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The role of structure in dietary approaches for the treatment of pediatric overweight and obesity: A critical review

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Summary

A multicomponent approach for the treatment of pediatric overweight/obesity, which includes behavioral strategies to alter diet and physical activity/sedentary behavior, has graded recommendations for its use. Dietary interventions to be used within this approach do not. In adults, research indicates that strongly graded dietary interventions providing greater structure (or more control over the types/amount of food consumed) produce better weight outcomes. For this critical review, dietary interventions recommended by the Expert Committee for the treatment of pediatric overweight/obesity were categorized according to their potential degree of dietary structure, and their impact on weight outcomes was described. Four levels of dietary structure were reviewed, operationalized as alterations to the following: food groups, such as fruits and vegetables (low structure); daily eating occasions, such as meals (moderate structure); large nutrients, such as energy (high structure); and energy plus additional dietary alterations (very high structure). In total, 24 interventions (four low, three moderate, five high, and 12 very high structure) were identified and reviewed. Reductions in standardized body mass index increased with increasing structure, and interventions ≥ 6 months had better outcomes than interventions < 6 months. Future research should empirically test dietary intervention structure to determine its impact on weight status during pediatric overweight/obesity treatment.

Keywords

childhood; diet; treatment; weight loss

1 | INTRODUCTION

The high prevalence of overweight and obesity in children and adolescents remains a public health concern in the United States.¹ Pediatric overweight and obesity increases the likelihood of children and adolescents experiencing overweight and obesity as adults.^{2,3} Children and adolescents with overweight or obesity are also at greater risk for developing

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CONFLICT OF INTEREST

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SUPPORTING INFORMATION

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associated comorbidities, such as prediabetes and hypercholesterolemia, during childhood, as well as adulthood.^{2,4} Finally, children and adolescents with overweight and obesity also experience more teasing and bullying than their healthy weight counterparts, which puts them at greater risk for experiencing psychosocial distress.⁵

As a consequence of the deleterious effects of pediatric overweight and obesity, professional organizations have developed recommendations for treatment, such as the recommendations from the Expert Committee⁶ (endorsed by 15 national health care organizations) and the clinical practice guidelines from the American Psychological Association.⁷ A recent scoping review of guidelines for the dietary management of childhood obesity found that, in general, recommendations encourage a multicomponent approach, in which diet and physical activity (PA) and/or sedentary behaviors are targeted to alter energy balance using family-based behavioral strategies.⁸ The US Preventive Services Task Force also provides similar recommendations for pediatric overweight and obesity.⁹ Additionally, current recommendations support treatment to begin as early as 2 years of age and to provide at least 26 h of contact time, as consistent, longer term support leads to greater improvements weight outcomes compared with low-intensity (or low-contact) interventions.^{7,9}

Although there are graded recommendations regarding the multicomponent approach (grading: strong),⁷ and there is some grading of the quality of the evidence for dietary interventions (grading: consistent evidence to suggest),⁶ there are no graded recommendations for dietary interventions to be used within this multicomponent approach. In adults, graded dietary recommendations for the treatment of overweight and obesity generally focus on changing the overall diet (i.e., reducing overall energy intake, altering macronutrient intake, and/or changing intake from all food groups in the diet).¹⁰ Moreover, dietary interventions in adult obesity treatment that provide greater structure, or more control over the types and amount of foods and beverages consumed, result in greater weight loss (e.g., a low-kilocalorie [kcal] diet using meal replacements versus a low-kcal diet using conventional foods).¹¹ In contrast, the nongraded dietary interventions recommended for the treatment of overweight and obesity in children and adolescents⁶ are more broad, ranging from altering only specific parts of the diet (e.g., sugar-sweetened beverages [SSBs] and breakfast) to the overall diet (e.g., the Traffic Light Diet,¹² which includes daily energy goals and daily servings from food groups that correspond to the colors of the traffic light). Thus, due to the lack of grading and the broadness of the recommendations, the purpose of this critical review was to describe the relative effectiveness of the nongraded dietary interventions recommended for the treatment of overweight and obesity in children and adolescents on improving weight status relative to the degree of structure imposed on the diet. A critical review, which is a narrative review that reinterprets the reviewed literature to identify a new concept, theory, or framework, was conducted to develop an innovative conceptual framework, based upon dietary structure, by which existing pediatric dietary interventions could be interpreted.¹³ This dietary structure framework has not been directly examined within the field of overweight or obesity treatment in children and adolescents.

2 | METHODS

2.1 | Search strategy and study selection

To increase the rigor of this critical review, a methodical search was conducted in PubMed and SCOPUS to identify dietary interventions for the treatment of overweight and obesity in children and adolescents published between January 1, 1980 (the approximate period when pediatric obesity rates began to rise in the United States¹⁴) and July 7, 2020. Dietary interventions recommended by the Expert Committee⁶ were used to develop broad search terms intended to capture all relevant studies. Key search terms (Table S1) included fruit, vegetable*, sugar-sweetened beverages, breakfast, meal timing, energy density, calorie restrict*, meal plan, structured meals, energy restrict*, low energy, low calorie, very low calorie, DASH, Mediterranean, stoplight diet, traffic light diet, very low energy diet, eating pattern, and meal replacement. Two authors (LG and SD) completed a title/abstract review of all unduplicated search results. For references not excluded during the title/abstract screening, a full text of the article was obtained and reviewed by the same authors. For both stages of review, the third author (HR) was consulted when consensus could not be reached.

2.2 | Inclusion criteria

Inclusion criteria were finalized through an iterative review of articles identified in the database searches until the final sample included only studies that contained at least one intervention that could be classified according to its dietary structure and could be compared by child weight outcomes. All articles included in this review had at least one intervention that met the following criteria: tested an intervention conducted in any setting (clinic, research facility, etc.) for children and adolescents (aged 2 to 19 years) with overweight or obesity, as defined by study authors (e.g., Centers for Disease Control and Prevention body mass index [BMI]-for-age cutoffs,⁶ International Obesity Task Force BMI cutoffs,¹⁵ percent overweight); used an experimental design in which a dietary intervention was implemented and there was a pre-post assessment; included at least one dietary intervention that directly targeted food, nutrient, and/or eating occasion intake recommended by the Expert Committee⁶ for the treatment of overweight or obesity in children and adolescents; was at least 8 weeks (2 months) in length; contained at least one behavioral strategy designed to assist with changing energy balance behaviors (goals and planning, comparison of outcomes, self-monitoring of diet, self-monitoring of outcome, reward and threat, stimulus control, modeling of healthy lifestyle behaviors by parents, problem solving, motivational interviewing, general parenting skills [e.g., positive parenting] or family conflict management); did not specifically recruit children and adolescents with underlying disorders or issues related to metabolism, growth, appetite, or feeding or health conditions that required specific dietary restrictions; assessed standardized body mass index (ZBMI) as an outcome of the intervention (to allow for comparisons between interventions); was conducted within a developed country¹⁶; and was published in English. Articles were excluded if the intervention(s) included medications or surgery as the primary intervention or if at least one of the recommended dietary interventions did not report specific dietary goals (e.g., reduce energy intake vs. 1200 to 1500 kcal/day), as the ability to determine how much structure was imposed on the diet became less accurate.

3 | CONCEPTUALIZING DIETARY STRUCTURE

The Expert Committee recommends nine dietary interventions for the treatment of pediatric overweight and obesity that directly target food, nutrient, and/or eating occasion intake.⁶ These include decreasing SSBs, increasing fruits and vegetables (FVs), eating breakfast, eating structured daily meals and snacks, limiting energy-dense foods and/or reducing energy density, consuming a macronutrient-balanced diet, reducing energy intake, very-low-kcal diets, and meal replacements.⁶ For this review, an additional dietary intervention, energy restriction plus additional dietary interventions, was included to allow for the combination of a commonly prescribed recommendation (reducing energy intake) with other recommendations.

These recommended dietary interventions were organized according to their potential degree of imposing dietary structure, or control over the types and amount of foods and beverages consumed (Figure 1). This method of dietary organization proposes that as more or larger parts of the diet are targeted, greater control over the types and amounts of foods and beverages consumed are expected. Structure was operationalized as having four levels: alterations to food and beverage groups, such as FVs (low structure); alterations to the structure or size of daily eating occasions, such as breakfast or structured daily meals (moderate structure); alterations in nutrients, such as energy or macronutrients (high structure); and alterations to energy intake combined with any additional dietary alterations, such as macronutrient goals (very high structure). For example, targeting FVs alone (low structure) is focused on changing the type and amount of one food group. In comparison, targeting energy intake (high structure) can change the type and amount of most foods and beverages consumed, influencing more areas of the diet (e.g., servings in multiple food groups could be reduced, snacking occasions could diminish, and total energy could decrease).

4 | RESULTS

A total of 8196 unduplicated citations were identified, of which 15^{17–31} included at least one intervention meeting eligibility criteria. These 15 articles contained a total of 38 interventions, of which 13 did not meet eligibility criteria^{17,18,20,23,24,27–29,31} (nine were control conditions or standard care interventions^{17,18,20,23,24,29,31} and four were dietary interventions not meeting inclusion criteria^{21,27,28}) and one did not implement a consistent dietary intervention across time (meal replacements followed by a conventional diet at 4 months).²¹ Thus, this study reviews a total of 24 interventions. Each included intervention was assigned to a structure category based on the component of the dietary intervention with the highest structure. For example, if a dietary intervention had goals to increase FVs (low structure recommendation) and eat structured daily meals (moderate structure recommendation), the intervention was assigned to the moderate structure category. The 24 included interventions were classified by structure as follows: four low structure,^{17,18} three moderate structure,^{19,20} five high structure,^{21–24} and 12 very high structure dietary interventions.^{21,25–31} Interventions were primarily conducted in the United States,^{17,18,20–30} with three interventions conducted in Australia,^{23,31} and two interventions conducted in Norway.¹⁹ Interventions were conducted in a variety of settings, with 11 in unreported

settings,^{17,21–23,25–27} five in outpatient settings,^{28,30,31} three in research settings,¹⁸ two in a school setting,^{19,20} one in a camp setting,¹⁹ one in a clinic and home setting,²⁴ and one in a primary care setting.²⁹ See Table 1 for a description of reviewed dietary interventions.

4.1 | Low structure interventions

Three investigations (published in two articles), representing four interventions, were identified that fit the criteria for the low structure category.^{17,18} All of the investigations were randomized controlled trials (RCTs) that predominantly enrolled non-Hispanic, White children in early and middle childhood (age range 4–10 years). Two of the four interventions included goals to increase FV intake,^{17,18} and three of the four interventions had goals to decrease SSB consumption.^{17,18} Other dietary goals that were targeted included low-fat dairy¹⁸ and sweet and salty snack foods.¹⁸ Specific goals were reported for all dietary interventions. All interventions, except for the intervention in Trial 2 by Raynor et al.,¹⁸ targeted at least two broadly defined foods groups. Two of the interventions^{17,18} also included goals to engage in the recommended³² 60 min/day of moderate- to vigorous-intensity PA for children, and one intervention¹⁷ additionally included a goal to reduce television watching. All interventions included the behavioral strategies of self-monitoring, modeling, stimulus control, and positive reinforcement, with the total number of implemented behavioral strategies ranging from four¹⁷ to eight.¹⁸ Initial frequency of contact ranged from twice per month¹⁸ to once a month.¹⁷ None of the interventions began with weekly contact. Contact time ranged from 2.5¹⁷ to 6 h.¹⁸

Changes in ZBMI from preintervention to postintervention were relatively small (Table 2), ranging from -0.08 ¹⁸ to -0.16 .¹⁸ As none of the low structure interventions met contact time recommendations, all are considered low-intensity contact interventions (2.5¹⁷ to 6 h¹⁸). All four interventions were 6 months in length.^{17,18}

4.2 | Moderate structure interventions

Two investigations, representing three interventions, were identified that fit the criteria for the moderate structure category.^{19,20} Study designs included one RCT¹⁹ and one cluster RCT²⁰ that predominantly enrolled White (ethnicity unclear) children in middle childhood through adolescence (age range 7–17 years). The moderate structure dietary interventions included breakfast consumption^{19,20} and structured daily meals.²⁰ Other dietary goals that were targeted included increasing FV intake^{19,20}; decreasing SSB consumption^{19,20}; eating whole grain products, fish, and lean meats¹⁹; and limiting portions.²⁰ One intervention²⁰ reported specific dietary goals for all dietary targets except limiting portions. The remaining two interventions¹⁹ reported specific goals for FV intake only (goals not specified for reducing SSBs; eating breakfast; or eating whole grain products, fish, and lean meats). All interventions also included goals to engage in at least 60 min/day of PA. Other leisure-time activity interventions included limiting screen time^{19,20} and/or reducing sedentary time.¹⁹ All interventions included the behavioral strategy of goal setting, with total the total number of implemented behavioral strategies ranging from three¹⁹ to four.²⁰ Initial frequency of contact ranged from just less than weekly²⁰ (six sessions over 2 months) to monthly.¹⁹ Contact hours could not be determined for two intensive interventions,¹⁹ whereas the third

intervention provided approximately 2.5 contact hours.²⁰ Two interventions were at least 6 months in length.¹⁹

Changes in ZBMI from preintervention to postintervention ranged from 0.00²⁰ to -0.44 ¹⁹ (Table 2). The study reporting no change in ZBMI provided a short length of treatment (2 months) and only 2.5 contact hours.²⁰ The intervention with the greatest ZBMI change (-0.44) provided 24 months of treatment (exact contact hours could not be calculated), which included time spent in an in-patient camp.¹⁹

4.3 | High structure interventions

Four investigations, representing five interventions, were identified that fit the criteria for the high structure category.^{21–24} All high structure dietary interventions were RCTs that predominantly enrolled non-Hispanic, White children (only two investigations^{22,24} reported ethnicity) in early childhood through adolescence (age range 2–17 years). All interventions targeted energy restriction and reported specific dietary goals (daily intake goals ranging from 1000–1600 kcal/day^{21,22,24} or a 500-kcal reduction/day²³), with no other dietary interventions prescribed. Three interventions also included goals to engage in 30²¹ to 60 min/day of PA.^{22,24} Other leisure-time activity interventions included weekly supervised PA,²² step goals,²⁴ and limiting screen time.²⁴ All interventions included the behavioral strategy of self-monitoring, with the total number of implemented behavioral strategies ranging from two^{23,24} to seven.²¹ Frequency of initial contact for all high structure interventions was weekly. Contact time could only be determined for three interventions,^{22,24} with none providing at least 26 h of contact time. Two of the interventions were at least 6 months in length.^{21,24}

Changes in ZBMI from preintervention to postintervention ranged from -0.09 ²¹ to -0.49 ²⁴ (Table 2). The intervention²¹ reporting the smallest decrease in ZBMI was the longest in length, but exact contact hours could not be calculated. The intervention²⁴ reporting the greatest change in ZBMI reported the most contact time (approximately 22 h) and was 6 months in length.

4.4 | Very high structure interventions

Eight investigations, representing 12 interventions, were identified that fit the criteria for the very high structure category.^{21,25–31} All very high structure dietary interventions were RCTs that predominantly enrolled White (ethnicity unclear) children in middle childhood through adolescence (age range 7–18 years). All interventions included goals for energy restriction, including calorie goals of 1000 to 1500 kcal/day,^{21,25,26,29,30} 500 kcal/day reduction,²⁷ or 20%–30% reduction in energy intake from estimated energy expenditure.^{28,31} One intervention²¹ provided meal replacements, along with goals for FVs, and also breakfast consumption as meal replacements was decreased over time. Six interventions used the Traffic Light Diet,¹² which included goals for decreasing non-nutrient-dense, high-energy-dense foods (RED foods)^{25,26,30} or goals for decreasing RED foods and increasing nutrient-dense, low-energy-dense foods (GREEN foods).²⁹ Four interventions included macronutrient distribution goals,^{27,28,31} and one intervention had goals for FVs and low-fat dairy.²⁶ Specific goals were reported for all dietary interventions. Ten interventions^{21,25–30}

also included goals to engage in 30^{21,25,27,28} to 90³⁰ min/day of PA, whereas five interventions^{21,25,31} included unspecified goals to decrease sedentary behavior. All interventions included the behavioral strategy of self-monitoring, with the total number of implemented behavioral strategies ranging from one²⁸ to seven.²¹ Nine^{21,25–27,29,30} of the 12 interventions had an initial frequency of contact of at least once per week. Most of the interventions did not report the number of contact hours for the intervention,^{21,25,28,29,31} but two interventions had 26 h of contact time.²⁶ Five of the interventions^{21,25,26} were at least 6 months in length.

Changes in ZBMI from preintervention to postintervention ranged from -0.05 ²⁹ to -0.85 ²⁵ (Table 2). The intervention²⁹ with the smallest change in ZBMI (-0.05) was less than 4 months in length (exact contact time not reported). The greatest decrease in ZBMI (-0.85) was observed after the completion of a 12-month intervention (exact contact time not reported).²⁵

5 | DISCUSSION

A multicomponent intervention, which includes behavioral strategies to alter dietary intake and time in PA and/or sedentary behavior, is recommended for the treatment of overweight and obesity in children and adolescents.^{7,9} Although there is some grading of the evidence for pediatric dietary interventions,⁶ there are no graded recommendations for the diet to be used within this multicomponent approach. Suggested dietary interventions for pediatric overweight and obesity treatment are broad,⁶ and it is not clear what impact these dietary interventions have on weight status in children and adolescents. As dietary interventions that provide greater structure have produced better weight loss outcomes in adults,¹¹ the purpose of this critical review was to classify dietary interventions recommended for the treatment of overweight and obesity in children and adolescents by the degree of structure that the intervention imposes on the overall diet and examine the impact on changes in ZBMI. In general, results suggest that dietary interventions that impose more structure demonstrate the ability to produce larger improvements in weight status. Similar to findings in adults,¹¹ the greatest reduction in ZBMI at the end of treatment for each structure category was as follows: low structure, -0.16 ¹⁷; moderate structure, -0.44 ¹⁹; high structure, -0.49 ²⁴; and very high structure, -0.85 .²⁵

While the purpose of this critical review was to assist with the development of an innovative conceptual framework by which existing pediatric dietary interventions could be interpreted, because the proposed framework is novel and, to date, has not been tested in an intentional or systematic way, it is important to note that the ability to draw strong conclusions from this critical review is limited. In particular, the reviewed interventions have substantial heterogeneity in participant age, intervention contact time, and length of treatment among the included interventions. The low structure interventions targeted younger children (4–10 years),^{17,18} whereas the moderate to very high structure interventions targeted older children and adolescents (7–18 years),^{19–23,25–31} with the exception of one high structure intervention in preschoolers.²⁴ Intervention contact time ranged from 2.5^{17,20} to 31.5 h,²⁶ with contact time not reported in 11^{19,21,23,25,28,29,31} of the 24 interventions. For interventions in which contact time was provided, only low^{17,18} and moderate²⁰ structure

interventions were <12 h, usually with more time between contacts (e.g., monthly versus weekly contact). Additionally, there were substantial differences in intervention length, which ranged from 2²⁰ to 24¹⁹ months (all interventions reported length of intervention). While all low structure interventions^{17,18} were at least 6 months in length, more than half of the high^{22,23} and very high²⁷⁻³¹ structure interventions were less than 6 months in length. In addition to the potential influence of dietary structure on weight outcomes, the heterogeneity in treatment length suggests that, in general, outcomes were improved with increased intervention length. Interventions of at least 6 months^{17-19,21,24-26} reported larger reductions in ZBMI compared with interventions of less than 6 months^{20,22,23,27-31} in each structure category (except low, for which there were no interventions less than 6 months). Although contact time could not be calculated for all interventions, longer intervention length may generally reflect increased contact hours and allow greater length of time for ZBMI change. Thus, the improved outcomes seen with increased intervention length align with the findings that have been used to support recommendations to provide at least 26 h of contact time in pediatric overweight and obesity interventions.^{7,9}

Although very high structure interventions (i.e., energy alterations plus additional dietary alterations) appear to have the potential to achieve the greatest reductions in ZBMI, a very high structure dietary intervention may not be ideal for all situations in which a multicomponent intervention is implemented. Dietary interventions with higher structure are considered more complex and thus may be most appropriately delivered by dietitians or other nutrition specialists. Higher structure dietary interventions may also require greater initial contact time to assist children and families with understanding the more complex intervention (the high²¹⁻²⁴ and very high^{21,25-27,29,30} structure dietary interventions were commonly delivered with weekly contact, whereas low^{17,18} and moderate^{19,20} structure dietary interventions were not). These two factors, specialized staff and greater initial frequency of contact, may limit the settings in which this type of dietary intervention can be implemented, as only specialty clinics and research settings may support these factors. These types of settings limit accessibility of the intervention to all families. Finally, higher structure dietary interventions may also be better suited to older children and adolescents who can understand more sophisticated dietary concepts. For example, one of the most highly studied pediatric dietary interventions, the Traffic Light Diet,¹² requires participants to understand caloric intake, as well as energy density and the classification of foods into traffic light colors. Being able to self-monitor dietary intake for this type of dietary intervention and identify whether intervention goals are met requires a fair degree of health and math literacy that younger children do not possess.

While dietary interventions of lower structure may not produce as significant reductions in ZBMI as those of higher structure, these interventions may be more suited for younger children and may be delivered by nonspecialist providers. Dietary interventions of lower structure include less complex dietary goals. This may allow more flexibility in who can provide the intervention (e.g., community workers or nurses versus dietitians) and may not require as much initial contact time for children and families to understand. Thus, this type of intervention could be provided in community or primary care settings, which may increase the accessibility of the intervention. The dietary intervention messaging may also be simpler due to reduced complexity of dietary goals, which may make the intervention

more suited to younger children. Still, the low and moderate structure interventions reported nonexistent to modest ZBMI reductions (-0.0^{20} to -0.16^{17}), with the exception of two interventions¹⁹ that appeared to provide high intensity of contact time (exact hours could not be calculated) and long intervention length (24 months) (ZBMI reductions of -0.33 and -0.44). As it is currently hypothesized that greater than -0.16 reduction in ZBMI is needed to improve cardiometabolic outcomes in children,³³ additional investigation into the efficacy of low structure interventions, with consideration for the roles of frequency of contact, total contact hours, and intervention length, is warranted.

As previously mentioned, there are graded recommendations for a multicomponent approach to pediatric weight loss,⁷ but there are no graded recommendations for dietary interventions to be used within this multicomponent approach.⁹ Research that specifically examines the degree of structure implemented by pediatric dietary interventions could help to address this gap. Trials that directly compare different degrees of dietary intervention structure (while controlling participant age, intervention length, contact hours, PA goals, and behavioral strategies) are needed to confirm whether higher structure dietary interventions really do produce greater improvements in weight-related outcomes compared with lower structure dietary interventions. Additionally, future research should examine the use of a stepped-care approach, similar to the recommendations of the Prevention Plus model,⁶ that increases dietary intervention structure if lower degrees of structure do not produce desired improvements in weight status. The use of contemporary study designs that consider not only weight-related outcomes but also optimization of treatment delivery, such as sequential, multiple assignment, randomized trials (also known as SMARTs),³⁴ may be advantageous for testing such a stepped-structure approach. Finally, pragmatic trials that test the alignment or misalignment of different degrees of dietary intervention structure with differences in participant characteristics (i.e., age) intervention length, contact hours, settings, and providers are needed to determine which dietary interventions will be most successful in which circumstances.

Strengths of this review include its novel focus on dietary structure in the treatment of overweight and obesity treatment in children and adolescents, the methodical approach to reviewing the literature, and the examination of dietary interventions specifically recommended by the Expert Committee.⁶ Additionally, the authors self-assessed the quality of this review using the Scale for the Assessment of Narrative Review Articles, or SANRA, and determined it to be high quality (12 out of 12 possible points).³⁵ Limitations include study variability in participant ages, intervention length, contact hours, intensity of the PA goals or sedentary behavior component, and the robustness of the included behavioral component. Also, outcomes were only examined at the end of the intervention. Long-term follow-up was not examined (the ability to do this was limited in the interventions that met inclusion criteria); thus, conclusions cannot be drawn about which interventions are better long term (i.e., do the high/very high structure interventions have greater weight regain over time). Additionally, examining only interventions implementing Expert Committee dietary recommendations may have excluded other potentially effective pediatric dietary interventions (e.g., intermittent energy restriction³⁶). Further, to allow for comparison between interventions, only those investigations reporting ZBMI were included. Although this allowed for comparisons between the interventions as they all reported the same

commonly utilized outcome, it is important to note that extrapolation of ZBMI beyond the 97th percentile can lead to compressed z scores,³⁷ which may have occurred within the reviewed studies. Furthermore, several investigations did not report any dietary adherence, ^{19,21–23,25} whereas others reported adherence to only some of prescribed dietary interventions.^{21,26,29–31} Only eight^{17,18,20,24,27,28} of the 24 investigations reviewed reported on dietary adherence on all aspects of the dietary interventions. More consistent reporting of adherence to the prescribed interventions is needed to improve the body of evidence published on pediatric dietary interventions to be able to draw strong conclusions regarding the influence of any diet intervention on weight outcomes.

Finally, it is important to note that all studies in which race and ethnicity were reported were conducted in predominantly non-Hispanic, White populations, despite children from racial and ethnic minorities experiencing disproportionately high rates of overweight and obesity.³⁸ As a greater percentage of children from racial and ethnic minorities are of lower socioeconomic status and are underserved, they may experience a greater number of barriers, such as competing demands, lack of health care access, and food insecurity, which may hinder ability to engage in child or adolescent interventions for overweight or obesity intervention.^{39,40} This is particularly true for interventions that may be designed to provide a large amount of contact, which may compete with parental work responsibilities and present a need for reliable transportation, require specialty settings that can only be covered by health insurance or be paid out-of-pocket, and/or require large changes in the diet, which may increase the cost of the diet. Due to the lack of diversity within the samples of the investigations reviewed and these issues, more research is needed to determine if factors such as race, ethnicity, and socioeconomic status may be moderators in the relationship between dietary structure and improved weight status in children during overweight or obesity treatment.

6 | CONCLUSION

This critical review methodically appraised the pediatric overweight and obesity intervention literature to examine the relationship between the amount of structure imposed by dietary interventions and subsequent weight outcomes to develop a new conceptual framework. Findings indicate that as dietary interventions for the treatment of overweight and obesity during childhood and adolescence increased in structure, larger improvements in weight status may be achievable. To better establish the relationship between dietary intervention structure and weight outcomes in overweight and obesity interventions in children and adolescence, trials that empirically test different degrees of dietary intervention structure, while maintaining consistency in other aspects of the intervention, are needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

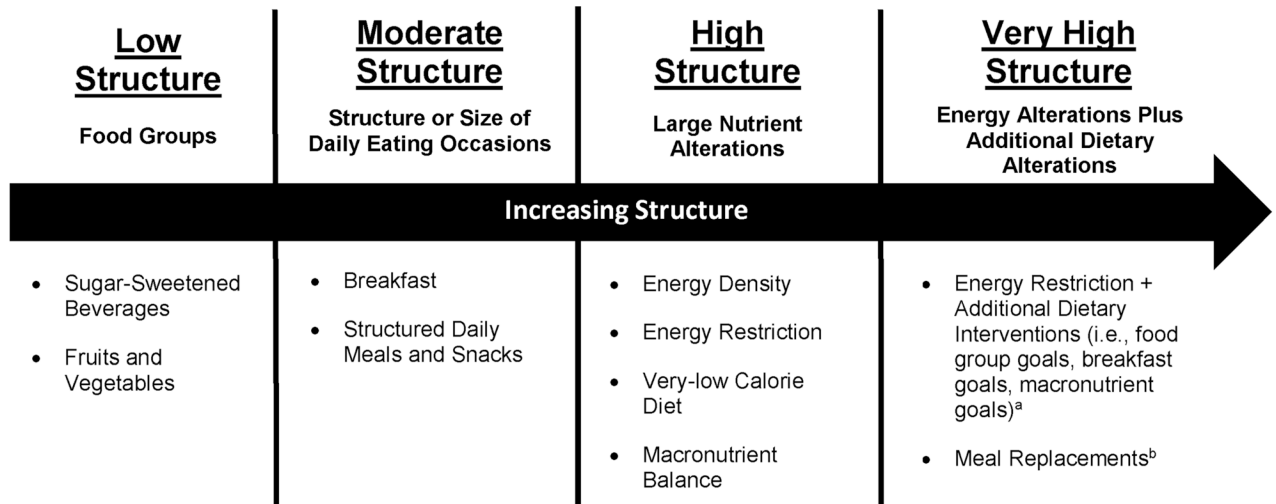
FVs	fruits and vegetables
kcal	kilocalories
PA	physical activity
RCTs	randomized controlled trials
SSBs	sugar-sweetened beverages
ZBMI	standardized body mass index

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^aAllows combining of a commonly prescribed high structure recommendation with additional recommendations.

^bThis intervention specifically combines energy restriction, structured daily meals, and macronutrient balance.

FIGURE 1. Dietary interventions recommended by the Expert Committee⁶ for the treatment of overweight and obesity for children and adolescents organized by degree of dietary structure

Multicomponent interventions for the treatment of overweight or obesity in children and adolescents using a dietary intervention recommended by the Expert Committee⁶ categorized by the degree of structure implemented in the diet

TABLE 1

Author/year (country/setting)	Study design: interventions	Sample description ^a (n, age range, demographics)	Intervention characteristics (length, frequency of contact ^b , contact hours, length of follow-up ^c)	Dietary interventions	Leisure-time activity interventions	Behavioral strategies	Dietary intake assessment	ZBMI ^d
Low structure								
Looney 2014 ¹⁷ (USA/NR)	RCT: N + GM + BC, N + GM, e N ^e	N ± GM ± BC: n = 7 4–10 years 86% female 71% White 14% Hispanic	N ± GM ± BC: 6-month intervention Monthly contact (3 in-person mtgs, 3 phone calls) 2.5 contact hours Follow up at 6 months	N ± GM ± BC: <3 svgs/week of SSBs 1/2 cups/day of whole vegetables 1 cup/day of whole fruit	N ± GM ± BC: 60 min/day of MVPA <2 h/day of television	N ± GM ± BC: Self-monitoring, modeling, stimulus control, positive reinforcement	3-day food records (all dietary goals assessed)	N ± GM ± BC: -0.16 (p value NR)
Raynor 2012 ¹⁸ Trial 1 (USA/research)	RCT: Decrease, Increase, Growth Monitoring ^e	Decrease and Increase: n = 68 4–9 years 62% female 84% White 18% Hispanic	Decrease and Increase: 6-month intervention Two mtgs/month for 2 months, monthly mtgs for months 3–6 6 contact hours Follow-up at 6 and 12 months	Decrease: 3 svgs/week of sweet and salty snack foods Increase: 3 svgs/week of SSBs 2 svgs/day of whole fruit 3 svgs/day of vegetables 2 svgs/day of LF dairy	Decrease and Increase: None	Decrease and Increase: Self-monitoring, pre-planning, problem-solving, shaping, goal setting, positive reinforcement, stimulus control, parental modeling	3-day food records (all dietary goals assessed)	Decreased: ^f 6 months: -0.08 (p value NR) 12 months: -0.10 (p value NR) Increased: ^f 6 months: -0.10 (p value NR) 12 months: -0.13 (p value NR)
Raynor 2012 ¹⁸ Trial 2 (USA/research)	RCT: Traditional, Substitutes, e Growth Monitoring ^e	Traditional: n = 26 4–9 years 65% female 85% White 12% Hispanic	Traditional: 6-month intervention Two mtgs/month for 2 months, then monthly mtgs for months 3–6 6 contact hours Follow-up at 6 and 12 months	Traditional: 3 svgs/week of SSBs	Traditional: 60 min/day of MVPA on most day/week	Traditional: Self-monitoring, pre-planning, problem-solving, shaping, goal setting, positive reinforcement, stimulus control, parental modeling	3-day food records (all dietary goals assessed)	Traditional: ^f 6 months: -0.11 (p value NR) 12 months: -0.17 (p value NR)
Moderate structure								
Benestad 2017 ¹⁹ (Norway/camp, school)	RCT: Summer Camp, Lifestyle School	Summer Camp and Lifestyle School: n = 90 7–12 years 50% female 86% White Ethnicity NR	Summer Camp: 24-month intervention Lifestyle School: Monthly contact with local coordinator; group mtgs at months 0, 12, 24; 2-week inpatient Camp at months 2; 4, 2-day	Summer Camp and Lifestyle School: 5 portions/day of FV Reduce/avoid sugary drinks (goal not specified) Eat	Summer Camp and Lifestyle School: 2 h/day of screen time 60 min/day of PA Reduce sedentary time	Summer Camp and Lifestyle School: Motivational interviewing, parenting skills, goal setting	Not assessed	Summer Camp: -0.44 (95% CI = -0.85 to 0.04) (p value NR) Lifestyle School: -0.33 (95% CI =

Author/year (country/setting)	Study design: interventions	Sample description ^a (n, age range, demographics)	Intervention characteristics (length, frequency of contact ^b , contact hours, length of follow-up ^c)	Dietary interventions	Leisure-time activity interventions	Behavioral strategies	Dietary intake assessment	ZBMI ^d value NR
Pbert 2013 ²⁰ (USA/school)	Cluster RCT: Intervention, Control ^e	n=42 Grades 9–11 64% female 74% White 14% Hispanic	Intervention: 2-month intervention 6 sessions over 2 months ~2.5 contact hours Follow-up at 2 and 6 months	Intervention: 5 svgs/day of FV 3 structured meals/day, including breakfast 0 svgs/day SSBs Limit portions (goal not specified)	Intervention: 60 min of PA on 5 days/week 2 h/day of screen time	Intervention: Self-monitoring, goal setting, problem solving, pre-planning	24-h dietary recall 8-item instrument to assess healthful/unhealthful dietary behaviors targeted by Intervention (all dietary components with goals assessed)	-0.64 to 0.01) (p value NR)
High structure								
Berkowitz 2011 ²¹ (USA/NR)	RCT: CD ^g MR/MR ^h MR/CD ⁱ	n=42 13–17 years 79% female 26% White Ethnicity NR	CD: 12-month intervention Weekly migs for months 1–4, 2 migs/week for months 5–7, then monthly migs for months 8–12 Contact hours could not be calculated Follow-up at 12 months	CD: 1300–1500 kcal/day	CD: 30 min/day of PA Reduce sedentary behavior (goal not specified)	CD: Self-monitoring, stress management, stimulus control, problem solving, contingency management, cognitive restructuring, social support	Not assessed	CD: -0.09 (p value NR)
Jelalian 2010 ²² (USA/NR)	RCT: CBT + EXER, CBT+PEAT	n = 118 13–16 years 68% female 76% White 9% Latino	All Groups: 16-week intervention Weekly migs: 16 contact hours Follow-up at 4 and 12 months	All Groups: 1400–1600 kcal/day	All Groups: 60 min/day of PA on most day/week CBT ± EXER: An additional 35 min/week supervised PA	All Groups: Cognitive behavioral therapy, self-monitoring, goal setting, stimulus control, relapse prevention	Not assessed	CBT ± EXER: 4 months: -0.16 (p < 0.01) 12 months: -0.11 (p < 0.01) CBT ± PEAT: 4 months: -0.21 (p < 0.01)

Author/year (country/setting)	Study design: interventions	Sample description ^a (n, age range, demographics)	Intervention characteristics (length, frequency of contact ^b , contact hours, length of follow-up ^c)	Dietary interventions	Leisure-time activity interventions	Behavioral strategies	Dietary intake assessment	ZBMI ^d
Jensen 2011 ²³ (Australia/NR)	RCT: Intervention, Wait-list Control ^e	n=13 ^f 8–17 years 23% female Race/ ethnicity NR	Intervention: 10-week intervention Weekly contact (in-person weeks 0, 1, 2, 4, 6, 8, 10 and phone calls weeks 3, 5, 7, 9) Contact hours could not be calculated Follow-up at 10 weeks	Intervention: Energy deficit of 500 kcal/day	Intervention: None	Intervention: Goal setting, self-monitoring	Not assessed	12 months: -0.17 (<i>p</i> < 0.01) Intervention: -0.20 (<i>p</i> < 0.05)
Stark 2011 ²⁴ (USA/clinic and home)	RCT: LAUNCH, Standard Care ^e	LAUNCH: n = 8 2–5 years 25% female 75% White 25% Hispanic	LAUNCH: 6-month intervention Weekly mtgs for 12 weeks, then every other week for 12 weeks ~22 contact hours Follow-up at 6 and 12 months	LAUNCH: 1000–1200 kcal/day	LAUNCH: 2 h/day of screen time 60 min/day of active play 5000 steps/day	LAUNCH: Self-monitoring, child behavior management skills (praise and attention; ignoring and time-out to manage tantrums; contingency management; modeling)	24-h dietary recall (all dietary goals assessed)	LAUNCH: 6 months: -0.49 (<i>p</i> value NR) 12 months: -0.37 (<i>p</i> value NR)
Very high structure								
Berkowitz 2011 ²¹ (USA/NR)	RCT: CD, ^g MR/MR, ^h MR/CD ⁱ	MR/MR/and MR/CD^k: n = 71 13–17 years 82% female 26% White Ethnicity NR	MR/MR: 12-month intervention Weekly mtgs for months 1–4, 2 mtgs/month for months 5–7, then monthly mtgs for months 8–12 Contact hours could not be calculated Follow-up at 12 months	MR/MR: For months 1–4: 1300–1500 kcal/day 3 MR/day 1 prepackaged meal/day 2 svgs/day of fruit 3 svgs/day of vegetables For months 5–12: 1300–1500 kcal/day 2 MR/day 1 prepackaged meal/day breakfast of conventional foods 5 svgs/day of FV	MR/MR: 30 min/day of PA Reduce sedentary behavior (goal not specified)	MR/MR: Self-monitoring, stress management, stimulus control, problem solving, contingency management, cognitive restructuring, and social support	Questionnaire on MR and prepackaged meal use	MR/MR: -0.10 (<i>p</i> value NR)
Epstein 2005 ²⁵ (USA/NR)	RCT: Behavioral Economic Treatment, Standard Treatment	All Groups: n = 41 8–12 years 56% female Race/ ethnicity NR	All Groups: 12-month intervention Eight mtgs in first 7 weeks, followed by 4 biweekly mtgs and 2 bimonthly mtgs in first 6 months; monthly mtgs in	All Groups: 1000–1500 kcal/day 14 svgs/week of REID foods	All Groups: 30 min of MVPA accumulated in increments of 10 min bouts 6 days/week Decrease	All Groups: Praise and reinforcement, self-monitoring, pre-planning	4-day food record (dietary goals not assessed)	Behavioral Economic Treatment:^l 12 months: -0.63 (<i>p</i> value NR) 24 months: -0.84 (<i>p</i> value NR)

Author/year (country/setting)	Study design: interventions	Sample description ^a (n, age range, demographics)	Intervention characteristics (length, frequency of contact ^b , contact hours, length of follow-up ^c)	Dietary interventions	Leisure-time activity interventions	Behavioral strategies	Dietary intake assessment	ZBMI ^d
Epstein 2008 ²⁶ (USA/NR)	RCT: Increase Healthy Food, Reduce High-energy-dense Food	All Groups: n=41 8–12 years 44% female Race/ethnicity NR	All Groups: 6-month intervention Weekly mtgs for 2 months, biweekly mtgs for 2 months, and 1 monthly mtg 31.5 contact hours Follow-up at 6 and 24 months	Increase Healthy Food: 1000–1500 kcal/day 5 svgs/day of FV 2 svgs/day of LF dairy Reduce High-energy-dense Food: 1000–1500 kcal/day 2 RED foods/day	All Groups: 60 min of MVPA accumulated in increments of 15 min bouts 6 days/week	All Groups: Self-monitoring, stimulus control, parental role modeling, positive reinforcement, preplanning, problem-solving	Food intake questionnaire (FV, LF dairy, and RED food intake assessed)	Standard Treatment: 12 months: -0.85 (p value NR) 24 months: -0.86 (p value NR) Increase Healthy Food: 6 months: -0.25 (p value NR) 24 months: -0.27 (p value NR) Reduce High-energy-dense Food: 6 months: -0.31 (p value NR) 24 months: -0.11 (p value NR)
Kirk 2012 ²⁷ (USA/NR)	RCT: Portion-controlled, Low-CHO, ^e Reduced Glycemic Load ^e	Portion-controlled: n=31 7–12 years 74% female 71% White Ethnicity NR	Portion-controlled: 3-month intervention Weekly mtgs 12 contact hours Follow-up at 3 and 12 months	Portion-controlled: 55–60% kcal CHO, 10–15% kcal protein, and 30% kcal fat with 500-kcal deficit	Portion-controlled: 30 min/day of PA on most day/week	Portion-controlled: Contracted goals, self-monitoring, positive reinforcement	3-day food records (all dietary goals assessed)	Portion-controlled: 3 months: -0.21 (p 0.0001) 12 months: -0.32 (p 0.0001)
Krebs 2010 ²⁸ (USA/outpatient clinic)	RCT: LF, HPLC ^e	LF: n=22 12–18 years 55% female Race and ethnicity NR	LF: 12-week intervention Followed at 2-week intervals Contact hours could not be calculated Follow-up at weeks 12 and 36	LF: Energy goal of 70% of resting EEE and 30% kcal fat	LF: 30 min/day MVPA	LF: Self-monitoring	3-day food records (all dietary goals assessed)	LF: 12 weeks: -0.14 (p 0.05) ^f 36 weeks: -0.15 (p = 0.002)
Saelens 2002 ²⁹ (USA/primary care)	RCT: HH, TC ^e	HH: n=23 12–16 years Sex, race, and ethnicity NR	HH: 4-month intervention Weekly phone calls for 8 weeks, 3 biweekly calls Contact hours could not be calculated Follow-up at 4 and ~11 months	HH: 1200 to 1500 kcal/day 40 svgs/week of GREEN foods 15 svgs/week of RED foods	HH: 60 min/day of MVPA on 5 days/week	HH: Self-monitoring, goal setting, problem solving, stimulus control, self-reward, preplanning	2-day dietary recall (kcal assessed)	HH: 4 months: -0.05 (p value NR) ~11 months: -0.06 (p value NR) ^f

Author/year (country/setting)	Study design: interventions	Sample description ^a (n, age range, demographics)	Intervention characteristics (length, frequency of contact ^b , contact hours, length of follow-up ^c)	Dietary interventions	Leisure-time activity interventions	Behavioral strategies	Dietary intake assessment	ZBMI ^d
Saelens 2011 ³⁰ (USA/ outpatient clinic)	RCT: Added, Standard	All Groups: n = 29 7–11 years 55% female 66% White 14% Hispanic	All Groups: 14-week intervention Weekly mtgs ~16 contact hours Follow-up at 14 weeks	All Groups: 1000–1200 kcal/day 5 days/week 15 svgs/week of RED foods	Added: 90 min of MVPA on at 6 days/week Standard: 60 min of PA on most day/week	All Groups: Monitoring, goal setting, contingency management, stimulus control	3-day food records (kcal assessed)	Added: –0.21 (p value NR) Standard: –0.32 (p value NR)
Truby 2016 ³¹ (Australia/ outpatient clinic)	RCT: Structured Modified CHO, Structured Modified LF, Control ^e	Structured Modified CHO and Structured Structured Modified LF: n = 73 10–17 years 73% female 92% White Ethnicity NR	Structured Modified CHO and Structured Modified LF: 12-week intervention In-person mtgs for weeks 0, 2, 4, 8, 12 and phone calls for weeks 6 and 10 Contact hours could not be calculated Follow-up at 12 weeks	Structured Modified CHO: 20% reduction in energy from EEE, 35% kcal CHO, 30% kcal protein, and 35% kcal fat Structured Modified LF: 20% reduction in energy from EEE, 55% kcal CHO, 20% kcal protein, and 25% kcal fat	Structured Modified CHO and Structured Modified LF: Decrease sedentary behavior (goal not specified)	Structured Modified CHO and Structured Modified LF: Goal setting, problem solving, self-monitoring	Percent kcal from macronutrients reported but dietary assessment method not described	Structured Modified CHO: –0.13 (p 0.001) Structured Modified LF: –0.12 (p 0.001)

Abbreviations: CBT + EXER, cognitive-behavioral treatment with exercise; CBT + PEAT, cognitive-behavioral treatment with peer-enhanced adventure therapy; CD, conventional diet; CHO, carbohydrate; CI, confidence interval; EEE, estimated energy expenditure; FC, Family Connections; FC-IVR, Family Connections and interactive voice response; FV, fruits and vegetables; HH, Healthy Habits; HPLC, high-protein, low-carbohydrate; kcal, kilocalories; LAUNCH, Learning about Activity and Understanding Nutrition for Child Health; LF, low fat; MR, meal replacement; mtg(s), meeting(s); MVPA, moderate-to vigorous-intensity physical activity; n, number; N, newsletter; N + GM, newsletter and growth monitoring; N + GM + BC, newsletter and growth monitoring plus family-based behavioral counseling condition; NR, not reported; PA, physical activity; RCT, randomized controlled trial; SSBs, sugar sweetened beverages; svgs, servings; TC, typical care; USA, United States of America; ZBMI, standardized body mass index.

^aSample description is for participants receiving an intervention that met inclusion/exclusion criteria.

^bMeetings occurred in-person unless otherwise specified.

^cFollow-up at end of intervention. If additional follow-up is reported, it is the longest reported follow-up assessment.

^ddenotes within-group change from baseline to follow-up.

^eCondition that did not meet inclusion/exclusion criteria.

^fData obtained from author, as it was not available in the publication.

^gConventional Diet: This group received the conventional diet throughout the 12 months of intervention.

^hMeal Replacement/Meal Replacement: This group received meal replacement throughout the 12 months of the intervention.

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^jMeal Replacement/Conventional Diet: This group received meal replacements for the first 4 months of the intervention, and then the conventional diet for months 5 to 12 of the intervention. No results are presented as the dietary intervention was not consistent across the intervention.

^kSixteen participants were randomized to this condition, but demographics were provided on 13 participants.

^lDemographics for the sample are reported on all participants randomized to a meal replacement condition, rather than reporting demographics for the two meal replacement conditions separately.

^mZBMI change estimated from Figures through consensus of two authors.

TABLE 2

Minimum and maximum change in ZBMI from preintervention to postintervention by structure category and length of intervention

Intervention structure category	ZBMI change at end of treatment	
	Interventions <6 months in length	Interventions 6 months in length
Low ^a (<i>n</i> = 4)	N/A	-0.08 ¹⁸ to -0.16 ¹⁷
Moderate ^b (<i>n</i> = 3)	0.0 ²⁰	-0.33 ¹⁹ to -0.44 ¹⁹
High (<i>n</i> = 5)	-0.16 ²² to -0.21 ²²	-0.09 ²¹ to -0.49 ²⁴
Very high (<i>n</i> = 12)	-0.05 ²⁹ to -0.32 ³⁰	-0.10 ²¹ to -0.85 ²⁵

^aNo low structure interventions were <6 months in length.

^bOnly one moderate structure intervention was <6 months in length.