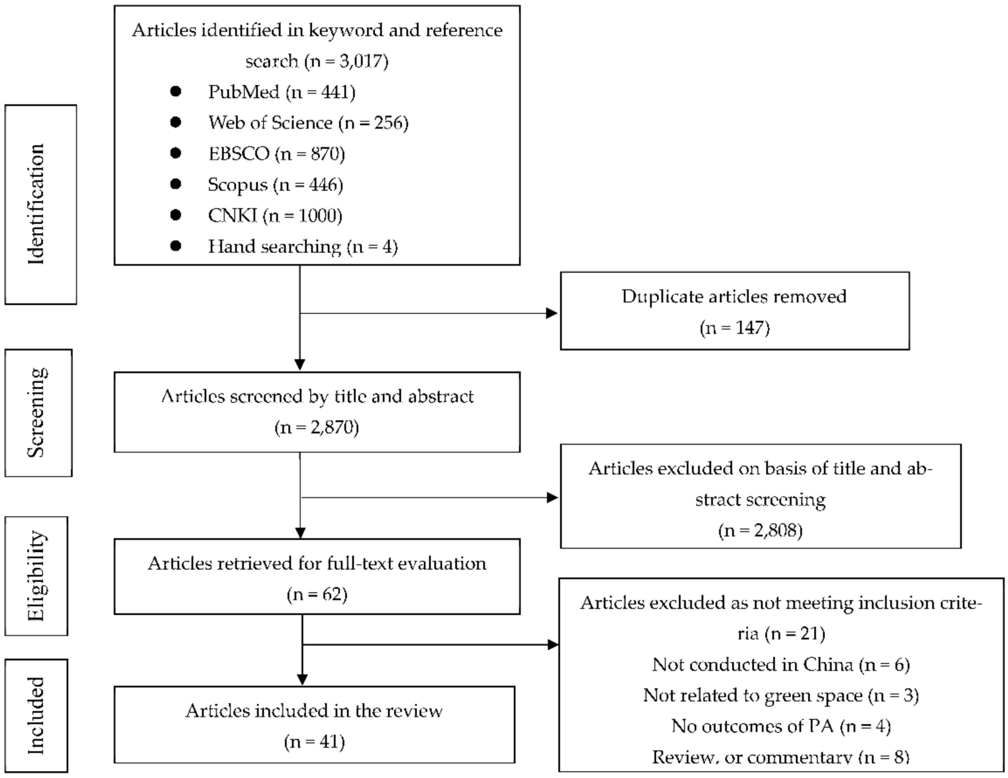

Figure 1. Study selection flowchart.

3.2. Characteristics of the Included Studies

Table 1 summarizes the essential characteristics of the 41 studies included in the review. All studies were published within the past six years (two in 2015, one in 2016, three in 2017, five each in 2018 and 2021, ten in 2019, and fifteen in 2020). Six exclusively focused on residents in Beijing, twelve in Hong Kong, six in Shanghai, four in Guangzhou, four in Shenzhen, two each in Dalian and Harbin, and one each in Baoji, Nanning, Nanjing, and Wuhan. Thirty-nine studies adopted a cross-sectional design, and two adopted a longitudinal design. The sample sizes were generally large but varied substantially across studies. One study analyzed 20 million cycling trips, three analyzed 6126 to 581,354 head-counts or park visits, and the remaining 29 studies included 180 to 90,445 participants. Ten studies focused on seniors aged 60 years and older, nine on adults aged 18 years and older, two on residents aged 15 years and older, one on residents aged 11 years and older, five on children and adolescents aged 18 years and younger, and six on people of all ages, while the remaining eight did not report the age range. Twelve studies did not report the sex distribution in their sample, and the remaining 29 studies included both sexes. The percentage of females across studies ranged from 35.0% to 64.3%. Various statistical models were applied across studies, including ordered logistic or probit regression, multi-level regression, structural equation models, negative binomial regression, and correlation analysis. The majority of studies (n = 20) adjusted for some individual sociodemographics (e.g., age, gender, education, marital status, household income, employment status, body mass index, and health condition) in the statistical analyses. Ten studies adjusted for some contextual characteristics (e.g., land-use mix, population density, street intersection density, number of bus stops, social environment, and travel characteristics) in the statistical analyses.

Table 1. Basic characteristics of the studies included in the review.

Study ID	First Author (Year)	City	Study Design	Sample Size	Age (Years)	Female (%)	Sample Characteristics	Statistical Model	Adjustment Variables	Non-Response Rate (%)	Geographical Coverage	Setting
1	Zhang Wenjuan, 2015	Beijing	Cross-sectional	1062 participants	15–40	53	Young urban residents	Ordinal logistic regression			Urban green spaces	Urban
2	Zhang Ying, 2015	Shanghai	Cross-sectional	1100 participants	46–80		Adult residents	Hierarchical linear models	Gender, age, and education	6	Neighborhood environment	Rural and urban
3	Chen, 2016	Shenzhen	Cross-sectional	35,090 headcounts			Public open space users	Multivariate regression			Community open spaces	Urban
4	Liu, 2017	Beijing	Cross-sectional	308 participants	11–60	51.5	Residents	Hierarchical regression analysis		61.5	Parks	Urban
5	He, 2017	Shanghai	Cross-sectional	297 participants	9–17	49.2	Children and adolescents	Ordinal logistic regression	Gender, age, grade, and parental education	25	Greenness around neighborhood and school	Urban
6	Zhai, 2017	Beijing	Cross-sectional	5026 and 2293 participants	60+	63	Senior park users	Correlation analyses Content analysis			Parks	Urban
7	Lu, 2018a	Hong Kong	Cross-sectional	1390 participants	53 ± 20	51	Residents	Multi-level regression	Gender, age, household income, and other built environment factors		Street greenery	Urban
8	Lu, 2018b	Hong Kong	Cross-sectional	24,773 and 1994 participants	5+	51.9 and 56.5	Public housing residents	Logistic regression Linear regression	Gender, age, household income, and other built environment factors	29 and 0	Street greenness	Urban
9	Lu, 2018c	Hong Kong	Cross-sectional	90,445 and 6770 participants	2+	53	Residents	Multi-level regression	Gender, age, household income, and other built environment factors		Street-level greenery	Urban
10	Zhang Lin, 2018	Guangzhou	Cross-sectional	1003 participants	19–59	50	Residents	Structural Equation Modeling	Gender, age, marital status, education, and personal income		Greenspace	Urban
11	Zhang Sai, 2018	Beijing	Cross-sectional	581,354 visits			Weibo users	Multiple linear regression			Parks	Urban
12	Dai, 2019	Guangzhou	Cross-sectional	776 participants	19+	50.4	Residents	Multiple linear regression	Gender, age, marital status, education, employment, and income	24.6	Neighborhood greenness	Urban
13	Gao, 2019	Baoji	Cross-sectional	906 participants	All ages	42.8	Stressed individuals	Generalized linear model		8.7	Urban green spaces	Urban
14	Lu, 2019	Hong Kong	Cross-sectional	5701 participants	15+	51.1	Residents	Multi-level logistic regression	Gender, age, household income, and other built environment factors	29	Eye-level greenness	Urban
15	Sun, 2019	Dalian	Cross-sectional	649 participants	22–64	52	Residents	Multi-level regression	Age, gender, education, household income, private car ownership rate, and health-related covariates	27.1	Urban green spaces	Urban
16	Wang, 2019	Nanning	Cross-sectional	513 participants			Adult residents	Order Probit regression	Gender, personal income, and marital status	10.2	Green open space	Urban
17	Yang, 2019	Hong Kong	Cross-sectional	10,700 and 1083 participants	65+	50.5 and 53.5	Senior residents	Multi-level logistic regression	Gender, age, household income, and other built environment factors		Street greenery	Urban
18	Yuen, 2019	Hong Kong	Cross-sectional	554 participants	48.1 ± 21.0	64.3	Adult residents	Pearson's correlation analysis		0.36	Urban green space	Urban
19	Zhai, 2019	Shanghai	Cross-sectional	403 participants	6–18		Children and adolescents	Order logistic regression, linear regression		42.4	Built environment	Urban
20	Zhang Hongyun, 2019	Guangzhou	Cross-sectional	673 participants	18+	35	Adult residents	ANOVA		10.3	Greenway	Urban
21	Zhang Ru, 2019	Hong Kong	Cross-sectional	317 participants	69.9 ± 6.8	46.7	Older adults	Negative binomial regression	Gender and age		Parks	Urban
22	Chen, 2020	Shenzhen	Cross-sectional	901,760 trips			Shared bicycle users	Linear regression			Street greening	Urban
23	Fu, 2020	Harbin	Cross-sectional	436 participants	12–18		Teenagers	Correlation analysis One-way ANOVA Logistic ordinal regression		11.86	Park	Urban
24	He, 2020	Wuhan	Cross-sectional	1161 participants	60+	53.6	Senior residents	Multi-level logistic regression	Park area, population density, street connectivity, and land-use mix	4	Street greenery	Urban

Table 1. *Cont.*

Study ID	First Author (Year)	City	Study Design	Sample Size	Age (Years)	Female (%)	Sample Characteristics	Statistical Model	Adjustment Variables	Non-Response Rate (%)	Geographical Coverage	Setting
25	Jiang, 2020	Nanjing	Cross-sectional	385 participants	60+	50.4	Senior residents	Logistic regression	Gender, age, education, family structure, living with grandchildren, employment, income, driver's license, and chronic disease		Urban greenery	Urban
26	Leng, 2020	Harbin	Cross-sectional	4155 participants	54.6 ± 10.3	47.7	Adult residents	Logistic regression	Age, gender, and education		Neighborhood green space	Urban
27	Tu, 2020	Beijing	Cross-sectional	5786 participants	19+	53.3	Adult residents	Correlation analysis			Parks	Urban
28	Wagner, 2020	Hong Kong	Cross-sectional	306 participants	60+	46.7	Older adults	Multiple linear regressions	City, gender, marital status, education, and BMI		Parks	Urban
29	Wang Ruoyu, 2020	Shenzhen	Cross-sectional	20 million cycling trips			Cycling behaviors	Multivariate Poisson regression			Eye-level greenness	Urban
30	Wang Xiaoyue, 2020	Dalian	Cross-sectional	204 participants	71	48.0	The elderly	Correlation analysis Multivariate regression			Green space	Urban
31	Wang Xin, 2020	Shanghai	Cross-sectional	6126 park users			Park users	Two-way chi-squared test			Neighborhood parks	Urban
32	Wu, 2020	Beijing	Cross-sectional	709 participants	All ages	55.5	Residents	Multi-level logit regression and multi-level linear regression	Individual attribute variable and travel attribute variable	10.4	Street greenery	Urban
33	Yang, 2020	Hong Kong	Cross-sectional	1148 participants	11–13	48.7	Primary school students	Multi-level regression analysis and Structural Equation Modeling	Other built environment and individual confounding variables	0	Urban greenery	Urban
34	Zang, 2020	Hong Kong	Cross-sectional	180 participants	65+	57	Older adults	Bivariate correlation analysis		50	Eye-Level street greenery	Urban
35	Zhai, 2020	Shanghai	Cross-sectional	257 participants	69.5 ± 7.5	43.6	Senior park users	Multiple stepwise regression analyses	Demographic attributes	8.9	Neighborhood parks	Urban
36	Zhou, 2020	Guangzhou	Cross-sectional	972 participants	60+	56.9	Older adults	Structural Equation Model	Incomes, gender, marital Status, and registered residence status (hukou)		Neighborhood greenspaces	Urban, suburban, rural
37	Dong, 2021	Shanghai Changchun	Longitudinal	T1: 1214 T2: 1247 1091 participants	14.74 ± 1.92	54.6	Adolescents	Cross-lagged panel models	Gender and grades	T1: 7.75 T2: 4.15	School natural environment	Urban
38	Gao, 2021	Shenzhen	Cross-sectional				Shared bicycle users	Geographically weighted regression			Urban greenness	Urban
39	Wang, 2021	Shanghai	Cross-sectional				Park users	Ordinal logistic regression			Urban green space	Urban
40	Yang, 2021a	Hong Kong	Cross-sectional		All ages		Park visitors	Linear regression	Built environment		Community parks	Urban
41	Yang, 2021b	Hong Kong	Longitudinal	661 participants	All ages	46.2	Residents	Difference-in-differences	Individual and neighborhood covariates		Urban greenery	Urban

Table 2 summarizes the measures for green space and PA-related behaviors among the included studies. The majority (n = 22) of studies adopted objective green space measures, nine used subjective green space measures, and ten used both objective and subjective measures. Objective green space measures included satellite-based remote sensing images from Gaode Map, Google Street View, and Baidu Street View; geographical data collected by the Lands Department of Hong Kong and the Nanning Bureau of Land Management; and measures constructed using geographical information systems (GIS). Subjective green space measures included field visits, observations and questionnaires administered to study participants. Buffer sizes commonly used in the studies include 400 m [33,39,40,56], 500 m [28,35], 800 m [33,39,40,56], and 1000 m [32,35], centering a respondent's home [28,32,33,39,40,56], school [56], nearby subway station [61], or other landmark (e.g., workplace, supermarket, restaurant, fitness center, or snack bar) [35]. Buffer sizes were chosen in consideration of physical activity mode (e.g., walking, running, or biking) or characteristics of the built environment.

Eleven studies examined the accessibility of green space, four examined the availability of green space, 12 examined certain features of green space, and 26 examined greenness (e.g., Normalized Difference Vegetation Index [NVDI], street greenness). PA-related behaviors measured in the studies included PA participation or duration (n = 26), physical inactivity or sedentary behavior (n = 2), metabolic equivalent of task (MET) (n = 2), energy expenditure (n = 1), active commuting (n = 2), and park use or visits (n = 5). The majority of studies (n = 28) measured PA levels using questionnaires reported by participants, four measured PA behaviors through site observations, while seven studies adopted an objective measure (e.g., a pedometer, Weibo PA check-in data, or Mobike). One study used both on-site observations and questionnaires, while another adopted both an objective measure (i.e., a pedometer) and questionnaires. PA-related questionnaires included both standardized instruments (e.g., the International Physical Activity Questionnaire [IPAQ] and the Hong Kong Travel Characteristics Survey) and investigator-designed question items.

Table 3 summarizes the key findings reported in the studies included in the review regarding the estimated influence of green space on PA among Chinese residents. Among the 41 studies that provided quantitative estimates of the relationship between green space measures and PA, 39 reported at least one statistically significant relationship in the expected direction. The remaining two reported a null finding. The findings can be classified into five aspects.

Table 2. Measures of green space and physical activity in the studies included in the review.

Study ID	First Author(Year)	Type of Green Space Measure	Detailed Measure of Green Space	Type of Physical Activity Measure	Detailed Measure of Physical Activity
1	Zhang Wenjuan, 2015	1. Online survey 2. Objective measure: the scene of Landsat TM5 image	1. The availability of and accessibility to urban green spaces 2. Perceived quality of green spaces 3. The amount of green spaces in the 500 m radius from each residential unit	Self-reported questionnaire: Online survey	1. Perceptions of the suitability of the green space for PA 2. Types of activities conducted in green spaces
2	Zhang Ying, 2015	Objective measure: GIS	Parkland and square proximity	Objective measure: Pedometer	1. Total PA level 2. Total steps of walking
3	Chen, 2016	Site investigation	Spatial configuration, facilities, and landscape features in public open spaces	Observation	The number of users and the users' activity engagements
4	Liu, 2017	1. Objective measure: Gaode Map 2. Self-reported questionnaire	1. Park accessibility 2. Perceived quality (accessibility, maintenance, aesthetic and comfort of the park)	Self-reported questionnaire: IPAQ	Time of PA and MVPA
5	He, 2017	Objective measure: remote sensing imagery, Arc GIS	Green space ratio, greenness around neighborhood and schools	Objective measure: ActiGraphGT3X + accelerometer	MPA, VPA, MVPA
6	Zhai, 2017	1. On-site observations 2. Objective measure	1. Pathway design characteristic 2. Pathway length	1. On-site observations 2. Face-to-face interviews	Walking behavior
7	Lu, 2018a	1. Objective measure: GSV images, ArcGIS 2. Audited: GSV images, field observation	The quality and quantity of street greenery	Self-reported questionnaire: IPAQ	Recreational PA: walking, jogging, or cycling
8	Lu, 2018b	Objective measure: GSV images, Pyramid scene parsing network (PSPNet) technique	Street greenness: green view index	Self-reported questionnaire: HKTCS	1.Likelihoods of walking 2.Walking time
9	Lu, 2018c	Objective measure: GSV images	Urban greenspaces in neighborhoods: street greenery and parks	Self-reported questionnaire: HKTCS	Walking behavior
10	Zhang Lin, 2018	Objective measure: Remote sensing images using ENVI and ArcGIS	Vegetation coverage, physical activity site coverage, and accessibility to the nearest greenspace	Self-reported questionnaire	1. The duration and frequency of PA 2. METs
11	Zhang Sai, 2018	Objective measure: Google Earth imagery, ALOS image data	1. Park characteristics: park size, the presence of an entrance fee, the presence of water, and the vegetation cover percentage 2. Park accessibility 3. Number of parks nearby	Weibo check-in data	Recreational visits, park visits
12	Dai, 2019	Objective measure: green space distribution, satellite imagery, Point of Interest data	Community and neighborhood greenness coverage rate, distance to the nearest park square, number of fitness facilities	Self-reported questionnaire: IPAQ	Walking, MVPA frequency and time
13	Gao, 2019	Self-reported questionnaire	Eight perceived sensory dimensions of greenspace: serene, nature, rich in species, space, prospect, refuge, social and culture	Self-reported questionnaire	The types of recreational activities: parent-child activities, fitness and health activities, sports and leisure activities, social activities, specialized activities, quiet activities and public participation activities
14	Lu, 2019	Objective measure: GSV, deep learning technique of fully convolutional neural network (FCN)	Street greenness, overall greenness, NDVI	Self-reported questionnaire: HKTCS	Cycling behavior
15	Sun, 2019	Objective measure: LANDSAT 8 satellite images, ArcGIS, Baidu Map API	NDVI, the number of parks within the buffer	Self-reported questionnaire: IPAQ	Walking and MVPA frequency and time
16	Wang, 2019	1. Objective measure: Nanning city land bureau institute of green spot figure data 2. Self-reported questionnaire	Safety, accessibility, landscape quality, space environment, entertainment facilities, size of the green open space, area of the green space, and infrastructure	Self-reported questionnaire	Time and frequency of exercising
17	Yang, 2019	Objective measure: GSV images	The level of eye-level street greenery	Self-reported questionnaire: HKTCS	1. Likelihood of walking 2. Walking time
18	Yuen, 2019	Objective measure: SPOT satellite images, ArcGIS	The percentage of green space	Self-reported questionnaire: IPAQ	1. MET-min/week 2. PA levels
19	Zhai, 2019	Self-reported questionnaire	Park accessibility	Self-reported questionnaire	Frequency, duration, and intensity of outdoor activities
20	Zhang Hongyun, 2019	Self-reported questionnaire	Proximity of the greenway	Self-reported questionnaire	PA level
21	Zhang Ru, 2019	Self-reported questionnaires	Perceived park environment: park safety, attractiveness, and park feature	1. System for Observation Play and Recreation in Communities (SOPARC) 2. Self-reported questionnaires	Park-based PA: the number of older adults observed being active in parks
22	Chen, 2020	Tencent street view A high-resolution multispectral full-color spot-5 image	Street greening: eye-level greenness (green view index), overhead greenness (green coverage index)	Captured by a web crawler	Bicycle use density: the amount of bicycle trips per unit area
23	Fu, 2020	Self-reported questionnaires	Urban park green space quality: the distance to the park, environment, facilities, design, safety, maintenance	Self-reported questionnaire	PA frequency, intensity, duration
24	He, 2020	Objective measure: extracted from street view photographs with the machine learning technique	Street greenery index, park area, street connectivity, and land-use mix	Self-reported questionnaire: IPAQ	Duration and frequency of PA

Table 2. *Cont.*

Study ID	First Author(Year)	Type of Green Space Measure	Detailed Measure of Green Space	Type of Physical Activity Measure	Detailed Measure of Physical Activity
25	Jiang, 2020	Objective measure: remote sensing image	Urban green space, park density, perceived park accessibility, perceived natural landscape attraction	Self-reported questionnaire	Walking time
26	Leng, 2020	1. Objective measure: Land-use data 2. First-hand field surveys	Green space ratio, green vision index, type of evergreen tree configuration, and type of sports field.	Self-reported questionnaire	PA, physical inactivity
27	Tu, 2020	Objective measure	Travel distance to park and park size	Self-reported questionnaires	Urban park visits: park visit frequency, time and activity type
28	Wagner, 2020	Self-reported questionnaires	Perceived environmental factors: park safety, attractiveness of parks, PA areas and features, park accessibility	Self-reported questionnaires	Park-based PA: PA type, amount of PA (frequency and duration per week) and intensity levels of PA in parks during a typical week (low, moderate and vigorous).
29	Wang Ruoyu, 2020	Objective measure: Tencent Online street-view Map, OpenStreetMap, convolutional neural network of segment images with artificial intelligence	Eye-level greenness exposure	Objective measure: Cycling data was obtained from Mobike	Cycling frequency
30	Wang Xiaoyue, 2020	Online Map, GIS, Self-reported questionnaires	Accessibility to green space, the attraction of green space	Self-reported questionnaires	Frequency of green space use
31	Wang Xin, 2020	Site observations	Landscape features in park: water, plaza, and lawn	Site observations	Sedentary, walk, and MVPA
32	Wu, 2020	Objective measure: Baidu Map API	Street green view index	Objective measure: GPS	Walking, cycling.
33	Yang, 2020	Objective measure: 1. Land Department of Hong Kong SAR. 2. Satellite imagery 3. GSV images	Urban greenery: number of parks, NDVI, and street greenness	Self-reported questionnaire	AST
34	Zang, 2020	Objective measure: Baidu Street View images	Green View Index	Self-reported questionnaire: IPAQ	Walking time
35	Zhai, 2020	Objective measure	Park area, total trail length, total paved activity zone area, total natural area, presence of water, presence of outdoor fitness equipment, presence of court	1. Objective measure: Pedometer 2. Self-reported energy expenditure	1. Total steps 2. Energy Expenditure 3. METs
36	Zhou, 2020	1. Field surveys from digital photographs 2. Objective measure: Satellite-based remote sensing images	Streetscape greenery, NDVI	Self-reported questionnaire	Average time spent on PA
37	Dong, 2021	Self-reported questionnaires	School natural environment	Self-reported questionnaires	PA frequency, intensity, duration
38	Gao, 2021	1. BMap API 2. Deep learning segmentation 3. Convolutional neural network 4. Landset8 images	Eye-level urban greenness (greenness view index, GVI), NDVI	Obtained from the bike-sharing operators	Bike-sharing record data
39	Wang, 2021	On-site observation GIS	Paved area, enterable paved area ratio, green coverage ratio, green view ratio, the density and the diversity of trees, shrubs, and groundcover	Observation	Types of PA
40	Yang, 2021a	Observation, GIS, GEOINFO MAP system, machine learning technique (PSPNet), LANDSAT 8 satellite imagery, 6-item assessment tool	Green view index, the normalized difference vegetation index	Observation	Park usage: the number of park visitors
41	Yang, 2021b	LANDSAT 5 Thematic Mapper satellite images	The overall greenery level: NDVI	Self-reported questionnaire	Duration of leisure-time PA

Notes: a. GIS = Geographic Information System; b. NDVI = Normalized Difference Vegetation Index; c. GSV = Google Street View; d. IPAQ = International Physical Activity Questionnaire; e. HKTCS = Hong Kong Travel Characteristics Survey; f. AST = Active School Transport; g. MVPA = moderate-to-vigorous physical activity; h. MET = Metabolic Equivalent; i. PA = physical activity.

Table 3. Estimated effects of green space on physical activity in the studies included in the review.

Study ID	First Author (Year)	Estimated Effects of Green Space on Physical Activity	Main Findings
1	Zhang Wenjuan, 2015	1. Travel time to the nearest park (β = −0.42, SE = 0.07, $p < 0.01$), counts of types of green spaces available for PA (β = 0.19, SE = 0.09, $p < 0.05$), and the rating of vegetation (β = 1.49, SE = 0.09, $p < 0.01$) had a significant effect on the respondents' PA satisfaction level. 2. The vegetation cover rate in the 500 m radius of a respondent's residential unit did not significantly affect the respondent's satisfaction level.	1. Time to park related to PA satisfaction levels: − 2. Usable green space related to PA satisfaction levels: + 3. Rate of vegetation related to PA satisfaction levels: + 4. The vegetation cover rate in the 500 m radius related to PA satisfaction level: 0
2	Zhang Ying, 2015	1. Proximity of parkland (t = −2.208, $p = 0.027$) and square (t = −3.326, $p = 0.001$) were significantly inversely associated with the likelihood of PA. A 1-unit (10%) increase in the distance of parkland or square was associated with an 18% or 27% reduction in PA. 2. The green and open spaces area was not shown to be significantly associated with PA (Coefficient = 0.093, $p = 0.407$).	1. Parkland and square proximity related to the likelihood PA: − 2. Green and open space area in the 500 m buffer related to walking: 0
3	Chen, 2016	1. The accessible lawn area is important in attracting visitors (β = 0.14, t = 3.07, $p < 0.01$). When the lawn area increases by 100 m^2, the number of visitors in this area is expected to increase by nine and four during weekdays and weekends, respectively. 2. The woodland is not significantly associated with the number of users (β = −0.13, t = −1.01, $p > 0.1$).	1. Large areas with accessible lawns related to the use of community open spaces: + 2. The woodland related to the number of users: 0 3. Adding green vegetation and landscape accessories in open spaces has limited effects on increasing the outdoor activities of residents.
4	Liu, 2017	The number of parks within 500 m of home was associated with MVPA time (β = 1.2, St β = 0.1, $p = 0.046$).	1. The number of parks within 500 m of home related to PA: + 2. The number of parks within 1000 m of home related to PA: 0 3. The number of parks within 1500 m of home related to PA: 0 4. Walking time to nearest park related to PA: 0 5. Shortest road distance to nearest park related to PA: 0 6. Proportion of residential greenspace related to PA: 0 7. Perceived park quality related to PA: 0
5	He, 2017	Greenness around neighborhood and school is not significantly associated with MVPA among children and adolescents.	Greenness around neighborhood related to MVPA: 0 Greenness around school related to MVPA: 0
6	Zhai, 2017	1. Pathway length is positively related to the number of observed seniors in both Rendinghu Park, r (32) = 0.58, $p < 0.01$, and Yuetan Park, r (39) = 0.52, $p < 0.01$. 2. Pathways with flowers ($p < 0.001$) and without steps ($p = 0.073$) are used more frequently by seniors in Rendinghu Park. Pathways without connection to activity zones are used the most compared with the pathways that connect with two activity zones in Yuetan Park ($p < 0.001$). 3. There are no correspondences between the number of observed seniors and pathway form, degree of shade, degree of enclosure, presence of water on side, and visual connection with water in neither of the parks.	1. Park pathway length related to seniors walking: + 2. Seniors prefer pathways that have soft or even pavements (plastic tracks and bricks), benches, flowers, and light fixtures. 3. Seniors are attracted to pathways that are long, are between 3–3.9 m wide, and are without connection to activity zones. 4. Other pathway design characteristics, such as being along a body of water, providing shade, providing lateral visibility and visual connection with water, and lacking visual connection with landmarks may also encourage senior walking.
7	Lu, 2018a	1. Participants exposed to a high quantity of street greenery were significantly more likely to engage in regular recreational green PA than those exposed to low quantities of street greenery (OR = 1.20, 95%CI = 1.08, 1.33). 2. Residents exposed to high-quality street greenery also had a greater likelihood of achieving regular recreational green PA than those exposed to low-quality street greenery (OR = 1.10, 95%CI = 1.05, 1.25). 3. Participants exposed to a high level of total park area had a greater likelihood of PA than those exposed to a low level of total park area in the buffer (OR = 1.22, 95%CI = 1.10, 1.36).	1. High quality and quantity of street greenery related to recreational PA: + 2. Medium quality and quantity of street greenery related to recreational PA: 0 3. High total park area related to recreational PA: + 4. Medium total park area related to recreational PA: 0
8	Lu, 2018b	1. The green view index was related to higher odds of walking in both the 400 m buffer (OR = 1.149, 95%CI = 1.035, 1.276) and the 800 m buffer (OR = 1.193, 95%CI: 1.070, 1.330). An increase of one standard deviation in the green view index increases the likelihood of walking by 14.9% and 19.3% in the 400 m and the 800 m buffers, respectively. 2. Eye-level greenness was associated with more walking time in both the 400 m buffer (β = 0.149, 95%CI: 0.045, 0.253) and the 800 m buffer (β = 0.233, 95%CI = 0.133, 0.333).	1. Eye-level greenness related to the odds of walking: + 2. Eye-level greenness related to walking time: +
9	Lu, 2018c	1. Participants exposed to the third (OR = 1.07, 95%CI = 1.01, 1.13) and fourth quartiles (OR = 1.09, 95%CI = 1.02, 1.16) of street-level greenery had significantly higher odds of walking. 2. In reference to participants in the lowest quartiles of the number of parks within the 800-m neighborhood, those in the third (OR = 1.07, 95%CI = 1.02, 1.13) and fourth quartiles (OR = 1.07, 95%CI = 1.01, 1.14) reported significantly higher odds of walking. 3. Street greenery was positively associated with total walking time (β = 0.09, SE = 0.03, $p < 0.001$). 4. The number of parks was not positively associated with walking time (β = 0.01, SE = 0.03, $p = 0.783$).	1. Street-level greenery related to the odds of walking: + 2. Street-level greenery related to walking time: + 3. The number of parks related to the odds of walking: + 4. The number of parks related to walking time: 0
10	Zhang Lin, 2018	Green space exposure has a significant positive effect on PA (Path Coefficient = 0.14, C.R. = 3.213, $p < 0.01$).	Green space exposure related to the PA level: +
11	Zhang Sai, 2018	1. Park size (Coefficient = 2.84×10^{-2}, standardized coefficient = 0.36, $p < 0.01$) and entrance fees (Coefficient = 1.16, standardized coefficient = 0.22, $p < 0.05$) were associated with increased numbers of visits for all types of parks. 2. Distance to an urban center significantly affected park use (Coefficient = -2.03×10^{-4}, standardized coefficient = −0.48, $p < 0.05$).	1. Park size related to the number of visits: + 2. Distance to an urban center related to park use: − 3. The vegetation cover rate related to park visits: 0
12	Dai, 2019	1. Neighborhood greenness cover rate (B = 0.035, $p < 0.01$) and the number of fitness facilities (B = 0.015, $p < 0.01$) was significantly positively associated with leisure PA. 2. Distance to the nearest park square (B = −0.398, $p < 0.01$) was significantly negatively associated with leisure PA.	1. Greenness cover rate related to leisure PA: + 2. Distance to the nearest park square related to leisure PA: −
13	Gao, 2019	1. The perception degree of rich-in-species sensory dimension had significant effects on the possibilities of conducting fitness and health activities ($p = 0.02$). 2. Serenity was significant for the sports and leisure activities ($p = 0.00$). 3. Culture significantly related to specialized activities ($p = 0.02$) and public participation activities ($p = 0.03$). 4. Nature had significant relationships with quiet activities ($p = 0.01$).	Quiet and natural green space was associated with increased odds of exercise, recreational activities, and quiet activities for the highest-stressed respondents.

Table 3. *Cont.*

Study ID	First Author (Year)	Estimated Effects of Green Space on Physical Activity	Main Findings
14	Lu, 2019	1. Street greenness was positively associated with odds of cycling in the 400 m buffer (OR = 1.21, 95%CI = 1.00, 1.46), in the 800 m buffer (OR = 1.25, 95%CI = 1.04, 1.51), and in the 1600 m buffer (OR = 1.36, 95%CI = 1.11, 1.67). 2. Overall greenness measured by NDVI was not significantly associated with cycling in any of three buffer zones.	1. Street greenness related to the odds of cycling: + 2. Overhead-view greenness assessed by NDVI related to the odds of cycling: 0
15	Sun, 2019	1.The number of parks was not significantly associated with PA. 2. The number of fitness facilities within the 400 m buffer was significantly positively associated with PA. 3. NDVI was negatively associated with walking. 4. NDVI was associated with weekly walking frequency within the 400 m buffer (Coefficient = −0.106, 95%CI = −0.268, −0.012, $p < 0.05$), daily walking time within the 800 m buffer (Coefficient = −0.130, 95%CI = −0.280, −0.042, $p < 0.05$), and commuting walking time within the 1200 m (Coefficient = −0.116, 95%CI = −0.223, −0.026, $p < 0.05$) and 1600 m buffers (Coefficient = −0.116, 95%CI = −0.246, −0.045, $p < 0.05$). 5. NDVI was positively associated with MPA within the 1200 m buffer (Coefficient = 0.097, 95%CI = −0.118, 0.167, $p < 0.05$).	1. The number of parks related to PA: 0 2. NDVI related to walking: − 3. NDVI related to MPA within 1200 m buffer: +
16	Wang, 2019	1. Accessibility is significantly positively correlated with residents' PA. 2. Nature space environment, landscape quality and safety are not significantly correlated with residents' PA. 3. Infrastructures (β = 0.220, $p < 0.01$), the area of green space (β = −0.0003998, $p < 0.1$), the size of open space (β = 0.000107, $p < 0.1$) and entertainment facilities are significantly correlated with residents' activity.	1. Accessibility related to PA: + 2. Nature space environment, landscape quality and safety related to PA: 0 3. Infrastructures related to PA: + 4. The area of green space related to PA: − 5. The size of open space related to PA: +
17	Yang, 2019	1. Street greenery was positively associated with the odds of walking (OR = 1.206, 95%CI = 1.039, 1.400). 2. Street greenery was positively associated with total walking time (OR = 0.187, 95%CI = 0.071, 0.304); with every increase of one standard deviation in street greenery, old adults' walking time rises by approximately 0.2 standard deviations.	1. Street greenery related to the odds of walking: + 2. Street greenery related to walking time: +
18	Yuen, 2019	1.MET-min/week was significantly associated (Pearson r = 0.092; $p < 0.05$) with the green space percentage. 2. Regarding the IPAQ levels, the "medium" and "high" green space subgroups tended to perform moderate-to-high levels of PA, while the PA levels of those living with low green space were mainly at a moderate level.	1. Green space percentage related to MET-minutes/week: + 2. Green space level related to IPAQ level: +
19	Zhai, 2019	Distance to the park was significantly positively associated with children's VPA time (β = 1.014, $p < 0.01$) and intensity of total PA (β = 51.903, $p < 0.1$) within the 10 min walking distance buffer, and was not significantly associated with parents' outdoor PA.	1. Distance to the park related to children's VPA time: + 2. Distance to the park related to children's intensity of total PA: + 3. Distance to the park related to parents' outdoor PA: 0
20	Zhang Hongyun, 2019	Proximity of greenway was significantly positively associated with low-intensity walking ($p = 0.005$) and was not significantly associated with MVPA level.	1. Proximity of greenway related to low-intensity walking: + 2. Proximity of greenway related to MVPA level: 0
21	Zhang Ru, 2019	1. Types of activity space were positively associated with the number of active older adults in Hong Kong parks, Wald χ^2 (6) = 538.18, $p < 0.001$. 2. Perceived park safety (β = 0.10, $p = 0.11$), attractiveness (β = 0.10, $p = 0.09$), park features (β = 0.01, $p = 0.94$), and park distance (β = −0.05, $p = 0.38$) did not have a significant relationship with park-based PA among older adults in Hong Kong parks.	1.The types of activity areas related to the number of active older adults in parks: + 2. Perceived park safety, attractiveness, park features, and park distance related to park-based PA: 0
22	Chen, 2020	1. Eye-level greening (street green view index) has a positive impact on the density of shared bicycle use (β = 0.054, $p < 0.001$). 2. Green coverage index has no significant impact on cycling.	1. Street green view index related to cycling: + 2. Green coverage index related to cycling: 0
23	Fu, 2020	1. Distance to green space was significantly negatively associated with the frequency of PA. 2. Distance to green space was significantly positively associated with the duration of PA.	1. Distance to green space related to the odds of PA: − 2. Distance to green space related to the duration of PA:+
24	He, 2020	1. Street greenery was positively associated with the odds of achieving 300 min or more of PA/week (OR = 1.287, 95%CI = 1.105, 1.498, $p = 0.001$). 2. Park area had no significant association with the frequency or the total time of PA.	1. Street greenery related to the odds of PA: + 2. Park area related to the frequency of PA: 0 3. Park area related to the total time of PA: 0
25	Jiang, 2020	1. Green space ratio (0.4005) was positively associated with commuting walking within 1000 m walking distance buffer, and weekly commuting walking time ≥ 150 min frequency among senior residents. 2. Park density was positively associated with the odds of leisure walking and the odds of walking time above 150 min among seniors. 3. Perceived park accessibility (0.2488) was positively associated with the odds of leisure walking among seniors within 1000 m walking distance buffer. 4. Perceived natural attraction significantly reduced the odds of walking.	1. Green space ratio related to commuting by walking: + 2. Park density related to the odds of leisure walking: + 3. Park density related to the odds of walking time above 150 min: + 4. Perceived park accessibility related to the odds of leisure walking: + 5. Perceived natural attraction related to the odds of walking: −
26	Leng, 2020	1.Neighborhoods with a Green Space Ratio lower than 28% are at higher risk of physical inactivity, compared to those in neighborhoods with a Green Space Ratio higher than 28% (OR = 0.62, 95%CI = 0.44, 0.87, $p = 0.006$). 2. Participants living in neighborhoods with a Green View Index of more than 15% had a lower risk of physical inactivity (OR = 0.53, 95%CI = 0.39, 0.72, $p = 0.000$). 3. Evergreen tree configuration type was not significantly correlated to physical inactivity. 4. Sports field type was not significantly correlated to physical inactivity.	1. Green space ratio lower than 28% related to physical inactivity: + 2. Green view index of more than 15% related to physical inactivity: − 3. Evergreen tree configuration type related to physical inactivity: 0 4. Sports field type related to physical inactivity: 0
27	Tu, 2020	1. Travel distance was negatively correlated with the ratio of visitors (r = −0.344, $p < 0.001$). 2. Park size showed no significant pattern with the ratio of visitors.	1. Travel distance related to the ratio of visitors: − 2. Park size related to the ratio of visitors: 0
28	Wagner, 2020	1. There was no significant relationship between perceived park features and energy expenditure in Hong Kong [β = −0.05, t (253) = −0.77, $p = 0.44$]. 2. There was no significant relationship between perceived park time distance and energy expenditure in Hong Kong [β = 0.05, t (253) = 0.83, $p = 0.41$].	1. Perceived park features related to energy expenditure: 0 2. Perceived park time distance and energy expenditure: 0
29	Wang Ruoyu, 2020	1. Eye-level greenness was positively associated with cycling frequency on weekdays within 500 m buffer size (β = 1.983, SE = 0.026, $p < 0.01$), 1000 m buffer size (β = 2.095, SE = 0.023, $p < 0.01$), and 1500 m buffer size (β = 2.551, SE = 0.028, $p < 0.01$) around metro stations. 2. Eye-level greenness was positively associated with cycling frequency on weekends within 500 m buffer size (β = 2.520, SE = 0.027, $p < 0.01$), 1000 m buffer size (β = 2.728, SE = 0.024, $p < 0.01$), and 1500 m buffer size (β = 3.807, SE = 0.029, $p < 0.01$) around metro stations. 3. The effect of eye-level greenness on cycling frequency was greater on weekends than on weekdays.	Eyelevel greenness related to cycling frequency: +

Table 3. *Cont.*

Study ID	First Author (Year)	Estimated Effects of Green Space on Physical Activity	Main Findings
30	Wang Xiaoyue, 2020	The actual travel distance and the number of road intersections were significantly negatively associated with the frequency of green space use for the elderly.	Travel distance related to the odds of green space usage for the elderly: −
31	Wang Xin, 2020	The amount of use and level of activity were affected by the shade of trees in the plaza. People preferred to conduct MVPA in the plazas with taller trees providing abundant shade (χ^2 = 31.87, p < 0.001, Cramér's V = 0.128). Plazas with fitness or playground equipment attracted more people engaged in MVPA than those without (54.19% compared to 43.17%), and the difference was significant (χ^2 = 27.70, p < 0.001, Cramér's V = 0.119).	1. Plazas with taller trees related to people conducted MVPA: + 2. Plazas with fitness or playground equipment related to people engaged in MVPA: +
32	Wu, 2020	1. The higher the accumulated value of GVI is, the less likely it is to increase the probability of AT (Coefficient = −0.001, SE = 0.000, p < 0.01). 2. The mean GVI significantly raises the occurrence of AT (Coefficient = 5.873, SE = 0.648, p < 0.01). 3. The accumulation of GVI is significantly positively correlated with the two kinds of AT distance (Coefficient = 0.003, SE = 0.000, p < 0.01 and Coefficient = 0.002, SE = 0.000, p < 0.01). 4. The mean GVI has significant negative effects on walking and bicycle travel respectively (Coefficient = −1.513, SE = 0.215, p < 0.01 and Coefficient = −2.195, SE = 0.374, p < 0.01).	1. The accumulated value of GVI related to the odds of AT: − 2. The mean GVI related to the occurrence of AT: + 3. The accumulation of GVI related to AT distance: + 4. The mean GVI related to walking or cycling distance: − Urban green spaces have a two-way effect on AT distance, and road classification plays a regulating role in such effect.
33	Yang, 2020	1. Street greenness and the number of parks surrounding schools were both positively associated with the odds of engaging in AST within the 400 m buffer (OR = 1.32, 95%CI: 1.18, 1.51; OR = 1.21, 95%CI: 1.13, 1.32 respectively). 2. The overall greenness surrounding schools was also positively associated with the odds of engaging in AST within the 800 m buffer (OR = 1.09, 95%CI: 1.02, 1.17).	1. Street greenness related to the odds of engaging in AST within the 400 m buffer: + 2. The number of parks surrounding schools related to the odds of engaging in AST within the 400 m buffer: + 3. The overall greenness surrounding schools related to the odds of engaging in AST within the 800 m buffer: +
34	Zang, 2020	Green view index has significant effects on walking time of the elderly (β = 0.137, p = 0.05).	Green view index related to walking time: +
35	Zhai, 2020	1. Total steps was positively associated with total natural area in the park (β = 0.158, p = 0.015) and the presence of outdoor fitness equipment (β = 0.149, p = 0.021). 2. Seniors' energy expenditure was positively associated with the presence of outdoor fitness equipment (β = 0.161, p = 0.024).	1. Total natural area in the park related to total steps: + 2. The presence of outdoor fitness equipment related to total step: + 3. The presence of outdoor fitness equipment related to energy expenditure: +
36	Zhou, 2020	Neighborhood streetscape greenery was positively related to older adults' average time spent on PA (Standardized estimates = 0.18, p < 0.01).	Neighborhood streetscape greenness related to PA time: +
37	Dong, 2021	The natural environment of schools is significantly positively related with physical exercise (p < 0.001).	Natural environment of schools related to physical exercise: +
38	Gao, 2021	Eye-level greenness was positively associated with bike-sharing usage on weekdays, weekends, and holidays. Overhead-view greenness was found to be negatively related to bike usage on weekends and holidays, and insignificant on weekdays.	Eye-level greenness related bike-sharing usage: + Overhead-view greenness related to bike usage on weekend and holidays: − Overhead-view greenness related to bike usage on weekdays: 0
39	Wang, 2021	1. Green coverage ratio and diversity of shrubs are positively related to PA diversity. 2. Diversity of trees has an inverse impact on PA diversity. 3. The paved area shape index and green view ratio are negatively correlated with PA diversity.	Green coverage ratio related to PA diversity: + Green view ratio related to PA diversity: −
40	Yang, 2021a	1. The total number of park users was significantly and positively associated with the GVI, but not the NDVI, in both the 400-m and 800-m buffers. 2. The quality of greenery has stronger associations with the total number of park visitors than the quantity. Both the quantity and quality of greenery had stronger associations with the number of elderly visitors (apparent aged 65 or above) than with the numbers of children or adults.	1. GVI related to the number of elderly park visitors in both the 400-m and 800-m buffers: + 2. NDVI related to the number of elderly park visitors in both the 400-m and 800-m buffers: 0
41	Yang, 2021b	Compared with those living in low-greenery neighborhoods, participants living in high-greenery neighborhoods reported lesser decreases in the durations of leisure-time physical activity conducted in neighborhoods (DiD = 37.914) and at home (DiD = 21.040), and in the total leisure-time physical activity (DiD = 78.598).	Neighborhoods greenery related to PA time decreases: −

Notes: a. NDVI = Normalized Difference Vegetation Index; b. AST = Active School Transport; c. PA = physical activity. d. correlation: + positively, − negatively, 0 insignificantly.

First, the overall greenness in a local area was associated with PA, but findings were inconsistent across the studies. Eight studies found a positive association, while two studies found a negative association, and seven found a null association. For different age groups, four of five studies focusing on adults reported a positive association. Four of five studies examining all age groups reported a null result. For different domains of PA, three of five studies examining leisure-time PA reported a positive association, while the remaining two reported a null result. Two of six studies examining transport PA reported a positive association, and the remaining four reported a negative or null association. Three of seven studies examining the total PA reported a positive association, while four reported a negative or null association. The overall greenness was usually measured with a bird's eye perspective using NDVI, the green coverage index, or the total acreage of green spaces. Specifically, greenness surrounding schools had a positive effect on the odds of active transport to and from school among children within an 800-m buffer [56]. By contrast, greenness around neighborhoods and schools was not found to be associated with MVPA among children and adolescents [30]. NDVI, which was widely used to assess overhead-view greenness, was positively associated with MVPA within a 1200-m buffer [40]. By contrast, NDVI was not associated with the odds of cycling [39] and the total number of park users within a 400-m and 800-m buffer [63], and was inversely associated with weekly walking frequency within a 400-m buffer, daily walking time within an 800-m buffer, and active commuting time within a 1200-m and 1600-m buffer [40]. Greenness cover rate was positively associated with leisure-time PA duration [37] and PA diversity [62]. A higher ratio of green space was associated with a lower risk of physical inactivity [50], longer duration of total PA time [64], higher MET-minutes per week, higher IPAQ-measured PA levels [42], and increased active commuting frequency [49]. By contrast, the vegetation cover rate was not associated with park visits [36], cycling [46], MVPA time [20], and PA satisfaction level [17]. Bird's eye-view greenness was found to be inversely related to bike usage on weekends and holidays but not on weekdays [61].

Second, street greenness, namely streets with greater vegetation coverage, was usually assessed using the Green View Index (GVI). 14 studies found a consistent positive association between street greenness and PA. Among the 11 studies that reported age groups, four studies focused on people of all ages, four on elders, two on adults, and one on children or adolescents. For different PA domains, eight studies examined transport PA, four examined overall PA, and two examined leisure-time PA. Street greenness was found to be positively associated with the odds of walking [33,34,41], cycling [39,53], achieving 300 min of total PA per week [48], achieving 150 min of recreational PA per week [32], engaging in regular recreational PA [32], and engaging in active commuting to school [56]. Street greenness was also associated with increased walking duration [33,34,41], bike-sharing usage [61], and older adults' average PA duration [59]. GVI was positively associated with the total number of park users [63], density of shared bicycle use [46], and walking duration among older adults [57]. Participants living in neighborhoods with a GVI of over 15% had a lower risk of physical inactivity [50].

Third, 14 studies found that accessibility to green space was positively associated with PA, while five studies reported a negative or null result. For different age groups, six of seven studies focusing on adults, two of three studies focusing on children or adolescents, two of four studies focusing on elders, and one of two studies focusing on people of all ages reported a positive association. For different PA domains, six of nine studies examining leisure-time PA reported a positive association, while three reported a negative or null finding. Seven of nine studies examining overall PA reported a positive association, while two reported a null association. Accessibility to green space (e.g., lawns in urban areas, parks, and public open spaces) were positively associated with the use of open space [29], PA level [16,20], intensity of total PA within a 10-min walking distance buffer among children [43], the odds of leisure walking among seniors within a 1000-m buffer [49], low-intensity walking [44], green space visiting frequency [47], and physical fitness among residents [42]. The distance or travel time to green space was inversely associated with residents' PA satisfaction level [17], green space use [36,54], number of visits [51], leisure-time PA duration [37], and the odds of PA participation [28,47]. By contrast, distance to green space was positively associated with PA duration [47]. Proximity to a greenway was not associated with MVPA levels [44]. Walking time to the nearest park was not associated with PA [20]. No association was found between perceived distance to parks and PA or energy expenditure among older adults in Hong Kong [45,52].

Fourth, the availability of green space was associated with PA. Counts of various types of green spaces available for PA significantly affected respondents' PA satisfaction levels [17]. The number of parks was positively associated with residents' weekly MVPA time within a 500-m buffer [20] and the likelihood of walking within an 800-m buffer [34]. The number of parks surrounding schools was positively associated with the odds of active commuting [56]. Park density was positively associated with the odds of leisure-time walking and the odds of walking time exceeding 150 min per week among older adults [49]. Types of activity areas were positively associated with the number of older adults being active in parks [45]. The presence of outdoor fitness equipment was positively associated with total steps taken among residents [58]. The number of fitness facilities was positively associated with PA within a 400-m buffer [40] and leisure-time PA [37]. By contrast, the number of parks was not associated with PA [40] and walking time [34].

Fifth, design characteristics of green space were associated with residents' PA. Pathway length was found to be positively associated with the number of older adults exercising in parks [31]. Different environmental settings such as water, plaza, lawn, and architecture supported different types and levels of PA [55]. Overall acreage of the natural area in a park was positively associated with total steps taken [58]. Park size was found to be associated with an increased number of visits [36] and recreational PA [32]. By contrast, perceived natural attraction was inversely associated with the odds of walking [49]. Landscape accessories in open spaces showed limited effects on residents' outdoor activities [29]. Woodland was not associated with the number of visitors [29]. Size of the natural environment [16], landscape quality [16], attractiveness [45], park features [45,52], and park safety [16,45] were not associated with residents' PA. Park size was not associated with PA frequency and weekly PA duration [48].

3.3. Study Quality Assessment

Table 4 reports criterion-specific and global ratings of the study quality assessment. The included studies scored six out of 14 on average (ranging from four to eight). All studies included in the review clearly stated the research question or objective, defined the study population, had a participation rate of over 50%, recruited subjects from the same or similar populations during the same period, and prespecified and uniformly applied inclusion and exclusion criteria to all potential participants. Most studies implemented valid and reliable exposure measures (n = 32). Twenty studies implemented valid and reliable outcome measures. Twenty-three studies measured and statistically adjusted key potential confounding variables for the associations between exposures and outcomes. Fourteen studies examined different levels of exposure concerning the outcome. By contrast, two studies had a reasonably long follow-up period that was sufficient for changes in outcomes to be observed. Only a single study assessed the exposures more than once during the study period. None of the studies had the outcome assessors blinded to the exposure status of the participants, provided a sample size justification using power analysis, or measured exposures of interest before the outcomes.

Table 4. Study quality assessment.

Study ID **Criterion**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
1. Was the research question or objective in this paper clearly stated?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2. Was the study population clearly specified and defined?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3. Was the participation rate of eligible persons at least 50%?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5. Was a sample size justification, power description, or variance and effect estimates provided?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	0	0	1	0	0	0	1	0	1	0	0	0	0	1	1	0	0	1	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1	0	1	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1
10. Was the exposure(s) assessed more than once over time?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	0	1	0	1	1	0	1	1	1	0	1	0	0	1	0	0	1	1	0	0	1	1	0	1	0	0	0	0	1	0	0	1	0	1	1	0	0	1	1	0	1
12. Were the outcome assessors blinded to the exposure status of participants?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. Was loss to follow-up after baseline 20% or less?	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	0	1	0	0	1	0	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	0	1	0	0	0	1	1	0	1	1	1	0	0	1	1
Total score	5	7	5	6	7	5	8	7	8	6	6	6	4	8	7	6	7	7	5	5	6	6	5	7	6	7	6	5	7	5	4	7	7	6	7	6	8	6	6	7	8

Notes: This study quality assessment tool was adopted from the National Institutes of Health's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies. For each criterion, a score of one was assigned if "Yes" was the response, whereas a score of zero was assigned otherwise. A study-specific global score, ranging from zero to 14, was calculated by summing up scores across all 14 criteria. Study quality assessment helped to measure the strength of scientific evidence, but was not used to determine the inclusion of studies.

4. Discussion

This study reviewed the scientific literature linking green space to PA among residents in China. A total of 41 studies met the eligibility criteria for inclusion. All but two studies identified at least one measure of green space to be associated with PA. Street greenness was associated with increased odds of active commuting (e.g., cycling), walking, and a reduced risk of physical inactivity. Accessibility to green spaces was associated with increased PA levels and green space usage. Distance to green space was inversely associated with the odds of PA. By contrast, evidence linking overall greenness exposure to PA remains limited.

Findings from this review confirmed the documented relationship between green space and PA in developed countries. For example, Krenn et al., reported that street greenness was positively associated with cyclists' route choices in Austria [65]. Nawrath et al., examined the attractiveness of streets for cycling in European cities and found that most respondents preferred cycling in green streets [66]. Tsai et al., reported that street greenery was positively associated with PA in the US [67]. The studies pointing out the consistencies of the positive association between street greenness and PA in this review mainly focused on examining transport PA across all-ages population, and overall PA in elderly population. For the distance to green space, most studies found accessibility to green space was positively associated with PA in China across the adult population. Sugiyama et al., also reported that accessibility to green space was associated with walking in Australia [68]. Coombes et al., found that increasing distance was associated with the declined frequency of green space use in England [14]. Future research examining the effect of accessibility to green space on PA needs to be conducted on the sub-population of vulnerable groups, especially elderly people. This is also in line with current needs regarding the construction of a healthy aging environment. Findings from this review stressed the importance of designing new green spaces or modifying existing ones to promote PA for residents in China.

The effects of overhead-view greenness, the availability of green space, and the design characteristics of green space remain mixed. As a complex behavior, PA could be correlated with a broader perspective of greenness rather than a traditionally used measure of green space [18]. For example, Giles-Corti et al., reported that residents preferred attractive green spaces over simple proximity [69]. Frank et al., reported that the number of green spaces was more important than the total size of green space for PA within a certain distance [70]. In addition, older adults may prefer parks, corridors [42], and benches in green space that could provide a seating area; young people might prefer the availability of sports facilities in green space [42]; and children and teenagers might prefer green space with a playground and attractive scenery [71,72]. Teenagers are more willing to visit parks without benches when participating in sports activities [73]. Therefore, the accessibility, vegetation percentage, quantity, and attraction of green space should be considered in combination with population characteristics in future research. Policymakers and landscape architects may need to consider the distinct needs of different age groups.

Mechanisms connecting green space to PA were inadequately examined. Only two studies explored the specific mechanisms linking green space to PA [34,39]. The primary mediator identified pertained to the aesthetic, amenity, and attractive environment of green space [34,39]. In addition, Bauman et al., reported that social support could serve as a mediator for behavioral change when exposed to green space [74]. Hunter et al., argued that social interaction was inherent to the bond between PA and green space, as green space provided interaction opportunities for exercisers [8]. Another pathway through which green space promotes PA could be nature itself, as experiencing nature or the need for "fresh air" motivates people to engage in PA in green spaces [75]. Future studies should measure a wide range of potential mediators of PA initiation and maintenance to test the hypothesized pathways [8].

Affluence may play an important role in the association of green space and PA, resulting in health inequalities and disparities [76]. Those in low-income areas have less parkland and participate in less PA than those in high-income areas [77]. A review also reported that income has an effect on using green spaces for PA [78]. These findings are consistent with a study conducted in China [37]. Dai et al., reported that there were community differences in the effect of green space on leisure PA, and residents' leisure PA in low-income communities was mainly constrained by the effects of time and money [37]. Therefore, future work should take income level as a significant covariate in the relationship of green space and PA.

Building new and improving existing green space has become a priority in the urban planning policies of some Chinese cities. For instance, Healthy Beijing 2030 puts forward a strategic plan for improving urban green space [79]. The plan includes expanding forest coverage, upgrading parks for leisure, and implementing the street greenway project [79]. The plan aims for a forest coverage rate of 45%, a per-capita green space of 16.8 square meters, and a 1000-km municipal green street by 2030 [79]. Findings from this review suggest that these policy interventions are likely to enhance PA engagement among residents. Meanwhile, green space designs that incorporate sports facilities, playgrounds, walking paths, seats, and sceneries could also contribute to PA promotion and green space use. Street greenness designed with aesthetics, safety, and connectivity would be a promising way to encourage both leisure PA and active travel.

Despite the merits of this study, several limitations of this review and the included studies should be noted. First, all studies adopted a cross-sectional study design, which was prone to confounding bias and did not infer causality between green space and PA. Second, most studies used self-reported PA measures, which were subject to recall error and social desirability bias [80]. Third, some studies did not consider the potential moderators of traffic, safety, weather, or green space maintenance and condition, as relevant data were not always available to researchers. Fourth, a limited number of mechanisms (e.g., aesthetics, attractiveness) have emerged in the literature, and the roles of those mediating mechanisms in the relationship between green space and PA were inadequately assessed. Future studies adopting experimental study design are warranted to establish more robust scientific causality evidence between green space and PA in China. Objective measures of PA (e.g., GPS, pedometer, accelerometer, and mobile applications) are recommended for future studies. Due to the important roles of temperature, noise, air pollution, safety, and aesthetics in promoting PA in green space, such data should be added to the modeling analysis in future studies. Furthermore, we suggest combining objective and subjective measures of green space to better understand the mechanism between greenspace and PA. Place of residence might also be an important moderator in the associations between nature exposure and PA [81]. Most of the studies focused on the urban area, while few studies explored the differences in the effect of green space and PA considering the urban or rural place of residence. Future work examining the association of green space and PA should incorporate rural areas when considering the place of residence.

Beyond the above, this review has two primary limitations. First, the literature search identified articles written in English and Chinese but excluded those reported in other languages. Second, this review only included published literature. Future reviews could conduct a grey literature search to include relevant and useful unpublished studies.

5. Conclusions

This study systematically reviewed the scientific literature regarding the relationship between green space and PA among Chinese residents. Street greenness was associated with increased odds of active commuting (e.g., cycling) and walking, and a reduced risk of physical inactivity. Accessibility to green space was associated with increased PA levels and green space usage. Distance to green space was inversely associated with the odds of PA. By contrast, evidence linking overall greenness exposure to PA remains limited. Future studies adopting experimental study design are warranted to establish more robust scientific causality evidence between green space and PA in China. Future studies are also warranted to examine the underlining mechanisms and the differential impacts of green space on population subgroups in China.

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Appendix A

Appendix A is Search Algorithm in PubMed.

((“greenspace”[TIAB] OR “greenspaces”[TIAB] OR “green-space”[TIAB] OR “green space”[TIAB] OR “green spaces”[TIAB] OR “green infrastructure”[TIAB] OR “green infrastructures”[TIAB] OR “green area”[TIAB] OR “green areas”[TIAB] OR “green belt”[TIAB] OR “green belts”[TIAB] OR “green environment”[TIAB] OR “green environments”[TIAB] OR “greening project”[TIAB] OR “green element”[TIAB] OR “green elements”[TIAB] OR “urban green”[TIAB] OR “greenery”[TIAB] OR “greenness”[TIAB] OR “greenbelt”[TIAB] OR “greener”[TIAB] OR “normalized difference vegetation index”[TIAB] OR “NDVI”[TIAB] OR “natural element”[TIAB] OR “natural elements”[TIAB] OR “natural environment”[TIAB] OR “natural environments”[TIAB] OR “natural outdoor environment”[TIAB] OR “natural outdoor environments”[TIAB] OR “natural surroundings”[TIAB] OR “natural space”[TIAB] OR “natural spaces”[TIAB] OR “natural area”[TIAB] OR “natural areas”[TIAB] OR “natural land”[TIAB] OR “open space”[TIAB] OR “open spaces”[TIAB] OR “open land”[TIAB] OR “open area”[TIAB] OR “open areas”[TIAB] OR “walkable area”[TIAB] OR “walkable areas”[TIAB] OR “vegetated area”[TIAB] OR “vegetated areas”[TIAB] OR “public space”[TIAB] OR “public spaces”[TIAB] OR “public area”[TIAB] OR “public areas”[TIAB] OR “public land”[TIAB] OR “wild land”[TIAB] OR “wild area”[TIAB] OR “wild areas”[TIAB] OR “nature”[TIAB] OR “vegetation”[TIAB] OR “park”[TIAB] OR “parks”[TIAB] OR “parkland”[TIAB] OR “garden”[TIAB] OR “gardens”[TIAB] OR “forest”[TIAB] OR “forests”[TIAB] OR “tree”[TIAB] OR “trees”[TIAB] OR “landscape”[TIAB] OR “woodland”[TIAB] OR “woodlands”[TIAB] OR “wilderness”[TIAB] OR “walkability”[TIAB]) AND (“exercise”[MeSH] OR “motor activity”[TIAB] OR “motor activities”[TIAB] OR “sport”[TIAB] OR “sports”[TIAB] OR “physical fitness”[TIAB] OR “physical exertion”[TIAB] OR “physical activity”[TIAB] OR “physical activities”[TIAB] OR “physical inactivity”[TIAB] OR “sedentary behavior”[TIAB] OR “sedentary behaviour”[TIAB] OR “sedentary behaviors”[TIAB] OR “sedentary behaviours”[TIAB] OR “sedentary lifestyle”[TIAB] OR “sedentary lifestyles”[TIAB] OR “inactive lifestyle”[TIAB] OR “inactive lifestyles”[TIAB] OR “exercise”[TIAB] OR “exercises”[TIAB] OR “active living”[TIAB] OR “active lifestyle”[TIAB] OR “active lifestyles”[TIAB] OR “outdoor activity”[TIAB] OR “outdoor activities”[TIAB] OR “walk”[TIAB] OR “walking”[TIAB] OR “running”[TIAB] OR “bike”[TIAB] OR “biking”[TIAB] OR “bicycle”[TIAB] OR “bicycling”[TIAB] OR “cycling”[TIAB] OR “stroll”[TIAB] OR “strolling”[TIAB] OR “active transport”[TIAB] OR “active transportation”[TIAB] OR “active transit”[TIAB] OR “active commuting”[TIAB] OR “travel mode”[TIAB] OR “physically active”[TIAB] OR “physically inactive”[TIAB]) AND (“China”[MeSH] OR “China”[ALL] OR “Chinese”[ALL])AND English[lang] AND “humans”[MeSH]).

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