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Mapping the development of research on physical activity and the built environment

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ABSTRACT

Objective. The importance of the built environment for physical activity has been recognized in recent decades, resulting in new research. This study aims to understand the current structure of physical activity and built environment (PABE) research and identify gaps to address as the field continues to rapidly develop.

Methods. Key PABE articles were nominated by top scholars and a snowball sample of 2764 articles was collected in 2013 using citation network links. Article abstracts were examined to determine research focus and network analysis was used to examine the evolution of scholarship.

Results. The network included 318 PABE articles. Of these, 191 were discovery-focused, examining the relationship between physical activity and built environment; 79 were reviews summarizing previous PABE work; 38 focused on theory and methods for studying PABE; six were delivery-focused, examining PABE interventions; and four addressed other topics.

Conclusions. Network composition suggested that PABE is in the discovery phase, although may be transitioning given the large number and central position of review documents that summarize existing literature. The small amount of delivery research was not well integrated into the field. PABE delivery researchers may wish to make explicit connections to the discovery literature in order to better integrate the field.

Introduction

Ecological approaches to behavioral science and public health have been proposed throughout the last decades and have focused on the interaction between individuals and their physical and sociocultural context (McLeroy et al, 1988; Stokols, 1992). More recent work from Sallis et al. has emphasized the inclusion of an additional layer that includes the physical environment in which people live, an important determinant of active and healthy living (Sallis et al, 2006). Given the rising levels of non-communicable chronic diseases worldwide such as obesity, cardiovascular disease, type 2 diabetes, metabolic syndrome, and some types of cancer, attention has turned to investigate relevant and modifiable risk factors including physical inactivity (Eyre et al, 2008; Knowler et al, 2002; Laaksonen et al, 2002; Sallis et al, 2012; Thompson, 2003).

Factors associated with physical inactivity include global economic transitions, urbanization patterns, and technological changes that create and perpetuate obesogenic physical (built) and social environments (Brownson et al, 2005; Hill and Peters, 1998). The built environment (e.g., freeways and sidewalks, access to healthy foods and parks) is one of the most commonly cited barriers to physical activity at the population level. Improving opportunities for active lifestyles through built environment is recognized as a promising intervention (Heath et al, 2006; Wang et al, 2004) and has been advocated by internationally recognized health agencies such as the Centers for Disease Control and Prevention, the Institute of Medicine, and the World Health Organization (National Research Council Committee (US) on Physical Activity, et al, 2005; Centers for Disease Control and Prevention, 2013; Edwards and Tsouros, 2006).

Over the past decade researchers have explored the association between built environment and active lifestyles (Ferdinand et al, 2012; Frank et al, 2003; Owen et al, 2004; Saelens et al, 2003; Sallis et al, 2006; Van Holle et al, 2012). Objective and perceived environment characteristics have been found to be associated with the likelihood of physical activity in high-income countries (Baker et al, 2008; Bedimo-Rung et al, 2005; Hoehner et al, 2005; Kramer et al, 2013; Roux et al, 2007). Recent evidence identifying a relationship between physical activity and the built environment has also emerged from low and middle-income countries, suggesting widespread importance (Gomez et al, 2010; Hallal et al, 2012; Parra et al, 2010, 2011).

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This study aims to understand the development and current state of physical activity and built environment (PABE) research to identify gaps and structures that PABE researchers may wish to address or develop as the field continues to evolve. The status and progress of PABE research are tied directly to public health practices and policies and can influence current and future research and practice.

Methods

We applied a citation network approach to understand the development and composition of PABE research from 1986 to 2013. Citation network approaches are useful for characterizing the structure of a research area through examination of the relationships among articles, books, and other documents comprising the field (Hummon and Doreian, 1989).

Data collection

Citation Network Analyzer (CNA), a citation network data collection tool developed in 2007, was designed to efficiently collect an inclusive sample of documents comprising a field of study (Lecy and Moreda, 2011). CNA overcomes bias in traditional literature reviews that identify articles based upon keywords since terminology varies within and across fields. CNA instead builds a network of documents representing a field by identifying seed articles deemed influential in the domain, then capturing a network of documents stemming from these seeds by following citations forward in time (identifying articles that cite the seeds) for a set number of levels (distance from the seed) using a specified sampling rate (percentage of articles collected at each level).

Seed articles were identified by 21 top PABE scholars that were invited to nominate prominent publications in the field. The 21 PABE scholars were active researchers selected on the basis of recognition and prominence in the field. For example, they are commonly keynote speakers at conferences focused on physical activity and built environment topics. To nominate key articles, the scholars were emailed the following: "we are hoping to identify about 10–15 of the earliest key publications in BE & PA research … [please identify articles] you feel are the top 3 to 5 seminal or key articles on BE & PA research." Fourteen responded identifying 67 unique articles. From this list we selected the 25 most highly cited articles with the earliest publication dates (Table 1).

We collected two levels of data (articles that cite seeds, and articles that cite those articles). We constrained the sample to only include the top 5% of highly cited articles at each level. The 5% rate is justified by research showing that constrained snowball samples reduce the size of the database by up to 99% while identifying over 80% of the most highly-cited articles in the literature (Lecy and Beatty, 2012). The resulting network included 2764 documents including all 67 of the articles initially identified as key to the field by the 14 scholars.

Abstract coding

Based on abstracts, we coded each document as discovery, delivery, theory and methods, review, other PABE topics, or non-PABE. Following Harris et al. (2009), *discovery* was defined as empirical studies with the purpose of discovery or confirmation of association between built environment and physical activity; *delivery* was defined as empirical studies of implementation or evaluation of an intervention to increase physical activity through the built environment. *Theory and methods* documents included development of new theory or methods to study physical activity and the built environment. *Review* documents summarized previous empirical work on PABE. Documents coded as *other* were about PABE, but did not fit one of the categories. A document was coded as *non* if it was not PABE.

Four coders coded 25 randomly selected abstracts to establish reliability (see Fig. 1 for decision rules). The resulting kappa of .83 is considered nearly perfect by Landis and Koch (1977); articles were then divided among coders and coded independently.

Analysis

The citation networks were analyzed using (1) descriptive network analysis; and (2) main path analysis.

Descriptive network analysis: key journals, articles, and authors

Descriptive measures were used to identify prominent articles, authors, and journals. Citation networks are directed; links among articles represent the direction of information flow in the network. So, if article B cites article

Table 1
Twenty-five seeds used for data collection.

Title	Type	First author	Journal	Year	# cited by
Neighborhood of residence and incidence of coronary heart disease	Article	Roux	NEJM	2001	850
The effectiveness of interventions to increase physical activity	Article	Kahn	AJPM	2002	771
Travel and the built environment: a synthesis	Article	Ewing	Transportation Research Record	2001	688
Environmental and policy interventions to promote physical activity	Article	Sallis	AJPM	1998	618
Travel by design the influence of urban form on travel	Book	Boarnet		2001	431
Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking	Article	Frank	Transportation research record	1994	395
Predictors of adoption and maintenance of physical activity in a community sample	Article	Sallis	PM	1986	375
The influence of urban form on travel: an interpretive review	Article	Crane	Journal of Planning Literature	2000	348
Predictors of adoption and maintenance of vigorous physical activity in men and women	Article	Sallis	PM	1992	288
Assessing perceived physical environmental variables that may influence physical activity	Article	Sallis	Research Q for Exercise & Sport	1997	265
Distance between homes and exercise facilities related to frequency of exercise among San Diego residents	Article	Sallis	Public Health Reports	1990	238
Physical activity preferences, preferred sources of assistance, and perceived barriers to increased activity among physically inactive Australians	article	Booth	PM	1997	222
Travel choices in pedestrian versus automobile oriented neighborhoods	Article	Cervero	Transport Policy	1996	216
Urban form and pedestrian choices: study of Austin neighborhoods	Article	Handy	Transportation Research Record	1996	187
Understanding the link between urban form and nonwork travel behavior	Article	Handy	J of Planning Educ & Research	1996	186
Environmental and policy approaches to cardiovascular disease prevention through physical activity: issues and opportunities	Article	King	Health Education & Behavior	1995	164
Policy as intervention: environmental and policy approaches to the prevention of cardiovascular disease	Article	Schmid	AJPH	1995	132
Geographic information systems and public health: mapping the future	Article	Richards	PHR	1999	131
Residential density and travel patterns: review of the literature	Article	Steiner	Transportation Research Record	1994	104
Associations of location and perceived environmental attributes with walking in neighborhoods	Article	Humpel	AJPH	2004	103
Can the physical environment determine physical activity levels?	Article	Ewing	Exercise and Sport Sciences Reviews	2005	99
Measuring the determinants of physical activity in the community: current and future directions	Article	Baker	Research Q for Exercise & Sport	2000	71
Indicators of activity-friendly communities	Article	Ramirez	AJPM	2006	50
Community design and transportation policies	Article	Killingsworth	Physician and Sports Medicine	2001	28

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A, the information flows from A to B and is shown as A → B in the network. Descriptive network measures included: (1) in-degree: how many articles each article cites in the network, and (2) out-degree: how many times an article was cited within the network.

Main path analysis

The main path is a set of connected articles and the links among them considered the backbone of the network. The main path is identified by calculating traversal weights for all nodes and links in the network. These weights represent the proportion of all paths through the network that contain a specific node or link (De Nooy et al, 2011), so a traversal weight of .1 would indicate that an article is on 10% of the citation paths through the network.

Results

The network included 2764 unique documents published between 1986 and 2013 and connected by 5043 citation links. There were 2511 journal articles (90.8%), 224 books or chapters (8.1%), and 29 documents of other types (1.1%). Because most documents in the network were articles, the term *article* will be used to represent any document in the network for the remainder of this manuscript.

There were 1909 unique lead authors contributing an average of 1.4 articles (s.d. = 1.3) to the network. Most lead authors (n = 1503) contributed one article. The seven authors contributing 10 or more articles were: James F. Sallis (n = 22); Lawrence D. Frank (n = 15); Ross C. Brownson (n = 11); Bess H. Marcus (n = 11); Adam Drewnowski (n = 10); Reid Ewing (n = 10); Michael D. Marmot (n = 10). Those contributing the highest number of PABE articles were: Frank (n = 11); Sallis (n = 8); Billie Giles-Corti (n = 7); Susan L. Handy (n = 6); John Pucher (n = 6); Brownson (n = 5), and Brian E. Saelens (n = 5).

There were 617 journals contributing an average of 4.1 articles (s.d. = 10.11); 369 journals contributed a single article to the network. The top ten most common journals were: *American Journal of Preventive Medicine* (AJPM; n = 131); *Medicine and Science in Sports and Exercise* (n = 92); *American Journal of Public Health* (AJPH; n = 87); *Preventive Medicine* (PM; n = 80); *Social Science & Medicine* (n = 56); *Journal of the American Medical Association* (JAMA; n = 50); *Circulation* (n = 49); *Journal of Epidemiology and Community Health* (n = 38); *Annual Review of Public Health* (ARPH; n = 37); and *Pediatrics* (n = 36). For PABE articles only, the most common journals were *AJPM* (n = 50); *PM* (n = 22); *AJPH* (n = 16); *American Journal of Health Promotion* (n = 13); *Health and Place* (n = 13); *Medicine and Science in Sports and Exercise* (n = 13); and *International Journal of Behavioral Nutrition and Physical Activity* (n = 10).

Articles in the sample were cited between zero and 7633 times overall on Google Scholar (median = 133). Within the network, each article was cited zero to 322 times. Table 2 shows the top 10 cited articles in the network. Note that three of these were professional publications by the Centers for Disease Control and Prevention and the American College of Sports Medicine. Overall, each article in the network cited between zero and 43 other articles in the network (m = 1.8; s.d. = 2.6).

Many articles in the sample focused solely on physical activity or obesity and related health problems or discussed methods for measuring and analyzing physical activity or obesity and related issues (n = 2446; 88.5%). However, 318 articles focused specifically on PABE. Of these, 191 (60.1%) were discovery-focused; 79 (24.8%) were review; 38 (11.9%) were theory and methods; six (1.9%) were delivery-focused examining policies (n = 5) or programs (n = 1); and four addressed other PABE topics.

Citation patterns (Table 3) revealed that 70.8% of citations in the network were citing non-PABE articles. With 88.5% of articles in the network identified as non-PABE, this indicates that a disproportionate number of ties in the network are going to the small proportion of articles that focus on PABE (29.2%). Specifically, PABE review articles were cited 479 times (9.5% of citations), but comprise just 2.9% of the network; PABE discovery articles were cited 776 times (15.4%), but comprise 6.9% of the network. No articles in the network cited the six delivery articles, although these articles had an average of 83.7 citations on Google Scholar and were published as early as 2004. The delivery articles cited 11 network members, seven *non*, three *discovery*, and one *review*.

Main path analysis

To identify the key articles in the development of this research area, we calculated the traversal weight for each article in the network. Based on patterns in the descriptive network analysis, we hypothesized that (1) PABE articles would have significantly higher average traversal weight than non-PABE articles, (2) review articles would have significantly higher average traversal weight than other types of articles in the network, and (3) delivery articles would

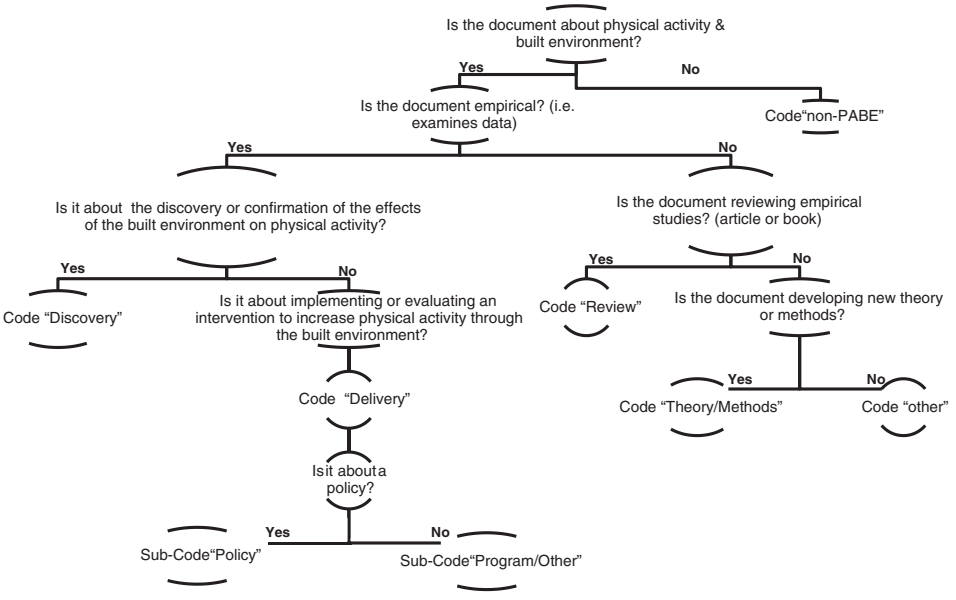

Fig. 1. Flow chart for coding articles comprising or connected to the field of physical activity and built environment research.

Table 2
Ten most highly cited articles within the citation network.

First author	Year	Title	Journal	Cited (in scholar)	Cited (in network)
Pate	1995	Physical activity and public health: A Recommendation From the Centers for Disease Control and Prevention and the American College of Sports Medicine	JAMA	6388	322
Haskell	2007	Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association	Circulation	3443	176
Nelson	2007	Physical activity and public health in older adults. Recommendation from the American College of Sports Medicine and the American Heart Association	Circulation	1402	70
Marmot	2004	Status syndrome	Significance	1388	69
Kahn	2002	The effectiveness of interventions to increase physical activity	AJPM	1230	62
French	2001	Environmental influences on eating and physical activity	ARPH	1123	56
Cervero	1997	Travel demand and the 3Ds: density, diversity, and design	Transportation Research Part D: Transport and Environment	1005	50
Humpel	2002	Environmental factors associated with adults' participation in physical activity: A review	AJPM	976	49
Saelens	2003	Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures	Annals of behavioral medicine	950	47
Bandura	1998	Health promotion from the perspective of social cognitive theory	Psychology and Health	875	47

have significantly lower traversal weights than all other types of articles in the network. An analysis of variance (ANOVA) identified a significant difference in the mean traversal weight across the six types of articles ($F(5,2758) = 36.0$; $p < .001$). Planned comparisons testing the three hypotheses found that: (1) PABE articles do have significantly higher average traversal weights than non-PABE articles ($t = 3.7$; $p < .001$); review articles have significantly higher average traversal weights than other article types ($t = 4.4$; $p < .001$); and delivery articles have significantly lower traversal weights than other article types ($t = 4.8$; $p < .001$). Fig. 2 shows the average traversal weights for the six article types.

The main path, which is the set of connected articles with the highest traversal weights, included 57 articles by 28 first authors in 28 journals and 4 books between 1986 and 2011. The path was comprised of 40.4% discovery articles, 26.3% reviews, 8.8% theory and methods, and 24.6% non-PABE articles. No delivery or other PABE topic articles were in the main path.

The main path included nine of the 25 seeds and articles from both search levels. On average, main path articles were cited 24.9 times (s.d. = 41.7), which is significantly higher than the 1.8 times (s.d. = 9.2) articles in the overall network were cited ($t = 4.3$; $p < .001$). *AJPM* contributed 10 main path articles (17.5%), while *Preventive Medicine* contributed six (10.5%) articles; no other journal contributed more than four articles to the main path. Sallis contributed the most main path articles (17.5%), while Brownson, Ewing, Frank, and Giles-Corti each contributed four (7.0%). Fig. 3 shows the main path with nodes sized by traversal weight and color showing article type. A list of main path articles is included as Appendix A.

Discussion

In the 1990s physical activity researchers turned to the built environment as a key facilitator of, and barrier to, physical activity. Early built environment studies focused on the convenience of recreation facilities and progressed to focus on transportation, city planning, and land use (Sallis, 2009). While there have been reviews conducted summarizing trends and findings across the last 20 years of PABE research, this is the first to map citation patterns demonstrating development of the field. We found that PABE review articles were most prominent across the network by virtue of being the most highly cited and having significantly higher traversal weights than other types of articles. The high traversal weights show that these reviews are key in holding the network together. Discovery-focused articles were also prominent, second only to reviews in terms of being highly cited and having high traversal weights. Delivery articles were scarce ($n = 6$) and were not cited within the network. These findings suggest three important features of current PABE research that may aid in strategic planning for the field: (1) The composition of the network suggests PABE research is still largely in the discovery phase, although may be transitioning given the prominent network location of review documents; (2) the small amount of delivery research that currently exists is not well integrated into the field; and (3) summary documents, such as guidelines and systematic reviews, are occupying prominent positions in this network of research.

The progression from scientific discovery to delivery of interventions is fundamental in public health (Harris et al, 2009). Not surprisingly given its youth, a majority of PABE articles were discovery-focused with only a few delivery-focused studies connected to the field at the time of data collection. The structure of the main path suggests early PABE and related research took place beginning in the late-1980s and early 1990s and was synthesized by several review articles in the early 2000s. This first 10–15 years of PABE work was then followed by a second generation of discovery articles in the early 2000s and subsequent reviews in the late 2000s. While only six articles in the network fit the operational definition of delivery, it may be worth noting that none of these articles were connected to the main path. The exclusion from the main path may be explained by a lack of connection between discovery and delivery

Table 3
Patterns of citation links by article type in the citation network examining the field of physical activity and built environment.

	Cited							
		n	Non	Delivery	Discovery	Other	Review	Theory	Total
Cited by	Non	2446	2836	7	257	5	167	69	3341
	Delivery	6	0	0	0	0	0	0	0
	Discovery	191	350	3	311	2	189	64	919
	Other	4	28	0	0	0	1	0	29
	Review	79	144	1	298	2	87	51	583
	Theory	38	60	0	64	1	35	11	171
	Total	2764	3572	11	776	10	479	195	5043

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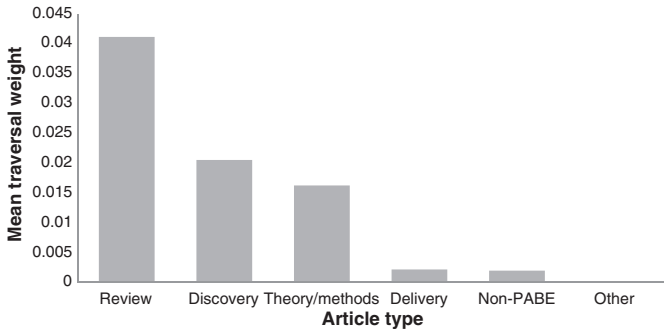

Fig. 2. Average transversal weights by article type in the citation network.

research, a pattern also seen in secondhand smoke research (Harris et al, 2009). In the case of the PABE network, there were no articles in the network citing the delivery studies, even though half were published five years or more prior to data collection. The six delivery studies (Buehler and Pucher, 2011, 2012; Economos et al, 2007; Giles-Corti et al, 2008; Pucher et al, 2011; Schwanen et al, 2004) cited an average of 1.8 articles in the network (Table 3). Connections between discovery and delivery research can aid in ensuring that public health researchers and practitioners doing delivery work are incorporating existing evidence about relationships between physical activity and built environment. Likewise, discovery researchers can build on delivery research to focus on new areas of discovery and continue to grow the field.

As this number of delivery studies grows, delivery researchers and practitioners who seek to apply findings in real world settings are likely to benefit from the growing field of dissemination and implementation science (Brownson et al, 2012). Research from this field has provided key lessons: 1) dissemination generally does not occur spontaneously and naturally (Glasgow et al, 2004b), 2) passive dissemination approaches are largely ineffective (Bero et al, 1998; Lehoux et al, 2005), 3) single-source prevention messages are generally less effective than comprehensive approaches (Richard et al, 2011; Zaza et al, 2005), 4) stakeholder involvement in the research or evaluation process is likely to enhance dissemination (Glasgow et al, 2004a; Green, 2008; Greene, 1987; Mendel et al, 2008; Minkler and Salvatore, 2012; Wandersman et al, 2008), 5) theory and frameworks for dissemination are beneficial (Tabak et al, 2012; Wilson et al, 2010), and 6) the process of dissemination should to be tailored to specific audiences (Lomas, 2006).

Many of the highly cited documents in the network and in the main path were scientific review articles and guidelines about physical activity behavior and interventions. This focus on summary documents is not unique to PABE research; a citation network analysis of secondhand smoke research found that the Surgeon General Reports, Environmental Protection Agency guidelines, and other summary documents were cited by both delivery and discovery researchers, filling a gap between the two (Harris et al, 2009). While summary documents are useful for quickly understanding an area, they take time to compile and sometimes do not include the most recent research, which can limit progress in a field.

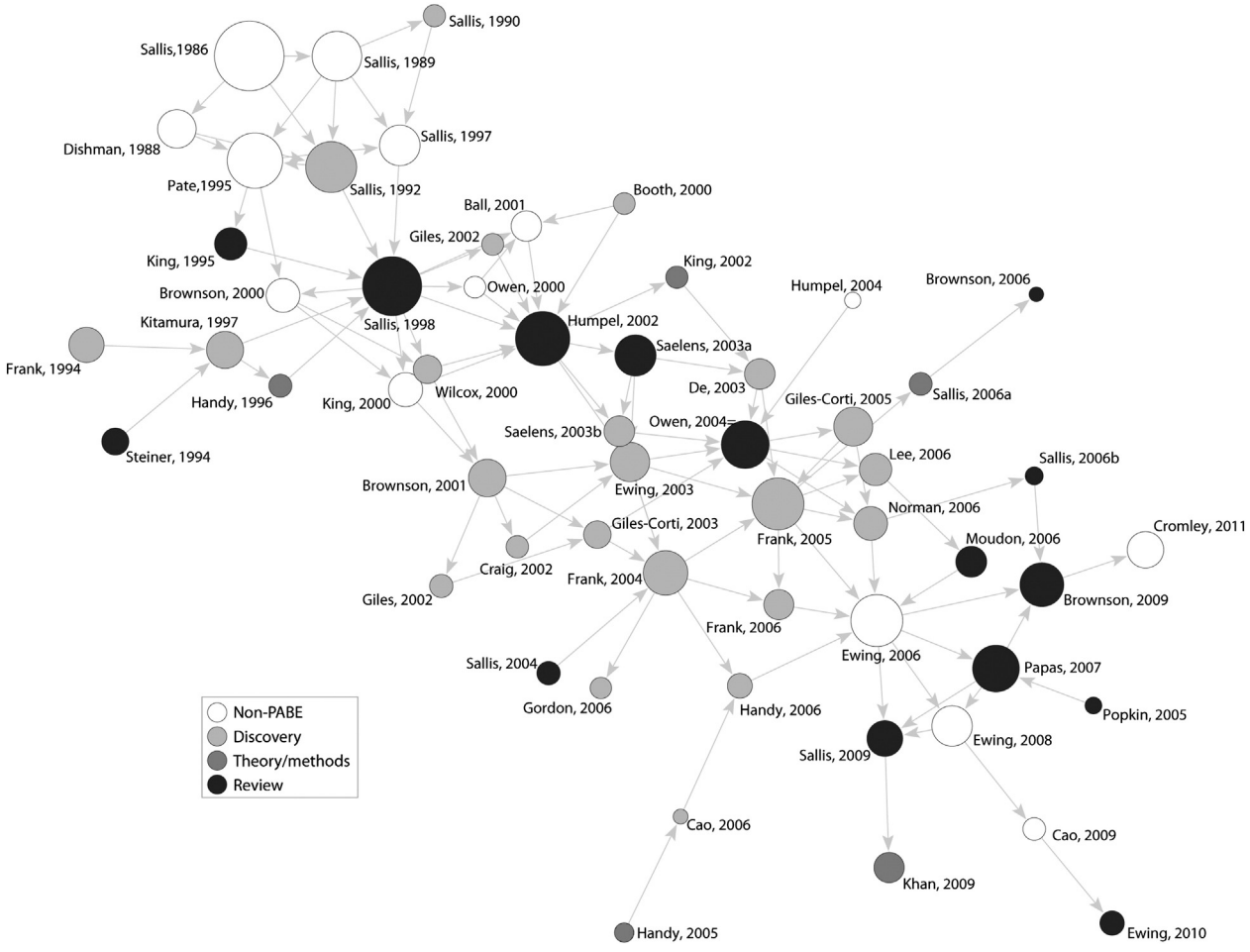

Fig. 3. The main path of articles forming the field of physical activity and built environment research.

Limitations to this study include data collection. First, CNA moves forward in time to collect the sample of articles; because the earliest seed article was from 1986, earlier research is not included. The sampling technique is designed to identify a representative, not exhaustive, sample; it is possible that some relevant articles were missed. Finally, the sample includes non-PABE research. Despite these limitations, this is the first study to examine the structure of PABE research development.

Conclusions

As PABE research progresses into the delivery phase, we have three primary recommendations for researchers working in this area: (1) look beyond summary documents to find the most current evidence on which to build, (2) actively seek out, and make explicit connections with, existing evidence from discovery-focused articles, and (3) broaden research agendas to include dissemination and implementation research of discovery-related interventions.

Conflict of interest

The authors declare there is no conflict of interest.

Appendix A. Articles in the main path

Ball K, Bauman A, Leslie E, Owen N, 2001. Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults. Preventive Medicine, 33(5), 434–440.

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