Preventive Medicine Reports 3 (2016) 303–316

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: http://ees.elsevier.com/pmedr

Review Article

Built environmental correlates of physical activity in China: A review

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ARTICLE INFO

Article history:
Received 21 October 2015
Received in revised form 13 January 2016
Accepted 11 March 2016
Available online 15 March 2016

Keywords:
China
Physical activity
Environment
Transportation
Recreation

ABSTRACT

Objective. China faces growing levels of physical inactivity and obesity, associated with increasing urbanization and changing lifestyles in recent years. China is expanding its cities to accommodate a growing urban population. This paper identifies built environment factors that are associated with physical activity in China. Findings can inform urban design and development in China to support increased physical activity.

Methods. This paper is modeled on a review of built environment correlates of walking by Saelens and Handy (2008). Saelens and Handy reviewed research in developed countries. The present paper reviews 42 empirical studies that were conducted in China and were published between 2006 and 2014.

Results. Results discuss the association of built environment features and physical activity for transportation, recreation and work. Studies focus on adults and on major cities. Data on the built environment is typically self-reported. Strongest evidence was found for the positive association of physical activity with proximal non-residential locations, pedestrian infrastructure, aesthetics, and non-park physical activity facilities, and for the negative association of physical activity with urban residence. In terms of physical activity for transportation, evidence is strongest for associations between physical activity for transportation and proximal non-residential locations.

Conclusion. More research is needed on the built environment and physical activity, especially including research on significant features of Chinese cities, such as air pollution, high density levels, traffic safety, and others. Research on associations between built environment features and physical activity should consider the specific social and built environment contexts of Chinese cities.

Contents

1. Introduction

Rising obesity, declining physical activity, and growing rates of chronic disease are major concerns in China and in other developing countries. According to the World Health Organization (WHO) (2015), 36.2% of adults in China are now overweight and 5.9% are obese. Nearly 80% of deaths in China are attributable to noncommunicable (or chronic) disease (World Health Organization, 2005). Between 1991 and 2006, the average weekly rate of physical activity dropped by approximately 32% among adults (Ng et al., 2009). For men, self-reported occupational, domestic, transportation, and leisure physical activity, fell from 350 MET (metabolic equivalent) hours per week in 1997 to 253 MET hours per week in 2006. Women's physical activity declined from 390 MET hours per week in 1996 to 246 MET hours in 2006 (Ng et al.,

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http://dx.doi.org/10.1016/j.pmedr.2016.03.007

2009). Insufficient physical activity is a leading contributor to diseases such as diabetes, cancer and cardiovascular disease (WHO, 2015).

To reduce obesity and overweight and to combat noncommunicable diseases, the World Health Organization advocates strategies that target entire populations, including the design of environments to promote physical activity for transportation and recreation as part of everyday life (WHO, 2015), or "active living." Historically, research on active living has examined developed countries, especially the USA and Canada, Australia, European countries, and Japan. Active living research from developed countries is not necessarily generalizable to developing countries such as China, where the cultural context and the built environment may differ (Sallis, 2011). Indeed, physical activity in China is shaped by specific built environment factors and also by Chinese cultural norms surrounding physical activity, health, and travel (for an overview of cultural factors, public policies, and current urban planning practices that affect physical activity levels in China, see Day et al., 2013).

The design of Chinese cities to promote physical activity is a timely issue. China is expanding its cities at a rapid rate to accommodate enormous growth in its urban population—including an additional 200 million residents between 1990 and 2000 (The State of China's Cities, 2010). Accommodating this population could require an estimated 170 new mass-transit systems, 5 billion square meters of road, and 40 billion square meters of new floor space. Though the rate of development may slow in China's current economic situation, it is important to understand the links between the built environment and physical activity to help inform these extensive city building efforts.

This paper reviews existing research on the relationship between the built environment and physical activity in China. It identifies what is known so far, suggests key questions for future research, and highlights some potential differences in the relationship between the built environment and physical activity in China compared to research findings from developed countries.

2. Methods

This paper reviews 42 published empirical studies on physical activity and the built environment in China. The paper is modeled closely on a paper by Saelens and Handy (2008). Saelens and Handy (2008) are widely cited—701 times as of July 6, 2015, according to Google Scholar. Saelens and Handy (2008) reviewed 13 published literature reviews and 29 empirical research reports on the association between walking and the built environment. Their paper offers a systemic framework for analysis of literature that is replicable and that, importantly, allows for comparison with the present review. Saelens and Handy's (2008) review provides a guide for the organization of this paper and for the methods of analysis. Note that Saelens and Handy (2008) review studies from developed countries only (reflecting the available literature at that time). They focus exclusively on walking. The present paper, in contrast, reviews studies from China only and includes research on various types of physical activity, including walking and others.

For the present paper, a systematic search was conducted to identify studies published on the association between the built environment and physical activity in China. Search terms used in Web of Science (science and social science) included "physical activity," "walk," "bicycle," "bicycling," "travel," "transportation," "exercise," "recreation," "mode share" AND "environment," "park," "sidewalk," "trail," "mixed use," "urban," "suburban," "urban design," "walkability," "walkable," "bike-friendly," AND "China." Additional search terms included "active living," "active design," "walkability" AND "China." Search terms used for this analysis were those identified by Saelens and Handy (2008), plus additional terms to include non-walking physical activity and to narrow the focus to China. A few search terms used by Saelens and Handy (2008), including environment, design, and neighborhood, were not included because these terms were overly broad for this analysis. Bibliographic lists prepared by the Robert Wood Johnson Active Living Research program from 2002 through 2011 were also searched, as was the Active Living Research program's list of research studies from outside of the USA. The reference lists of several published literature reviews on the built environment and physical activity were reviewed to identify studies on China. Finally, the reference lists for all studies that were included in this paper were reviewed to identify possible studies for inclusion.

Each study that as included in this paper met the following criteria: (1) published as a full paper (not only an abstract); (2) included a primary report of methods, analysis and findings; (3) published in a peer-reviewed journal; (4) included an examination of the association between the objective and/or perceived built environment and physical activity; (5) included research that was conducted (all or in part) in China; (6) published before or during 2014; and (7) written in English. Because of the focus of this paper on implications for planning and design of the built environment to support physical activity, studies that examined only the social, cultural or economic environment, were not included (as in Saelens and Handy, 2008). The built environment was defined broadly, and included concepts such as urban versus rural distinction, natural environment features, and also population density, which impacts transportation planning.

Studies were reviewed using a preliminary coding scheme based on Saelens and Handy (2008). The coding scheme specified factors such as year of publication, built environment data sources, built environment factors examined, and geographic unit of analysis. Twenty studies were reviewed using the preliminary coding scheme. Based on the review of the first 20 studies, the coding scheme was revised to include additional factors, such as disciplinary orientation of authors and additional types of physical activity (for work as well as for recreation and transportation). All studies were reviewed again using the revised coding scheme.

Review procedures included the following. Each study was characterized in terms of the country in which the data were collected, sample, built environment factors, geographic unit of analysis, type of physical activity, covariates, and major results. Studies were also coded in terms of methods used to collect data (e.g., survey, interview, observation) and on whether environmental data were objective or perceived. (For perceived environmental factors, data on the environment was provided by respondents themselves through self-report.) Studies were further characterized in terms of their geographic unit of analysis. This information was often vague. (The same was true in Saelens and Handy (2008).) Studies were further coded in terms of the types of environmental factors examined, and the environmental scale of the study (micro, meso or macro). As in Saelens and Handy (2008), micro-environments referred to the environments immediately around where an individual lives (or works or goes to school, for studies of workplaces or schools). Individuals who live on the same street could potentially vary in their micro-environments. Meso environments included the small scale environments in which an individual lives, such as a neighborhood or census block group. Macro-environments were the larger scale environments in which an individual lives, such as the city or county. All individuals within that scale are considered to have the same environment.

The review also identified the type(s) of physical activity measured (recreation, transportation, work, and/or general); and whether results were expected, unexpected, and null. Expectedness was based on prior empirical research and conceptual models on the relationship between the built environment and physical activity. "More" of the following built environment factors were expected to be associated with more physical activity: density; proximity to nonresidential land uses (includes mixed land uses, transit access); street connectivity; parks and open/green space (quality and availability); non-park physical activity facilities; pedestrian infrastructure (presence and condition); bicycle infrastructure (presence and condition); traffic safety; aesthetics (including cleanliness). "Less" of the following built environment factors were expected to be associated with more physical activity: distance to specific non-residential land uses; crime; traffic volume and noise; high

temperatures or oppressive weather conditions; pollution and emissions; and stray animals. Existing literature in developing countries links urban residence with higher obesity and lower levels of physical activity (c.f., Andegiorgish et al., 2012; Muntner et al., 2005; Ramons de Marins et al., 2002), so urban location was also expected to be associated with less physical activity. As noted earlier, the existing literature focuses heavily on developed countries. The discussion section addresses where relationships in China differ from what is "expected" according to existing literature. For ease and because the current literature does not permit greater specificity, "expectedness" was considered the same for physical activity for recreation, transportation, work, and general. For built environment factors that were measured but for which significant or nonsignificant findings were not reported, the relationship with physical activity was characterized as "null." Finally, studies were coded in terms of which factors, if any, were included as covariates.

3. Results

3.1. Active living research in China

A total of 42 empirical research reports were identified that were published before or in 2014 (see Table 1). The earliest identified studies were published in 2006 (Li et al., 2006; Shi et al., 2006). Rate of publication increased modestly over time, to a total of nine studies published in each of 2013 and 2014. Papers are treated as discrete studies. Note that in some cases, a single study may have produced multiple papers. In terms of disciplinary orientation of authors (as identified by each author's academic department or professional affiliation), health-related disciplines (including public health, medicine, epidemiology, and others) were most well represented, with 21 papers having one or more authors from a health-related discipline. Urban planning-related disciplines were also common (including architecture, urban design, etc.). Research by investigators in sports and exercise-related fields was also well represented (see Fig. 1). Multidisciplinary research was common; almost half the studies included authors from more than one field.

Most research focused on China only. A small number of studies included China and one or more additional countries. Much of the research was conducted in China's largest cities: Hong Kong, Beijing, Shanghai, and others. Most studies examined adults.

Most studies included both men and women participants. (A few studies did not report participants' gender.) Most studies in this paper examined adults. Smaller numbers of studies examined seniors (age 65 and older) and children (under age 18). Only studies that explicitly noted that they included adults over age 65, were characterized as including seniors. Thirteen studies explicitly included seniors (over age 65), but only six studies reported results separately for seniors. Five of these six studies reported associations between nearby non-residential locations and physical activity among seniors. Nine studies included children under age 18; only six studies reported results separately for children. There was no consistent support for specific associations between the built environment and physical activity among children.

The most common method for collecting data on built environment characteristics was by survey or interview (see Table 2). Such built environment data was self-reported rather than objectively observed. Fewer studies used observation or environmental audit or GIS (Geographic Information System) as a source of data on built environment characteristics. For physical activity data, several studies used the IPAQ (International Physical Activity Questionnaire, 2009) or modified IPAQ. Most studies used another survey or interview, often created for the study itself. Only two studies used accelerometers to collect physical activity data. Studies examined transportation-related physical activity (21 studies) and recreation-related physical activity (12 studies). Sixteen studies examined "general" physical activity that was not further specified by purpose. Four studies examined physical activity for work.

As in Saelens and Handy (2008), individual level demographic variables were a common co-variate and were included in the multi-variate analyses for most studies. Other co-variates varied (e.g., attitudes about the environment and health status). In contrast with Saelens and Handy (2008), most research in China investigated environmental factors at the meso scale (e.g., neighborhood) rather than at the micro-scale (the physical environment immediately radiating from where an individual lives) (see Table 2). This distinction reflects how built environment data were collected in research in China, which was most often through participants' self report about their neighborhoods. In contrast, in the studies in developed countries reviewed by Saelens and Handy (2008), built environment information was frequently generated through GIS data linked to individual residences.

Table 3 summarizes the built environment features that are associated with physical activity for transportation, recreation, work, and general, in terms of whether results are expected or unexpected (as in Saelens and Handy, 2008). Individual studies may contain results tied to more than one type of physical activity, and may include results that are both expected and unexpected. Studies with results for composite measures of the built environment are assigned to each relevant built environment feature in this table and also noted as "composite."

Built environment features were considered in terms of their associations with specific types of physical activity (transportation, recreation, or work). Physical activity for transportation was examined in 21 studies. Evidence is strongest for associations between physical activity for transportation and proximal non-residential locations. Twelve studies examined physical activity for recreation. Evidence supported the association between physical activity for recreation and proximal non-residential locations and non-park physical activity destinations. Only four studies examined physical activity for work, so these findings were not conclusive.

4. Discussion and conclusions

This review included a limited number of studies overall, and all built environment features were not included in all studies. At this stage, one cannot speak definitively of the associations between physical activity and specific built environment in China. Some conclusions can be made, however, by considering the overall number of times a variable was studied and the percentage of studies that found positive associations. Studies in this review provided most support for the association between physical activity and proximal non-residential locations, pedestrian infrastructure, aesthetics, and non-park physical activity facilities, and for the negative association of physical activity with urban residence. Findings also suggested an association between physical activity and parks/open space and bicycling facilities, though only a small number of studies examined these factors. Findings also supported associations between composite features and physical activity, though the type of environment defined by "composite measures" varied somewhat. Findings were mixed on the association between physical activity and distance to specific non-residential land uses, network characteristics, crime safety, traffic safety, and density. Only one or two studies examined the association between physical activity and the presence of stray animals, weather/temperature, and pollution, so these findings are inconclusive.

In their meta-analysis of literature reviews on the built environment and walking, Saelens and Handy (2008) find strongest support for associations between walking for transportation and density, distance to nonresidential destinations, and land use mix. Their findings on built environment features linked to recreational walking were less conclusive. The present study focuses on all forms of physical activity, not only walking, and it deals with 42 studies (total) and not the large number of studies covered by Saelens and Handy (2008). Still, it is worth

Table 1
Characterization of studies by country, sample, environmental factors and data source, geographic unit of analysis, type of physical activity and how measured, covariates, and major results. Results are reported for findings that are statistically significant, typically at $P < 0.05$ but occasionally at $P < 0.10$. When multiple models were included in the articles, the most complete model result was considered (as in Saelens and Handy, 2008).

Reference	Country[1]	Sample	Environmental factors, data source[2]	Environmental factors examined	Analyzed geographic unit	Physical activity type/physical activity measure	Covariates[3]	Results
Adams et al. (2013)	China, Belgium, Brazil, Canada, Columbia, Japan, Lithuania, New Zealand, Norway, Sweden, USA	11,541 adults aged 18 to 64 in Hong Kong	Survey, interview	Residential density; access to shops/services, public transit, and recreational services; sidewalks; bike paths; personal safety from crime	Neighborhood	Transportation and recreation/IPAQ or modified IPAQ	Demos	(1) Residents in activity supportive neighborhoods more likely to meet guideline for overall physical activity. (2) Residents in high walkable and unsafe neighborhoods with few recreation facilities more likely to meet guideline for total physical activity and for walking. (3) Residents in dense neighborhoods with transit and shops with few amenities less likely to meet guideline for total physical activity. (4) Respondents in overall activity supportive neighborhoods more likely to meet guideline for walking.
Aldinger et al. (2008)	China	191 administrators, teachers & staff, students, parents from elementary, middle, junior high, high, & vocational schools in Zhejiang Province	Qualitative description of physical environment	Composite description of intervention: schools improved facilities such as dining rooms, dormitories, teaching and sports facilities, enhanced cleanliness and did beautification projects [intervention also includes non-physical environment changes.]	School	General (not specified)/survey or interview	None	Enhanced schools were associated with increased physical activity for some participants.
Alfonzo et al. (2014)	China	853 adults in Hangzhou, Shanghai	Survey	Density/building height, proximity/land use mix, connectivity, form, parks and public space, pedestrian infrastructure/amenities, bike infrastructure/amenities, personal safety, traffic safety, aesthetics, recreational facilities. Perceived neighborhood convenience for walking	Neighborhood	Transportation and recreation/survey or interview	Demos, other	(1) Respondents in neighborhoods with higher walkability more likely to spend more time walking for commuting, non-commuting, and exercise, and on overall walking, compared to respondents in neighborhoods with below average walkability. (2) Respondents who believe neighborhood's built environment was less convenient for walking, spent more time walking overall and more time walking for non-commuting purposes.
An and Zheng (2014)	China	2532 respondents from urban areas and 1784 respondents from rural areas in 10 provinces	Observation/environmental audit	Time to walk to nearest exercise facility	Distance to exercise facility	Recreation/accelerometer	Demos	(1) Individuals in 10 min walking distance to exercise facility more likely to have some leisure time physical activity. (2) Rural residents aged 18 or older less likely to have leisure time physical activity, compared to urban residents. (3) Association between proximity to exercise facility and leisure time physical activity greater for women than for men. (4) Association between proximity to exercise facility and leisure time physical activity greater for working age adults than for older adults. (5) Association between proximity to exercise facility and leisure time physical activity greater for those with college or graduate degree. (6) Association between proximity to exercise facility and leisure time physical activity greater for urban dwellers.
Bauman et al. (2011)	China, Australia, Fiji, Malaysia, Nauru, Philippines	142,693 (China), 6763 (Fiji), 2572 (Malaysia), 2085 (Nauru), 3307 (Philippines) non-institutionalized adults aged 18–64 living in private dwellings	Survey	Urban vs. rural residence (only measured for China, Fiji, Malaysia and Australia). Definition of urban based on level of economic development (China)	Urban area	General (not specified)/survey or interview	Demos	(1) Residents of urban areas more likely to be active during leisure time compared to rural populations. (2) Residents of urban areas were less likely to be active in work, compared to rural population (3) Men living in urban areas engage in less walking or cycling for commuting, compared to rural residents
Bosdriesz et al. (2012)	China and 37 additional countries	177,035 adults aged 18 to 69	Climate temp web site of world temperatures, World Bank Database, CIA World Factbook	Average yearly temperature in capital city, percentage of rural population, economic development (GDP).	Country	General (not specified)/IPAQ or modified IPAQ	Demos	(1) Negative association between GDP and physical activity. (2) Higher average daily temperature associated with less physical activity. (3) Lower percentage of rural

								population (higher urbanization) associated with less vigorous and less moderate physical activity.
Cerin et al. (2012a)	China	484 Chinese speaking elders with no cognitive impairment and able to walk without assistance in 32 communities in Hong Kong	Survey	Perceived availability of destinations (land use mix- diversity, land use mix-access to shops, access to public transport); accessibility and pedestrian infrastructure (street connectivity, infrastructure for walking, indoor places for walking, physical barriers to walking); easy access to residential entrances; residential density; crowdedness; personal safety (presence of people, crime); traffic and road hazards; availability of sitting	Neighborhood	Transportation/IPAQ or modified IPAQ and survey or interview	Demos	(1) Perceived land use mix-diversity, access to shops, physical barriers to and infrastructure for walking, crowdedness, traffic and road hazards, easy access to residential entrances and sitting facilities in neighborhood associated with frequency and/or weekly minutes of within-neighborhood walking for transport. (2) Perceived land use mix-diversity, access to shops, infrastructure for walking, crowdedness, easy access to residential entrances and sitting facilities in neighborhood, perceived access to public transport and dwelling density associated with measures of overall transportation-related walking. (3) Access to shops, crowdedness, easy access of residential entrance, infrastructure for walking, presence of sitting facilities associated with overall and within-neighborhood walking. (4) Access to public transport associated with overall walking. (5) Land use mix-diversity and physical barriers to walking associated with within-neighborhood walking.
Cerin et al. (2012b)	China	484 elders age 65 +, from 4 elderly health centers in 4 catchment areas in Hong Kong	Survey	Perceived: residential density, land use mix, street connectivity, infrastructure for walking, indoor places for walking, aesthetics, presence of people, crowdedness, traffic and road hazards, traffic speed, social disorder/littering, crime, pedestrian infrastructure, ease of residential entrance, sitting facilities	Individual respondent	Recreation/IPAQ or modified IPAQ	Demos	(1) Perceived bridge/overpass connecting to services associated with overall recreational walking. (2) Perceived proximity to recreational facilities, infrastructure for walking, indoor places for walking, presence of bridges/overpasses connecting to services associated with within-neighborhood recreational walking.
Cerin et al. (2013a)	China	484 elders able to walk unassisted, living in 32 neighborhoods in Hong Kong	Observation/environmental audit	Recreation and commercial destinations (pool, gym/fitness center, community/senior center, playground, sports field, commercial facilities); infrastructure facilities (public facilities, path quality, path obstructions, indoor/covered walking places); safety (crime, traffic, pedestrian safety, stray animals); aesthetics and cleanliness, including pollution	Neighborhood	Recreation/IPAQ or modified IPAQ	Demos	(1) Parks, signs of crime/disorder, building attractiveness, noise/air pollution associated with walking for recreation. (2) Public facilities (sitting, toilets), indoor/covered places for recreation, natural sights, noise/air pollution, litter associated with nonparticipation in walking for recreation. (3) Path quality, traffic load, noise/air pollution associated with leisure time activity other than walking (OLTPA). (4) Outdoor sports fields, senior center, park, public facilities, sign of crime/disorder, traffic load, trees associated with nonparticipation in OLTPA. (5) Path quality, pollution moderated associations of odds of non-participation in OLTPA with playground, park and pool. (6) Stray animals moderated associations of odds of non-participation in OLTPA on parks, playground. (7) Signs of crime/disorder moderated associations of odds of non-participation in OLTPA on park, sport field. (8) Availability of public facilities moderated associations of odds of non-participation in OLTPA with parks.
Cerin et al. (2013b)	China	484 elders with no diagnosed cognitive impairment who can walk unassisted and live in 32	Observation/environmental audit	Public transit points; recreational facilities; places of worship; health clinics; government/public facilities; entertainment facilities; non-food retail and services; food	Neighborhood	Transportation and recreation/IPAQ or modified IPAQ and survey or interview	Demos	(1) Signs of crime/disorder positively associated with overall walking and with within-neighborhood walking for transport. (2) Prevalence of streetlights positively

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Table 1 (*continued*)

Reference	Country[1]	Sample	Environmental factors, data source[2]	Environmental factors examined	Analyzed geographic unit	Physical activity type/physical activity measure	Covariates[3]	Results
Cerin et al. (2013b)		neighborhoods in Hong Kong		and grocery stores; restaurants; safety; infrastructure (path obstructions, good path conditions, sloping street); public services				associated with within-neighborhood walking for transport. (3) Prevalence of stray animals negatively associated with within-neighborhood walking for transport. (4) No significant association between pedestrian safety, sloping streets, public facilities, path obstructions, or good path conditions AND walking for transport or overall walking. (5) Prevalence of public transit points and diversity of recreational destinations associated with weekly minutes of overall walking for transport. (6) Health clinic/service and place of worship, higher diversity in recreational destinations, and greater prevalence of non-food retail and services, food/grocery stores, and restaurants in neighborhood were predictive of more within-neighborhood walking for transport. (7) Prevalence of public transit points in safe neighborhoods (only) associated with overall walking for transport. (8) Diversity of recreational and entertainment destinations in safe neighborhoods (only) associated with within-neighborhood walking for transport. (9) Composite destinations indices associated with walking for transport.
Cerin et al. (2014)	China, Belgium, Brazil, Columbia, Czech Republic, Denmark, Mexico, New Zealand, Spain, UK, USA	6968 adults in 16 city regions in 12 countries	Survey	Perceived residential density, land use mix-diversity, land use mix-access, street connectivity, infrastructure and safety for walking, aesthetics, traffic safety, safety from crime, streets having few cul-de-sacs, no physical barriers to walking	Neighborhood	General (not specified)/accelerometer	Demos	(1) Perceived aesthetics and land use mix-access were significant predictors of weekly minutes of MVPA and meeting PA guidelines for cancer/obesity prevention. (2) Perceived environment had beneficial effect on probability of meeting PA guidelines for cancer and weight gain prevention in Hong Kong.
Ding et al. (2013)	China, Belgium, Brazil, Canada, Columbia, Japan, Lithuania, New Zealand, Norway, Sweden, USA	11,541 adults age 18 to 65, living in towns in Hong Kong with populations ≥30,000	Survey, interview	Main type of housing in neighborhood as measure of residential density (not calculated for Hong Kong); access to shops; presence of transit stops; presence of sidewalks, bicycle facilities, free or low cost recreation facilities; crime	Neighborhood	General (not specified)/IPAQ or modified IPAQ	Demos	(1) Shops near home, transit stops near home, sidewalks, bicycling facilities, and free or low cost recreational facilities associated with higher odds of meeting physical activity recommendations. (2) Crime-related safety associated with lower odds of meeting physical activity recommendations.
Feng et al. (2014)	China	3894 adults in 8 districts in Nanjing	Survey	Population density, accessibility, distance to nearest metro station, housing type	1000 m area around Transportation Analysis Zone (TAZ)	Transportation and recreation/survey or interview	Demos	(1) High population density associated with greater levels of walking or cycling to work. (2) Accessibility of employment not associated with mode choice for commuting trips. (3) Housing type has strong impacts on mode choice for commute and shopping-leisure trips: those in former danwei housing use non-motorized transport more than do people in commodity housing. (4) Population density, distance to nearest metro station have no significant impact on mode choice for shopping-leisure trips. (5) Higher densities of shopping-leisure facilities associated with increased walking trips, compared to public transport trips.
Jiang et al. (2012)	China	2155 BRT users in Jinan, including 1233 with information on distance	GIS, interview	Protection (security against traffic safety risk and crime); comfort (ease of walking, including sidewalk quality, street	Length of walk to BRT station, 600-m buffer	Transportation/survey or interview, GIS analysis of distance walked	Demos	(1) Integrated boulevard Bus Rapid Transit (BRT) corridor stations (poor protection, average comfort, good enjoyment, good

		walked to BRT station		cleanliness); enjoyment (aesthetic and utilitarian aspects tied to presence of activities, relief from elements); directness (relative detour factor)	area surrounding BRT stations			directness) associated with longer walking distance, compared to arterial edge BRT corridor stations (poor protection, good comfort, poor enjoyment, poor directness) and compared to below expressway BRT corridor stations (poor protection, poor comfort, average enjoyment, good directness). (2) Terminal stations have longer distance walked and transfer stations have shorter distance walked, compared to typical stations. (3) Density concentrated near BRT station associated with shorter distance walked. (4) Density lower near BRT station associated with longer distance walked, compared to area away from station. (5) Stations located farther from city center associated with longer distance walked.
Li et al. (2006)	China	1787 adolescents aged 11–17 attending junior high schools in Xi'an City	Survey, survey of school environment by school doctor	Recreational facilities in the community, places around the home to play, transportation, level of residence, safety concern, household facilities for playing games, school environment	Home, area near home, community	Transportation and recreation/survey or interview	Demos, other	(1) Access to public facilities, concerns about neighborhood safety associated with inactivity. (2) Adolescents living in a house without sidewalks were more inactive. (3) Living in areas without nearby vacant fields and unavailability of video games near home associated with inactivity for boys. (4) Greater inaccessibility of public facilities and lack of sidewalks near home associated with inactivity in girls.
Li et al. (2014)	China	497 dyads of parents and children in 4 primary schools in Guangzho and Hechi	Survey	Parents' perceived walkability of their neighborhood environments (types of residences, types of other facilities, access to services, distance to facilities, safety from traffic, aesthetics, safety from crime, street qualities, presence of cul-de-sacs, barriers, hilly)	Neighborhood	Recreation/survey or interview	Demos, other	No association between perceived environmental factors and children's daily moderate to vigorous physical activity level.
Monda et al. (2007)	China	8760 adults	Survey	Level of urbanization	Community	Work/survey or interview	Demos	Increased urbanization associated with decreased occupational physical activity for men and women.
Naess (2009)	China, Denmark	28 interview respondents, 3000+ survey respondents who are residents in 5 areas in Hangzhou	Survey	Type of residence, workplace/school location, location of activities, distance to downtown and local centers	Community	Transportation/survey or interview	Demos, other	(1)Those who lived near city center have longer average travel distance by non-motorized modes. (2) Living close to city center associated with greater likelihood of non-motorized travel, but with shorter non-motorized travel distances; and with higher proportion of total travel distance through non-motorized modes. (3) Living near second order center associated with higher likelihood of using non-motorized modes. (4) Living near third order center associated with somewhat higher likelihood of non-motorized modes; and with somewhat higher proportion of total traveling distance during weekends by non-motorized modes.
Naess (2010)	China	28 interview respondents, 3154 survey respondents age 15 or older in 40 residential areas in Hangzhou (242 respondents from other areas)	Survey, interview	Residential distance from central city and distance from residence to second- and third-order center	Community	Transportation/survey or interview	Demos, other	The closer to city center residents live, the higher their proportion of travel on foot and/or by bicycle.
Naess (2013)	China	28 adults living in 5 regions in Hangzhou	Interview	Distance to destinations (linked to residence in inner city vs. suburbs); perceived conditions of route (traffic safety, congestion)	Individual respondent	Transportation/survey or interview	None	(1) Shorter distance to destination, increased traffic congestion, and fewer parking spaces associated with increased likelihood of active travel. (2) Bad weather and concern for traffic

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Table 1 (*continued*)

Reference	Country[1]	Sample	Environmental factors, data source[2]	Environmental factors examined	Analyzed geographic unit	Physical activity type/physical activity measure	Covariates[3]	Results
Naess (2013)								safety associated with decreased likelihood of active travel.
Ng et al. 2009	China	58,112 adults	Survey, data from local area administrators and official records	Level of urbanization represented by infrastructure development over time, including population, density, access to markets for household goods, transportation, educational institutions, health facilities, sanitation and housing infrastructure	Community	Transportation and recreation, work/survey or interview	Demos	(1) Availability of educational institutions, improved sanitation and housing infrastructure, access to markets associated with declines in occupational and total physical activity. (2) Health facilities associated with declines in occupational activity. (3) 10 community level urbanization dimensions associated with significant declines in occupational activity over time, especially for men.
Pan et al., (2009)	China	1709 individuals in 4 neighborhoods in Shanghai	Observation/environmental audit, census, GIS	Design differences in neighborhoods from different times (1930's-60's traditional, 1970's–80's planned community, late 1980's private sector). Differences include distance to CBD, land use mix, human scale, residential building height, road width, street pattern, population density, road network density, block size, transit availability	Neighborhood	Transportation/survey or interview	Demos	(1) Traditional neighborhood associated with shortest average distance of walking bicycling trips, compared to planned neighborhood; private sector neighborhood has highest average distance of walking, bicycling trips. (2) Traditional neighborhood has highest non-motorized travel. (3) For nonwork trips, residents in traditional neighborhood have most frequent non-motorized travel. (4) Greater trip distance associated with decrease in non-motorized travel. (5) Neighborhood type not associated with transit vs. non-motorized travel for travel to work. (6) One planned community associated with greater likelihood of non-motorized travel versus driving.
Pan et al. (2010)	China	900 individuals at 4 transit stations in Shanghai	Survey	Distance to destination, transit station; availability of bike parking	Individual respondent	Transportation/survey or interview	None	(1) Shorter distance associated with increased likelihood of active travel. (2) Increased distance to rail station associated with decreased probability of walking, bicycling to transit station. (3) Living closer to rail station associated with increased probability of walking to station. (4) Increased distance to bus stop associated with increased probability of walking, bicycling to transit station. (5) No bicycle parking facility at transit station associated with not bicycling to transit station.
Sallis et al. (2009)	China, Belgium, Brazil, Canada, Columbia, Japan, Lithuania, New Zealand, Norway, Sweden, USA	11,541 adults age 18 to 65, living in towns with populations ≥30,000 in Hong Kong	Survey, interview	Main type of housing in neighborhood as a measure of residential density; access to shops; presence of transit stops; presence of sidewalks, bicycle facilities, free or low cost recreation facilities; crime; neighborhood activity-friendliness	Neighborhood	General (not specified)/IPAQ or modified IPAQ	Demos	(1) Many shops nearby, transit stop in neighborhood, sidewalks on most streets, bicycle facilities, and low-cost recreational facilities associated with physical activity prevalence. (2) Number of physical activity-supportive built-environment attributes associated with meeting guidelines for physical activity.
Shan (2014)	China	595 park visitors age 15 and older in Guangzhou	Interview	Distance from urban green space	Distance from residence	Transportation/survey or interview	Demos	Respondents who must walk more than 20 min to urban green space are less likely to walk to urban green space, compared to residents within 10 min walking distance.
Shi et al. (2006)	China	824 Students from 16 classes in grades 7 and 8, in 8 schools in Xuzhou and Zhenjiang prefectures	Assignment of schools to urban/rural by authors	Urban vs. rural school	Community	Transportation and recreation, work/survey or interview	Demos	(1) Urban vs. rural boys have no significant difference in vigorous physical activity, mode of commuting, level of house work, or total physical activity. (2) Urban vs. rural girls have no significant difference in vigorous physical activity. (3) Rural girls participated in significantly more housework and more total

								physical activity, compared to urban girls.
Su et al. (2014)	China	1434 residents of 30 neighborhoods in 3 types of administrative planning units in Hangzhou	Observation/environmental audit, survey	Perceived residential density, access to commercial and physical activity destinations, access to public services, street connectivity, sidewalk and bike lane quality, aesthetic quality, safety from traffic and crime.	Neighborhood	Recreation/IPAQ	Demos	(1) Men with higher perceived access to physical activity destinations have higher levels of leisure time physical activity. (2) Women with higher perceived aesthetic quality had more leisure time walking. (3) Neighborhood density inversely associated with leisure time walking in women.
Van de Poel et al. (2009)	China	6484 adults from 189 communities in 1991; 6197 adults from 192 communities in 2004	Survey	Measure of urbanicity, including land use, transportation infrastructure, services, and socioeconomic context	Community	General (not specified)/survey or interview	Demos, other	Rural residence associated with participation in heavy or very heavy physical activity as part of daily activities.
Xu et al. (2009)	China	2375 students age 13–15 in 24 junior high schools in 10 urban districts in Nanjing	GIS, measure of public green space in district	Residential density, public green space	Urban district	Recreation/IPAQ or modified IPAQ	Demos, other	(1) Living in higher density residential areas associated with less time on physical activity. (2) Residents in higher and middle residential tertile had lower odds of being in higher physical activity category. (3) For boys, residential density negatively associated with physical activity.
Xu et al. (2010)	China	2660 students age 13–15 in 24 junior high schools in 10 urban districts in Nanjing	GIS	Residential density	Community	Recreation/IPAQ or modified IPAQ	Demos	Students in higher residential density tertile spent less time on physical activity
Yang et al. (2010)	China	4092 commuters in Nanjing	Survey	Trip distance, perceived safety of bicycling	Individual respondent	Transportation/survey or interview	Demos	(1) Trip distance associated with likelihood of commuting by bicycle. (2) Perceived safety not significantly associated with tendency to commute by bicycle.
Yang (2010)	China	Members of 25 households in each of 48 urban neighborhoods in Beijing	GIS	Distance to city's geometric center, distance to the closest job center, distance to the closest subway station	Neighborhood	Transportation/survey or interview	Demos	Living closer to urban rail stations associated with increased travel by rail and decreased travel by bicycle.
Yang et al. (2012)	China	1499 workers in 48 neighborhoods in Beijing	Division of city into three areas by age, by authors	Central core, suburban zone, and hybrid area between core and suburbs (defined by age)	Area of city	Transportation/survey or interview	Demos	Suburban areas have higher non-motorized travel for commuting, compared to central core and hybrid areas.
Zacharias (2007)	China	1326 pedestrians 141 observed itineraries in Tianjin central area	Survey, observation/environmental audit	Retail location	Individual	Transportation/survey or interview, tracking study	None	Pedestrian generators and large shopping centers at ends of pedestrian shopping street associated with longer walking trips.
Zhang et al. (2011)	China	1100 residents age 40–80 in 13 communities in three districts in Shanghai	Survey	Environmental design, environmental greenness and sanitation, residential environment, land-use accessibility, traffic environment, environment safety	Individual	General (not specified)/pedometer	Demos, other	Body building club, traffic safety, street design, ground surface, crossing the street, and activity environment (safety from pets) were PE factors with greatest impact on physical activity.
Zhang et al. (2014a)	China	1572 older residents (age 60+) of 102 rural neighborhoods in Zhongshan Metropolitan area	GIS	Density, bike lane density, distance to transit, distance to the central business district (destination accessibility), and land use diversity	Neighborhood	General (not specified)/survey or interview	Demos, other	(1) Living in most-populated (rural) environment, high land use mixture, and dense bike lanes associated with more and longer cycling trips. (2) Convenient bus service and greater distance to central business district associated with fewer cycling trips.
Zhang et al. (2014b)	China	4308 older residents (age 60+) in Zhongshan Metropolitan area	GIS	Population density, sidewalk density, percentage of green space land use, bus-stop density, commercial accessibility, and land use diversity	Neighborhood	General (not specified)/survey or interview	Demos, other	(1) Population density, sidewalk density, increased green space, and bus stop density associated with decreased probability of having zero walking trips. (2) Neighborhoods with dense sidewalks, abundant and easily accessible commercial establishments in walking distance, high percentage of green space, and dense bus stops, associated with increased frequency of walking trips. (3) High density and high land use mixture associated with lower frequency of walking trips. (4) Sidewalk density, percentage of green space, dense bus stops, and more commercial destinations, associated with increased duration of walking.

(continued on next page)

Table 1 (*continued*)

Reference	Country[1]	Sample	Environmental factors, data source[2]	Environmental factors examined	Analyzed geographic unit	Physical activity type/physical activity measure	Covariates[3]	Results
Zhao and Lu (2011)	China	370 employed residents living on the urban fringe in Beijing	Census, GIS	Density, mixed land use, transport accessibility, local jobs-housing balance, transport access	Urban subdistrict	Transportation/survey or interview	Demos, other	(1) In higher density and higher jobs-housing balance areas, probability of choosing walking, cycling or another mode of transit is higher than choosing public transit. (2) In areas with high density and high jobs-housing balance, probability of choosing walking, cycling or another mode of transit is higher than probability of commuting by car.
Zhao (2013)	China	712 employed residents in 60 communities in central and inner suburban areas of Beijing	Census	Net density of residents and employment, local jobs-housing balance, density of main and secondary roads, transit access, distance to city center	Residential subdistrict	Transportation/survey or interview	Demos	(1) Jobs-housing balance and higher residential density associated with increased likelihood of commuting by non-motorized transport. (2) Higher job density associated with decreased likelihood of commuting by non-motorized transport. (3) Higher density of main roads and increase in distance to city center associated with increase in motorized transport, compared to non-motorized transport. (4) Higher density of secondary roads associated with increase in non-motorized transport. (5) Higher transit access associated with increase in public transport use, compared to non-motorized transport.
Zhao and Deng (2013)	China	1544 riders at 16 Rapid Rail Transit stations in Nanjing	GIS	Station type (elevated or underground, station function); station density gradient; distance to city center; length of side streets; number of feeder bus lines	800 m buffer surrounding rail stations	Transportation/survey or interview	Demos	(1) Terminal station associated with walking longer distances, transfer station associated with walking shorter distances, compared to typical station. (2) Elevated station associated with walking longer distances, compared to an underground station. (3) Underground station associated with walking longer distances, compared to bus rapid transit station.
Zhao (2014)	China	613 employed heads of households in Beijing	GIS, survey	Population density, employment density, jobs-housing balance, distance to old city center, land use diversity, local street density, number of street crossings (connectivity), density of main roads and expressways, crossings of main road and expressways, exclusive bike lanes, proximity to transit.	Community	Transportation/survey or interview	Demos	(1) Jobs-housing balance, destination accessibility, employment density, number of local street crossings, land use diversity, and exclusive bike lanes associated with commuting by bicycle (compared to motorized mode). (2) Population density has no significant effect on commuting by bicycle. (3) Higher levels of public transit service and larger numbers of main-road crossings associated with reductions in commuting by bicycle.
Zhou et al. (2013)	China	478 parents of students at 2 urban and suburban Shanghai junior high schools (completed questionnaires), 235 also provided accelerometer data	Survey	Residential density, land use diversity, facility access, street connectivity, walking and cycling facilities, aesthetics, pedestrian safety, crime safety	Neighborhood	Transportation and recreation/IPAQ or modified IPAQ, accelerometer	Demos	(1) Living in downtown area more positively associated with transportation and leisure time physical activity, compared to living in suburbs. (2) Residential density and poorer street connectivity associated with higher levels of leisure-time physical activity.

[1] For studies that included China and other countries, only results for China are reported where it was possible to distinguish such results. Studies that include results for other countries (in addition to China) are noted. (See Table 2).

[2] "Survey" or "interview" indicates that respondents provided information about their neighborhoods or local environments. "Observation/environmental audit" denotes that built environment data were collected through observation by the researchers.

[3] "Demos" refers to demographic covariates of individual respondents (e.g., age, income, gender) and household characteristics (e.g., car ownership, household income). Other covariates are labeled "other." Other covariates include attitudes (e.g., towards walking, driving); lifestyle factors (e.g., alcohol or tobacco use); health status (e.g., BMI); and other factors.

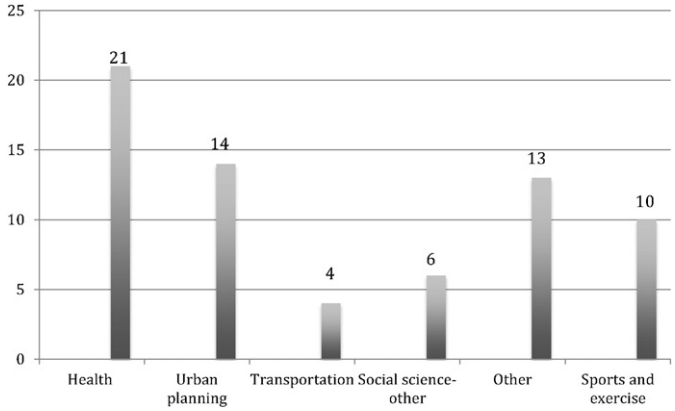

Fig. 1. The number of studies that contain one or more authors from various disciplines. Many studies include multiple authors and represent more than one discipline.

noting that the present study also finds support for the association between physical activity for transportation and land use mix (proximal non-residential locations) in Chinese cities.

As these studies demonstrate, the built environment of Chinese cities and physical activity are clearly associated. Evidence for this association should increase as the number of studies grows over time. This review is limited by its exclusion of studies published in languages other than English. Research published in Chinese, in particular, should be considered.

Additional research on active living in China is greatly needed. For improved validity, future studies should follow the trend in this field towards objective measures of the built environment, while also continuing to include explicit measures of the perceived environment. Though GIS is the standard measure of objective built environment features for much active living research in developed countries, it is unreasonable to expect widespread use of GIS in China, where detailed GIS data is not uniformly available. In the mean time, environmental audits offer one alternative to measure objective built environment features. Some environmental audits have been developed or modified for use in China, including the Irvine Minnesota Inventory—China (Alfonzo et al., 2014), Environment in Asia Scan Tool (Cerin et al., 2013a, 2013b); and the China Urban Built Environment Scan Tool (Su et al., 2014).

Most existing active living research in China is correlational (as in Saelens and Handy, 2008). There is a need for longitudinal and quasi-experimental studies to establish stronger causal relationships between features of the built environment and physical activity outcomes. Research is also needed on smaller Chinese cities that are less well represented in existing research. Indeed, Tier Two and Tier Three cities in China are among the most rapidly developing (Craig and Qiang, 2010). Their built environments and population characteristics may vary from those of megacities such as Hong Kong and Beijing that are the focus of much existing research.

As in Saelens and Handy (2008), many questions remain about associations between specific built environment features and specific forms of physical activity. Needed are future studies that test explicit conceptual frameworks. Sixteen of the 42 studies reviewed in this paper measured physical activity in a general way. Needed is more consistency in defining physical activity as tied to transportation, recreation, or work, to better understand its potential relationship with the built environment.

Going forward, active living research should be framed within a specific Chinese context in terms of conceptual models, variables, and interpretation of findings. Take, for example, the issue of urban residence, which is associated with lower rates of physical activity in China (Bauman et al., 2011; Bosdriesz et al., 2012; Monda et al., 2007; Ng et al., 2009; Shi et al., 2006; Van de Poel et al., 2009). In developed countries, urban residence is routinely linked to higher rates of physical activity, and especially active travel (Saelens and Handy, 2008). In research in developed countries, urban residence is typically compared to suburban residence. Research in China, however, often contrasts urban with rural rather than suburban residence. Urban residence in China is frequently associated with higher rates of affluence, greater access to automobiles and more sedentary occupations (Day et al., 2013), compared to rural residence. Rural residents in China frequently walk or bicycle for travel, unlike many rural and suburban residents in developed countries. Thus, findings on the link between urban residence and physical activity must be interpreted carefully.

Also, it is important to know more about the specific characteristics of urban residents in China, to understand their physical activity patterns. China has seen enormous growth in the number of residents who have moved from rural to urban areas in recent years. Place of origin (urban versus rural) may affect urban residents' behavior and their attitudes towards some built environment features (e.g., density, traffic safety). Future research should include information about respondents' urban or rural registration status (or *hukou*) to help make sense of these behaviors and attitudes.

In many Chinese cities, the wide availability of public transportation means that individuals frequently have choices among active travel modes (bus, subway, bicycling, walking), and not only between active and motorized travel. Researchers may be interested in shifts within active travel modes (which have different physical activity implications) as well as shifts between active and motorized travel. Also note that not all bicycling in China is active. The huge popularity of electronic or e-bikes in China (Ramzy, 2009) means that many residents who bicycle for travel or recreation, do not necessarily engage in physical activity. Future research should be sensitive to this distinction.

Air pollution was included as a built environment factor in only two studies in this review (Cerin et al., 2013a; Zhang et al., 2011). Yet air pollution is a huge concern among Chinese citizens and a growing priority among policy makers (c.f., Secretariat for Clean Air Alliance of China, 2013). Future research should include air pollution as both independent and dependent variables, since high air pollution levels may reduce outdoor activity and reduced active travel may increase air pollution (through increased motorized travel).

Density is another issue that may have distinct consequences for physical activity in China and other developing countries. In research in developed countries, density is commonly associated with increased physical activity (Saelens and Handy, 2008), typically reflecting the availability of active travel modes in dense urban areas. In this paper, however, density is linked to physical activity in some studies (Alfonzo et al., 2014; Cerin et al., 2012a; Feng et al., 2014; Pan et al., 2009; Zhao and Lu, 2011; Zhao and Deng, 2013) but not in others (Jiang et al., 2012; Pan et al., 2009; Zhao and Deng, 2013; Zhao, 2014; Zhou et al., 2013). Also, some studies find a negative association between density and physical activity for recreation (Su et al., 2014; Xu et al., 2009, 2010). It may be that the very high density levels in Chinese megacities discourage recreational physical activity by limiting per capita park space and causing perceived overcrowding. This relationship needs further examination.

Future active living research should also examine the impact of traffic safety (Cars in China: Dream machines, 2005). China is a nation of many new drivers (Hessler, 2007) and traffic accidents are common. Concerns about traffic safety may impact walking and bicycling, especially for children. In this review, findings on the association between traffic safety and physical activity were mixed (Alfonzo et al., 2014; Cerin et al., 2012a, 2012b; Cerin et al., 2013a, 2013b, Cerin et al., 2014; Jiang et al., 2012; Li et al., 2014; Naess, 2013; Su et al., 2014; Yang et al., 2010; Zhang et al., 2011; Zhou et al., 2013). More research is needed to understand the association between perceived traffic safety and physical activity.

Several studies examined associations between fear of crime and physical activity (Adams et al., 2013; Alfonzo et al., 2014; Cerin et al., 2012a, 2012b; Cerin et al., 2013a, 2013b, 2014; Ding et al., 2013; Jiang et al., 2012; Li et al., 2006, 2014; Sallis et al., 2009; Su et al., 2014;

Table 2
Characterization of studies by how environmental factors were measured, the environmental scale of the study, the type(s) of physical activity measured, and which results were expected, unexpected, and/or null.

Article	How environmental factor measured		Environmental scale			Physical activity type				Expected	Unexpected	Null
	Objective (O)	Perceived (P)	Micro (Mi)	Meso (Me)	Macro (Ma)	Transport (T)	Recreation (R)	Work (W)	General (G)			
Adams et al. (2013)		X		X		X	X			PMeG$^{2+6+7+10+12a}$	PMeG^{7+10b}	PMeG^{2b}
Aldinger et al. (2008)	X		X						X	OMiG$^{9+10+11}$		
Alfonzo et al. (2014)	X	X		X		X	X			OMeT$^{3+4+5+6+7+8+9+10+12}$; OMeR$^{3+4+5+6+7+8+9+10+12}$	PMeG^{11}; PMeR^{11}	
An and Zheng (2014)		X	X				X			PMiR^{2,10}		
Bauman et al. (2011)	X				X	X	X			OMaW^{1}; OMaT^{1}	OMaR^{1}	
Bosdriesz et al. (2012)	X				X	X			X	OMaG^{1,11,15b}		
Cerin et al. (2012a)		X		X		X				PMeT^{2,3,4,6,8,11,12}; PMeG^{2,6,11}		PMeT^{4,7,10}; PMeG^{4,7,10}
Cerin et al. (2012b)		X		X			X			PMeR^{3,4,6,10}		PMeR^{3,4,7,8,9,11}
Cerin et al. (2013a)		X		X	2		X			OMeR^{5,7,8,9,10,11,16}		OMeR^{10}
Cerin et al. (2013b)	X			X		X	X			OMeT^{3,7,10,14}	OMeG^{7}; OMeT^{7}	OMeT^{4,6,8}; OMeG^{4,6,8}
Cerin et al. (2014)		X		X					X	PMeG^{3,9b}; PMeG$^{3+4+7+8+9+12b}$		
Ding et al. (2013)		X		X					X	PMeG^{2,6,10,13}	PMeG^{7}	
Feng et al. (2014)	X			X		X	X			OMeT^{11,12}; OMeR^{2,11}		OMeT^{2}; OMeR^{2,12}
Jiang et al. (2012)	X			X		X				OMeT^{7+8+9}	OMeT^{2,11,12}	
Li et al. (2006)	X		X	X		X	X			OMeG^{3,5,6,10}; PMeG^{7}		OMeG^{10,11}
Li et al. (2014)		X		X			X					PMeR^{2,3,4,7,8,9}
Monda et al. (2007)	X				X			X		OMaW^{1}		
Naess (2009)	X			X		X				OMeT^{2}		
Naess (2010)	X			X		X				OMeT^{2}		OMeT^{2}
Naess (2013)		X	X	X	X	X				PMeT^{2}; PMaT^{11,15}	PMeT^{8}	
Ng et al. (2009)	X				X	X	X	X		OMaWG^{1}; OMaWG$^{1+3+11+12}$	OMaW^{3}	OMaG^{11,12}
Pan et al. (2009)	X			X		X				OMeT$^{2+3+4+11+12}$		OMeT$^{2+3+4+11+12}$
Pan et al. (2010)	X			X		X				OMeT^{2,13}	OMeT^{3}	
Sallis et al. (2009)		X		X					X	PMeG^{2,6,10,13b}; PMeG$^{2+6+7+10+11+12b}$		PMeG^{7,12b}
Shan (2014)	X			X		X				OMeT^{2}		
Shi et al. (2006)	X				X	X	X	X		OMaG^{1}; OMaW^{1}		OMaR^{1}; OMaW^{1}; OMaG^{1}
Su et al. (2014)		X		X			X			PMeR^{9,10}	PMeR^{12}	PMeR^{2,4,6,7,8,13}; PMeR$^{2+6+7+8+9+10+11}$
Van de Poel et al. (2009)	X				X				X	OMaG^{1}		
Xu et al. (2009)	X				X		X				OMaR^{12}	
Xu et al. (2010)	X				X		X				OMaR^{12}	
Yang (2010)	X			X		X				OMeT^{2}		OMeT^{2}
Yang et al. (2010)	X			X		X				OMeT^{2}		OMeT^{8}
Yang et al. (2012)	X				X	X					OMaT^{11}	
Zacharias (2007)	X			X		X					OMeT^{2}	
Zhang et al. (2011)		X		X					X	PMeG^{6,8,10,14}		PMeG^{2,4,5,7,8,11,12,16}
Zhang et al. (2014a)	X			X					X	OMeG^{2,3,11,12,13}		
Zhang et al. (2014b)	X			X					X	OMeG^{2,3,5,6,12}	OMeG^{3,12}	
Zhao and Lu (2011)	X			X		X				OMeT^{3,12}		OMeT^{3}
Zhao (2013)	X				X	X				OMaT^{2,3,4,12}	OMaT^{12}	
Zhao and Deng (2013)	X			X		X				OMeT^{11}		OMeT^{2,4}
Zhao (2014)	X			X		X				OMeT^{3,4,13}	OMeT^{3,4}	OMeT^{12}
Zhou et al. (2013)		X		X		X	X			PMeT^{11}; PMeR^{11,12}	PMeR^{4}	PMeT^{3,4,6,9,7,8,10,12,13}

[a] Findings of composite characterization of built environment are indicated by +.
[b] Findings pertain to multiple countries, including China.

Table 3
Results in the expected or unexpected/null direction, organized by environmental factors and by type of physical activity. Each study may have multiple results.

	Types of physical activity							
	Transportation		Recreation		Work		General	
	Expected	Unexpected or null	Expected	Unexpected or null	Expected	Unexpected or null	Expected	Unexpected or null
1 Urban (vs. rural)	1	0	1	2	4	1	4	1
2 Distance to specific non-residential land uses	9	7	1	3	0	0	2	1
3 Proximal non-residential destinations	9	5	4	2	0	1	8	2
4 Network characteristics	5	7	2	4	0	0	1	3
5 Parks and open space	1	0	2	0	0	0	2	1
6 Pedestrian infrastructure	3	2	2	1	0	0	7	1
7 Crime	3	3	2	3	0	0	4	6
8 Traffic safety	3	4	2	3	0	0	2	2
9 Aesthetics	2	1	3	3	0	0	2	0
10 Non park physical activity facilities	2	2	4	2	0	0	6	3
11 Other	4	3	2	2	0	0	6	4
12 Density	6	5	2	4	0	0	6	4
13 Bicycling facilities	2	1	0	1	0	0	3	1
14 Stray animals	1	0	0	0	0	0	1	0
15 Weather	1	0	0	0	0	0	1	0
16 Pollution	0	0	1	0	0	0	0	1
Composite	3	1	1	1	1	0	5	1

"Composite" indicates cases where environmental factors were combined to examine their association with physical activity.

Zhang et al., 2011; Zhou et al., 2013), with mixed findings. Crime rates have increased significantly in China during the market reforms of the last three decades (Nielson and Smyth, 2005.) Researchers should consider unique factors tied to perceived danger and safety for Chinese residents. Consider, for example, the concept of *guanxi*, the network of personal bonds that shapes all aspects of life in China and which has been linked to perceived safety (Zhang et al., 2009). Guanxi may mediate the relationship between the built environment, fear of crime, and physical activity at the neighborhood level.

Few studies in this review included children, yet growing childhood obesity is a significant concern in China (Gui et al., 2010; Markey, 2006). Boys especially are at risk, due to their special status in Chinese society. Parent and grandparents are tempted to spoil boys with food. Youth are the focus of much active living research in the United States and in other developed countries because of the long-term impacts of low physical activity among young people. More research is needed on the association between built environments and physical activity among youth in China.

Several studies examined composite features of the entire neighborhoods that are associated with physical activity (Adams et al., 2013; Aldinger et al., 2008; Alfonzo et al., 2014; Cerin et al., 2014; Jiang et al., 2012; Ng et al., 2009; Pan et al., 2009; Sallis et al., 2009; Su et al., 2014). Many studies compared walkable versus nonwalkable neighborhoods; results were most often in the expected direction. Future research should consider the associations with physical activity of popular development types in Chinese cities (e.g., suburban new towns).

Urban planning scholars, policy makers, and practitioners have identified alternate models for urban development in China, that challenge prevailing auto-centric patterns (c.f., Energy Innovation Institute, 2011; Han et al., 2014; Harvey and Busch, 2012; Urban Land Institute, 2013). Recommendations are familiar: greater transit reliance, smaller blocks and lively street fronts to encourage walking, dense networks of streets and paths, and others. Findings from active living research can provide valuable empirical evidence to support efforts to maximize health and environmental benefits in future planning and development in Chinese cities.

Conflict of interest

The author declares that there are no conflicts of interest.

Transparency Document

The Transparency Document associated with this article can be found, in online version.

Acknowledgments

Sincere thanks to Xinyi Liu, who assisted with identifying studies for this review. Thanks also to Brien Saelens and Susan Handy, whose paper served as a model for this review.

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