

## Review

## Scoping review of obesity interventions: Research frontiers and publication status

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## SUMMARY

**Obesity and overweight are significant global health issues, and numerous obesity intervention studies have been conducted. Summarizing current knowledge of interventions aims to inform researchers and policymakers to keep up-to-date with the latest scientific advancements and trends. In this review, we comprehensively retrieved and screened 4,541 studies on obesity intervention published between 2018 and 2022 in the Web of Science Core Collection, and objectively presented research frontiers using bibliometric analysis. The research frontiers of intervention are mainly focused on dietary, exercise, pharmacological interventions, bariatric surgery, environmental, and cognitive interventions. Time-restricted eating is the hottest research topic, followed by probiotics and Roux-en-Y gastric bypass. Gut microbiota is located in the “Basic and transversal themes” quadrant with a high centrality and low density, which has great development potentiality. Obesity intervention is becoming increasingly common, and we advocate for researchers to undertake more focused research endeavors that consider the specific characteristics of diverse populations or patients.**

## INTRODUCTION

With the acceleration of industrialization and urbanization worldwide, obesity has become the highest incidence of chronic diseases, affecting approximately 650 million individuals.<sup>1</sup> Obesity and overweight are global health problems and have been associated with a variety of diseases such as diabetes, cardiovascular diseases, skeletal diseases, and digestive system diseases.<sup>2</sup> Scientists have increasingly understood that obesity is a complex multifactorial metabolic disease that involves central and peripheral energy balance regulation, and helping some obese individuals recover and maintain weight through lifestyle regulation alone may prove difficult.<sup>2–4</sup> In recent years, there has been a surge in obesity intervention studies worldwide, with new and diverse measures emerging to improve weight loss and combat obesity. Relevant researchers and stakeholders are required to grasp the scientific research progress and hot spot trends in the fields. However, to date, in the face of the multitude of complex research information, a systematic and objective review of obesity intervention is lacking to assist with understanding the complexity and hotspots of research topics and to extract accurate and valuable information effectively.

The bibliometric and visual analysis can objectively provide a unique perspective to show an overall view of the current status of the research on obesity intervention and reveal the context of scientific research.<sup>5</sup> Research frontiers can also be identified through analysis of the cited patterns and clusters of articles on specific topics, especially the frequent co-citation of clustered highly cited articles.<sup>6</sup> This has become particularly important with the development and rise of evidence-based practice. In addition to mapping the research status, bibliometrics can also determine the topic “hotspots,” that is, the topic clusters of related topics, which can be displayed by knowledge maps or inductive lists, which will provide guidance for clinical practitioners and researchers. In this study, we utilized the aforementioned analytical method to more fully demonstrate and explore the developmental context of research to obesity intervention. Specifically, our aim was to summarize popular interventions aimed at improving obesity and weight loss, present the research frontiers in this field, analyze the contributions of different nations, institutions, authors, and journals, as well as conclude on the most cutting-edge interventions to improve obesity and overweight. This study is expected to help researchers gain a better understanding of the current research status of obesity intervention and identify new directions for future research.

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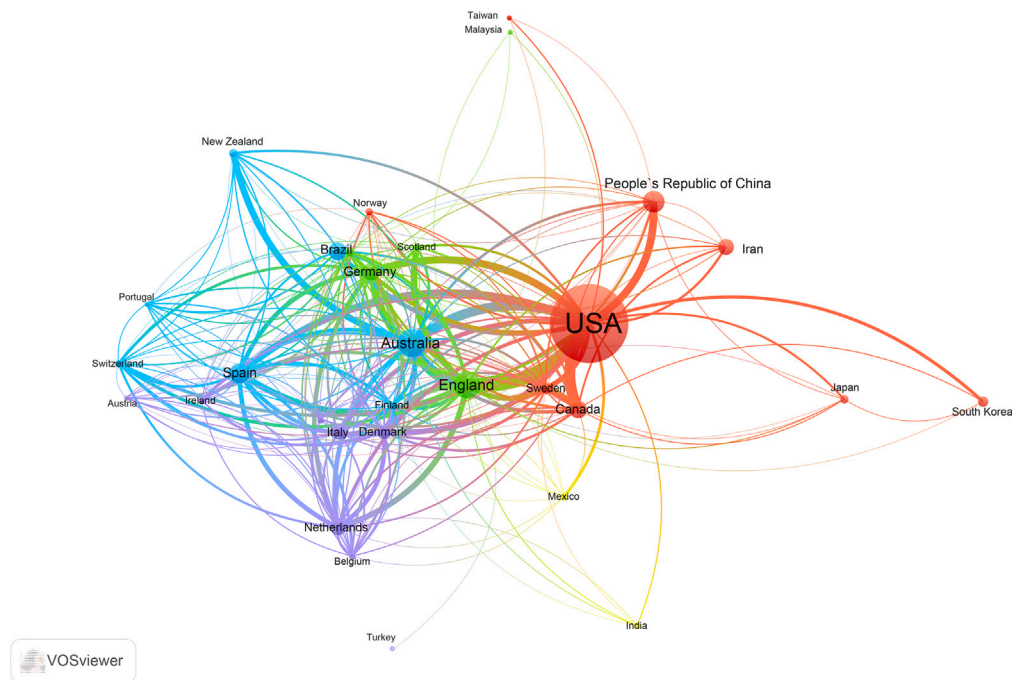
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**Figure 1. Country/region cooperation network in obesity intervention**

The node represents the country/region, the size of the node represents its publications, and the color of the connection between nodes represents the degree of cooperation between the nodes.

## RESULTS

A total of 4,541 English-language articles were retrieved and screened from the Web of Science Core Collection. The h-index is a metric used to measure the impact or influence of a researcher's publications, based on Web of Science citation data. Self-citation is defined as citations that refer to a work by one of its authors. They, in the Web of Science databases, play important roles in evaluating the productivity, impact, and influence of researchers' work. The total h-index of the 4,541 publications was 63, the average number of citations was 9.32, and the total number of citations was 42,314 (without self-citations 39,214). From 2018 to 2022, the number of publications generally increased, with the highest number in 2021 (1,042), but slightly decreased in 2022 (874). These articles were published in 1,128 journals, of which the most published journals were *Nutrients* (292, 6.43%), *International Journal Of Environmental Research And Public Health* (111, 2.44%), and *Bmc Public Health* (104, 2.29%).

### Mapping publication status

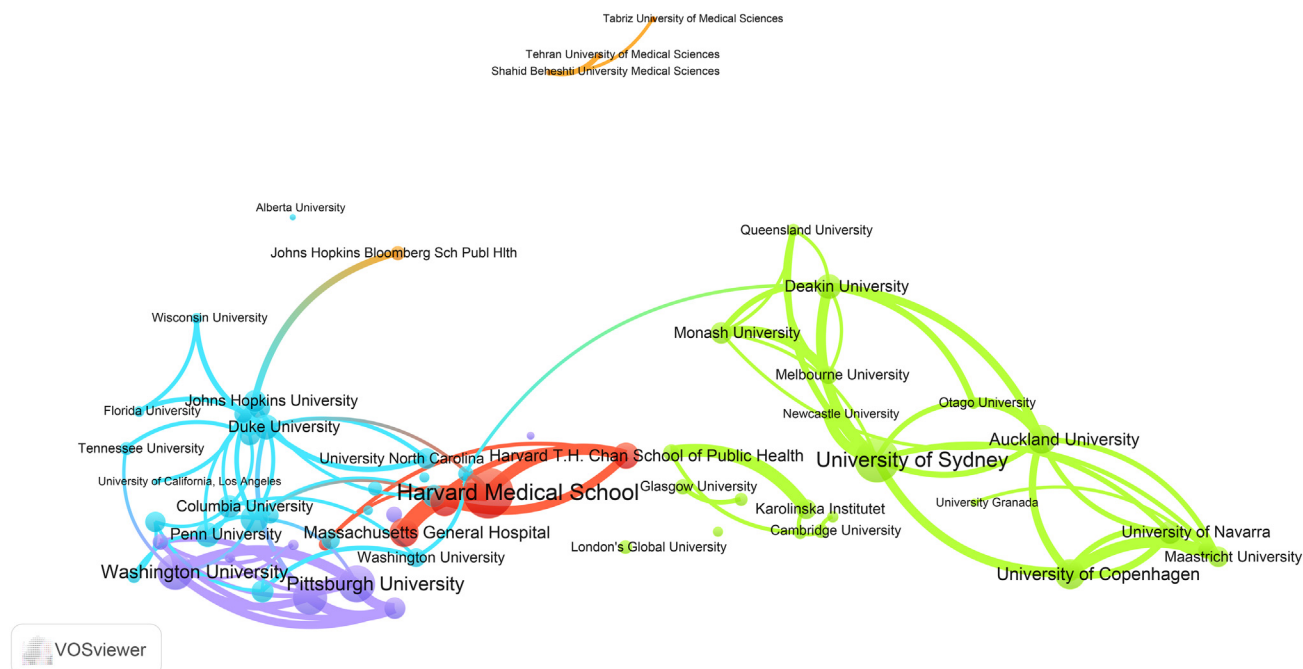
#### *Country/region distribution and cooperation network*

A total of 99 countries and regions were involved in publishing these 4,541 articles. Specifically, the top 10 countries that published most articles were the United States (1,756, 38.67%), Australia (443, 9.76%), the United Kingdom (429, 9.45%), China (305, 6.72%), Spain (270, 5.95%), Canada (235, 5.18%), Brazil (233, 5.13%), Germany (230, 5.07%), Iran (207, 4.56%), and the Netherlands (193, 4.25%), in which only China and Brazil are developing countries. There is a greater number of developed countries that are actively involved in and conducting research in related fields, while the number of developing countries is comparatively smaller. Evidently, the contribution of developing countries in obesity intervention research publications lagged behind that of developed countries.

From the perspective of the national cooperation network, the countries involved in the included literature were primarily divided into four groups according to their internal connections, among which the two groups led by the United States of America and England occupied a major position in the entire network, as shown in Figure 1. The number and thickness of the connections reflect the frequent and close cooperation between groups led by the United States of America and England, including Germany, Spain, Australia, Canada, and Denmark.

#### *Institutional cooperation*

More than 5,000 institutions participated in the publication of these articles, of which the top three institutions were Harvard University (184, 4.05%), University Of California System (161, 3.55%) and Pennsylvania Commonwealth System Of Higher Education Pcshe (119, 2.62%). Among the leading publishing institutions, the vast majority were universities and research institutions in developed countries in Europe and America, which exemplified the lagging behind of research in the field in developing nations. In the institutional cooperation network,



**Figure 2. Institutional cooperation network in obesity intervention**

The node represents the institutions, the size of the node represents its publications, and the color of the connection between nodes represents the degree of cooperation between the nodes.

five dominant cooperation groups were identified — the University of Washington, Columbia University, the Harvard Medical School, the University of Sydney, and the University of Tehran Medical Sciences, as shown in Figure 2. In general, the cooperation group headed by the University of Washington and the University of Sydney had relatively numerous participating institutions, and internal cooperation was frequent and active; the other three cooperation groups had relatively few internal participating institutions, and the cooperative partners among them were relatively fixed. Moreover, the cooperation group represented by Tehran Medical University had less connections with other cooperation groups, exhibiting a more independent and stable research cooperation.

### Research frontiers of obesity interventions

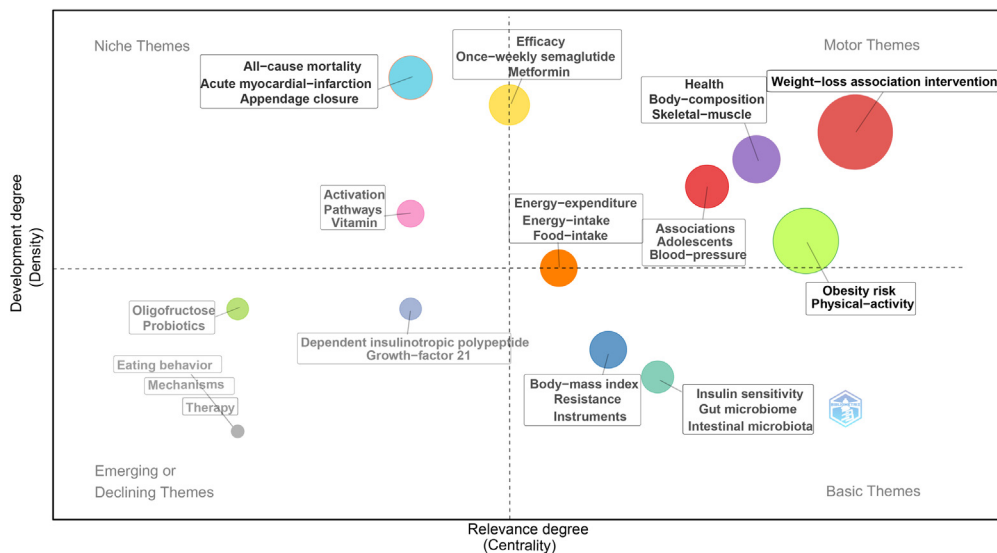
Based on the above three ways in the “Methods” section, the most cutting-edge research topics in the field of obesity intervention were identified (Table 1). Firstly, we obtained a total of 13,292 research fronts through the Research Fronts in Essential Science Indicators (ESI), and eventually screened 6 fronts related to obesity intervention, which according to the research hotspots, were time-restricted eating, probiotic supplementation, surgical bariatric surgery (Roux-en-Y gastric bypass), Semaglutide, low-carbohydrate diet, environmental (family) intervention (Way 1). Considering citation counts and the authority of the journals in the field where the articles were published, we selected 42 top articles. Among these top articles in the field, 25 discussed the effects of different interventions on obesity. The interventions involve time-restricted eating, a Mediterranean diet, a low-carbohydrate diet, Semaglutide, Bimagrumb, Liraglutide, Metformin, aerobic and resistance exercise, and bariatric surgery (laparoscopic sleeve gastrectomy and Roux-Y-gastric bypass) (Way 2). Meanwhile, we used citespace to perform a collinear analysis on the topics and keywords of 4,541 documents. The co-citation analysis of cited references, cited authors, and cited journals was conducted. Research clusters obtained by clustering showed the research hotspots of obesity intervention are focused on family intervention, exercise intervention, bariatric surgery, wearable devices, smartphone intervention, time-restricted eating, community intervention, self-monitoring, mindfulness intervention, high-intensity intermittent training, and resistance training (Way 3). After reading relevant literature on the above research fronts, we classified and summarized that the research frontiers mainly focused on various obesity interventions for the following: dietary interventions (e.g., intermittent energy restriction, ketogenic diets, probiotics, Mediterranean diet, mindful eating), exercise interventions (high-intensity interval training (HIIT) vs. moderate intensity continuous training (MICT), aerobic exercise vs. resistance physical exercise), pharmacological intervention (Semaglutide, Metformin, Liraglutide), bariatric surgery (Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (SG), adjustable gastric banding (AGB)), intelligent device-based interventions, environmental, and cognitive interventions. Interestingly, time-restricted eating is the hottest research topic, followed by probiotics and Roux-en-Y gastric bypass. As shown by Figure 3 (thematic map), we can see that the gut microbiota is located in the “Basic and transversal themes” quadrant, where the internal linkages are weakly developed but the external linkages are important and have a great potential for development. The gut microbiota has great development potentiality.

**Table 1. Top topic in research of obesity intervention**

Rank	Way 1	Top papers	Mean year
Top 1	Effects of Time-Restricted Eating (TRE) on obesity	23	2019.6
Top 2	Effects of Probiotics on obesity	6	2019
Top 3	Effects of Laparoscopic Roux-En-Y Gastric Bypass on obesity	5	2017.4
Top 4	Effects of Semaglutide on obesity: results from clinical trials	3	2020.7
Top 5	Effects of Low Carbohydrate Diet on obesity	3	2017.7
Top 6	Effects of Environmental intervention (Home or School-Based) on Childhood Obesity	5	2018.7
Rank	Way 2	Top papers	Mean year
Top 1	Effects of Semaglutide on obesity: results from clinical trials	7	2021
Top 2	Effects of Time-Restricted Eating (TRE) on obesity	6	2021
Top 3	Effects of Laparoscopic Roux-En-Y Gastric Bypass on obesity	4	2018.3
Top 4	Effects of Low Carbohydrate Diet on obesity	3	2020.7
Top 5	Effects of Liraglutide on obesity	3	2020
Top 6	Effects of Aerobic and Resistance Exercise on obesity	1	2018
Top 7	Effects of Mediterranean diet intervention on obesity	1	2020
Top 8	Effects of setmelanoid on obesity	1	2020
Rank	Way 3	Cluster size	Silhouette
Top 1	Effects of family-based intervention on Childhood Obesity	128	0.758
Top 2	Effects of behavioral weight loss intervention on Childhood Obesity	128	0.861
Top 3	Effects of exercise intervention on obesity	104	0.788
Top 4	Effects of bariatric surgery on obesity	76	0.786
Top 5	Effects of mindfulness-based intervention on obesity	35	0.888
Top 6	Effects of vitamin D-3 on obesity	22	0.963
Top 7	Effects of smartphone intervention on obesity	21	0.952
Top 8	Effects of wearable device on obesity	4	0.999

### *Dietary interventions*

Dietary intervention is the most commonly used measure to improve obesity as well as the most popular direction in obesity intervention research. Research hotspots in the direction of dietary intervention are as follows : 1) Intermittent energy restriction (IER): In recent years, there has been an increasing number of researches on the improvement of obesity through IER, primarily focusing on both intermittent fasting (energy restriction)<sup>7-9</sup> and time-restricted eating (meal time restriction).<sup>8,10-18</sup> Compared to traditional continuous energy restriction (CER), IER patterns generate equivalent weight loss. CER is relatively ineffective in achieving and maintaining weight loss, while IER helps research subjects adhere for longer durations.<sup>8</sup> 2) Ketogenic Diets (KD): The ketogenic diet can be used as a quick and effective way to lose weight and reduce abdominal fat in overweight or obese patients. However, some studies suggested that the effect of KD is not due to the loss of appetite but primarily depends on adherence to calorie restriction. Therefore, weight gain and treatment failure are inevitable.<sup>19-21</sup> 3) Probiotics: The intake of probiotics has a certain regulatory effect on weight and BMI. In populations with longer treatment durations, there is a greater magnitude of weight loss. Probiotic intervention can improve anthropometric biomarkers and levels of short-chain fatty acids related to human obesity.<sup>22-24</sup> Studies on the application of probiotics in obesity management are valuable. 4)



**Figure 3. Thematic map of obesity intervention based on Bibliometrics**

The first quadrant, characterized by high density and centrality, represents “motor themes” that are well-developed both internally and externally. The second quadrant is labeled as “highly developed-and-isolated themes” as it deals with niche themes. The third quadrant, with low density and centrality, is termed the “emerging-or-declining themes” quadrant. Themes in this quadrant are characterized by weak ties at both internal and external levels. Finally, the “basic-and-transversal themes” quadrant, with low density and high centrality, comprises themes that are weakly developed in terms of internal ties but have important external ties, characterized by high development potentiality.

Mediterranean diet: The Mediterranean diet is an effective way to ameliorate obesity and can further reduce the risk of cardiovascular disease.<sup>25</sup> 5) Mindful eating: Mindful eating aims at fostering awareness and focuses on eating and on paying attention to hunger and satiety cues. Mindful eating is not only a practical option for weight loss when compared with no intervention controls but also an equivalent alternative to dieting approaches based on limited energy intake and nutrition plans. However, research on mindful eating has shown contradictory and inconsistent results so far. And such studies with long-term follow-up to evaluate the long-term effects of mindful eating are also required in the future.<sup>26,27</sup> 6) Low carbohydrate diet: Low carbohydrate diet has been one of the hot research directions in recent years to assess the energy consumption of diets with different carbohydrate-fat ratios. Lowering dietary carbohydrate intake increases energy expenditure during weight loss maintenance. This metabolic effect may improve the success of obesity treatment, especially among those with high insulin secretion.<sup>28,29</sup>

### Exercise interventions

Exercise intervention achieves weight loss through increase of energy consumption, which has been the most popular direction in recent years. The research hotspots of exercise intervention are as follows: 1) High-intensity interval training (HIIT) vs. Moderate intensity continuous training (MICT) : Most studies suggest that HIIT is similarly effective at losing weight as MICT, and HIIT has recently been recognized as a time-efficient alternative to traditional MICT for the treatment of chronic diseases.<sup>30,31</sup> 2) aerobic exercise vs. resistance physical exercise: Both aerobic and resistance exercise are effective in treating obesity and its comorbidities. Aerobic exercise is more effective at reducing body fat and improving cardiorespiratory fitness, while resistance exercises are preferably suitable for muscle strengthening.<sup>13,32–35</sup>

### Pharmacological interventions

Although lifestyle intervention may be essential to weight loss, some individuals find it difficult to maintain long-term perseverance. Pharmacological weight loss is an important treatment option in addition to lifestyle interventions and bariatric surgery. In recent years, evidence has also suggested that some novel drugs have potential weight loss effects. However, the advantages and disadvantages of existing drugs and potential weight loss drugs are unclear. The efficacy and safety of weight loss drugs have become a hot research direction in this field. Among the multitude of weight-loss drugs, Semaglutide,<sup>36–44</sup> metformin,<sup>45–47</sup> and liraglutide<sup>48–50</sup> are popular in the study of their effect on obesity. They have positive effects in the treatment of obesity, all of which can lead to weight loss in patients. However, adverse events of varying degrees occur, suggesting that pharmacological interventions may not be suitable for all patients. In obese adolescents, the use of liraglutide (3.0 mg) as an adjuvant treatment resulted in a greater decrease in BMI score and standard deviation compared to placebo. However, a higher incidence of gastrointestinal adverse events was observed with liraglutide, suggesting that this treatment may not be suitable for all patients.<sup>49</sup>

### *Bariatric surgeries*

Bariatric surgery is an effective treatment for severe obesity (body mass index  $\geq 40$ , or  $>35$  kg/m<sup>2</sup> with comorbidities) that provides rapid and durable improvements in obesity but may increase the risk of postoperative adverse events and postoperative complications. In recent years, Roux-en-Y gastric bypass (RYGB),<sup>51–53</sup> laparoscopic sleeve gastrectomy (SG),<sup>52,54–57</sup> and adjustable gastric banding (AGB)<sup>58–61</sup> have become the three most commonly used procedures for the treatment of morbid obesity worldwide. Although bariatric surgery is beneficial for patients to lose weight, it may lead to problems such as nutritional deficiencies in patients or the requirement for additional abdominal surgery.

### *Cognitive remediation therapies*

Cognitive remediation therapy is an effective weight loss method that achieves the purpose of treatment through psychological intervention and behavioral guidance. In addition to conventional weight loss methods such as exercise and dietary interventions, psychological interventions such as behavioral therapy, cognitive behavioral therapy, and hypnotherapy have been shown to produce superior long-term effects,<sup>62–64</sup> as a result they have also received attention.

### *Intelligent device-based interventions*

With the rapid development of science and technology, the demand and reliance on the Internet and mobile devices are becoming increasingly stronger, and carrying out obesity intervention through network and artificial intelligence technology has become a hot research field. In recent years, an increasing number of researchers have started to explore the development of mobile devices based on artificial intelligence technology for the management and improvement of obesity. Mobile apps and wearable devices are effective self-regulating tools for weight loss. Smart apps guide users to maintain specific nutritional goals by determining daily energy intake and expenditure and providing users with future meal recommendations. Smart applied interventions have the potential to become a labor-efficient, effective, and low-cost program that can be implemented throughout the clinical setting, especially for childhood weight management, and are a viable and innovative treatment approach that, in addition to standard care, yields superior treatment outcomes than standard treatment alone.<sup>65–71</sup> Future studies should assess treatment effects with longer follow-ups and larger samples.

### *Environmental intervention*

Losing weight through environmental intervention has also been a research hotspot in recent years. The above-mentioned interventions all directly or indirectly act on individual obese patients, while environmental interventions act on the population as a whole, which is beneficial for national or local government agencies to regulate and control the prevalence of obesity at the macro level. Popular directions for environmental interventions are: 1) Urban planning intervention: Through establishing appropriate distances between parks, trails, supermarkets, convenience stores, and other places of residence and living places, the frequency of activities, shopping frequency, shopping volume, and road energy consumption can have a positive impact on obesity improvement.<sup>72–77</sup> 2) Community intervention: improve community obesity through community health promotion and guidance, health activity organization, and exercise equipment optimization.<sup>78–84</sup> 3) Family based intervention: Through family intervention, promote a good health culture, interact with family members, and form good living habits to improve obesity.<sup>85–89</sup>

## **Discussion**

In this scoping review, we found that obesity intervention is becoming more prevalent. We summarized and classified research frontiers of intervention into seven categories: dietary interventions (e.g., intermittent energy restriction, ketogenic diets, probiotics, Mediterranean diet, mindful eating), exercise interventions (high-intensity interval training (HIIT) vs. moderate intensity continuous training (MICT), aerobic exercise vs. resistance physical exercise), pharmacological intervention (Semaglutide, Metformin, Liraglutide), bariatric surgery (Roux-en-Y gastric bypass (RYGB), laparoscopic sleeve gastrectomy (SG), adjustable gastric banding (AGB)), intelligent device-based interventions, environmental, and cognitive interventions. Time-restricted eating is the most prevalent, followed by probiotics and Roux-en-Y gastric bypass. The gut microbiota is a very promising topic of research. Although methods such as restricted eating and the use of semaglutide for weight loss have been popular research topics in recent years, they may not necessarily be the most suitable in every situation, suggesting the need to develop more clinical researches/trials for exploring the optimal interventions for different obesity situations.

In recent years, similar studies have also been carried out by bibliometric analysis of obesity-related research status and frontier hot spots. However, earlier studies (including data prior to 2018) have not provided a comprehensive analysis of the research hotspots of obesity intervention, as well as classify and summarize the recent research frontiers in the field. For instance, Ozsoy, Z et al. conducted 2 bibliometric analyses of bariatric surgery and reported that the most advanced surgery was Roux-en-Y gastric bypass, while the most popular surgery was sleeve gastrectomy.<sup>90,91</sup> In addition, Paolino, L's team also conducted a bibliometric analysis of weight loss surgery, concluding that the most common surgery was Roux-en-Y gastric bypass (RYGB), followed by sleeve gastrectomy (SG) and adjustable gastric banding (AGB).<sup>92</sup> Toro-Huamanchumo et al. also conducted a bibliometric analysis of bariatric surgery to analyze the current status of research in this field in Latin America, and countries with the highest output (the number of publications) were Brazil (64.7%) and Chile (14.5%), and countries outside the region were Brazil (64.7%) and Chile (14.5%). Cooperation is primarily with the United States.<sup>93</sup> In addition, Yao et al. conducted a bibliometric analysis of the related research on the role of gut microbiota in obesity.<sup>94</sup> Zhao N's team searched for research hotspots and trends of obesity

in the future through bibliometrics, and concluded that “weight loss surgery” (especially “sleeve gastrectomy”) and “obesity complications” (especially “diabetes,” “metabolic syndrome,” “depression,” and “polycystic ovary syndrome”) most likely maintain the research hotspots of obesity next decades.<sup>95</sup> Obesity intervention is increasingly prevalent, against this situation, our scoping review presents the most comprehensive and elaborate latest summary of obesity intervention to date.

In addition, compared with using bibliometric analysis alone in these above researches, we employed two other approaches to extract and determine research frontiers. We found that using bibliometric analysis alone in the process of clustering makes it difficult to accurately explain the correlation between high-frequency keywords and in turn summarize clear research hotspots. This deficiency can be considerably offset by employing the above two approaches coupled with reading of the literature.

Through analysis of research frontiers in this field, we expect a number of obesity intervention research will be continuously carried out, producing a large number of scientific research results with a high impact, such as gut microbiota, intermittent energy restriction,<sup>96</sup> artificial intelligence device intervention in the era of big data, exercise training of different intensities, comparison between different weight loss drugs,<sup>97</sup> and Roux-en-Y gastric bypass (RYGB). The developed countries and institutions in Europe and the United States will undoubtedly continue to lead the research and exploration in the short term, however, as developing countries are increasingly gaining attention to obesity, we expect an increase in research activity accordingly. Research methods and research hotspots carried out by developed countries such as the European Union and the United States can help stakeholders in developing countries find their own ways to improve interventions for obesity or weight loss.<sup>98</sup>

There are also limitations in this study. In the retrieval process, we only considered the database of the core collection of Web of Science, which may lead to omissions in the generalization of the field. However, on the other hand, the core collection of Web of Science has a high reputation in the academic field, and the included journals represent reliable academic quality. Moreover, this study lacked a comparison and summary of obesity intervention for the population of different ages. Hence, research on the frontiers of obesity intervention by age group is worth in-depth exploration.

## CONCLUSIONS

This study describes the research status and distribution of obesity intervention through bibliometric analysis and comprehensively identifies and summarizes the research hotspots of obesity intervention in three ways. Research on obesity interventions are still in a highly developed stage at present. Among various research topics, time-restricted eating is the hottest research topic, followed by probiotics and Roux-en-Y gastric bypass. In addition, although intervention studies such as intermittent dietary restriction and Roux-en-Y gastric bypass are popular, they are not necessarily most suitable in every situation. More research is required in the future to explore the optimal intervention for different obesity situations, as well as to systematically evaluate the advantages and disadvantages of different interventions. In summary, this study raises awareness and promotes appreciation for research on obesity intervention. It also provides valuable insights for researchers and policy-makers to engage in obesity intervention research.

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## AUTHOR CONTRIBUTIONS

XS and LZ conceived the study. XS acquired the funding. XS and LZ designed the study. LHZ, SD, and WL developed the search strategy. LZ and LHZ developed and tested the data collection forms. LHZ, YFC, TTJ, and WL acquired the data. LHZ, JP, and WL conducted the analysis and interpreted the data. LHZ and SD drafted the article. LHZ, SD, XS, and LZ critically revised the article. All authors read and approved the final article.

## DECLARATION OF INTERESTS

The authors declare no competing interests.

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