A visualized and scientometric analysis of research trends of weight loss in overweight/obese children and adolescents (1958–2021)

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Background: Weight loss is an appropriate approach to reduce the health risks associated with overweight/obese children and adolescents, and the optimal method of weight loss requires further research. This study systematically explores scientific co-operation, disciplinary interaction, hotspots and trends in the field of weight loss in overweight/obese children and adolescents (WLOCA), and provides references for further research.

Methods: Citespace 5.8.R1 (64-bit) was adopted to conduct a comprehensive visualization analysis of the literature on WLOCA from Web of Science Core Collection, including publication, institution, country/region, author, journal, keywords and reference.

Results: 2,513 papers were found in the Web of Science Core Collection, and the annual number of papers published has increased significantly since 2003. Cincinnati Children's Hospital is the institution with the largest number of publications, while Washington University plays a pivotal role in the collaboration network. In terms of nations, USA has made greater contributions than the rest in terms of the number of publications and global co-operation research. The most influential authors in this field are Thomas H. Inge, Thomas Reinehr, Todd M. Jenkins, Epstein LH, Ogden CL, etc. The most active journals are "*Obesity*," "*International Journal of Obesity*," "*Obesity Surgery*," "*Pediatrics*," etc. which are characterized by interdisciplinary interactions. Research hot topics mainly include "assessment of obesity and pathophysiological mechanism," "comprehensive intervention," and "bariatric surgery," and there's a gradual shift from "lifestyle intervention" and "pathophysiological mechanism" to "clinical surgical application." In addition, disciplinary integration and comprehensive research, targeted intervention and treatment, and prospective research are the future research trends.

Conclusion: The overall trend in WLOCA study is positive. The main contribution of this study is to reveal the overall picture of the research in this field with visual maps and detailed data by combining quantitative with

qualitative approaches, which can provide valuable references for relevant researchers to quickly understand the status of studies on WLOCA, to seek co-operation, and grasp research hotspots and frontier trends.

Introduction

Overweight/obesity in children and adolescents is one of the most important public health problems. Globally, the total prevalence rate of overweight/obesity increased by 27.5% in adults and 47.1% in children during 1980–2013 (1). Over the past 40 years, the rising trend of overweight/obesity among children and adolescents has leveled off in some high-income countries, but its proportion is still very high. Meanwhile, rates of overweight/obesity are accelerating in some Asian countries (2, 3). According to WHO, the number of overweight/obese children and adolescents aged 5–19 years exceeded 340 million in 2016, and 39 million children under the age of 5 were overweight or obese in 2020 (4). It is worrying that the global spread of COVID-19 has further increased the number of obese children since 2019 (5, 6).

Overweight/obesity in children and adolescents are associated with higher risk and earlier onset of chronic diseases such as T2DM and cardiovascular (CV) disease (7, 8), which may lead to lifelong overweight/obesity (9), with adverse psychosocial consequences and lowered education (10, 11), and has great negative impacts on society and economy (12). To make it worse, obesity may lead to earlier puberty in children (13), irregular menstruation in adolescent girls (14), and obstructive sleep apnea syndrome (OSAS) (15). Further research found that OSAS is closely related to CV disease, chronic neurodegenerative diseases, and inflammatory diseases, leading to a high risk of cognitive impairment (16). Obesity also contributes to childhood CV disease and impairs autonomic function in children and adolescents, with reduced vagal or HRV parasympathetic activity being the most common, along with concurrent reductions in sympathetic activity and reduced baroreflex sensitivity (17). Interaction between obesity and OSAS increases CV morbidity in children (18), and overweight in adolescence leads to additional CV events (19).

As early as 2002, overweight/obesity in children and adolescents has been ranked by WHO as one of the 10 leading global risks for burden of disease. In 2014, WHO established the "Ending Childhood Obesity Committee," which proposed several key behaviors to end childhood obesity. Countries around the world have also taken action to address overweight/obesity in children and adolescents. For example, in 2017, the American Endocrine Society updated its practical guidelines on prevention, assessment and treatment of childhood obesity (20). Studies have also found that WLOCA is effective in reducing the risk of various diseases and significantly improving weight-related quality of life (21–24). Over the past few decades, researchers have conducted extensive studies on how to effectively reduce the weight of overweight/obese children and adolescents. Several review articles generally focus on the effectiveness of weight loss, such as motivation (25), behavior (26), exercise (27, 28), and comprehensive intervention of combined nutrition (29). Although there are certain risks, drug combined behavioral therapy (30, 31) and bariatric surgery (32, 33) have also achieved good weight loss and improved quality of life. Some systematic reviews have also reviewed the efficacy of different interventions and treatments (34–36). However, facing the current challenge of high numbers of overweight/obese children and adolescents, the best way to weight loss has yet to be found. Traditional research mostly focuses on the discussion of local knowledge or qualitative analysis on the whole, and cannot quantitatively analyze the progress of knowledge in a specific field from a large number of literatures, such as scientific co-operation, disciplinary interaction, research hotspots and trends, etc., which is not conducive to researchers' quick understanding of the current research status in the field. In order to promote the further development of the research, it is necessary to use scientific research tools to comprehensively and intuitively reveal the characteristics and rules of the existing research. Therefore, there is a strong need for scientometric and visualization analysis of research trends of WLOCA.

Scientometrics is a science that applies statistical and computational techniques to quantitatively analyze the inputs, outputs, and processes of scientific activities so as to find out the corresponding laws. Citespace is an information visualization analysis tool developed under the background of scientometrics and data visualization, which can visually analyze the network, structure, interaction, crossover and evolution of knowledge units (37, 38). In recent years, it has been widely adopted not only in information science, but also in such disciplines as medicine (39–41), public health (42–44), artificial intelligence (45, 46), environmental ecology (47), and educational science (48). Therefore, this paper adopts Citespace to systematically

investigate the literature on WLOCA, attempting to identify the potential and valuable information for further research from a new perspective, and provides references for the formulation or improvement of relevant policies for the prevention and treatment of overweight/obesity in children and adolescents.

This paper addresses the following questions: (i) How did the researcher' concerns change in this field? (ii) Which research institutions, countries/regions, scholars, journals, subject categories and references play important roles in this field? (iii) What are the research hotspots and frontier trend?

Materials and methods

Data source and retrieval

All data used in this study were obtained from the Web of Science Core Collection (WoSCC), indexed by SCI-EXPANDED (1900-present), SSCI (1998-present), A&HCI (1998-present), CPCI-S (1998-present), CPCI-SSH (1998-present), ESCI (2015-present), CCR-EXPANDED (1985-present), and Index Chemicus (1993-present). WoSCC is adopted because it contains a comprehensive indexing record of many influential

and high-quality journals around the world. At the same time, WoSCC is more comprehensive than PubMed, which only focuses on biomedical fields (49). Compared with Scopus, the databases covered by the two have little difference (43). Scopus did not have references before 1996 (50), which is not convenient for overall retrieval. Moreover, it has been shown that Knowledge mapping drawn by WoSCC articles is more desirable compared to other databases when using Citespace for visualization analysis (51). In addition, WoSCC has been used as the only data source in numerous previous scientometric and visualization studies (52–56).

The data retrieval process is as follows: First, all the search terms of overweight/obese, children/adolescents, and weight loss are determined respectively through MeSH and entry terms, and the synonyms of "weight loss" in the literature are selected for combined retrieval to ensure a comprehensive search. Second, a multi-topic retrieval was conducted: TS = ("obesity" OR "obese" OR "overweight") AND TS = ("child*" OR "adolescent*" OR "teen*" OR "youth*") AND TS = ("weight loss*" OR "loss*, weight" OR "weight reduction*" OR "reduction*, weight" OR "lose weight" OR "losing weight" OR "weight reducing" OR "reduce weight" OR "reducing fat" OR "reduce fat" OR "anti-obesity"), time spans = 1900–2021, document types = article
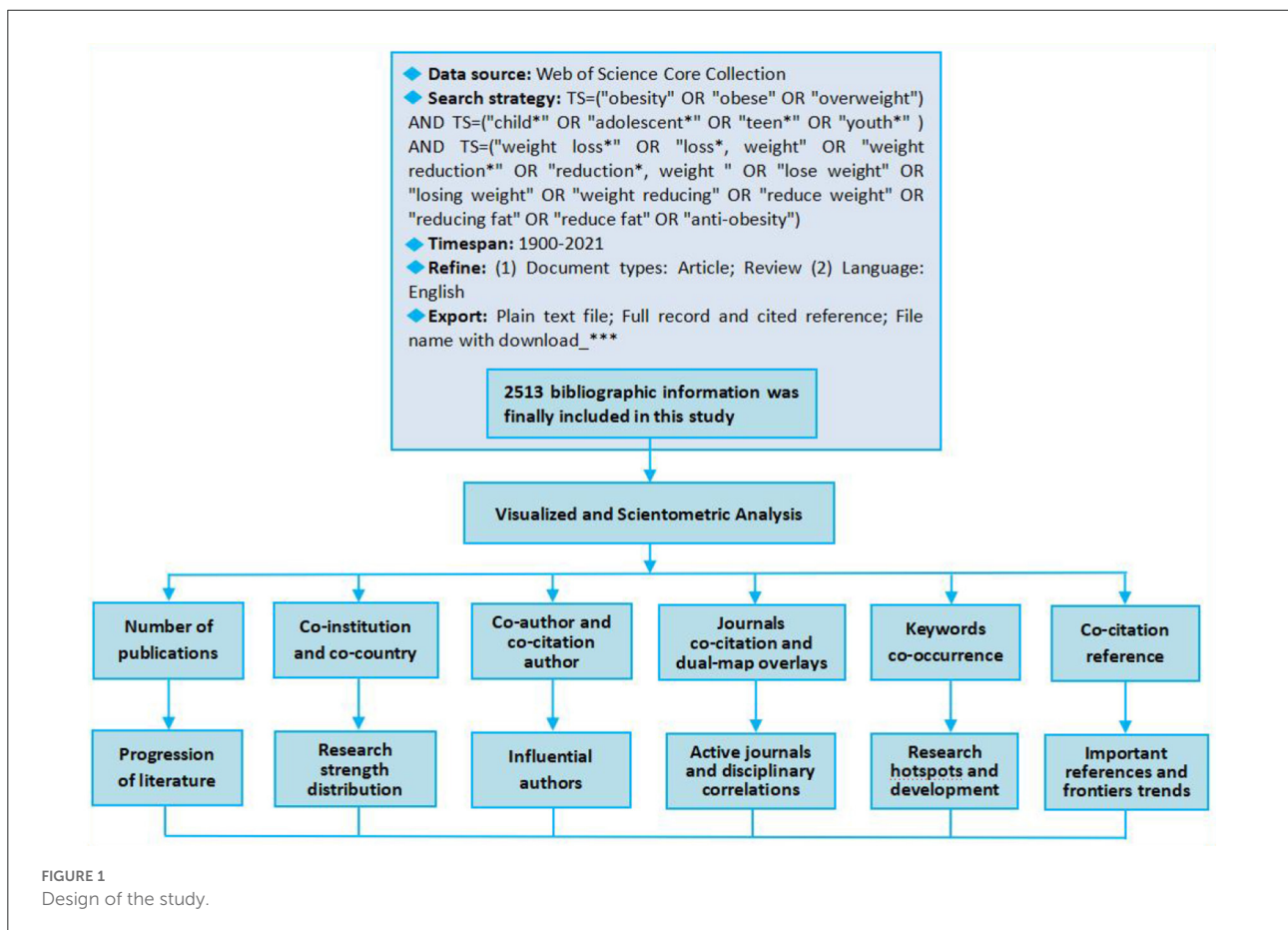

FIGURE 1
Design of the study.

and review, language = English. Finally, the relevance of the retrieved documents was identified one by one through the title and abstract, irrelevant documents were eliminated, and the bibliographic information of 2,513 documents that met the requirements was downloaded according to the corresponding format of the analysis software (The retrieval time is December 31, 2021). There are two main reasons for the exclusion: first, the research subjects must be overweight/obese children and adolescents (excluding athletes) and their related problems; second, the research content directly points to overweight/obesity, not just mentioned in the background or suggestions of the abstract. The overall research design of this paper is shown in Figure 1.

Methods

Citespace 5.8.R1 (64-bit), the analysis tool adopted in this paper, is a free visualization analysis software developed by Dr. Chaomei Chen of Drexel University, USA. The visualization and analysis methods mainly include co-institution and co-country/region, co-author and co-citation author, co-citation journal, dual-map overlays, keyword co-occurrence, co-citation reference, and bursts detection. The parameters in the specific operation of Citespace in this paper are as follows: the time span is 1958–2021, because the first literature retrieved was published in 1958, and the slice length = 2. In each time slice the top 25 nodes were selected for keyword co-occurrence, the top 20

nodes for reference co-citation, and the top 30 nodes for the rest. The network pruning used the pathfinder except for the minimum spanning tree (MST) for keyword co-occurrence and literature co-citation.

In Citespace, Modularity Q and Mean Silhouette (S) are the basis of the map rendering effect. Q > 0.3 means that the network structure is significant, S > 0.5 indicates that the clustering is reasonable, and S > 0.7 suggests that the clustering is highly convincing (57). Therefore, in order to meet the above requirements, we finally determined the parameters and algorithms by repeatedly debugging them. At the same time, in view of the partial overlap of some nodes in the co-occurrence and co-citation knowledge graph, we moved them appropriately without changing the network structure to ensure the best visual presentation effect. The nodes in the knowledge graph are the actual knowledge units analyzed, corresponding to institution, country/region, author, journal, category, keyword, and reference, and their size corresponds to how often the nodes appear or are cited, while the color represents the historical chronology of their appearances or citations, and the nodes marked with purple indicate their greater centrality. The thickness of the connecting line indicates the affinity between nodes, and the color of the connecting line represents the time of first co-occurrence or co-citation, from light to dark corresponding to the time from far to near, and the higher centrality indicates that the node is more important in the network (58).
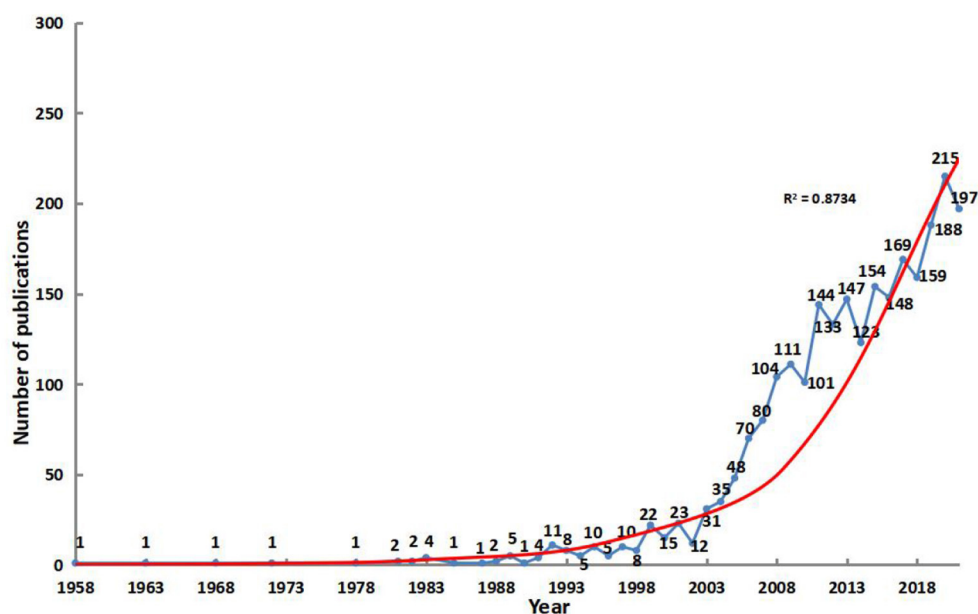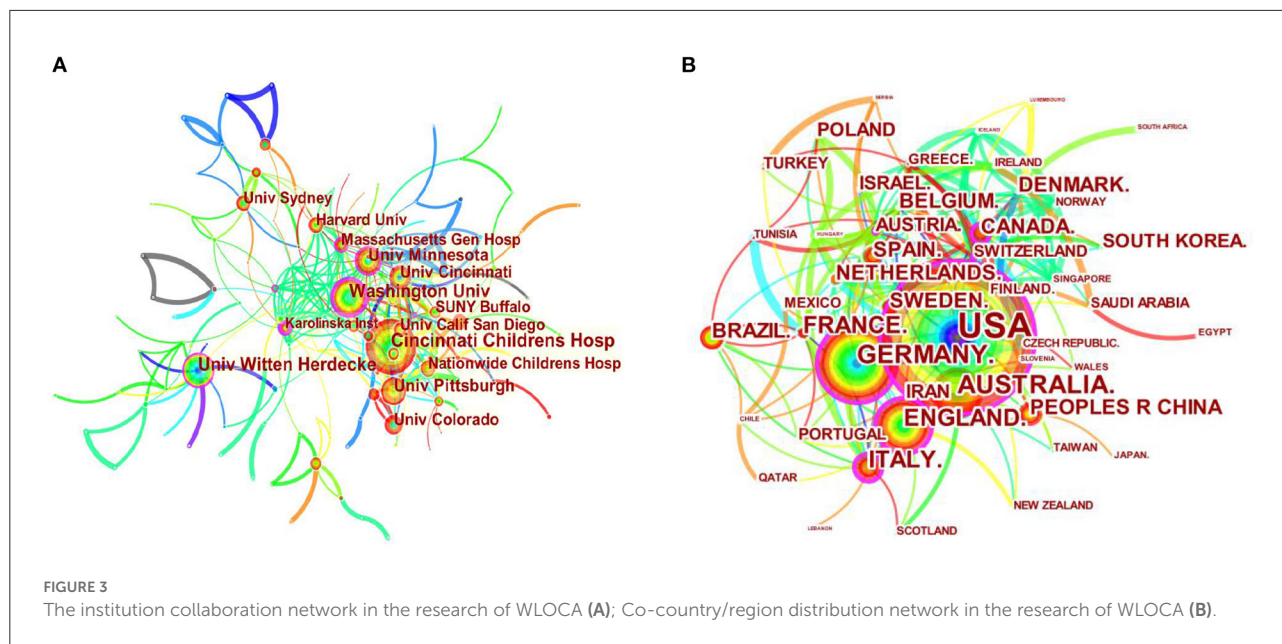

FIGURE 2
Literature on WLOCA published from 1958−2021.

FIGURE 3
The institution collaboration network in the research of WLOCA **(A)**; Co-country/region distribution network in the research of WLOCA **(B)**.

Results

Visualization and analysis on publication outputs

To some extent, the numbers of publications reflect the changes in researchers' concerns in a specific field. Figure 2 shows that the papers on WLOCA were few and far between before 2002. After a period of sustained growth, it exceeded 100 for the first time in 2008, and then fluctuated but maintained an overall increasing trend, reaching a maximum of 215 in 2020. The trend forecasting model for the number of papers on WLOCA ($R^2 = 0.8734$) indicates that this field is receiving increasing attention and the related research will be on the rise.

Visualization and analysis on co-institutions and co-countries/regions

Collaboration across institutions has always been common, expected, necessary, and valued in academic research. As shown in Figure 3, 174 institutions and 52 countries/regions, respectively, participated in collaborative research on weight loss of children and adolescents, with an institutional collaboration network density of 0.0224 and a national or regional collaborative network density of 0.1403, the latter being relatively close. Details of the top 10 institutions and countries/regions are shown in Table 1. All are universities except a children's hospital, and seven of the universities are in the United States. Cincinnati Children's Hospital ranks the

first place with 105 papers in terms of the number of papers published. The top three institutions in terms of centrality are Washington University (0.22), University of Minnesota (0.18) and the University of Witten Herdecke (0.14). As for the country/region distributions, USA ranks the first place with 1,123 papers published, followed by Germany, Australia, England, Italy, France and etc. Meanwhile, the centrality reveals that USA/England (0.17), Italy/Canada (0.14) and Germany (0.11) play key roles in the collaboration. Among the top 10 countries, only Brazil and China are developing countries.

Visualization and analysis on co-authors and co-citation authors

Figure 4A shows that there are 428 nodes and 684 lines forming the co-author network, while the density is only 0.0075. However, only the nine largest co-author networks are shown in the figure, with Thomas H. Inge, Thomas Reinehr, Denise E. Wilfley, and Lian Tock representing the four relatively large academic communities. The top 10 authors in terms of publications are shown in Table 2, with Thomas H. Inge (68 publications) and Thomas Reinehr (55 publications) in the lead and only five authors with some centrality. Figure 4B shows that the author co-citation network consist of 263 nodes and 751 links with density of 0.0218. The citation frequencies of the top 10 co-cited authors are shown in Table 2, with Ogden CL (616 citations) in the lead and Epstein LH (0.41), Freedman DS (0.29), Must A (0.23), and Inge TH (0.17) had the relatively highest centrality and their publications were focused on by researchers.

TABLE 1　Top 10 contributing institutions by countries/regions and centrality.

Rank	Institution	Publications	Centrality	Country	Publications	Centrality
1	Cincinnati Children's Hosp (USA)	105	0.04	USA	1,123	0.17
2	Washington Univ(USA)	78	0.22	Germany	196	0.11
3	Univ Witten Herdecke(Germany)	74	0.14	Australia	150	0.06
4	Univ Minnesota (USA)	64	0.18	England	146	0.17
5	Univ Pittsburgh (USA)	59	0.02	Italy	116	0.14
6	Univ Cincinnati (USA)	51	0.03	France	102	0.03
7	Univ Colorado (USA)	46	0	Spain	90	0.07
8	Univ Sydney (Australia)	42	0.05	Brazil	90	0.01
9	Harvard Univ (USA)	41	0.08	Canada	87	0.14
10	Univ Calif San Diego (USA)	37	0.01	China	81	0.09

FIGURE 4
Co-author network in the research of WLOCA (A); Co-citation author network in the research of WLOCA (B).
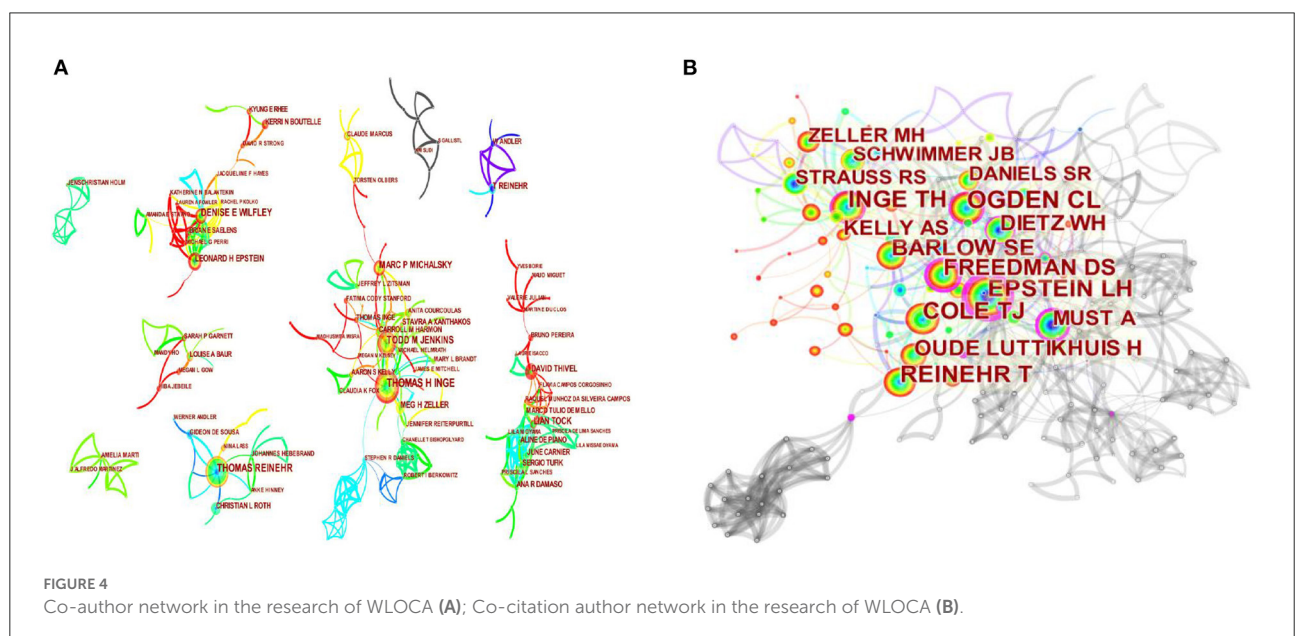
TABLE 2　Top 10 co-author and co-citation author by frequency.

Rank	Co-author	Frequency	Centrality	Co-citation author	Co-citation frequency	Centrality
1	Thomas H. Inge	68	0.02	Ogden CL	616	0.11
2	Thomas Reinehr	55	0	Epstein LH	471	0.41
3	Todd M. Jenkins	42	0.01	Cole TJ	462	0.07
4	Denise E. Wilfley	34	0	Inge TH	443	0.17
5	Lian Tock	28	0.01	Reinehr T	418	0.01
6	Marc P. Michalsky	28	0.01	Barlow SE	346	0.08
7	Leonard H. Epstein	27	0	Freedman DS	327	0.29
8	David Thivel	25	0	Oude Luttikhuis H	269	0.04
9	Meg H. Zeller	24	0.01	Dietz WH	246	0.14
10	T. Reinehr	23	0	Must A	197	0.23

TABLE 3 Top 10 journals and co-citation journals by publications and co-citation frequency.

Rank	Journal	Publications	Co-citation journal	Co-citation frequency	Centrality
1	Obesity	96	*Int J Obesity*	1,695	0.18
2	International Journal of Obesity	95	*Pediatrics*	1,637	0.32
3	Obesity Surgery	80	*J Am Med Assoc*	1,328	0.17
4	Surgery for Obesity and Related Diseases	66	*Obesity*	1,237	0.05
5	Pediatric Obesity	61	*New Engl J Med*	1,187	0.12
6	Pediatrics	54	*Am J Clin Nutr*	1,110	0.14
7	Obesity Reviews	39	*J Pediatr-US*	1,005	0.1
8	Journal of Clinical Endocrinology & Metabolism	37	*J Clin Endocr Metab*	944	0.23
9	Journal of Pediatric Endocrinology & Metabolism	37	*Obes Res*	940	0.04
10	Childhood Obesity	36	*Obes Rev*	870	0.04

Visualization and analysis on co-citation journals and dual-map overlays

Active journals in this study refer to both source journals and co-citation journals. The top 10 journals are listed in Table 3. *Obesity* ranks the first place with 96 papers, followed by *International Journal of Obesity*, *Obesity Surgery*, and *Surgery for Obesity and Related Diseases*. The co-citation networks of journals consist of 114 nodes and 422 links, with density of 0.0655 (Figure 5A). Seven out of the top 10 journals in terms of co-citation frequency have more than 1,000 co-citations, with *International Journal of Obesity* being the highest, followed by *Pediatrics, Journal of the American Medical Association, Obesity,* etc. The top three journals in terms of centrality are *Pediatrics* (0.32), *Journal of Clinical Endocrinology & Metabolism* (0.23), and *International Journal of Obesity (0.18).*

Disciplinary association is mainly established through the connection between the discipline of the citing document and the discipline where the cited document is located. Overlay maps in Citespace can realize the subject distribution and inter-subject association involved in the research (59). The left and right sides of Figure 5B represent the subject areas involved in the citing literature and the cited references, respectively. The connection lines represent the citation relationship. The thicker the connection, the closer the links between the subject areas. Among them, "Psychology, Education, Health" is mainly based on the knowledge of such disciplines as "Health, Nursing, Medicine", while "Medicine, Medical, Clinical" mainly refer to the knowledge of such fields as "Molecular, Biology, Genetics" and "Health, Nursing, Medicine". At the same time, "Neurology, Sports, Ophthalmology" and "Molecular, Biology, Immunology" are also the focus areas of citing literature, while "Environmental, Toxicology, Nutrition" "Sports, Rehabilitation, Sport", and "Psychology, Education, Social" are also important sources of knowledge for citing literature.
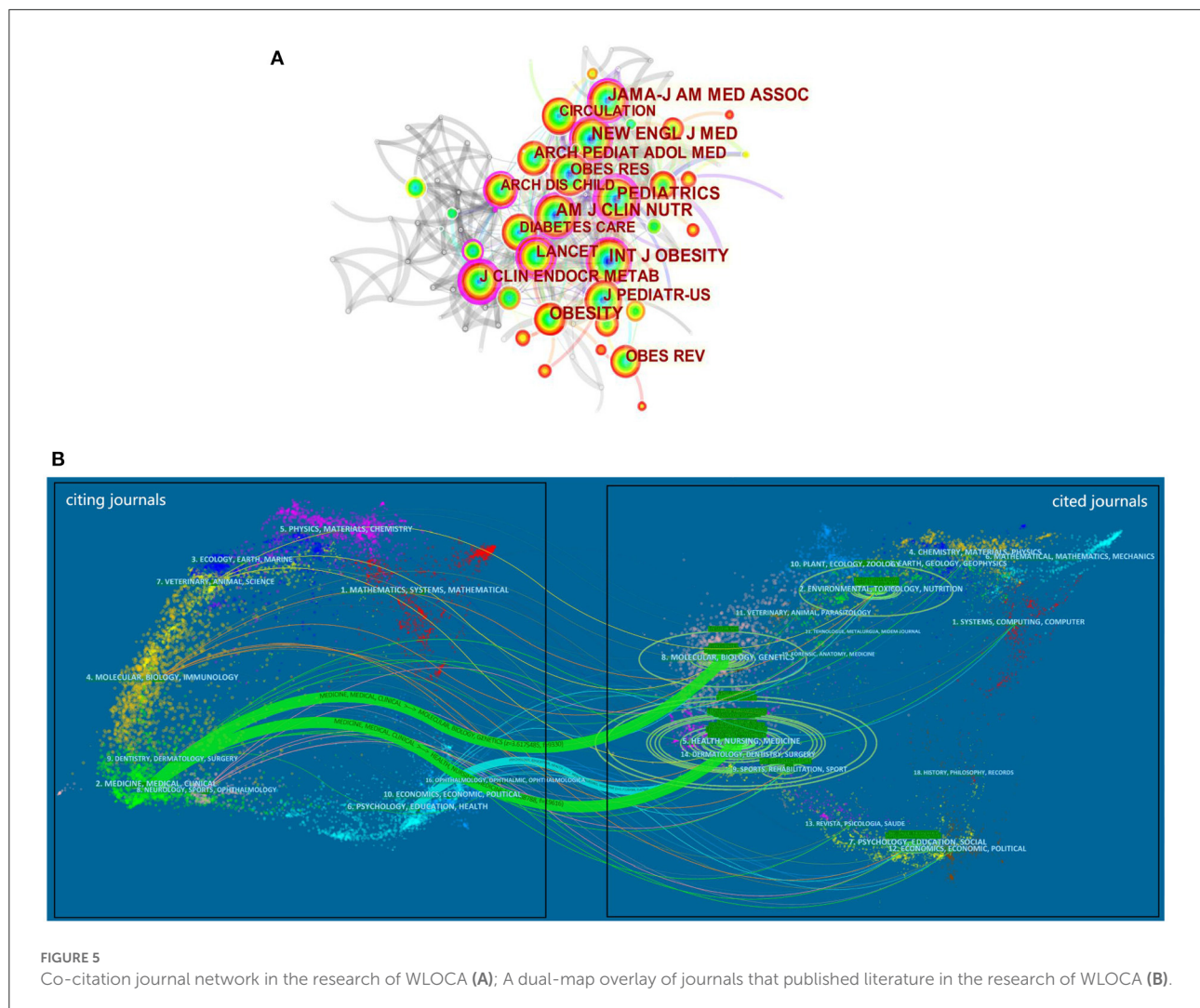
Visualization and analysis on keywords co-occurrence

Keywords are highly generalized and refined topics of a paper. Frequency analysis of keywords is critical for identifying the hot research topics in a given field (60). The synonymous keywords "child" were merged into "children" and "family-based treatment" into "family based treatment". The map of keyword co-occurrence is shown in Figure 6A. The top 20 keywords in terms of frequency and their centrality are listed in Table 4. It can be seen that such keywords as "body mass index, physical activity, bariatric surgery, insulin resistance, prevalence, intervention, metabolic syndrome, health, risk factor, prevention, and quality of life" constitute the main hot topics of research in this field.

Figure 6B is a timeline map produced with clustering analysis of the keywords of the papers. There are six categories in total. The keywords representing the same kind of research content are presented on the same line in chronological order. The right tags are the most representative keywords extracted by Log-likelihood rate algorithm. Judging from the frequency and chronological order of keywords, with the lapse of time, the hotspots of researchers have changed and gradually decreased. Relatively, "#0 insulin resistance," "#3 overweight" and "#2 childhood obesity," "#5 bariatric surgery" received relatively great attention.

Visualization and analysis on co-citation reference

Co-citation occurs when two studies from the early literature are both cited in a later study (61). Co-citation reference clustering can be regarded as a frontier field of academic research, and co-citation documents with strong burstiness can predict the frontier trend of future research in a certain

FIGURE 5
Co-citation journal network in the research of WLOCA **(A)**; A dual-map overlay of journals that published literature in the research of WLOCA **(B)**.

field (62), especially the literature that has lasted so far (63). Figure 7A (Q = 0.7545 > 0.3, S = 0.9339 > 0.7) shows the top two documents with the highest frequency in each cluster. Relatively, the literature published after 2003 attracted attention of many researchers. Table 5 lists the top five co-citation articles ranked by frequency and centrality. The intervention treatment on childhood obesity has the highest co-citation frequency (36), while the randomized controlled trial of Sibutramine for the treatment and behavior therapy of adolescent obesity has the strongest centrality (30). These documents, as the knowledge basis for further research, play an important role in the study on WLOCA. Figure 7B shows the specific details of 11 frontier fields, relatively, "#1 bariatric surgery" is the current focus area of researchers. This study limited the minimum burst duration to 2 years and generated 108 bursts of references co-citation, and Figure 7C demonstrates the top 50 bursts. Among them, the study of Inge et al. (23) on health status in adolescents by bariatric

surgery after 3 years had the highest burstiness of 58.16. The literature marked in Figure 7C are mainly on the topics of bariatric surgery, assessment and comprehensive treatment, and overweight/obesity prevalence survey.

Discussion

The literature on WLOCA can be divided into three stages (Figure 2): the initiating stage (1958–1991), with little attention from the researchers and sporadic literature; the slowly developing stage (1992–2002), with a relatively gentle rise in literature and related fields beginning to attract the attention of researchers; and the rapidly developing stage (2003–2021), with fluctuations but significant overall increase. It's predicted that the global studies on WLOCA will further increase in the future, as a response to the epidemic of overweight and obesity in children and adolescents.
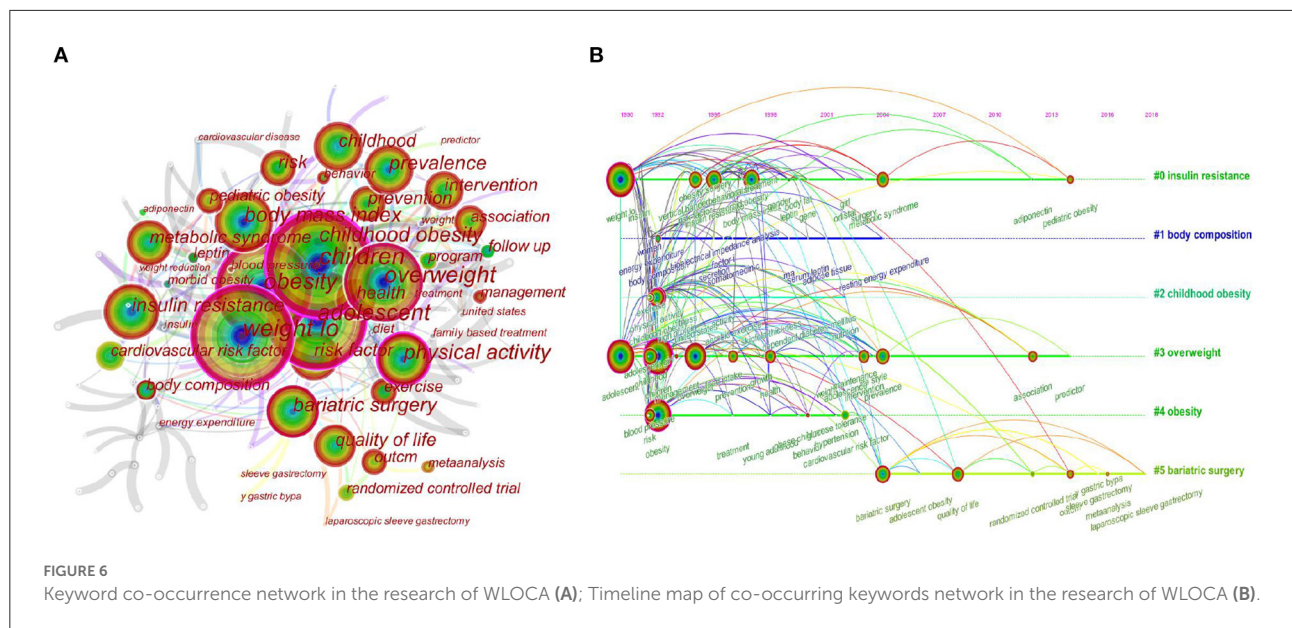
FIGURE 6
Keyword co-occurrence network in the research of WLOCA **(A)**; Timeline map of co-occurring keywords network in the research of WLOCA **(B)**.

TABLE 4 Top 20 keywords by frequency.

Rank	Keyword	Frequency	Centrality	Rank	Keyword	Frequency	Centrality
1	Weight loss	1,129	0.34	11	Prevalence	272	0.06
2	Children	1,098	0.42	12	Intervention	244	0.01
3	Obesity	1,050	0.22	13	Childhood	236	0.09
4	Adolescent	960	0.21	14	Metabolic syndrome	232	0
5	Overweight	845	0.13	15	Health	213	0.11
6	Childhood obesity	509	0.15	16	Risk factor	198	0.04
7	Body mass index	501	0.09	17	Prevention	190	0.01
8	Physical activity	446	0.31	18	Quality of life	180	0.01
9	Bariatric surgery	396	0.16	19	Risk	179	0.03
10	Insulin resistance	306	0.06	20	Association	143	0

Institutional co-operation shows (Figure 3) that universities are the main forces in collaborative research, and children's hospitals are important co-operative members. Co-operative research is mainly concentrated in such developed countries as USA, Germany, England, and Australia. And the US has contributed the most. The types of co-operative institutions and cross-regional and cross-border co-operation are still relatively limited, which is not conducive to the global promotion and application of research findings. Co-operation between countries and institutions should be further strengthened, and the developing countries, in particular, should be given more concerns and supports. The co-operation between authors is not close enough (Figure 4), which shows that the low centrality of both high-yield authors and high-cited authors, and the core authors are few. However, the academic community represented by Thomas H. Inge, Thomas Reinehr, Todd M. Jenkins, Lian Tock, etc.,

as well as high co-citation, high centrality authors, and institutional co-operation information such as Epstein LH and Freedman DS can provide important clues for researchers to seek co-operation.

The journals that publish papers on WLOCA are quite extensive. Relatively, *Obesity, International Journal of Obesity, Obesity Surgery*, *Pediatrics*, and *Journal of the American Medical Association* are more preferred in this field, and researchers should keep track of these active journals to understand the latest research trends. Besides, the studies on WLOCA are characterized by being multidisciplinary and comprehensive (Figure 5B), mainly involving Medicine, Medical Clinical, Psychology, Education, Health, Sports, Neurology, Molecular, Biology, Immunology, etc. In addition, such disciplines as Nursing, Genetics, Environmental, Toxicology, Nutrition, Rehabilitation, Social are also important knowledge bases for WLOCA study.
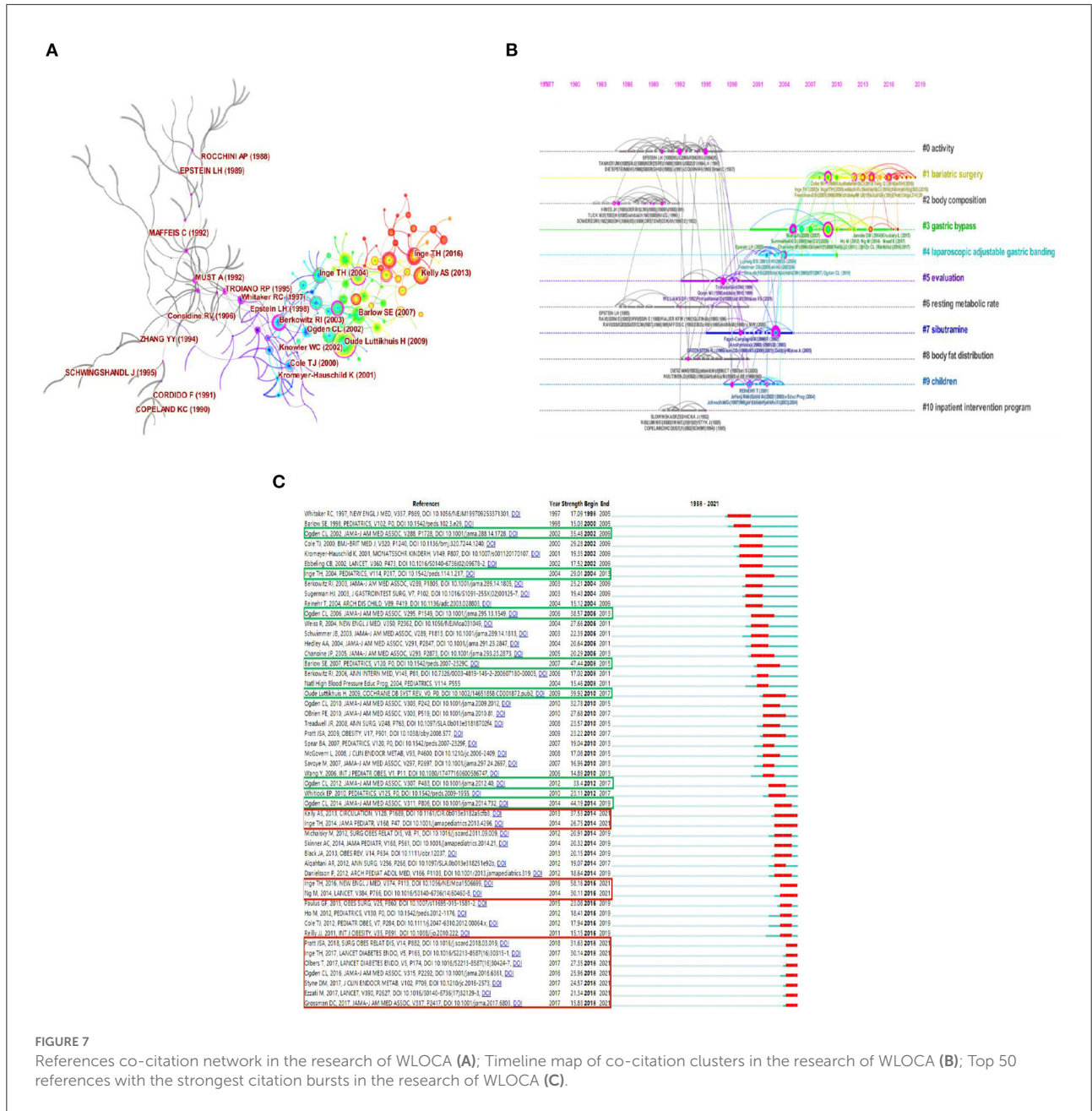
FIGURE 7
References co-citation network in the research of WLOCA **(A)**; Timeline map of co-citation clusters in the research of WLOCA **(B)**; Top 50 references with the strongest citation bursts in the research of WLOCA **(C)**.

TABLE 5 Top five references by co-citation frequency and centrality.

Rank	Frequency	Co-citation reference	Centrality	Co-citation reference
1	195	Oude et al. (36), *Cochrane Database Syst Rev*, V0, P0	0.74	Berkowitz et al. (30), *JAMA-J Am Med Assoc*, V289, P1805
2	161	Inge et al. (23), *New Engl J Med*, V374, P113	0.56	Chanoine et al. (31), *JAMA-J Am Med Assoc*, V293, P2873
3	138	Kelly et al. (64), *Circulation*, V128, P1689	0.47	Troiano et al. (65), *Arch Pediatr Adol Med*, V149, P1085
4	132	Barlow (66), *Pediatrics*, V120, P0	0.45	Must et al. (67), *New Engl J Med*, V327, P1350
5	111	Ogden et al. (68), *JAMA-J Am Med Assoc*, V311, P806	0.44	Whitaker et al. (69), *New Engl J Med*, V337, P869

Clustering of high-frequency keywords (Figure 6) shows that the 6 types of hotspots in the field of WLOCA study mainly focus on three aspects:

Firstly, assessment and pathophysiological mechanism ("#0 insulin resistance"). It mainly includes high-frequency keywords such as BMI, insulin resistance, metabolic syndrome, risk factor, leptin, insulin, and adiponectin. Studies show that BMI varies significantly with ages for children (70), measuring metabolic status by adopting a composite measures of BMI, waist-to-hip ratio, gender, genetic ethnicity, and metabolic markers may be of greater value in risk stratification of obesity (71). The etiology of obesity involves a variety of factors including genetic, epigenetic, environmental, dietary and lifestyle habits, and endocrine disorders (72), the molecular basis of which has not been fully elucidated (73). Adiponectin, leptin and plasminogen activator inhibitor 1 can be used as biomarkers to predict metabolic syndrome among adolescents (74). Leptin, resistin, interleukin-6, tumor necrosis factor-α, visfatin, and adiponectin play certain roles in energy homeostasis and glucose and lipid metabolism (75).

Secondly, comprehensive interventions ("#2 childhood obesity," "#3 overweight"). It contains high-frequency keywords such as physical activity, exercise, program, family based treatment, behavior modification, prevention, and intervention. Numerous empirical studies on the time, intensity, and pattern of exercise, as well as in conjunction with dietary and behavioral changes have been conducted. Studies have shown that more physical activity and more intense exercise (76), and 155–180 min of moderate-to-high-intensity aerobic exercise per week (27), are beneficial in reducing body fat in overweight children. Combination of high-repetition resistance training, moderate aerobic exercise, and behavioral modification may be most effective in reducing body fat of overweight/obese children (77). A family therapy program that combines authoritative parenting styles with family function training can have a positive impact on the prevention and intervention of adolescent obesity (78), parents as the only modifiable factor can induce more behavioral changes in obese children and help them achieve more weight loss in the short term (26). Combined diet-behavior-physical activity interventions have both the short and long term beneficial effects for obese children (29), but the optimal combination remains unknown (79). Cognitive behavioral therapy (CBT) and motivational approaches are the most commonly used ones to carry out psychological therapy to achieve changes in dietary and exercise habits (80). Intensive interventions such as drugs or meal replacements should be combined with behavioral therapy (66). Olistat is currently the only approved drug for obese adolescents over 12 years old. It is limited in use with metformin, sibutramine and exenatide due to side effects of treatment (64, 72).

Finally, bariatric surgery ("#5 bariatric surgery"). It mainly includes keywords such as quality of life, randomized controlled trial, meta-analysis, y gastric bypass, laparoscopic sleeve gastrectomy. Inclusion criteria for bariatric surgery in obese adolescents are more stringent than adults and require a comprehensive preoperative assessment of potential health risks (81). Roux-en-Y gastric bypass surgery resulted in substantial and durable weight loss and cardiometabolic benefits for adolescents (82), LAGB significantly improves quality of life in most morbidly obese adolescents (24). LSG has become the first choice of patients with severe obesity in childhood worldwide, because it is a safe and effective solution to the the problem of obesity and its comorbidities (83–88). For long-term treatment success and healthy growth, post-operative micronutrient deficiencies, inadequate weight loss, weight rebound, psychosocial issues require further research (89, 90). In addition, the treatment of comorbidities such as cardiovascular disease caused by childhood obesity is also an important aspect ("#4 obesity").

The timeline map of keywords co-occurrence (Figure 6B) shows the differences in research hotspots of scholars in different periods: From 1992 to 2002, the high-frequency keywords are relatively more diverse, including "physical activity," "exercise," "body composition," "insulin," "insulin resistance," "risk factor," "prevention," "BMI," "leptin," etc. From 2003 to 2011, the research focus shifted to "metabolic syndrome," "intervention," "prevalence," "bariatric surgery," "quality of life" and so on. From 2012 to 2021, more attention were paid to "association," "randomized controlled trial," "y gastric bypass," "meta-analysis," "laparoscopic sleeve gastrectomy." On the whole, the research focus has gradually shifted from lifestyle intervention and pathophysiological mechanism to clinical surgical applications in severely obese adolescents. This research trend shows that interventions mainly based on physical activity and diet do not seem to be effective in addressing all obesity problems, and also reflects the complexity of overweight/obesity in children and adolescents. Therefore, it is necessary to further explore the influencing factors.

Obesity is not caused by a single factor, but the result of interactions between environmental, behavioral, developmental, biological, and genetic factors (91), gut microbiota, epigenetics, and intrauterine and generational effects are also recently identified contributing factors (92, 93). Specifically, due to infant and toddler feeding patterns, excessive parental dietary restrictions, peer interactions, mental health issues (depression, social isolation, bullying, stigma), frequent electronic device use, lack of sleep, sedentary, individual neurological Differences in hormonal regulation structure, gene-environment interaction, adolescent growth and development, etc., coupled with such social factors as school and family environment, community and socioeconomic resources, make it difficult for a single intervention and treatment plan to achieve the ideal long-term weight loss effect for children and adolescents. At the same time, the metabolic syndrome and related comorbidities, such as non-alcoholic fatty liver disease (NAFLD), polycystic ovary syndrome (PCOS), and OSAS, which are often accompanied

by obesity in children and adolescents, bring more challenges to appropriate weight loss programs. Due to multiple additive effects, a combination of drugs and bariatric surgery may eventually have to be selected. Notably, strict dietary control (low-calorie diet) can be effective in reducing the risk of obesity-related comorbidities, such as metabolic syndrome, T2DM, but caution is needed for serious consequences of eating disorders (91). A systematic review shows that tonsillectomy can improve the behavior cognition and quality of life of children with OSAS (94). In morbidly or severely obese adolescents, the improvement of comorbidities varied by bariatric surgery (90, 95), while LSG and LAGB showed significant effect in relieving the symptoms of T2DM, dyslipidemia, bronchial asthma, NAFLD, and OSAS (96, 97), indicating certain advantages. More effective bariatric surgery or alternatives are yet to be discovered in practice, and multidisciplinary research is necessary as well.

At the same time, we should also be aware that there must be some differences in the intervention programs for overweight/obese children and adolescents under multiple causes, which are also reflected in the different stages of development of overweight/obesity. It is necessary to strengthen the monitoring of possible problems and adopt targeted combination programs to improve the effectiveness of intervention treatment. However, lifestyle interventions (physical activity, diet) are always an integral part of the prevention and treatment of overweight/obesity in children and adolescents. It should be emphasized that researchers should establish a good ethical awareness, maintain communication with the ethics committee and strictly implement management norms. The research or intervention and treatment process should put the protection of the rights and interests of the subjects in the first place.

Combined with the strong burstiness literature (Figure 7) and the research hotspots above and their development, it can be found that there are certain trends for future research: Investigation into the prevalence of overweight/obesity in children and adolescents will remain an important part of literature, while prospective studies on bariatric surgery will be more common. Besides, the study on pathophysiological mechanism will comprehensively take physiological, genetic, psychological and environmental factors into consideration. And Neuro-endocrinology, Molecular Biology, Immunology, Psychiatry and Social Ecology will be combined for interdisciplinary research. In addition, to cope with the worsening problem of overweight/obesity in children and adolescents, how to effectively improve health literacy to ensure "active health" will be further strengthened, while the school-age period, and prenatal, infant and preschool will be important stages of prevention research. Meanwhile, the studies on WLOCA will be more refined and differentiated, and characterized by multidisciplinary combination, classification and phasing, in light of different ages,

genders, cognitive development, obesity levels, ethnic groups, and cultural backgrounds. The "dose-effect" comparative study of intervention combination therapy for behavior change will further increase. New drug development and combination therapy based on adult treatment will continue to advance. Studies on laparoscopic sleeve gastrectomy will be on a rise due to its popularity in the treatment of severely obese adolescents, including possible nutritional deficiencies, weight regain, and psychological problems after surgery. However, more effective medical and surgical methods in the future are the direction of efforts, such as therapeutic interventions at different gut-liver axis levels. It is noteworthy that the COVID-19 pandemic has significant impacts on every aspects of human life, so the psychosocial and individualized interventions for overweight/obese children and adolescents should also be given attention. What's more, promoting the overall effect of schools, families, hospitals and communities in obesity management of children and adolescents also plays an important role in alleviating the problem of overweight/obesity in children and adolescents, which requires the joint efforts of various stakeholders, and supports from policies and research funding. Therefore, studies from such perspectives as sociology, politics and economics will also interest researchers.

Limitation and future research

The limitation of this study is that databases beyond WoSCC, books, non-English and unpublished government documents, dissertations, conference papers, scientific and technical reports, and other literature were not considered, which may lead to the consequence that the research findings may not be a panorama sketch of the field. What's more, the main focus of the interpretation is on the high frequency, high centrality, and high burst nodes, thus some other details may be overlooked. Therefore, future studies should extend the retrieval and read more relevant literature. Meanwhile, it is recommended that researchers should take the comprehensiveness and consistency of literature retrieved into consideration so as to ensure the reliability of the research results.

Conclusions

Research on WLOCA has seen positive developments in all aspects. Compared with general retrospective papers, the contribution of this study lies in its revealing of institutions, countries/regions, active journals, disciplinary interactions, core authors and their academic communities, and references that play an important role in the studied of WLOCA with rich maps and detailed tables. It intuitively presents the current research

hotspots and developments, and predicts future research trends. It can provide valuable information for relevant researchers to quickly understand the research status in this field, find co-operation, track research hotspots and frontier trends.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

GS: conceptualization, methodology, formal analysis, data curation, writing—original draft preparation, visualization, and funding acquisition. LL: validation, formal analysis, data curation, writing—review and editing, and supervision. XZ: methodology, validation, writing—review and editing, and supervision. All authors have read and agreed to the published version of the manuscript.

Funding

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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