

## Research Advances of Urban outdoor environment (UOE) and Children' Physical Activity

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### Abstract

Urban outdoor environment (UOE) is considered an important environmental setting for children's physical activity (PA) which is recognized as a promising non-pharmacological approach to improve children's health, particularly in addressing issues like obesity and over-weight. With a substantial increase in the volume of publications on the topics of UOE and PA, the study aims to understand the research advancements by exploring the publication pattern, knowledge foundation, hotspots, and trends. A total of 1203 publications (2000-2023) were re-trieved and processed by the scientometric analysis. Results show the growth of publications in an accelerating speed. The topics covered in the publications are becoming more diversified and interdisciplinary with an emphasis on the public health and environmental study. The hotspots within the domain include: (1) UOE's influence on children's health outcomes by PA; (2) the UOE and children's PA in the neighborhood setting; (3) UOE's characteristics associated with chil-dren's travel and recreational behaviors. The research frontiers are gradually moving towards: (1) multi-health benefits from UOE by encouraging PA; (2) UOE and children's PA in different en-vironmental settings; (3) UOE and children's PA in the less-developing countries and district, (4) perceptions of UOE and children's PA. Our findings highlight the importance of fostering the collaborations between different disciplines and districts to advance knowledge and promote evidence-based interventions aimed at improving children's PA through UOE.

### Keywords

Urban outdoor environment; children; physical activity; health; obesity.

### 1. Introduction

The prevalence of an inactive lifestyle has caused a global epidemic of early overweight-obesity in children due to the lack of physical activity (PA) (1-4). Childhood obesity is associated with many chronic diseases such as sleep apnoea, cardiovascular disease, type 2 diabetes, and some cancers (5). In 2010, a total of 43 million children were reported to be overweight and obese, with 35 million of them from developing countries. The rate was projected to reach 9% of the entire children population by 2024(6,7). The lack of regular PA, particularly Moderate to Vigorous Physical Activity (MVPA), has been proven to be a major facilitator of childhood obesity and overweight. A vast population of children in both developed and developing countries fails to meet the recommended level of PA according to WHO guidelines (8,9). This problem has been further deteriorated by the lockdowns and touchless practices due to COVID-19 pandemic(10). The closure of public spaces such as gyms, parks, and playgrounds limited

the PA opportunities for both adults and children, reducing their daily PA level (3). Studies have shown that outdoor PA levels for children decreased significantly after pandemic restrictions were imposed, particularly for boys (11). The decreasing level PA significantly resulted in an increase in sedentary behaviors and inactive lifestyle. Some experts worried that shortly changes due to COVID-19 could cause permanent negative influences on children's lifestyles and weight status when they grows up (3,12). They were reported to have less PA and higher screen time during lockdowns, leading to the risk of overweight and obesity (13). As a result, studies on encouraging PA to improve children's health are receiving growing research attention, and there are numerous studies and publications from multiple perspectives (14–16).

According to the ecological model of active living, PA is determined by multiple levels of factors including individual, social, built environment, and policy(17). Total interventions from all levels are thought to be effective in motivating individuals to engage with PA (18,19). Among them, UOE is thought to be the fundamental factor affecting PA. It refers to places and spaces built or designed (e.g., buildings, open space, transportation, land use, infrastructures) (17,18). High land use mixture indicates the diversity of functions the UOE could provide and was found to positively associate with children's PA (20,21). Connectivity represented by crossing and dead-end density was found to positively associate with children's walking and play. Children living in highly dense communities close to roads were more likely to be influenced by environmental factors during the pandemic (21,22). Moreover, one study examined park use and found that park and activity setting size and variety (e.g., playgrounds, picnic areas, football fields, basketball courts, pools and water) are influential on children's activity (23). The availability of and proximity to these recreational resources have been positively associated with greater PA levels particularly for children in low socioeconomic status (23,24). Environmental features such as landscape, shade, environmental quality, recreational facilities and size were found to be associated with children's PA levels to different extents (11). Children would like to engage in PA in parks with particular features and facilities even if they travel further (25). In brief, the role of UOE intervention in motivating children's PA has been recognized (26). A growing body of studies from multidisciplinary fields is emerging around this topic.

Over the years, the relevant knowledge has been advancing and volumes of publications are produced, leading to the formation of an internal knowledge network of fields and categories (e.g., public health, medicine, sociology, urban studies). Nonetheless existing systematic reviews and meta-analyses don't depict a comprehensive picture of knowledge linkage pattern evolution and research in this domain. Recently there are emerging scientometric studies on the UOE and PA, while few of them systematically depict the whole picture of the core research status, which is vital to the academic progress and practice of improving children's PA in the urban setting. Moreover, few scientometric studies are specifically conducted on children who are one of the most vulnerable groups of obesity and overweight. As a result, there is a need to analyze and reflect the existing publications and articles to understand the evolution of the research, current focus and trends for children's health and environmental design from the perspective of PA(26). Given the flood of relevant studies from various fields, analyzing research patterns, status and cutting-edge trends behind numerous studies would contribute towards understanding the domain. Hence this article aims at exploring research advances on UOE and children's PA by conducting a scientometric analysis on the recent studies to reveal guidance and insights in this domain. manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the

right to publish this material in their paper. Use *italic* for emphasizing a word or phrase. Do not use boldface typing or capital letters except for section headings (cf. remarks on section headings, below).

## 2. Materials and Methods

The Materials There are no human and animal participants in this study and no ethics permission and participant consent are required. A comprehensive approach, comprising a combination of narrative and scientometric analysis, was employed to address the limitations associated with traditional reviews, such as potential biases and challenges in practice (27). The systematic search of relevant literature was conducted initially, followed by the utilization of CiteSpace for scientometric analysis. The data obtained from CiteSpace, including research patterns, co-occurrence, and co-citation information, were then utilized to conduct an in-depth narrative review. This integrated method ensured a rigorous examination and synthesis of the literature, enhancing the overall quality and validity of the review process. Scientometric is a concept of applying quantitative methods to analyze research advance. It is related to the scientometrics and informetrics and had been used in the knowledge management (28). Scientometric analysis assesses scientific articles to by analyzing the emerging hotspots of studies, research frontiers in certain periods and regions (29). There were two approaches for conducting a scientometric analysis including normative and descriptive methods (30). This study applied the latter approach which was to identify the emphasis of research in the specific areas. The descriptive method was suitable for analyzing the emerging trends, frontiers, and internal relationship regarding the field of UOE and children's PA (31).

### 2.1. Data source

The study selected Web of Science (WOS) as the primary dataset, limiting the search scope within the core collection consisting of Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCIE), Conference Proceedings Citation and Index-Science (CPCI-S), Conference Proceedings Citation Index—Social Sciences and Humanities (CPCI-SSH). They were selected for the reliability and comprehensiveness (32,33), which were proved to be suitable for the review and scientometric analysis. WOS was the largest and comprehensive database in the world, covering more than 8700 academic journals. SCIE and SSCI were also considered by many researchers as the most authoritative scientific indexing tools.

### 2.2. Data search

Given the scope and purpose, the study applied the advanced search with combination of subject terms to collect the available studies as: TS= (children OR kid\*) AND TS= ("outdoor environment " OR "urban space" OR "outdoors"OR urbanization OR urban environment) AND TS= ("physical activity" OR play OR use OR behavior) AND TS= (health OR well-being) AND TS= (design OR planning).

Since this topic was emerging recently, the time span was set from Jan,1,2000-Dec,31,2023, and retrieval time was April,31,2024. The screening criteria was set as: 1) peer-reviewed research papers and reviews only,2) children as the main target study groups,UOE factors as main independent variables, articles written in English only. The irrelevant and repeated articles were ruled out after browsing the titles and abstracts. Eventually, the preliminary 1,384 articles were obtained and input to CiteSpace for further scientometric analysis (Figure 1).

### 2.3. Data processing

The study employed CiteSpace (5.7 R2 (64-bit)) and WOS analyzing tool to conduct the scientometric analysis. WOS analyzing tool was employed to conduct publication pattern analysis of the yearly number and categories of publication. As for Citespace, researchers sorted

publications downloaded from WOS by setting time slices to extract specific information in a certain field. In this tool, there was a specific format for each database (e.g., WOS, Scopus, Science Direct), resulting in its limitation to process different databases and rule out duplicates at the same time. Apart from scientometric analysis, researchers also reviewed data to gain a deep understanding of themes behind the results of CiteSpace, which could provide research trend forecasts and key evidence for practice.

CiteSpace was used to conduct scientometric analysis of cooperation networks of institutions, countries and authors; co-citation analysis of authors, articles and journals; keywords co-occurrence, co-citation clustering; timeline and burst analysis. The processing was made in the pathfinder and pruning sliced network mode at the pre-setting (scale factor  $k=25$ , Top  $N=50$ , Top  $N\%=10.0\%$ , value of  $c$ ,  $cc$ ,  $ccv=2, -2, -20$ ). Researchers first categorized basic information of articles into the dataset (e.g., titles, authors, abstracts, keywords, organizations and publication journals). These data were then input into CiteSpace for scientometric analysis to determine internal structure of knowledge in order to identify research hotspots and frontiers (34,35). In the first step, cooperation network analysis was performed to examine cooperation relationships between countries, authors and institutions which allowed locating research hubs. Second, keyword occurrence and clustering analysis would be performed to count most prominent keywords and groups that appeared in the same document which implied hotspots and research focus. Third, co-citation analysis was performed to measure linkage between documents. Co-citation meant that two documents were cited together by more than one other article. The number of articles cited at the same time was called co-citation frequency which indicated magnitude of relationship of cited publications. Furthermore, timeline analysis of keywords would be conducted to analyze structural changes of hotspots by identifying burst of keywords which could be used to predict research trends.

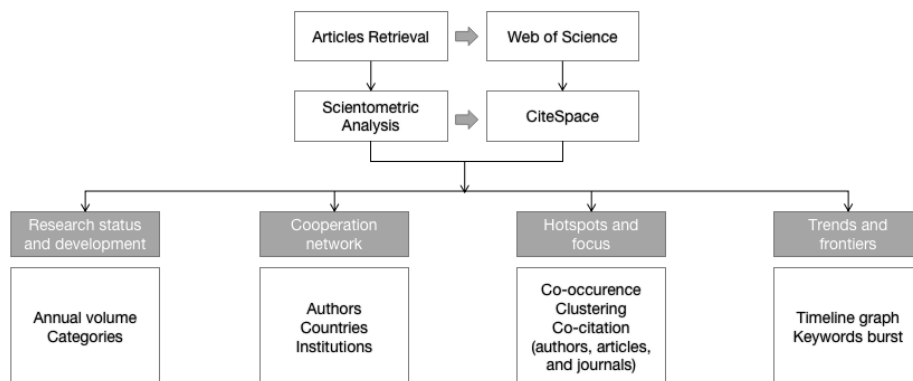


Figure 1 Research flowchart

### 3. Results

#### 3.1. Publication Pattern Analysis

The number of publications was sliced annually (2000 - 2023) to gain a general picture of publication volume pattern year by year. Generally, the annual volume of articles was increasing over the years with an accelerating speed. The research advances could be divided into three phases according to the trending pattern (figure 2). In the beginning stage (2000-2007), the average number of annual publications was 9.5. Researchers began to focus on the urban planning and design for the Children-Friendly Cities which were thought to be practical intervention to promote children's health and physical activity by UOE. UNICEF and the European Network of Child-Friendly Cities held Child-Friendly Cities on 2004, highlighting the necessities for creating child-friendly urban environments and encouraging the exchange of

best practices(36,37). In the development stage (2007-2015), the average number of annual publications increased to 38.5. There had been emerging research on the children’s PA, health and UOE from multi-perspectives and dimensions of medicine, environment and health studies. In the accelerating stage (2015-2023), the average number of annual publications dramatically increased to 107.1, almost 10 times compared with that in the beginning stage. The annual publications showed a speedy growth burst after 2015, indicating that the studies of the topic were receiving more attention from international academia. UNICEF published the handbook on children friendly cities, defining the research and practice foundation of Child-Friendly Cities, which might further boost the research attention in this field(38). Overall, although there were some fluctuations, the general trend of publications was upward, indicating that studies of this field were still vigorously evolving. The result showed that more directions and frontiers of children’s PA, health and UOE research were expected as the publication body was still growing quickly.

The papers totally covered 133 WOS categories (e.g., public health, medicine and environmental science) and a paper might cover more than one category according to the rule in WOS category. The top 10 categories were summarized as below (figure 3), showing that the majority of studies were laying in categories of public environmental occupational health (n=525), environmental science (n=206), medicine general internal(n=129), nutrition dietetics pediatrics (n=110). The leading category of the publications was public environmental occupational health, while the interdisciplinary nature of this field was apparent as emerging categories other than public health and medicine field such as urban studies (n=89), transportation (n=78) and geography (n=65). The presence of many categories related to the environmental studies implied that environmental exposure and health outcomes were still closely related to processes linking children’s PA to the UOE . Urban studies, geography and transportation were newly present in list of top categories which suggested that urban planning and design was increasingly playing an important role in this field. It was assumed that volumes of publications would continue to grow and topics of this field become deeply interdisciplinary.

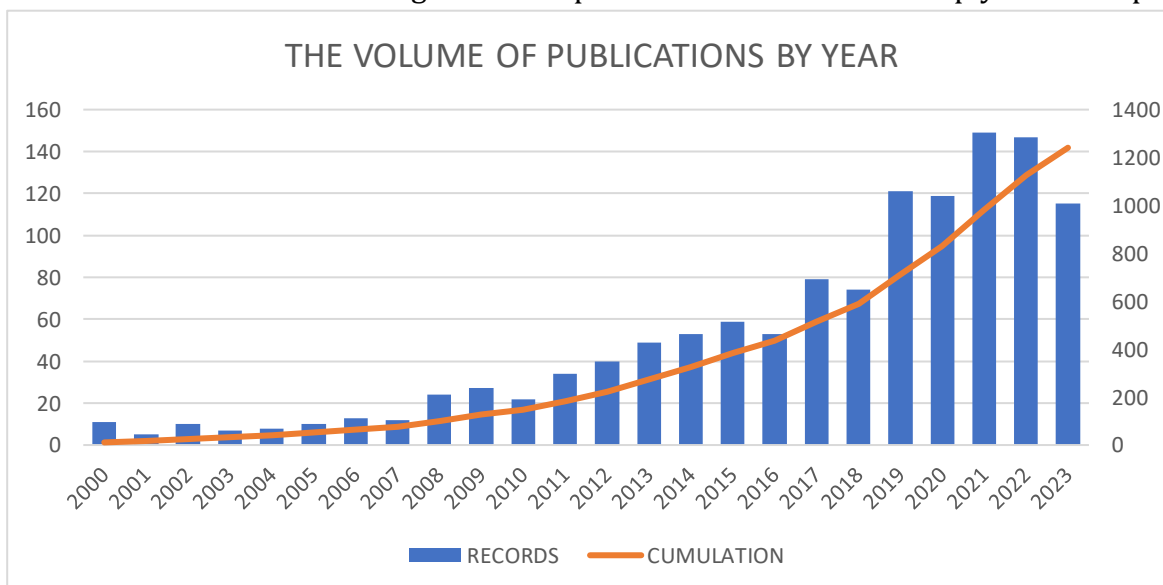


Figure 2. The volume of publications by year.

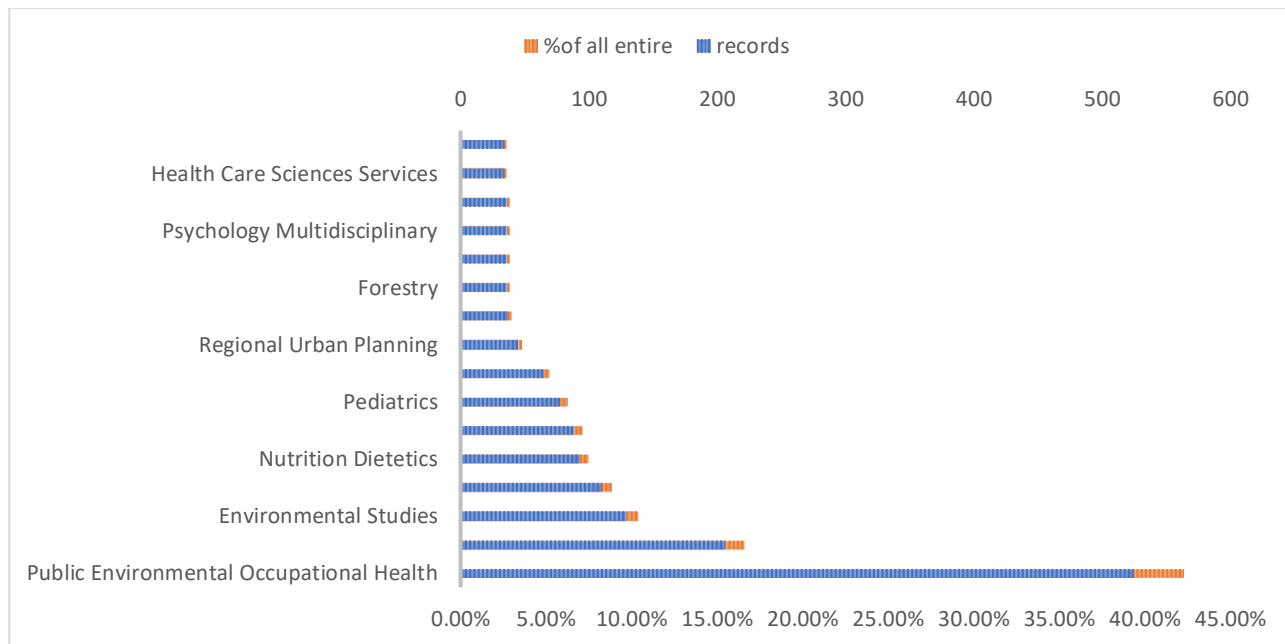


Figure 3. The top 15 categories of publications

### 3.2. Cooperation Network Analysis

#### 3.2.1. Country

The occurrence analysis of country was conducted to map the international cooperation network and geographical features. The cooperation network consisted of nodes (n=632) and links (E=1177) with a density value of 0.0059, indicating decent academic collaborations in the network (figure 4). However, it was not evenly distributed with several significantly large nodes, according to the mapping. The largest one was USA which represented the highest counts of publication (n=447), then it was followed by Canada (n=121), China (n=115), England (n=115) and Australia (n=98). Notably, China was the only developing and Asian country among the top 5 country list of publications with the first record in 2010 (table 1). It indicated its rapidly increasing work and influence in this field. Nonetheless, node centrality of China was rather low (0.07), much less than other four countries, showing lack of collaboration and influence with other leading countries in the field. Comparatively, the average centrality of the other four countries was 0.43 which was far higher than the rest. It showed that research hub of this field was still in the high-income countries from the West while China as a developing country was catching up quickly, showing an emerging potential. Hence, academic cooperation between developed countries and developing countries needed to be enhanced.

Table 1: The cooperation network of country.

Rank	Country	Year of the first records	Counts	Centrality
1	USA	2001	447	0.72
2	Canada	2001	121	0.42
3	China	2008	115	0.07
4	England	2004	115	0.26
5	Australia	2004	98	0.33

### 3.2.2. Institution

The cooperation network of institution was composed of 197 nodes and 591 links, which was more complex than that of the country (figure 5). University of North Carolina was the largest node representing the most publications over the years (n=22), then followed by University of Melbourne (n=21), University of Toronto (n=18), University of Washington (n=16) and University of Illinois (n=15). Three of them were located in US while the rest was in Canada and Australia respectively (table 2). All the countries were located in the top 5 countries in the previous cooperation network, which responded to the previous findings. University of North Carolina had the record in 2003 while University of Melbourne yielded its first record in 2013. Regarding the node centrality, University of North Carolina ranked first (0.09), then followed by University of Illinois (0.08), University of Washington (0.07), which were all located in the US. Notably, University of North Carolina, University of Illinois, and University of Washington (0.07) were ranked both in the leading place regarding the number of publications and centrality, implying their role in the institutional cooperation network. As the top institutions were all located in the top countries, proving the strong internal associations of country and institution cooperation in this field.

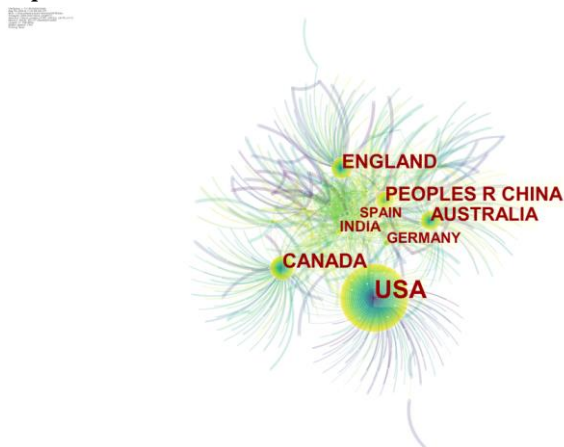


Figure 4. The cooperation network of country.



Figure 5. The cooperation network of institutions.

### 3.2.3. Authors

The cooperation network was consisting of 100 nodes and 226 links with a density of 0.0457, It was evenly organized with some sub-networks of cooperation with limited scale and low

aggregation. In terms of publications, the most out-standing author was James F Sallis, who had namely 220 articles since 2004 on this topic, then followed by WHO with 145 counts, and Brian E Saelens with 101 counts. In terms of node centrality, WHO yield the highest value of 0.13, then followed by James F Sallis (n=0.12). Expect for WHO and Sallis, the other top authors were all from US which was the leading country in this field in terms of institution and publication, responding to the previous analysis (Table 3). Only one author was from the leading institution of University of Washington, proving the cooperation of authors might not be associated with institution. Overall, the cooperation net-work of authors showed limited features of cluster pattern, indicating the uneven distributed cooperation in this field.

Table 3. The cooperation network of authors

Rank	Author	Institution	Country	Year of the first records	Counts	Centrality
1	James F Sallis	Australian Catholic University	Australia	2004	220	0.10
2	WHO	WHO	UN	2001	145	0.02
3	Lawrence Frank	University of California at San Diego	USA	2006	111	0.06
4	Brian E Saelens	University of Washington	USA	2006	101	0.07
5	Reid Ewing	University of Utah	USA	2008	88	0.06

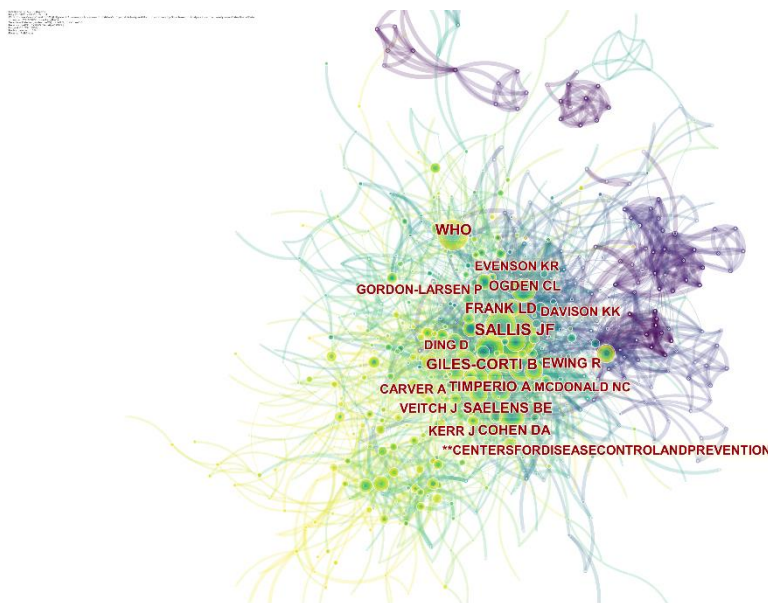


Figure 6 The cooperation network of authors

### 3.2.4. The Keyword Co-occurrence

The keyword co-occurrence network was composed of 646 nodes and 2933 links with a density of 0.0141 (figure 7). The size of node could reflect the frequency of keywords. The larger node was, the higher frequency was. The bandwidth of the links reflected the co-occurrence of the keywords in the same article. After ruling out the search keywords and broad-meaning words (e.g., children, UOE , physical activity), the top co-occurred keywords were “obesity”, “walking”, “neighbor-hood”, “school”, “BMI”, “overweight”, “urban form”, “behaviors”, and “urbaniza-tion”.



In terms of centrality, top keywords would be “urbanization”, and “behavior”. To summarize, “urbanization”, and “behavior” could be the most important keyword for the topic. The centrality and co-occurrence may not align as centrality was the capability of one node to connect two unrelated nodes which was used to measure the importance of connection in a network. It was necessary to consider both of centrality and frequency of co-occurrence when it came to determine the hotspots of a theme.

To further explore the hotspots of this field, the co-citation clustering mapping was produced to identify the clustering pattern of keywords (Figure 8). The larger the cluster, the more terms it consisted of, indicating greater influence in the field. The clustering values of degree of modularity  $Q = 0.4598 > 0.3$  and the cluster effect of the network  $S=0.7478 > 0.7$  were showing a high homogeneity of the network and ideal clustering results. Each cluster’s silhouette values are higher than 0.6, implying the clustering were convincing and qualified for further research (table 4) (39).

Fourteen clusters were detected and ranked by size. After ruling out irrelevant terms and search terms, “Neighborhood safety”, “Encouraging walking”, “Long-term exposure”, “BMI”, “MVPA” and “Childhood obesity” “Traffic exposure” were identified as target clusters. “Neighborhood safety” was the largest cluster (size=88), of which the top terms were “active school travel”, “neighborhood walkability” and “walking time”. All these clustering could be categorized into three parts. First, there were clusters focusing on the UOE of the field, such as “Neighborhood safety”, “Neighborhood characteristics”, “Land use choice” and “High income countries” (table 5). It indicated that the neighborhood environment was the most studied environmental settings, which could be closely related to the design and planning of communities (40). Second, the most commonly studied PA was walking, particularly for children’s transport means to school. Improving the children’s active travel to school and walking pattern could be considered as an important facilitator for their PA. As a result there were volumes of studies about the walkability around their neighborhood and school setting (41). Third, “childhood obesity” was the mainly studied health consequences, which include sub-clusters such as “natural environment”, “land use mix”, “walkability indices”, and “urban sprawl”. It showed the significant association of children’s obesity with the environmental characteristics of urban space. The role of urban design and planning in mediating this relationship was also indicated (42). Overall, the results showed many similarities between the keywords and clustering analysis, indicating that the research motivation was primarily to reduce obesity and overweight of children. Walking was one of the most common PA behaviors while school and neighborhood were the most common environmental settings. Based on the in-depth understanding of the specific contents under each cluster, three research hotspots were formulated:

(1) UOE’s influence on children’s health outcomes by PA, with an emphasis on overweight and obesity. It included the clusters of “BMI”, “Childhood obesity”. Promoting PA could benefit children’s body weight, reducing their risk of obesity and overweight. It might have constant impact on children’s health after they grew up. The childhood obesity was critical to shape a person’s lifestyle and attitude towards health in a life-span (43). UOE was considered an interventional mediator and path to improve children’s health on obesity by reducing the sedentary behaviors (20,44). Hence, the environmental design to promote PA was thought to be an effective intervention to benefit childhood obesity, and impact their life-long health outcome (45).

(2) The UOE and children’s PA in the neighborhood setting. It included the clusters of “Sedentary behavior”, “Traffic exposure”, and “MVPA”. The frequency of the keywords implied that primary and pre-school students were the main target in the study. These young children’s PA was more influenced by the environmental design as their activity range was often limited (46). The keywords about impact of neighborhood environment were another hotspot

as they were usually complicated and integrated, worth further study. Neighborhood was the most studied type of UOE setting as its impact on PA was significant (46). Overall, the results showed this research hotspot was encouraging children’s PA, either recreational and transportation, by the environmental design and planning of community. Two sub-hotspots were identified as environmental factors and influence of neighbourhood on children’s walking and sedentary behaviors.

(3) UOE’s characteristics associated with children’s travel and recreational behaviors. It included the clusters of “Encouraging walking”, “Neighborhood characteristics”, “Neighborhood safety” and “Land use choice”. Walking was the most studied behaviors for children’s PA, which was significantly associated with UOE . In other words, walking was an effective PA behaviors which could be intervened by environmental design(47). Some keywords implied different environmental setting might produce various impact on children’s PA. The environmental factors such as “accessibility”, “mixture of land” and “residential density” were also the common keywords within the clusters in the field. The factors could primarily impact the “walking” behaviors of children, which was receiving volumes of studies(48).

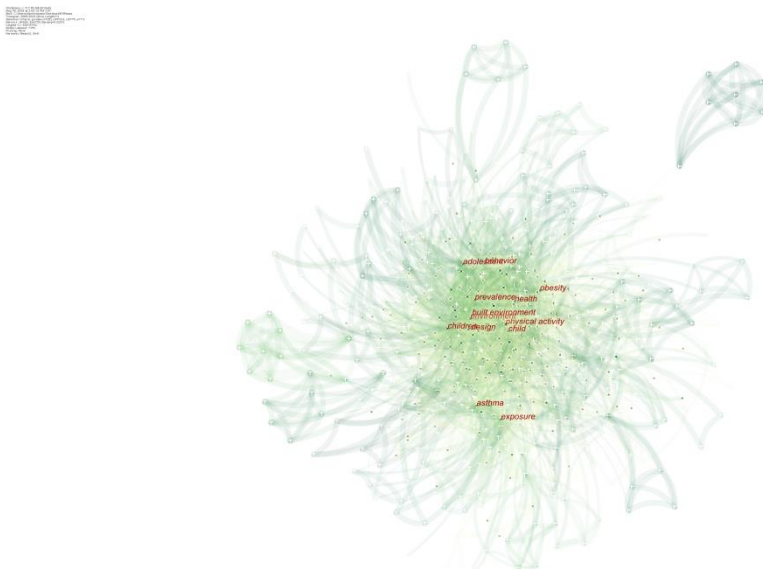


Figure 7. The co-occurrence analysis of keywords.

Table 4. The Analysis of keyword co-occurrence

keywords	Frequency	Centrality	year
children	520	0.13	2000
health	419	0.04	2000
physical activity	389	0.12	2002
environment	239	0.02	2000
obesity	172	0.06	2004
adolescent	157	0.04	2000
built environment	140	0.04	2003
association	140	0.01	2008
exposure	113	0.06	2000

Table 5. The cluster of keywords

ID	name	Size	Silhouette	mean(years)	Top terms
0	Environmental justice	76	0.68	2015	urban planning; environmental justice; spatial analysis; urban ecosystem services; unmanaged greenery; spontaneous vegetation; social capital; accessibility; mental health; green space   physical activity; outdoor environment; neighborhood green; environment; social capital; accessibility; mental health; green space; human exposure; supply air pollution; inhaled allergen; national health; nutrition examination survey; states; volatile organic compound; home dampness; blood lead level; respiratory symptom; risk assessment   personal exposure; volatile hydrocarbons; formaldehyde; passive sampling; risk assessment; urban commuting road; day car centers; urban heat island; indoor air quality; disservices
1	personal exposure	68	0.827	2009	physical activity; childhood obesity; urbanization level; high school; child labour; multi-level analysis; human development index; unhealthy behavior; cardiovascular risk factors; residence characteristics   environment; urban planning; body mass index; rural-urban migration; malnutrition; living conditions; socio-economic environment; nutrition transition; child labour; public health authorities
2	childhood obesity	66	0.702	2009	physical activity; feasibility; intervention; early years; walkability; sustainable development goals; logistic regression; pedestrian route directness; students' mobility; green space   environment; urban sprawl; public realm; environmental design; social capital; public open space; environments; mental health; sustainable development goals; new urbanism
3	physical activity	63	0.726	2011	physical activity; intervention; early years; feasibility; mental health; health equity; atopic dermatitis; green space; remote health; landscape ecology   environment; urban sprawl; mental health; health equity; atopic dermatitis; green space; remote health; landscape ecology; activity guideline; skin neoplasms
4	adolescence	62	0.721	2011	maternal; child health; primary health centers; medical equipment; physical facilities; service readiness; health education; indoor air quality; human
5	family planning	53	0.771	2013	

6	youth	48	0.659	2014	thermal comfort; teacher education   family planning; urbanization; population growth; child survival; health education; indoor air quality; human thermal comfort; teacher education; nature-based learning; gravitational settling physical activity; green open space; environmental characteristics; risk assessment; center auspices; school programs; source apportionment; co-construction; health research; first nations   environment; young children; neighborhood; Escherichia coli; drinking water; association; sedentary behavior; Canadian children; active recreation; micro environment physical activity; public health; cluster; baseline data; early childhood educators; landscape ecology; urban planning; fundamental movement skill; cross-sectional studies; Australian preschool children   cross-sectional studies; personal satisfaction; urbanization; family planning services; immunization; surveys; poverty areas; questionnaires; reproductive health; contraception physical activity; sedentary behavior; qualitative interviews; disadvantaged neighborhoods; school children; measures; body mass index; health examination; young adult; environment   environment; African American; eating behavior; qualitative research; special needs athlete; adult; preparticipation evaluation; life; features; adolescents nitrogen dioxide; solid fuel use; global burden; chronic bronchitis; particulate matter; comparative risk assessment; respiratory infection; spatial variability; low birth weight; household concentration   trends; social justice; death; space-time clustering; cause; poverty areas; urban population; socioeconomic factors; infant; health disparities children; injuries; basketball; sports; imaging; endemic cholera; community study; adults; oral disease patterns; policy feasibility   environment; perspective; rural children; intervention; endemic cholera; injuries; community study; adults; oral disease patterns; policy feasibility
7	child care	44	0.68	2013	physical activity; public health; cluster; baseline data; early childhood educators; landscape ecology; urban planning; fundamental movement skill; cross-sectional studies; Australian preschool children   cross-sectional studies; personal satisfaction; urbanization; family planning services; immunization; surveys; poverty areas; questionnaires; reproductive health; contraception physical activity; sedentary behavior; qualitative interviews; disadvantaged neighborhoods; school children; measures; body mass index; health examination; young adult; environment   environment; African American; eating behavior; qualitative research; special needs athlete; adult; preparticipation evaluation; life; features; adolescents nitrogen dioxide; solid fuel use; global burden; chronic bronchitis; particulate matter; comparative risk assessment; respiratory infection; spatial variability; low birth weight; household concentration   trends; social justice; death; space-time clustering; cause; poverty areas; urban population; socioeconomic factors; infant; health disparities children; injuries; basketball; sports; imaging; endemic cholera; community study; adults; oral disease patterns; policy feasibility   environment; perspective; rural children; intervention; endemic cholera; injuries; community study; adults; oral disease patterns; policy feasibility
8	Pregnancy	41	0.725	2009	physical activity; public health; cluster; baseline data; early childhood educators; landscape ecology; urban planning; fundamental movement skill; cross-sectional studies; Australian preschool children   cross-sectional studies; personal satisfaction; urbanization; family planning services; immunization; surveys; poverty areas; questionnaires; reproductive health; contraception physical activity; sedentary behavior; qualitative interviews; disadvantaged neighborhoods; school children; measures; body mass index; health examination; young adult; environment   environment; African American; eating behavior; qualitative research; special needs athlete; adult; preparticipation evaluation; life; features; adolescents nitrogen dioxide; solid fuel use; global burden; chronic bronchitis; particulate matter; comparative risk assessment; respiratory infection; spatial variability; low birth weight; household concentration   trends; social justice; death; space-time clustering; cause; poverty areas; urban population; socioeconomic factors; infant; health disparities children; injuries; basketball; sports; imaging; endemic cholera; community study; adults; oral disease patterns; policy feasibility   environment; perspective; rural children; intervention; endemic cholera; injuries; community study; adults; oral disease patterns; policy feasibility
9	poor	39	0.741	2013	physical activity; public health; cluster; baseline data; early childhood educators; landscape ecology; urban planning; fundamental movement skill; cross-sectional studies; Australian preschool children   cross-sectional studies; personal satisfaction; urbanization; family planning services; immunization; surveys; poverty areas; questionnaires; reproductive health; contraception physical activity; sedentary behavior; qualitative interviews; disadvantaged neighborhoods; school children; measures; body mass index; health examination; young adult; environment   environment; African American; eating behavior; qualitative research; special needs athlete; adult; preparticipation evaluation; life; features; adolescents nitrogen dioxide; solid fuel use; global burden; chronic bronchitis; particulate matter; comparative risk assessment; respiratory infection; spatial variability; low birth weight; household concentration   trends; social justice; death; space-time clustering; cause; poverty areas; urban population; socioeconomic factors; infant; health disparities children; injuries; basketball; sports; imaging; endemic cholera; community study; adults; oral disease patterns; policy feasibility   environment; perspective; rural children; intervention; endemic cholera; injuries; community study; adults; oral disease patterns; policy feasibility
10	behavior	34	0.887	2005	physical activity; public health; cluster; baseline data; early childhood educators; landscape ecology; urban planning; fundamental movement skill; cross-sectional studies; Australian preschool children   cross-sectional studies; personal satisfaction; urbanization; family planning services; immunization; surveys; poverty areas; questionnaires; reproductive health; contraception physical activity; sedentary behavior; qualitative interviews; disadvantaged neighborhoods; school children; measures; body mass index; health examination; young adult; environment   environment; African American; eating behavior; qualitative research; special needs athlete; adult; preparticipation evaluation; life; features; adolescents nitrogen dioxide; solid fuel use; global burden; chronic bronchitis; particulate matter; comparative risk assessment; respiratory infection; spatial variability; low birth weight; household concentration   trends; social justice; death; space-time clustering; cause; poverty areas; urban population; socioeconomic factors; infant; health disparities children; injuries; basketball; sports; imaging; endemic cholera; community study; adults; oral disease patterns; policy feasibility   environment; perspective; rural children; intervention; endemic cholera; injuries; community study; adults; oral disease patterns; policy feasibility
11	ambient	14	0.986	2008	airborne particulate matter; asthmatic children; elementary schoolchildren;

					activity pattern; measurement error; oxidative stress; time activity; Baltimore; particle; ambient
13	Urbanization	7	0.962	2005	urbanization; dietary habits; south Africa; black community; young children

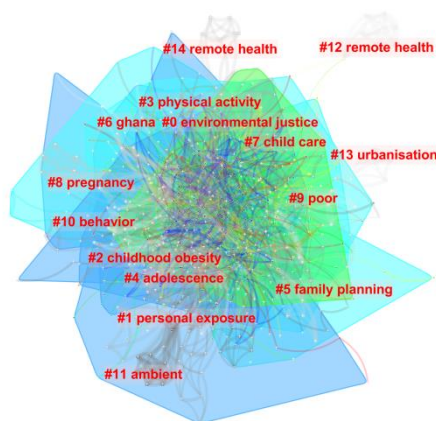


Figure 8. The clustering of keywords co-occurrence.

### 3.2.5. Co-citation analysis

The co-citation network of reference was composed of 945 nodes and 2408 links with a density of 0.0054 (figure 9). The top 5 co-cited references were as: Ding D (2011) reviewed the neighborhood environment correlates and children's PA, which mainly focused on urban design and planning patterns such as walkability, access or proximity to recreational destinations, land-use mix, and residential density (table 6). Gordon LP (2006) focused on the effect of inequalities in facility availability on ethnic and socioeconomic disparities in obesity and children's overweight patterns. Children of low socioeconomic status (SES) and minority groups always suffered limited access to facilities, which in turn could lead to an increased risk of overweight and obesity due to the lack of outdoor PA. Lawrence D. Frank (2004) highlighted the role of community design in influencing children's and obesity rates. It emphasized that communities with pedestrian-friendly infra-structure, such as sidewalks, bike lanes, and parks, tend to promote higher levels of PA and lower obesity rates. On the other hand, car-dependent communities, characterized by limited walkability and accessibility to amenities, are associated with increased obesity rates due to reduced opportunities for active transportation. Smith M (2017) found positive outcomes of walkability facility, provision of quality open space and grounds, transportation infrastructure for active travel on children's PA. All analyses pointed out that these environmental improvements may predominantly benefit low SES populations. Hallal P C (2012) provided a comprehensive overview of the current state of surveillance and monitoring of PA levels on a global scale, highlights the importance of monitoring PA levels as a critical component of public health initiatives for children and other vulnerable groups. It suggested improving standardization and increasing representation across different population groups and regions. Overall, these highly co-cited articles mainly showed diversified topics around health outcomes and environmental correlates around children's PA.

The co-citation network of authors consisted of 831 nodes and 2645 links (Figure 10). The most co-cited author was James F Sallis, with a total count of 220 with his first publication in 2004. The second most co-cited author was WHO, a proponent and advocate of children's health and urbanization programs, The organization had a total co-citation count of 189 and a centrality

of 0.13. The remaining top 5 co-cited authors were Lawrence D. Frank, (count=111, centrality=0.06), Timperio (count=107, centrality=0.06), A. and Saelens B E (count=101, centrality=0.07) (table 7). There were some overlaps of the top co-citation of authors with the co-occurrence of authors, indicating the association of publications and citations for the top researchers.

The co-citation network of journals consisted of 708 nodes and 3462 links, with a density of 0.0138 (Figure 11). The most co-cited journal in the field was the “American Journal of Preventive Medicine” (count=530, centrality=0.02) (table 8). In second place was “Preventive Medicine” (count=471, centrality=0.00), followed by “Health and Place” (count=470, centrality=0.00), the “American Journal of Public Health” (count=465, centrality=0.01), and “Lancet” (count=435, centrality=0.04). Overall, except for “Health and Place”, all the other four journals were in the field of public health and medicine, which aligns with the previous findings in the category analysis. These results imply that health outcomes from PA promotion, such as obesity and overweight reduction, remain the main focus of research in this field. It also responded to the result of cluster analysis for the research hotspot.

Table 6. Co-citation of the reference.

Author	Year	Frequency	Centrality	DOI	Name	Journal
Ding D, et al.,	2011	21	0.08	<a href="https://doi.org/10.1016/j.amepre.2011.06.036">https://doi.org/10.1016/j.amepre.2011.06.036</a>	Neighborhood environment and physical activity among youth	Pediatrics
Gordon L P, et al.,	2006	16	0.04	<a href="https://doi.org/10.1542/peds.2005-0058">https://doi.org/10.1542/peds.2005-0058</a>	Inequality in the built environment underlies key health disparities in physical activity and obesity	Pediatrics
Lawrence D. Frank, 2004 et al.,	2004	16	0.01	<a href="https://doi.org/10.1016/j.amepre.2004.04.011">https://doi.org/10.1016/j.amepre.2004.04.011</a>	The Influence of the physical obesity relationships with community design, physical activity, and time spent in cars	American Journal of Preventive Medicine
Smith M, et al.,	2017	15	0.01	<a href="https://doi.org/10.1186/s12966-017-0613-9">https://doi.org/10.1186/s12966-017-0613-9</a>	Systematic literature review of built environment effects on physical activity and active transport – an update and new findings	International Journal of Behavioral Nutrition and Physical Activity

Hallal P C, et al.,	2012	15	0.02	<a href="https://doi.org/10.1016/S0140-6736(12)60646-1">https://doi.org/10.1016/S0140-6736(12)60646-1</a>	on health equity	Global physical activity levels: surveillance progress, pitfalls, and prospects	The Lancet
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Table 7. Co-citation of the authors

Author	Year	Frequency	Centrality	Whether in the top 5 co-occurrence of authors
James F Sallis	2004	220	0.10	Y
WHO,.	2001	189	0.13	Y
Lawrence D. Frank,	2006	111	0.06	Y
Timperio, A	2006	107	0.06	N
Saelens B E	2006	101	0.07	Y

Table 8. Co-citation of the journals

Name	Year	Frequency	Centrality	JIF (2021)
American Journal of Preventive Medicine	2002	530	0.02	6.604
Preventive Medicine	2001	471	0.00	4.637
Health and Place	2004	470	0.00	4.931
American Journal of Public Health,	2004	465	0.01	11.576
Lancet	2001	435	0.01	202.731

### 3.3. Research Frontiers and Trends Analysis

#### 3.3.1. Keyword Clustering Timeline Analysis

The mapping of keyword clustering timeline analysis illustrated the historical results, trends, and interconnections between the themes of the research topic (Figure 12). The analysis was conducted by applying a yearly slicing approach and a clustering algorithm. In the figure, the horizontal axis represents the time span (2001-2022), and the vertical axis represents the order of clusters. The size of a cluster is determined by the number of keywords it contains. The arcs represent the connections of nodes over time, and 10 clusters were generated.

The cluster with the longest time span, starting from 2000 and continuing to the present, was the "UOE " "asthma" and "air pollution" cluster, which were also the largest cluster. "UOE " evolved from the early concept of a "healing environ-ment" to the notions of a "healthy community" and "urban environment," indicating its enduring role as a foundational knowledge base in this field(49). "Air pollution" and "asthma" showed the influence of outdoor environment on children’s health. In the one hand, the exposure to air pollution might cause some health issues on children’s respiratory system, leading to cluster of "asthma" . In the other

hand, parents would prevent their children to play and walk outside when there was serve air pollution. It was particularly obvious and common during the Covids pandemic(13). It indicated that outdoor space was the mainbody of UOE research, and air pollution was a significant variable in this field. Since "UOE " was consist-ently searched throughout the entire study period, it can be inferred that the sub-topic around it will continue to be research hotspots.

Another notable cluster with long active length was "exercise." The third larg-est cluster, active from 2009 to 2020, was "exercise." This cluster encompassed emerging keywords such as "active living," "active travel," "sedentary behavior," and "adverse childhood experiences." It also focused on "active travel" and under-went an evolution from "travel behavior" and "safe routes to school" to "wearable devices." The lasting role of the cluster indicated that reducing children's sedentary behaviors by promoting an active lifestyle is a significant motivation within the field. The most recently emerged clusters were "urban planning" (2004) and "neighborhood environment" (2003) respectively, indicating the newly research focus. There clusters were composed of "environmental design", "smart growth", "green space", "park", and "walkpath", showing that they underwent an evolution from "physical environment" to "environmental design and planning". It indicated the increasing focus on the quality and types of environment settings where chil-dren spent much time staying.

Recently, research focus gradually moved towards the geographical differ-ences among the developing countries. "China" and "Africa" were emerging clus-ters showing the differences from the developed countries. China particular, was showing a great potential since 2015, with mounting volumes. There were a emerging research shift from the high-income countries to the developing coun-tries which suffered the children’s overweight-epidemic but in a different envi-ronment setting(50). The timeline mapping reveals constant research focus of "UOE " and "exercise", while some new hotspots were appearing as time flew. Additionally, the places other than the developed countries such as "China" and "Africa" were receiving increasing attention.

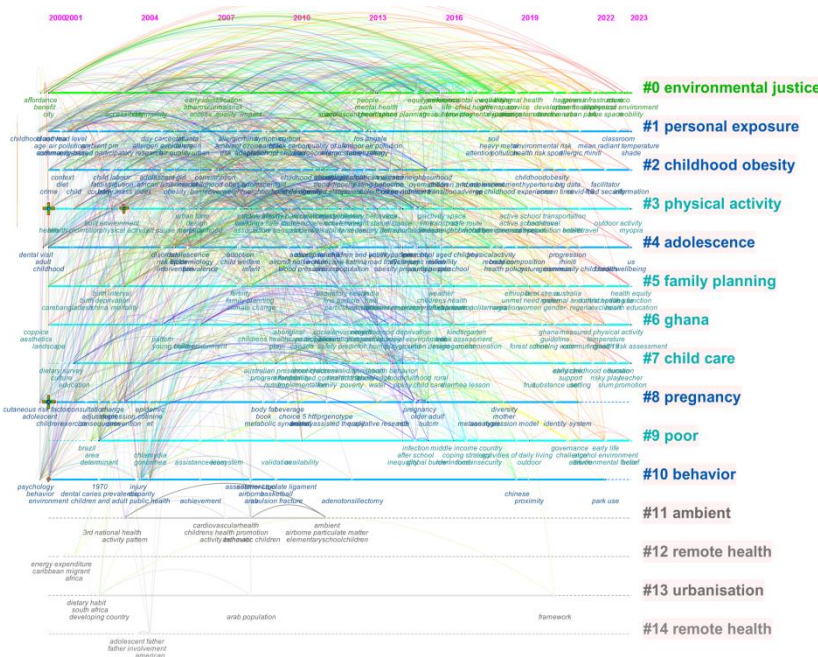


Figure 9. Timeline of keywords cluster

### 3.3.2. Keyword burst analysis

Bursts meant the explosive appearance of words and terms. The burst analysis could detect and predict the change of research topics in a given period. In Figure 13, the red bar represented



the burst length through 2001 to 2022, and the green bar showed no occurrence of burst. The longest burst was detected from “community” and “urban form” which was the most fundamental part of UOE affecting children’s PA. The two keywords were the earliest burst with a short length. The burst with the most strength was “design” with a value of 6.33 but a short burst length as well. The latest bursts were found in the keywords of “park” (2017-2019), “space” (2018-2019), “transport” (2018-2022), “urban planning” (2018-2019). Notably, “transport” lasted longer than the other three keywords burst. The most sustainable keyword burst was “community” while the least was “urban planning”, both of which were in the field of UOE. The keyword burst development could be divided into two stages: the first stage was around 2001 to 2011 when the influence of community and neighborhood environment on children’s PA received much attention. The second stage was from 2012 to 2022 when researchers focused on the environment characteristics influencing children’s active travel to school and the potential of green open space on encouraging children’s PA (e.g., parks, playgrounds, sports fields).

In general, it could be concluded that the hotspots of this domain were changing constantly with emerging new research trends and frontiers. Regarding the health outcomes of UOE’s influence on children’s health by PA, though reducing obesity and overweight was still the constant core focus, more studies were expanding the scope to more diversified health benefits. There was more focus on the mental and social aspect of PA health outcomes. As for PA behaviors, children’s travel and recreational behaviors were still the research focus, while more studies were emerging, of communicating and reducing sedentary behaviors, which enriched the types of PA in research. Regarding UOE’s settings, most of the studies involved neighborhood settings, while green open space, school, and transportation infrastructure were receiving much research attention because of multiple health benefits and regular use by children.

### Top 25 Keywords with the Strongest Citation Bursts

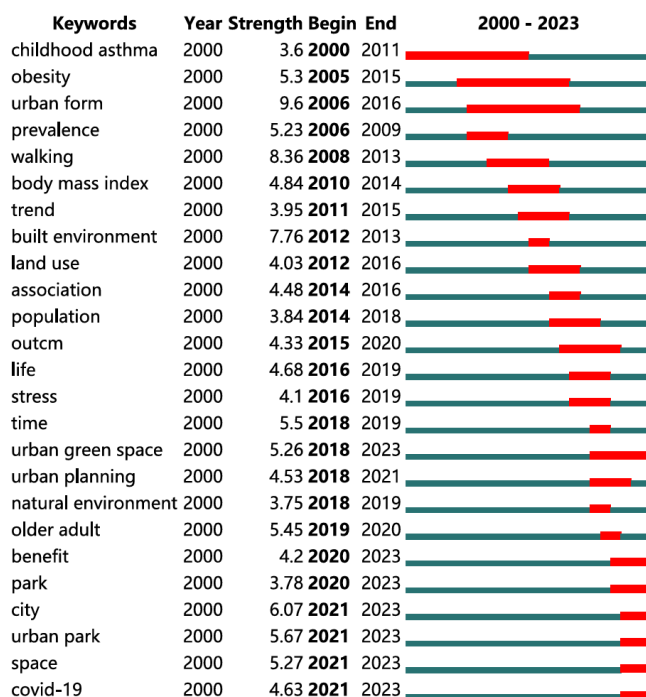


Figure 10. Burst of keywords

## 4. Discussion

### 4.1. Summary of findings

The studies of this field were mounting with an accelerating speed, indicating more research attention drawn to the dilemma of children's well-being and urbanization, which was hotspot for both practice and research regarding the UOE and children's PA (49). Empirical evidence showed that children's PA could be influenced by UOE setting of neighborhood, open space, and transportation infrastructure through PA (50). Well-designed and planned urban space could promote children's health by attracting and encouraging their PA participation and involvement (50). How to improve children's PA through UOE intervention was the main goal of this topic (51). Consequently, this field was expanding its scope to more disciplinary and yielding topics of diversification with emphasis on the scope of public environmental occupational health and pediatrics. It indicated that the obesity and overweight related health outcomes would still be the main drive for this do-main.

#### 4.1.1. Research hotspots for UOE and children's PA

##### (1) UOE's influence on children's health outcomes by PA

The research hotspots have changed over time and are showing a trend of di-versification and interdisciplinary nature. Initially, the majority of studies focused on walking behavior, which had close associations with keywords such as "obesity" and "BMI", which align with previous studies. Overweight and obesity is most academically concerned topic in this domain, which could not only threaten children's health status but also their mature health outcomes once grown up. They are of the most frequency in the keywords clustering, indicating preventing obesity and overweight were the main health outcomes driving the research and would continue to be the research focus. It aligns with the current review and studies on children's PA and UOE. Walking was the main behaviors studied to connect UOE al design to children's health by mediating PA. Neighborhood and home environment were the main design settings studied, as they were the most frequent places for children's PA (22). The result of keywords-occurrence and co-citation clustering analysis provided clues for the thematic hotspots in this field. The overlapping showed that obesity or overweight due to exposure to the UOE of neighborhoods would be a constant hotspot, and more interdisciplinary studies were needed to explore the relationship, correlates, and mechanism behind them. However, the result of keyword of "preschool" "elementary school" suggests some newly emerging focus on the sub-group of children, as their health outcomes of PA could be different. Nevertheless, there are not enough evidences and studies to explore the differences of these sub-groups.

##### (2) UOE and children's PA in the neighborhood setting

Neighborhood was the most co-cited UOE's setting, indicating its role in influencing children's PA as the most important UOE setting. The design and the planning of neighborhood exert significant influences on the PA levels of children. Several relevant keywords are identified in this context, including community safety, road connectivity, natural landscapes, and the quantity and accessibility of parks and recreational facilities. Specifically, there exists a negative correlation between residential density and the frequency as well as duration of PA among children. Conversely, community safety demonstrates a positive association with the distance covered and total duration of physical activity in this demographic. Gender differences are evident in the MVPA buffer zone radius, with boys having a radius of 800 meters and girls having a radius of 500 meters. Boys engage in significantly more outdoor PA compared to girls. The aesthetic appeal of community pedestrian planning, good road connectivity, and the abundance of sports facilities and parks in the vicinity positively correlate with the daily average MVPA activity level of children and adolescents. In other words, shorter distances and travel times to sports fields, facilities, and parks contribute to increased PA in this population.

Communities with high land use mix demonstrate a greater potential for children to involve with active commuting modes, including walking or cycling, to school.

### (3) UOE's characteristics associated with children's travel and recreational behaviors

The clustering analysis of keywords suggests some highly cited UOE's characteristics such as "walkability", "accessibility", which align with the previous findings. More studies would be conducted on specific environmental characteristics and typology with emphasis on their impact on children's health by PA in different scales. It would also be an effective channel to connect research to the practice of Children Friendly Cities and child inclusive urban design, which was essential to their well-being (52). In brief, children's health outcomes of obesity and overweight by UOE; impact of neighborhood environmental design on children's PA; environmental characteristics associated with children's walking behaviors. The distance between home and school emerges as a key factor determining the mode of transportation adopted by children and adolescents. In rural areas, as the distance to school increases, there is a 60% higher likelihood of passive transportation, such as school buses, being used, while in urban areas, this likelihood increases by only 30%. Additionally, the accessibility of urban open space, street design and planning, the number of pedestrian crossings, and traffic safety at inter-sections significantly influence children's choice to commute to school on foot or by bike.

## 4.2. Strength and Limitation

The study conducted a scientometric analysis on the field of children's PA and UOE by CiteSpace, which made it possible to analyze large amount of publication in a short time. The study examined the past relevant studies to offer the insights into the disciplinary structure and identify the underlying relationships by visualizing them. This method allowed researchers to comprehensively analyze its publication trends and pattern, the cooperation network of authors, regions and institutions, co-citation network, hotspots by keywords co-occurrence and clustering, which illustrate the knowledge foundation of this topic.

Nonetheless, as an exploratory study, some limitations were obvious. All the articles were written in English, leading to a neglect of data sources in other language. Self-citation should be accounted to draw more robust conclusions. Apart from CiteSpace, there were new emerging scientometric tools in function and methods such as VOSviewer, CitNetExplorer, etc, which could be utilized for the further comparison. More in-depth and detailed analysis would be conducted with new searching strategy and algorithms.

## 5. Conclusion

This study presents a detailed and insightful picture of the internal structure of the field, shedding light on various aspects related to children's health and environmental design. Additionally, the study's findings have practical implications, as they can inform policy makers and contribute to the development of effective strategies for promoting children's health. This field has been undergoing rapid development with a particularly constantly upward trend during the recent years. The trend of diversified and multidisciplinary nature in this topic has been apparent over the time. A number of studies from environmental science, urban studies and psychology are emerging. The most contributed countries, institutions and authors are mainly from developed countries in the West, indicating the research hub in the cooperation network. Three distinct research streams are identified. Health outcomes of reducing obesity and overweight by environmental intervention are still the hotspot, while some studies are gradually recognizing the other potential health benefits of encouraging PA on children in the emotions, mental health, social ability and cognition development. The neighborhood is thought to be the most frequently studied environmental setting, meanwhile open space, green space and transportation infrastructures are drawing increasing attention. Walking behaviors

is the most frequently studied PA behavior, while there are increasing studies focusing on the active travel, recreational behaviors and outdoor play, which accounts for a large part of children's PA on a daily basis. In the future, the research trend might move toward several directions including: the multiple health outcomes from environmental design on PA; the health impact of multiple environmental settings environmental such as green space, open space and recreational facilities; the environmental determinants active travel and recreational activities. Considering the different urban context, more studies should be considered into the developing countries because there is a huge demand to cope with the children's health issues due to the lack of PA. More practice-driven research should be encouraged in order to design and plan more physically active city for children. The multidisciplinary and joint efforts would be promoted as the major drive for the advancement in this field.

## 6. Conclusion

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