Effect of a Family-Based Weight Management Intervention on the Association Between Weight Loss and Children's Quality of Life

Mark Abbey-Lambertz

A thesis
submitted in partial fulfillment of the
requirements for the degree of

Master of Public Health

University of Washington

2021

Committee:
Todd Edwards
Brian Saelens

Program Authorized to Offer Degree:
Health Services

University of Washington

Abstract

Effect of a Family-Based Weight Management Intervention on the Association between Weight Loss and Children's Quality of Life

Mark Abbey-Lambertz

Chair of the Supervisory Committee:
Todd Edwards
Department of Health Services

Background and Significance: Childhood obesity is associated with numerous morbidities, and effective interventions are needed to provide children and their parents the tools and skills they need to make healthier lifestyle choices. Children with obesity are more likely to have poorer health-related quality of life (HRQOL) and poorer weight-specific quality of life (WSQOL) compared to their peers. The impact of weight management interventions on children's HRQOL and WSQOL is not fully understood. Whether and how weight loss changes parents' and children's perceptions of the children's quality of life can provide insight into interventions' effectiveness and highlight opportunities for adapting interventions.

Objective: To determine the association between pediatric participants' weight loss and change in their quality of life, specifically HRQOL and WSQOL, among participants enrolled in family-based behavioral weight management interventions.

Methods: This study used a one-arm quasi-experimental design and combined data from two previous pediatric weight management intervention studies. Parents with overweight/obesity and their children ages 7 to 11 with overweight/obesity participated in a 20-week, family-based weight management intervention focused on increasing healthier lifestyle eating and activity behaviors. Child height, child weight, and child self-reported and parent proxy-reported HRQOL and WSQOL were collected. Child self-reported and parent proxy-reported HRQOL and WSQOL scores were compared. Multiple regression was used to assess the association between change in child BMI z-score and change in child HRQOL and WSQOL.

Results: Parent proxy-reported WSQOL was significantly lower than child self-reported WSQOL at all timepoints, but quality of life significantly increased with treatment. Change in child BMI z-score was significantly negatively associated with change in child self-reported total WSQOL (improvements in child weight status associated with improvements in weight-related quality of life) but not child self-reported total HRQOL. Change in child BMI z-score was also significantly negatively associated with parent proxy-reported HRQOL and WSQOL.

Conclusions: The change in children's self-reported quality of life does not track with changes in their weight status as much as changes in parents' perceptions of child quality of life improvements. Parent perceptions of child HRQOL and WSQOL indicate significant improvement with intervention that is more linked to child weight status changes. Pediatric weight management interventions may need modification to show children how their weight loss is related to their improving quality of life.

Abbreviations:
BMI: body mass index
zBMI: child BMI z-score
QOL: quality of life
HRQOL: health-related quality of life
WSQOL: weight-specific quality of life

Background and Significance

The prevalence of obesity among children in America has increased over the last several decades and continues to rise.[1–4] Obesity among children is associated with cardiovascular morbidity and dysfunction,[5] asthma,[6] apnea and other sleep issues,[7] and many other morbidities affecting general, physical, and psychosocial health (e.g., internalizing and externalizing problems, school problems).[8] Children with obesity are also more likely to be obese as adults,[9–11] and childhood obesity has been associated with several adult risk factors for cardiovascular disease.[12] Parental obesity and child obesity are associated—children with parents who have overweight/obesity are twice as likely to be overweight/obese themselves.[13] Children learn and adopt many of their habits from their parents, so targeting the family as a unit for interventions can help create a healthier environment for children. Rather than continuing to model unhealthy behaviors, parents can begin modelling healthier behaviors, thereby reinforcing their children's new habits instead of undermining them.

There is strong evidence that family-based behavioral interventions can reduce both parents' BMI and children's BMI z-score (hereafter zBMI), though effect sizes are often small and short-term.[14] Effective treatments include some combination of dietary change, physical activity change, environmental control, monitoring, goal setting, contingency management, family therapy, and parental modeling.[15–17] Intervention intensity (hours of contact) has been identified as an important factor for intervention success,[18] and the US Preventive Services Task Force recommends moderate- to high-intensity programs with >25 hours of contact.[19] These longer interventions give more time for families' new behaviors to become habits. More research is needed to improve effectiveness, explain variations in effectiveness, improve scalability and reach, and fully understand the impact of each intervention beyond just change in weight status. It is particularly important to evaluate outcomes beyond weight status that children and parents perceive, including general and weight-specific quality of life.

Quality of life (QOL) is "an overall sense of well-being, including aspects of happiness and satisfaction with life as a whole."[20] Health-related quality of life (HRQOL) is an individual's quality of life as it relates to physical health, mental health, and function,[20] though there are several other definitions and interpretations of HRQOL.[21] Weight-specific quality of life (WSQOL) is the child's perception of how their weight impacts their self-concept and esteem, their social life, and their interactions with their environment. Condition-specific measures like WSQOL tend to be more responsive to the effects of weight management interventions than generic quality of measures. Compared to peers without obesity, children with obesity have lower self-reported quality of life: lower physical self-perception and self-worth;[22] more depression;[23,24] low HRQOL;[24,25] worse psychosocial health;[8] more teasing, loneliness, and negative feelings about appearance;[26] and worse general health, emotional well-being, and social life.[27–29] Children's lower HRQOL and WSQOL may impact the effectiveness of treatment and could serve either as motivation for children to make changes (e.g., children seeking to improve their general well-being) or as barriers to overcome (e.g., lower psychological well-being making behavior change more difficult). Improvement in HRQOL and/or WSQOL during treatment may reinforce lifestyle changes children are making and act as encouragement to continue their efforts, whereas a lack of improvement may be demotivating and lead to lower efforts to make changes.

HRQOL and WSQOL can both be measured in children by either child self-report or parent proxy-report. Considered widely as the gold standard, self-report provides the most direct measure of an individual's experience and minimizes potential bias from a proxy-report. However, a qualitative analysis of 8-12-year-old children and their parents completing an HRQOL instrument showed that the children and their parents considered different factors and had different thought processes when answering items about children's quality of life.[36] In this way, parent proxy-report provides a valuable and unique perspective on children's quality of life. Furthermore, as family-based interventions include parents, the intervention may impact their perspective on their child's quality of life but not the child's self-perception, or the intervention may lead to improvements that the parents see but their child does not.

HRQOL and WSQOL both provide an important lens for understanding parents' and children's perceptions and attitudes about the children's life, but WSQOL is not well represented in the pediatric weight management literature. Both observational longitudinal studies[30–33] and weight management intervention studies[14,25,29,34] have reported mixed findings on the relationship between change in children's weight and change in HRQOL. WSQOL is a less commonly measured construct, but children's attitudes about their weight and how they perceive its impact on their life (if any) may impact their engagement with the intervention. The increased specificity of WSQOL as compared to HRQOL captures how children's weight affects their lives, which is critical to understand when the aim of an intervention is weight change. Moreover, capturing WSQOL over time shows if and how children's lives have improved by reducing their weight.

The relationship between weight loss and HRQOL/WSQOL improvement during an intervention can provide valuable information about if/how children's and parents' perspectives change along with children's weight status. Depending on how children's weight status and quality of life change and whether the two are or are not associated, interventions would need to tailor content differently. If change in HRQOL and WSQOL are highly associated with weight change, then change in weight status is probably a driving factor for improvements to quality of life and interventions may not need to include separate or additional content aimed at improving children's quality of life, as it will improve as their weight status improves. If change in HRQOL or WSQOL are weakly associated with children's weight status, then interventions could aim to help children identify ways their quality of life has improved by losing weight, potentially strengthening the association and reinforcing their behavioral changes. If change in HRQOL or WSQOL are not associated with children's weight status, then other factors must be influencing child self-reported and parent proxy-reported HRQOL and WSQOL and interventions would need to include content to improve children's quality of life independent of content aimed at weight loss. Variations in how effective interventions are in the short-term and the long-term may be partially explained by the association between children's weight loss and their HRQOL or WSQOL. Children not feeling improvements in quality of life may prevent further improvements to zBMI.[35] For example, if children put forth significant effort and lose weight but do not believe that the negative effects of their weight on their lives have lessened, then they will have less incentive to continue practicing healthy habits and may be more likely to revert to earlier less healthful behaviors. Similarly, if parents make familial lifestyle changes and support their children in losing weight but do not believe that their children's lives have improved (even though their children's weight status has improved), they also will have less incentive to continue making familial lifestyle changes. Families who believe their children are better off will likely continue trying to make health choices, so understanding whether and how children's and parents' perceptions change with the children's weight can help improve the effectiveness of interventions. Making and sustaining lifestyle changes is difficult: participants experiencing more challenges may struggle to start making changes, and participants who do not believe their life is improving during an intervention may resist or stop the difficult work of behavior change and reduce an intervention's long-term effectiveness. If weight maintenance (post-intervention) is associated with improvements to children's HRQOL and WSQOL, then that suggests that interventions may be able to create a positive feedback loop between children's behaviors and their perceptions.

Few previous studies have examined the relationship between change in weight and change in HRQOL[29,37–41] or WSQOL[29,37] within an intensive pediatric weight management intervention, and those that did measure both types of quality of life failed to examine both child self-report and parent proxy-report. The present study addresses these gaps and seeks to explore the association between change in children's weight status and change in children's weight-related and general quality of life. For child self-report and parent proxy-report, physical HRQOL was expected to change in response to children's weight loss faster (and therefore be observable sooner) than self HRQOL, social HRQOL, or school HRQOL, and so was the HRQOL domain chosen for analyses. Children's weight loss was expected to have a greater impact on child self-reported self WSQOL than child self-reported social WSQOL or environment WSQOL. Parent proxy-reported social WSQOL was expected to change in response to children's weight loss faster than parent proxy-reported self WSQOL or environment WSQOL.

This study aims to assess the association between children's weight change (assessed via zBMI change) and change in HRQOL and WSQOL after participating in an intensive family-based behavioral weight management intervention. It is hypothesized that:

1) Reduction in zBMI will be associated with improvements to child self-reported <u>total</u> HRQOL
2) Reduction in zBMI will be associated with improvements to child self-reported <u>physical</u> HRQOL
3) Reduction in zBMI will be associated with improvements to child self-reported <u>total</u> WSQOL
4) Reduction in zBMI will be associated with improvements to child self-reported <u>self</u> WSQOL
5) Maintaining zBMI reductions after the intervention ends will be associated with improvements to child self-reported <u>total</u> WSQOL during the intervention
6) Reduction in zBMI will be associated with improvements to parent proxy-reported <u>total</u> HRQOL
7) Reduction in zBMI will be associated with improvements to parent proxy-reported <u>physical</u> HRQOL
8) Reduction in zBMI will be associated with improvements to parent proxy-reported <u>total</u> WSQOL
9) Reduction in zBMI will be associated with improvements to parent proxy-reported <u>social</u> WSQOL

Methods

Design

This study incorporates data from two previous studies assessing a family-based pediatric weight management intervention—the Familial Overweight: Comparing Use of Strategies (FOCUS) study[42] and the Success in Health: Impacting Families Together (SHIFT) study (unpublished). Data from those studies were combined for analyses here. Each study had different aims and designs but had similar recruitment procedures and identical eligibility criteria. Both included an arm that utilized the same intervention, delivered by trained behavioral health professionals. SHIFT also assessed the effectiveness of peers as interventionists, however only data from arms using professional interventionists are included here. FOCUS compared the effectiveness of two intervention delivery arms. One (prescribed condition) had interventionists be prescriptive and set eating and activity goals and encourage skills to use (e.g., food self-monitoring) throughout all intervention sessions, and the other (self-directed condition) started with prescribed goals and encouragement of families to use all skills but then switched during treatment to having families choose their own goals and skills to use. As there was no significant difference in effectiveness in changing children's weight status (zBMI) between the two arms (no group by time interaction) in the FOCUS study, they are aggregated in this study.

Setting

The FOCUS and SHIFT intervention studies were conducted by Dr. Brian Saelens and his research team at Seattle Children's Research Institute, in the Center for Child Health, Behavior, and Development. The FOCUS study's intervention took place at Seattle Children's Research Institute in downtown Seattle, with recruitment targeting families who could travel to downtown Seattle on a weeknight. The SHIFT study took place in Everett, Bellevue, Federal Way, and Renton, WA, with recruitment targeting families who lived in or near those cities. The Everett, Bellevue, and Federal Way locations are Seattle Children's satellite clinics; the Renton location is a clinic, HealthPoint Renton, that is unaffiliated with Seattle Children's. FOCUS was conducted from 2008 to 2010, and SHIFT was conducted from 2016 to 2020.

Participants

Program participants included a child and at least one parent/caregiver (hereafter, parent), though other parents were invited to attend treatment as well if the family desired. Eligibility criteria included the following: child aged 7-11 on the first day of treatment, child BMI ≥ 85th percentile, and one biological (not necessarily the participating) parent BMI ≥ 25.0. The 85th percentile and BMI ≥ 25.0 are the cutoffs between having normal weight and having overweight/obesity for children and adults, respectively.[43,44] Though the cutoffs were for overweight, 86.4% of children and 77.3% of parents had obesity (≥ 95th percentile and BMI ≥ 30.0, respectively) at enrollment. Exclusion criteria (both child and parent) included the following: having a medical condition or using a medication that affected body weight, concurrently attending a different weight management program, having an eating disorder or mental health diagnosis that was weight-related, being unable to be physically active, being unable to speak English, and being unable to attend treatment sessions on a consistent basis (although some absences were expected for illness, vacation, competing events). Child and parent weight and height were measured by staff and child BMI percentile and parent BMI were calculated. If the biological parent with BMI ≥ 25 was not available, verbal confirmation of their weight status by the participating adult was accepted. All other inclusion criteria were reported by the parent. Ability to speak English was required for participation in the interventions.

Participants were recruited for the intervention studies from the region surrounding the study locations via convenience sampling (self-selection and snowballing): mailed flyers using addresses from a marketing company, clinical referrals, radio and social media ads, and word of mouth. After learning about the study, participants contacted the study team and had a phone conversation about eligibility and what the study entailed (i.e., assessments and the intervention). Interested families (parent-child dyads, though other adults were welcome) then met in a group with staff members to learn more about the study, to confirm eligibility (height and weight measurements), and to sign consent forms if still interested and eligible. Participants received incentives for completing the post-treatment and the 6-month follow-up assessments. The intervention was provided at no cost to the family and families received reimbursement for transportation upon request. The current study was approved by the Seattle Children's Research Institute Institutional Review Board.

Intervention

The weight management interventions have been previously described and were professionally delivered family-based treatment (FBT).[42,45] In both FOCUS and SHIFT, the interventions were delivered in cohorts of approximately 10-15 families (parent-child dyads) at the same time to provide them behavioral and cognitive tools, feedback/accountability, and education about healthy eating and physical activity focused on child and parent weight management. The cohorts met once per week for 20 weeks, plus a skip (non-contact) week. Families received 75 minutes of treatment per treatment session, totaling 25 hours over all 20 weeks. The intervention was delivered by master's- or doctorate-level behavioral health specialists ("interventionists") trained and supervised in the intervention delivery. Each week's visit included three sessions (with groups occurring simultaneously):

- Family session (30 minutes): each parent-child child dyad met with an interventionist (same interventionist each week)
- Parent group (45 minutes): interventionists led a group session with all the parents
- Child group (45 minutes): interventionists led a group session with all the children

The stoplight eating approach[46] was used to help children and parents develop a frame of reference about the health value of different foods: foods and beverages are categorized as Green (go ahead and eat it), Yellow (slow down), or Red (stop and think before eating). Green foods are higher in nutrients and lower in sugar, fat, and calories, Yellow foods are in the middle, and Red foods are lower in nutrients and higher in sugar, fat, and calories. For example, all fruits and vegetables, skinless chicken breast, and multigrain non- or low-sweetened cereals are Green foods, and beef (<95% lean) and high-sugar cereals are Red foods. In addition to discussing food, interventionists also focused on physical activity, encouraging families to spend more time being physically active and less time being inactive. In the family sessions, interventionists and families worked together and discussed eating and activity goals, decided on rewards for goal completion (provided by parents/caregivers), problem-solved barriers to meeting goals, and explored ways to change the home and other amenable environments to promote healthier familial choices and lifestyle. Weekly goals included eating within a specified calorie range, eating more fruits and vegetables, limiting Red foods, increasing physical activity, and losing weight. In the parent group, parents and interventionists discussed different strategies parents could implement to facilitate their children's and their own healthy eating and physical activity, explored barriers to success, and reviewed problem-solving strategies for the upcoming week. In the child group, children and interventionists discussed nutrition and physical activity information, examined children's efforts to self-manage their weight, addressed unhelpful cognitions and emotions tied to eating, and practiced behavioral skills.

Data Collection

Both intervention studies had the same data collection procedures: participants completed assessments before treatment started (T1), immediately after treatment ended (T2), and at the 6-month follow-up (T3) that was 6 months after T2, during which there was no contact between the study team and the families. During the intervention, study staff recorded whether families attended the intervention each week. A parent attending alone or a child attending with a different parent/caregiver (e.g., grandparent) was counted as attending. Data were entered by one staff member and reviewed by a second staff member who identified and corrected any mistakes.

Measures

Anthropometric measures were taken of children and their participating parent, following National Health and Nutrition Examination Survey (NHANES) protocol.[47] Weight was measured with a calibrated digital scale to the closest 0.1 kg, and measurements were repeated until three of four consecutive measurements were within 0.1 kg. Those three proximal measurements were then averaged. Participants wore their clothes but removed bulkier items, such as shoes, jackets, and sweaters. Height was measured with a stadiometer to the closest 0.1 cm, and measurements were repeated until three of four consecutive measurements were within 0.5 cm. Those three proximal measurements were then averaged. Participants removed their shoes. Children's height, children's weight, and parents' weight were measured at T1, T2, and T3, but parents' height was measured only at T1 as assumed to remain stable.

To assess HRQOL, parents and children completed the PedsQL 4.0 at each timepoint. The PedsQL 4.0 is an established valid and reliable instrument that measures child self-reported and parent proxy-reported HRQOL.[48–51] Varni et al used Cronbach's α to measure test-retest reliability ($\alpha \geq 0.70$ for all domains for both child self-report and parent proxy-report) and used paired t-tests to measure sensitivity to change during intervention (all $p \leq 0.004$). Varni et al reported minimal clinically important differences for the PedsQL and cut-off points at 1 SD below the population mean (scores >1 SD below the mean are considered "at-risk for impaired HRQOL" and are similar to self-reported scores by children with a chronic health condition).[50] Both the child self-reported and parent proxy-reported versions were administered at T1, T2, and T3. The versions have 23 identical items, asking how much of a problem something has been for "you" (child self-report) or "your child" (parent proxy-report) in the past month. Responses are on a 5-point Likert scale (0-4; never, almost never, sometimes, often, almost always). All items are phrased such that a higher response corresponds to lower HRQOL (e.g., In the past one month, how much of a problem has this been for you…It is hard for me to walk more than one block). There are four domains: physical (8 questions), emotional (5 questions), social (5 questions), and school (5 questions). The child self-reported version was validated for 8-12-year-olds.

To assess WSQOL, parents and children completed an age-adapted version of the Youth Quality of Life Instrument-Weight module (YQOL-W) at each timepoint. The original YQOL-W is an established, valid, and reliable youth self-report instrument that measures WSQOL.[29,35,52] Morales et al used an intraclass correlation coefficient from a two-way random effects ANOVA model to measure test-retest reliability (all coefficients ≥ 0.70) and Patrick et al used multiple regression to measure sensitivity to change (all $p \leq 0.05$, except $p < 0.05$ in environmental domain for 11-14 year-olds). The YQOL-W was originally developed for participants aged 11-18 years and consisted of 21 items on an 11-point scale with adjectival anchors (0-10; not at all to very much), with each item corresponding to one of three domains: self (4 questions), social (12 questions), and environment (5 questions). For the child weight management intervention studies the YQOL-W was adapted for 7-11-year-olds. The number of items was reduced, removing those that were age inappropriate or were conceptually similar to other questions. Questions about family perceptions were added (social domain), replacing some questions about peers. A 5-point Likert scale was used with simple drawings of faces as the response options, with options ranging from a very large frown to a very large smile. The items on the original YQOL-W were phrased such that a higher response corresponded to lower WSQOL; this was reversed in the adapted version such that a higher response always corresponded to higher WSQOL. Survey questions asked children if how heavy they were affected how they felt or if it affected them in different ways. The adapted version had 9 items: 2 in the self domain, 6 in social, and 1 in environment. Of the 9 items, 8 were duplicated for inclusion in the YQOL-W parent proxy-report, only changing the pronouns of the question to “your child” instead of “I.” The 9th item asked children about their parents’ feelings towards them (social domain) and was not included in the parent version. These versions of the child self-report and parent proxy-report measures were administered.

Parents and children completed the instruments separately to allow for private responses. Staff provided assistance to children as needed. Parents also completed a demographic questionnaire at T1.

Analytic Variables

Height and weight were used to calculate BMI (kg/m^2). To standardize child weight status across age and sex, zBMI was calculated with the LMS (lambda-mu-sigma) method and CDC 2000 data.[53] To cap error in age in months at 15 days, 0.5 was added to each participant's age in months. Growth charts for age- and sex-specific median, standard deviation, and distribution skewness correction are available from the CDC (https://www.cdc.gov/growthcharts/percentile_data_files.htm).

PedsQL and YQOL-W responses were scored to create total scores and domain scores at each timepoint for child self-report and parent proxy-report. PedsQL scores were reversed so higher scores correspond to higher HRQOL. PedsQL and YQOL-W item responses were then linearly scaled to 0-100, such that 0 was the lowest possible reported HRQOL or WSQOL, and 100 was the highest score (possible values for a response were 0, 25, 50, 75, or 100). The total score was generated by averaging a participant's scaled responses to all questions; domain scores were generated by averaging a participant's scaled responses to each question in that domain. Partially complete instruments were considered missing if insufficient items were answered: PedsQL total scores and domain scores were considered missing if >50% of questions were missing; YQOL-W total scores and domain scores were considered missing if >20% of questions were missing.

Demographic variables were reported by parents and re-categorized for analysis. For race/ethnicity, SHIFT included a "multi-racial" category, whereas FOCUS did not. To minimize misclassification of SHIFT participants who selected multiracial and FOCUS participants who would have selected it, race/ethnicity was collapsed to two categories when used in models: Non-Hispanic White or Person of Color. The original responses are in Supplementary Table 1. Parent education was collapsed to individuals who have versus have not graduated college. While both intervention studies collected household income in $10,000 increments, FOCUS's highest category was ≥ $100,000 per year and SHIFT's highest category was ≥ $150,000 per year. All SHIFT participants reporting ≥ $100,000 per year were collapsed into ≥ $100,000 per year to match FOCUS. Household income was further categorized to < $50,000 per year, $50,000 - $99,999 per year, and ≥ $100,000 per year.

Statistical Analysis

This study used a one-arm quasi-experimental design. Data from FOCUS and SHIFT were compiled into a single dataset. Although multiple parents sometimes attended treatment, only data from one parent (the parent who came each week) were used for analyses, as this was the parent who completed the assessments. Mean and standard deviation were calculated for continuous variables, and N and percent were calculated for categorical variables.

Demographics were stratified by which study families participated in and compared using two-sample t-tests, Pearson's chi-squared test, or Fisher's exact test, depending on data type and distribution. Two-sample t-tests were used for continuous data, and Pearson's chi-squared test or Fisher's exact test were used for categorical data with expected cell sizes ≥ 5 or < 5, respectively.

To determine if there were differences in the study population, T1 zBMI, HRQOL scores, and WSQOL scores were stratified by potentially confounding demographics. When stratified by child sex, child race/ethnicity, and parent education (binary variables), Wilcoxon rank-sum tests were used for comparison. When stratified by household income (categorical variable), a Kruskal-Wallace test was used for comparison. Paired t-tests were used to determine if zBMI and HRQOL or WSQOL scores significantly changed between timepoints. Change between timepoints was reported as mean change (95% CI).

Patterns of missingness were assessed within and across timepoints. Comparisons were made between participants who *only* completed T1 and participants who completed T1 *plus* T2 and/or T3 to determine if there were significant differences between them. They were compared using two-sample t-tests (zBMI, parent BMI, HRQOL scores, and WSQOL scores) and chi-squared tests (child sex, child race/ethnicity, parent education, and household income).

Child self-reported and parent proxy-reported HRQOL and WSQOL were compared for similarity at each timepoint. Pearson's r was used to determine the magnitude of correlation between them and if the correlation was significant. Paired t-tests were also used to determine if child self-reported and parent proxy-reported quality of life scaled scores (total and domain) were significantly different from each other at each timepoint.

Multiple regression models were used to test for an association between change in zBMI and HRQOL and WSQOL. Participants were excluded from models if they were missing data as described previously for one of the variables used. Outliers were not excluded from analyses as they were believed to be representative of the underlying population: 1) relatively extreme zBMI and change in zBMI values were expected given the starting point of participants and the effectiveness of the intervention, and 2) instrument scores lie within a fixed range and even extreme values may have been representative of the underlying population. To test for homogeneity between SHIFT and FOCUS results, two models were run: interaction between change in zBMI and study participated in associated with T2 total HRQOL and with T2 total WSQOL.

Mean change in zBMI from T1-T2 was the main predictor of interest in all but one model (negative values being decreases in zBMI from T1-T2 – improvements in child weight status). The response variable for models was an HRQOL or WSQOL total or domain score at T2. The corresponding score at T1 was also included as an adjustment variable. These three variables were considered to be the base model for each hypothesis. The model with a different predictor used change in zBMI from T2-

T3 as the main predictor but used a similar response variable as other models. It assessed if child self-reported WSQOL at T2 was associated with subsequent weight maintenance (T2-T3 zBMI change), not if T2-T3 WSQOL change was associated with weight maintenance. To test if the models were robust, potentially confounding variables were separately added to each model one at a time: child sex, child race/ethnicity, parent education, household income, and study participated in (SHIFT or FOCUS).

To minimize bias from the multiple comparisons problem, only some domain scores from child self-report and parent proxy-report were used in regression analyses. Total score was analyzed for child self-report and parent proxy-report for both HRQOL and WSQOL. Physical HRQOL was also analyzed for child self-report and parent proxy-report as children's physical health was expected to improve first or most immediately in conjunction with weight loss, with other domains improving after physical health improved. Different domains from child self-report and parent proxy-report were analyzed for WSQOL. Child self-reported self WSQOL was analyzed, as children's feelings and perceptions about their weight were expected to be significant for and impacted by weight change, and also important for long-term weight maintenance. Parents cannot directly observe their children's feelings and mental state, so parent proxy-reported self WSQOL was considered to be less significant. Parent proxy-reported social WSQOL was analyzed instead, as parents can directly observe their children's social lives and how their weight does or does not affect it. Child self-reported total WSQOL was selected as the score for exploring weight change during maintenance because children's opinions on how their weight impacts their life across multiple domains were hypothesized to have the strongest influence on their motivation and dedication to continue maintaining more healthy eating and physical activity behaviors and trying to lose weight after the intervention ended.

All analyses were conducted in Stata version 14.2 for Windows. Significance was defined at $\alpha = 0.05$, Bonferroni adjusted for nine models set significance at $p \leq 0.0056$. The models used were:

1. $T2\ HRQOL\ child\ total\ score = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ HRQOL\ child\ total\ score) + \beta_3(rotating\ confounder)$

2. $T2\ HRQOL\ child\ physical\ domain = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ HRQOL\ child\ physical\ domain) + \beta_3(rotating\ confounder)$
3. $T2\ WSQOL\ child\ total\ score = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ WSQOL\ child\ total\ score) + \beta_3(rotating\ confounder)$
4. $T2\ WSQOL\ child\ self\ domain = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ WSQOL\ child\ self\ domain) + \beta_3(rotating\ confounder)$
5. $T2\ WSQOL\ child\ summary\ score = \beta_0 + \beta_1(T2 - T3\ zBMI\ change) + \beta_2(T1\ WSQOL\ child\ summary\ score) + \beta_3(rotating\ confounder)$
6. $T2\ HRQOL\ parent\ total\ score = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ HRQOL\ parent\ total\ score) + \beta_3(rotating\ confounder)$
7. $T2\ HRQOL\ parent\ physical\ domain = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ HRQOL\ parent\ physical\ domain\ ) + \beta_3(rotating\ confounder)$
8. $T2\ WSQOL\ parent\ total\ score = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ WSQOL\ parent\ total\ score) + \beta_3(rotating\ confounder)$
9. $T2\ WSQOL\ parent\ social\ domain = \beta_0 + \beta_1(zBMI\ change) + \beta_2(T1\ WSQOL\ parent\ social\ domain) + \beta_3(rotating\ confounder)$

Results

The SHIFT study follow-up and analyses are ongoing, so the CONSORT diagram is only partially complete (Figure 1; only includes participants eligible for participation in this study). There were 170 SHIFT families who were treated by professionals and therefore eligible to be included in this study. Those 170 families attended at least one week of treatment, 117 (69%) of them completed at least some assessments at T2 (child height and weight, child instruments, or parent instruments), and 100 (59%) of them completed at least some assessments at T3. For the FOCUS study, participant flow has been described previously.[42] Of the 72 families who attended at least one week of treatment, 58 families (81%) completed at least some assessments at T2, and 54 families (75%) completed at least some assessments at T3.

Participant Demographics and Baseline Quality of Life

Participant demographics are described in Table 1, presented in aggregate and for each individual study and timepoint. Participating children were majority female (57.0%) and non-Hispanic white (61.2%). Participating parents were majority non-Hispanic white (72.3%) women (84.3%) from two parent homes (84.3%); 58.3% of participating parents graduated college or higher and 46.7% were from households that made $100,000 or more annually. There were significantly more female children (p = 0.049) in FOCUS (66.7%) than in SHIFT (52.9%). SHIFT parents had significantly higher BMIs than FOCUS parents at T1 (p = 0.00003). Household income in SHIFT was significantly higher than in FOCUS (p = 0.003), and more SHIFT families (88.2%) than FOCUS families (75.0%) were two-parent households (p = 0.01).

Table 2 presents cross-sectional (at T1) comparisons of child zBMI, child HRQOL, and child WSQOL by potential confounders. Girls had significantly lower zBMI than boys (p = 0.028), and non-Hispanic white children had lower zBMI than participants of color (p = 0.005). All but one quality of life score was not associated with any demographic variables. Household income was associated with child self-reported emotional HRQOL, but the Bonferroni adjusted pairwise comparisons show the scores did not have an increasing or decreasing trend with income.

Table 3 presents cross-sectional (at T1) comparisons of parent proxy-reported HRQOL and WSQOL by potential confounders. Parents of girls reported significantly higher school HRQOL score than parents of boys (p = 0.001). Household income was associated with four HRQOL or WSQOL scores. There was an ordered trend for total HRQOL; parents in families earning ≥$100,000 per year reported significantly higher total HRQOL for their child than parents in households earning <$50,000 per year or $50,000 - $99,999 per year. While household income was associated with physical HRQOL, social HRQOL, and social WSQOL, Bonferroni adjusted pairwise comparisons show there was not an ordered trend.

No average child HRQOL scores were below the at-risk cutoff, and only the average parent proxy-reported emotional HRQOL at T1 was below the cut-off (0.49 lower).

Missingness

Among participants who completed each timepoint's assessments, data were missing completely at random. Compared to participants who only completed T1, participants who completed at least one follow up assessment (T2 and/or T3) were not missing randomly: it is very likely that the families who did not lose weight or improve their HRQOL or WSQOL would be the families who decided not to return for assessments. At baseline, families who did not complete T2 or T3 were significantly more likely to have a lower income, have a higher child zBMI, have a higher parent BMI, and have reported lower HRQOL or WSQOL in five domains (child self-reported physical HRQOL, child self-reported total WSQOL, child-reported social WSQOL, parent proxy-reported total HRQOL, and parent proxy-reported physical HRQOL).

Change across Timepoints

Table 4 presents zBMI, child self-reported HRQOL scores, and child self-reported WSQOL scores, change values, 95% CI, and p-values for significant change at each timepoint. zBMI significantly decreased from T1-T2 and significantly increased from T2-T3, resulting in a net significant decrease from T1-T3. For context, children reduced their absolute BMI on average by -2.0 ± 1.9 (mean ± SD) from T1-T2, increased their BMI by 1.2 ± 1.4 from T2-T3, and decreased it (net) by -0.84 ± 2.6 from T1-T3. Note that children's BMI is expected to increase as they age and grow, so weight status improvements are greater than absolute BMI change reveals. A metric standardized for age and sex, zBMI, is more appropriate for examining child weight status change. All child self-reported HRQOL and WSQOL scores significantly increased from T1-T2, except for school HRQOL. Although the increase to school HRQOL from T1-T2 was not significant, it was the only quality of life score to significantly increase from T2-T3, resulting in a significant overall increase from T1-T3. From T2-T3, child self-reported HRQOL and WSQOL improvements were maintained, with no significant decreases or increases other than school HRQOL.

From T1-T3, all child self-reported HRQOL and WSQOL scores significantly increased. Only the child self-reported total HRQOL and child self-reported emotional HRQOL average increases from T1-T2 and T1-T3 exceeded the minimal clinically important difference (minimal clinically important differences for WSQOL have not been reported). The percentage of children whose self-reported HRQOL scores exceeded the minimal clinically important difference between each timepoint are reported in Table 5.

Table 6 presents parent proxy-reported HRQOL scores and parent proxy-reported WSQOL scores, change values, 95% CI, and p-values for significant change for each timepoint. All parent proxy-reported scores significantly increased from T1-T2 and did not change significantly from T2-T3, resulting in significant improvements from T1-T3 for all HRQOL and WSQOL total and domain scores. From T1-T2, only the total HRQOL score, HRQOL physical domain, and HRQOL emotional domain increases surpassed the minimum clinically important difference, and from T1-T3 only the total HRQOL score, HRQOL emotional domain, and HRQOL social domain surpassed the minimum clinically important difference. The percentage of parents whose proxy-reported scores exceeded the minimal clinically important difference are reported in Table 5.

Comparison of Child and Parent Scores

Table 7 presents associations of corresponding child self-reported and parent proxy-reported HRQOL and WSQOL at each timepoint. At all timepoints and for all scores, children's self-reports and parents' proxy-reports were significantly correlated (all p's < 0.01). For HRQOL scores, paired t-tests show that children rated their HRQOL at T1 higher than their parent's proxy-report (total, physical, and social were significant), and that there were no differences at T2 or T3. Children rated their WSQOL significantly higher at all timepoints than their parent's proxy-report.

Relationship between zBMI and Quality of Life Changes

There was no interaction between change in zBMI and study participated in (FOCUS vs. SHIFT) when tested for an association with child self-reported or parent proxy-reported T2 total HRQOL or T2 total WSQOL (all p's > 0.05). There was low collinearity among potential confounders—all variance inflation factors were < 2.5. Tables 8 and 9 present model results, including the following parameters: Pearson's r between the dependent variable (HRQOL or WSQOL score) and the main predictor (change in zBMI), model slopes, 95% confidence intervals, standard errors, and p-values. All associations found were in the expected direction: greater decrease in zBMI associated with a greater improvement in HRQOL or WSQOL.

There was no evidence of non-linearity in any model. Residuals in most models were heteroskedastic, which is mostly attributable to a ceiling effect in the underlying data. Most child HRQOL, child WSQOL, and parent HRQOL scores were relatively high at T2 (Tables 4 and 6), meaning that there was an upper bound on how large positive residuals could be. This resulted in a narrower band of residuals for higher scores than for lower scores. The models used robust standard errors, mitigating concerns about heteroskedasticity. Most of the models had non-normal residuals, though the Central Limit Theorem minimizes any concerns. Table 8 and Table 9 present model results from multiple regression analyses for child self-report and parent proxy-report, respectively.

Child Self-Reported HRQOL and WSQOL

Multiple regression testing showed that the association between T1-T2 change in zBMI and T2 child self-reported total HRQOL (adjusting for T1 child self-reported total HRQOL) was not significant (p = 0.09), although the zero-order association was significant (p = 0.030). Including potential confounders one at a time did not significantly affect the model (all slopes similar and all p > 0.005).

The association between T1-T2 change in zBMI and T2 child self-reported physical HRQOL (adjusting for T1 child self-reported physical HRQOL) was not significant ($p = 0.29$). Including potential confounders one at a time did not significantly change the model (all slopes similar and all $p > 0.005$).

The association between T1-T2 change in zBMI and T2 child self-reported total WSQOL (adjusting for T1 child self-reported total WSQOL) was significant ($p = 0.003$), and the zero-order association was significant ($p = 0.0003$). Including potential confounders one at a time showed that the model is robust: $p \leq 0.005$ for household income, child race/ethnicity, parent education, and child sex, and $p = 0.006$ for study participated in.

The association between T1-T2 change in zBMI and T2 child self-reported self WSQOL (adjusting for T1 child self-reported self WSQOL) was not significant ($p = 0.049$), although the zero-order association was significant ($p = 0.004$). Including potential confounders one at a time did not significantly change the model (all slopes similar and all $p > 0.005$).

Finally, the association between T2-T3 change in zBMI (i.e., maintenance after the intervention ends) and T2 child self-reported total WSQOL (adjusting for T1 child self-reported total WSQOL) was not significant ($p = 0.42$). Including potential confounders one at a time did not significantly change the model (all $p > 0.005$ and all slopes similar).

Parent Proxy-Reported HRQOL and WSQOL

Multiple regression testing showed that the association between T1-T2 change in zBMI and T2 parent proxy-reported total HRQOL (adjusting for T1 parent proxy-reported total HRQOL) was significant ($p = 0.0005$), and the zero-order association was significant ($p = 0.0005$). Including potential confounders one at a time did not significantly affect the model (all slopes similar and all $p \leq 0.0012$).

The association between T1-T2 change in zBMI and T2 parent proxy-reported physical HRQOL (adjusting for T1 parent proxy-reported physical HRQOL) was significant ($p < 0.0001$), and the zero-order association was significant ($p = 0.0001$). Including potential confounders one at a time did not significantly affect the model (all slopes similar and all $p < 0.0001$).

The association between T1-T2 change in zBMI and T2 parent proxy-reported total WSQOL (adjusting for T1 parent proxy-reported total WSQOL) was significant ($p < 0.0001$), and the zero-order association was significant ($p < 0.0001$). Including potential confounders one at a time did not significantly affect the model (all slopes similar and all $p < 0.0001$).

Finally, the association between T1-T2 change in zBMI and T2 parent proxy-reported social WSQOL (adjusting for T1 parent proxy-reported social WSQOL) was significant ($p < 0.0001$), and the zero-order association was significant ($p = 0.0001$). Including potential confounders one at a time did not significantly affect the model (all slopes similar and all $p < 0.0001$).

Discussion

This study examined the association between change in child weight and change in child self-reported and parent proxy-reported HRQOL and WSQOL during participation in a family-based weight management intervention. On average, children significantly reduced their zBMI, and all but one child self-reported or parent proxy-reported HRQOL or WSQOL domain significantly increased from T1-T2; all significantly increased from T1-T3. Parent proxy-reported WSQOL was significantly lower than child self-reported WSQOL at all timepoints and for all domains. All associations between change in child zBMI and change in HRQOL or WSQOL were in the hypothesized direction. For child self-report, only total WSQOL was significantly associated with change in child zBMI in the full model. As a more specific construct, WSQOL was expected to change more and was therefore the most likely model to be significant. For parent proxy-proxy report, all tested domains were significant such that improvements in children's zBMI were related to improvements in parents' perceptions of their children's general and weight-specific quality of life.

Many other studies have also found that interventions improved children's zBMI,[54–57] HRQOL,[54,55,57–59] and/or WSQOL.[55,56] But, they did not compare the concepts quantitatively (e.g., correlations or associations). Intervention studies that reported the correlation or association between zBMI and HRQOL and/or WSQOL had both significant and non-significant findings.[29,37–41] These discrepancies suggest that improvements to children's HRQOL and WSQOL during intervention, at least as perceived by the children themselves, cannot be fully explained by weight loss. A cross-sectional study by Jalali-Farahani et al. similarly found that child self-reported HRQOL depended more on children's self-perception of their weight status than on their actual weight status.[60]

In the FOCUS and SHIFT interventions, reduction in zBMI was significantly associated with child-reported total WSQOL. Children reported very low WSQOL at T1 and on average experienced positive changes (i.e., reduction) in weight status by T2. Being at a lower weight through intervention was associated with significant reductions in the negative effects weight was having on their lives. However, there was not a significant association between children's WSQOL at post-treatment and their weight status change through follow-up. This is probably because the association was driven by positive weight status changes and WSQOL improvements during treatment. Lack of continued improvement in weight in the absence of being engaged with a weight intervention program thus nullified the association. Change in child self-reported total HRQOL, physical HRQOL, and self WSQOL were not significantly associated with zBMI reduction.

WSQOL is condition-specific and therefore may be more responsive to change than generic HRQOL. The absence of effects on children's report of general HRQOL found in this study may be explained by the length of the intervention or insufficient zBMI change. It is possible that a longer intervention would have yielded a greater number of significant associations between change in child zBMI and change in each of the child self-reported HRQOL domains. Children reduced their zBMI enough that they perceived fewer negative impacts of their weight on their quality of life, but greater zBMI change may have been required to improve their perceived health or physical functioning generally. This may also explain significant associations between weight loss and change in child self-reported WSQOL in other studies.[29,37,40] While others did find some associations between weight loss and change in child self-reported HRQOL,[37,38] most tested domains for both child self-reported HRQOL and WSQOL were not significant in prior research.[37–41] The association with child self-reported self WSQOL may not have been significant in this study for several possible reasons: because the intervention was not long enough for children to internalize fully the changes they made, because the intervention was not long enough for them to perceive positive effects on their lives, or because they had not lost enough weight to feel differently about their lives. Other interventions also reported non-significant associations between change in child weight status and change in children's perceptions within psychosocial domains. While psychosocial changes are less concrete, physical changes are more tangible, which may make it easier for children to identify these changes.

zBMI and child self-reported HRQOL each improved independently, indicating that improvements to HRQOL do not always follow weight loss in 7-11-year-old children. As such, interventions can aim to improve HRQOL regardless of change in weight, thereby improving children's perceptions of the impact of their health and weight on their lives. The intervention studied here was able to do so with great success, including four HRQOL domains that increased more than the minimal clinically important difference.

In the FOCUS and SHIFT studies, parents reported significant improvements in their children's HRQOL and WSQOL across all domains, and these changes were consistently associated with the magnitude of improvements in their children's weight status. This suggests that parents perceived improvements throughout different areas of their children's lives during these weight management interventions and that these perceptions were sustained for at least 6 months after the intervention. Few intervention studies have measured parent proxy-report of children's quality of life or change during intervention. Those that did also found a negative association between children's pre/post zBMI reduction and parent proxy-reported physical WSQOL[40] and a negative correlation between child pre/post zBMI reduction and parent proxy-reported physical HRQOL.[39] While child self-reported WSQOL was low at baseline, parent proxy-reported WSQOL was significantly lower. It also significantly increased, though did not quite reach the level of other scores—parents still saw negative impacts of their children's weight on their children's lives. Yet, children's weight loss was still associated with parent proxy-reported improvements in how their children's overall and physical health affected their lives, and in how their weight affected their lives (generally) and their social lives. Parents have an intimate window into their children's lives and are uniquely positioned to observe how their children's health and weight affect them, be it through observing how their children have more energy when doing activities or playing or seeing how their children interact with and talk about their friends. Interventions can work with parents to help them use this perspective to help their children appreciate the positive effects of losing weight, especially in the aforementioned psychosocial domains.

Children's self perceptions at baseline and the degree of change in their self-reported HRQOL and WSQOL scores could explain why so few models examining the relationship between child change in weight status and change in child self-reported quality of life were significant. Children's baseline quality of life scores were quite low, and of the domains used in child models, only child self-reported total HRQOL increased on average more than the minimal clinically important difference from T1-T2. However, all tested parent-proxy report quality of life domains were significant, but parent perceptions at baseline were even lower, and parent proxy-reported total HRQOL and parent proxy-reported physical HRQOL were the only domains that increased on average more than the minimal clinically important difference from T1-T2. Associations between change in zBMI and change in HRQOL and WSQOL do not seem to be dependent on whether HRQOL or WSQOL improvements exceeded the minimal clinically important difference, but instead appear to be determined by whether it was child self-report or parent proxy-report.

The relationship between an intervention's effect on zBMI and HRQOL and/or WSQOL could have significant implications for an intervention's effectiveness. Parents believed that reducing zBMI improved their children's lives, which may incentivize them to continue enforcing and encouraging healthy choices. And because parents make many of their child's eating decisions (what food they choose to buy and provide), their continued efforts could have significant long-term impacts on their child. If children's self-perceptions truly are slow to respond to weight loss and if they do not see improvements to the impact of their health or their weight on their lives within 20 weeks, then that may demotivate them and lead them to resist continued efforts to make healthier choices. Though parents make many eating decisions for their children, children still have some autonomy in their choices. Many participants struggle with long-term maintenance of lifestyle changes made during an intervention once it ends, but few trials explore the impact of HRQOL or WSQOL on maintenance.[14,61] In this study, improvements to total WSQOL were not associated with maintenance of weight loss at T3 despite being significant at T2. Factors that affect maintenance are not well understood and bear further study. Use of a longer intervention may reinforce total WSQOL improvements enough that they can have a larger impact on maintenance once the intervention ends.

There are potential strengths and weaknesses associated with both child self-reported and parent proxy-reported quality of life. Children know themselves and their lived experience best, but parents may have a broader perspective and be able to recognize changes in their child's attitudes and social interactions. Therefore, including the opinions of both children and their parents yields the most comprehensive data. However, previous studies are inconsistent in whether they measure child self-report and/or parent proxy-report, and whether they measure HRQOL and/or WSQOL. Some interventions only measured child self-report,[37,38,41,55–58] some interventions only measured parent proxy-report,[39,54] some observational studies only measured child self-report,[62,63] some observational studies measured both,[64–67] and some reviews reported both.[14,59,68] Because of this inconsistency in data collection, parents' unique perspectives of the impact of interventions on their children are absent from the literature. Child self-report and parent proxy-report have been found to have low to moderate agreement,[69] so in a family-based intervention such as the one used here, measuring both captures the family's perspective and the effect of the intervention more completely. Agreement between child self-report and parent proxy-report in this study was also low to moderate at each timepoint (although statistically significant), and child self-reported HRQOL and WSQOL were significantly higher than the matching parent proxy-reported scores at T1. However, child self-report and parent proxy-report both significantly increased from T1-T2, did not significantly change from T2-T3, and resulted in significant change in all domains from T1-T3. At T2, parent proxy-reported HRQOL improved by enough that it was no longer significantly different than child self-reported HRQOL, and parent proxy-reported WSQOL remained significantly lower than child self-reported scores—despite WSQOL being more responsive than HRQOL. This raises multiple possibilities: 1) that parents over-estimated the benefits that improved weight status had on their child's quality of life, possibly due to hope or confirmation bias, and/or 2) that children did not realize the extent to which improved weight status had increased their quality of life, possibly due to all-or-nothing thinking or lack of perspective.

Considering findings from regression models, improvements to child self-reported HRQOL were generally not associated with changes in child weight status and perhaps due to other aspects of the intervention (e.g., attention and engagement with their parent, opportunity to be in treatment with other children and discuss issues related to weight). In contrast, parent proxy-reported changes in quality of life were consistently associated with children's zBMI reductions. Parents perceived large negative impacts of weight on their children's lives at baseline, and their perceptions likely did not improve by enough to match children's perceptions because zBMI reductions were not great enough.

Similar to the findings from this study, it is significantly more common for child self-report to be higher than parent proxy-report,[65,66,68] though some previous studies found the opposite.[64,67] Ideally, child self-reported improvements in quality of life would be strongly associated with weight loss like parent proxy-report: that children, like parents in this study, would feel that the impact of their health and their weight on their life had improved, and that they would experience fewer morbidities associated with overweight/obesity. As it was the parents who mostly chose and consented for their families to enroll in the studies (and in the interventions), it is not surprising that parent proxy-reported quality of life started lower and increased more than child self-reported quality of life, as parents who perceived poor quality of life for their children would be more likely to join a weight management study. It also follows that if parents perceive impaired quality of life in their children due to their health or weight, then they would believe improved weight status would improve their children's quality of life.

To increase the negative association between zBMI (reduction) and HRQOL and WSQOL (improvements), it is unclear if interventions should focus on 1) helping children realize how the changes they are making are improving their quality of life (i.e., improving child self-perception so they recognize how their lives have improved), 2) identifying concrete ways to mitigate the impact of children's weight on their lives (i.e., losing weight has not significantly improved children's lives and parents are seeing what they want to see), or 3) modifying content to help further improve children's quality of life. The strong associations found between zBMI reduction and parent proxy-reported HRQOL and WSQOL provide evidence for the first possibility, and children still being overweight/obese at T2 despite zBMI reductions provides evidence for the second possibility. Regardless, interventions can incorporate content to help children appreciate how their lives have improved even if they are still overweight/obese and encourage parents to share the improvements that they see with their children so they recognize their progress.

Strengths and Limitations

This study had several strengths. zBMI is an objective measure and well-suited for assessing change in weight status over time for boys and girls of different ages. The PedsQL survey is a well-established survey for measuring HRQOL, and similarities between the content of the child self-reported and parent proxy-reported versions facilitated comparisons. Participants were recruited from a wide geographic area around Seattle, including cities with different demographic characteristics, including varying income levels. The weight management intervention has been previously validated and is effective, and inclusion of parents in the intervention also allowed for parent-child comparisons.

This study also had several limitations, including threats to internal validity, threats to external validity, and threats to construct validity. Threats to internal validity include the study design, history threats, maturation threats, regression to the mean, attrition, and a narrow range of zBMI change. The FOCUS and SHIFT study designs did not include a control group of non-intervention participants (i.e., usual care), so it is not definitive that changes made by participants are solely due to the intervention. Similarly, history threats and maturation threats are of concern. However, previous longitudinal data show that children with overweight/obesity who do not receive intervention tend to remain at their weight status[9,70] and have decreasing HRQOL over time.[63] Use of zBMI also mitigates concerns about maturation threats by adjusting for age. Regression to the mean may explain some of the observed zBMI reductions, but again, overweight/obese individuals tend to stay overweight/obese. Attrition at T2 and T3 are of concern, and data were missing not at random. Participants who did not complete T2 or T3 likely did not have success reducing their zBMI, which could artificially yield significant associations. Nearly all participants reduced their zBMI: zBMI change values had a narrow range, which may have reduced correlation coefficients (biased towards the null).

Threats to external validity and generalizability include recruitment methods and participant demographics. Participants were primarily white and high income, so the associations may not hold for other families. However, participants were recruited from five cities in the greater Seattle area, minimizing these concerns somewhat.

Threats to construct validity include use of an adapted instrument to measure children's WSQOL and presence of a ceiling effect. The PedsQL was not validated on 7-year-olds, but all children received assistance with instruments as needed. The versions of the YQOL-W used have not been rigorously tested. However, the child version was only changed to match the age group, and mirroring it for the parent version allowed for straightforward comparisons between child self-report and parent proxy-report. A ceiling effect also limits the accuracy of regression models, though use of robust standard errors minimizes heteroskedasticity concerns.

Future Directions

Child self-reported WSQOL, parent proxy-reported HRQOL, and parent proxy-reported WSQOL are relatively under-studied in intervention trials and should be explored further. Additionally, the association between change in children's zBMI and HRQOL/WSQOL is not well known. Conducting randomized control studies that measure HRQOL and WSQOL throughout the intervention would determine if they change concurrently or consecutively with zBMI, and including long-term follow up visits with both parents and children for multiple years after treatment would provide valuable information about intervention content, focus, and long-term effectiveness. Trials can also examine if change in HRQOL or WSQOL scores predict treatment success, in which case interventions can target HRQOL and WSQOL directly. Furthermore, a validated instrument to measure parent proxy-reported WSQOL in young children should be developed.

Conclusions

This study provides evidence that change in children's weight status in a family-based weight management intervention is significantly associated with child self-reported WSQOL and multiple aspects of parent proxy-reported HRQOL and WSQOL. Compared to children's self-perceived HRQOL and WSQOL, parents' perceptions of their children's HRQOL and WSQOL were more responsive to their children's weight change. As zBMI and HRQOL and WSQOL do not always improve concurrently, interventions can aim to help children realize the improvements that weight loss is having in their lives. This may increase the effectiveness of interventions and improve long-term maintenance. Child self-report and parent proxy-report provide different information and both should be measured to better understand the impact of family-based interventions.

Acknowledgements

This study was supported by the US Department of Health and Human Services, Health Resources and Services Administration's Maternal and Child Health Bureau (Title V, Social Security Act), grant #T76MC00011. The FOCUS study (R21 HD054871) and SHIFT study (R01DK104863) were funded by the National Institutes of Health. I would like to thank Maya Rowland for her assistance with obtaining and troubleshooting the data, and Cherie Abbey, Antonia Abbey, and Robin Abbey-Lee for their editing and feedback. I would like to thank Liliya Shtikel, Ashley Nguyen, Sara Magnusson, and Ami Hanna for their support.

Figure 1. Preliminary CONSORT diagram for the SHIFT study.

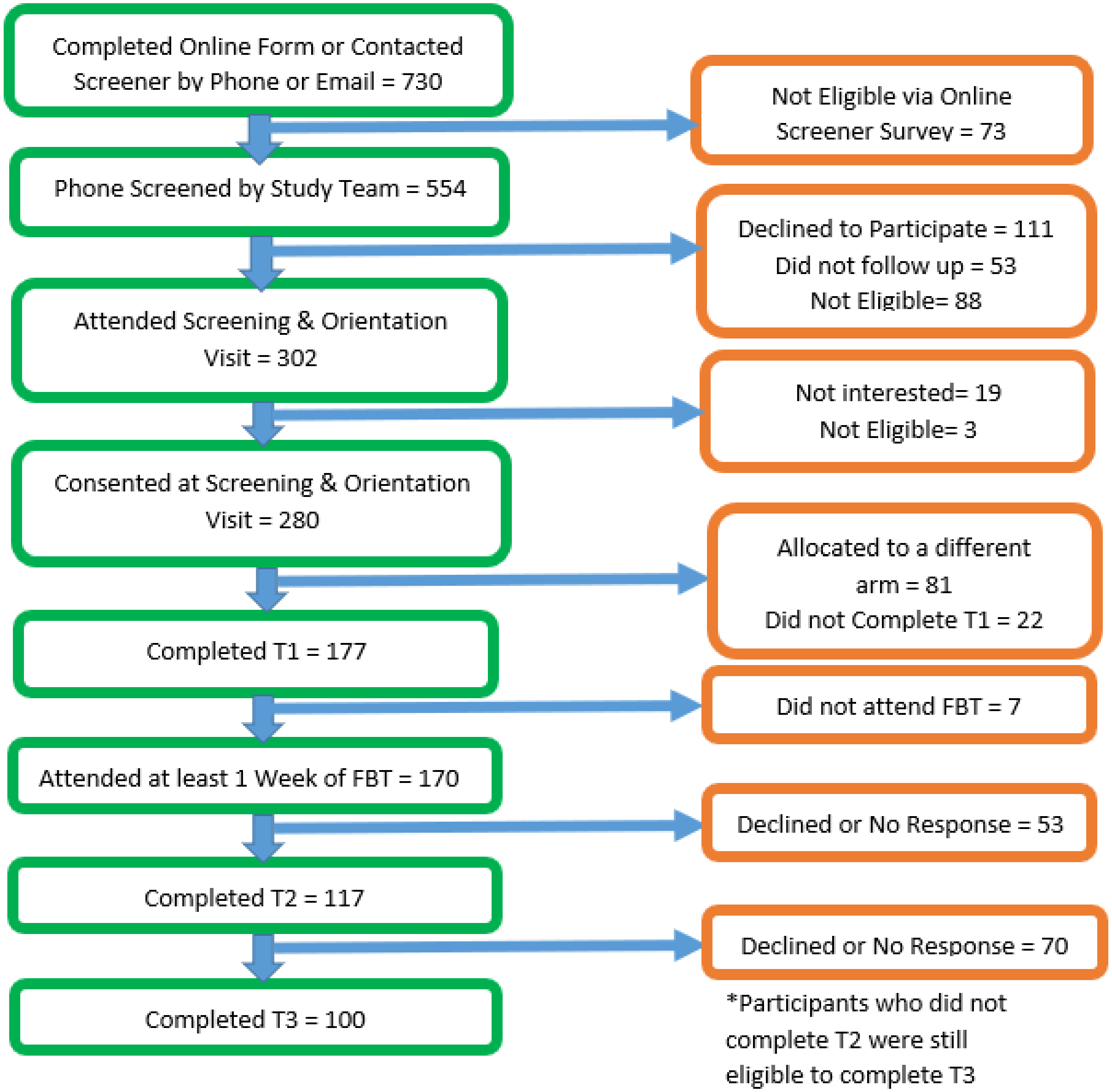

Table 1. Demographic characteristics of participants, stratified by study participated in and timepoint.

Child Characteristics	Combined (n = 242)	SHIFT (n = 170)	FOCUS (n = 72)	Comparison (p-value)
Age, mean ± SD*	9.9 ± 1.3	9.9 ± 1.3	9.7 ± 1.4	0.26
Female, n (%)**	138 (57.0)	90 (52.9)	48 (66.7)	**0.049**
Race/Ethnicity, n (%)**†				0.82
Non-Hispanic White	148 (61.2)	103 (60.6)	45 (62.5)	
People of Color	93 (38.4)	66 (38.8)	27 (37.5)	
Missing	1 (0.4)	1 (0.6)	0 (0.0)	
Parent Characteristics				
Age, mean ± SD*	42.4 ± 6.2	42.6 ± 6.1	41.9 ± 6.4	0.45
BMI, mean ± SD*	36.7 ± 8.6	38.1 ± 8.6	33.2 ± 7.7	**0.00003**
Female, n (%)**	204 (84.3)	141 (82.9)	63 (87.5)	0.37
Race/Ethnicity, n (%)**†				0.94
Non-Hispanic White	175 (72.3)	120 (70.6)	55 (76.4)	
People of Color	55 (22.7)	38 (22.4)	17 (23.6)	
Missing	12 (5.0)	12 (7.1)	0 (0.0)	
Education, n (%)**				0.80
Completed some college or less	100 (41.3)	71 (41.8)	29 (40.3)	
Graduated college or higher	141 (58.3)	98 (57.7)	43 (59.7)	
Missing	1 (0.4)	1 (0.6)	0 (0.0)	
Relationship to Child, n (%)***				0.69
Mother	205 (84.7)	142 (83.4)	63 (87.5)	
Father	36 (14.9)	27 (15.9)	9 (12.5)	
Other	1 (0.41)	1 (0.6)	0 (0.0)	
Household Characteristics				
Household Income, n (%)**				**0.003**
< $50,000 per year	47 (19.4)	26 (15.3)	21 (29.2)	
$50,000 - $99,999 per year	73 (30.2)	45 (26.5)	28 (38.9)	
≥ $100,000 per year	113 (46.7)	90 (52.9)	23 (31.9)	
Missing	9 (3.7)	9 (5.3)	0 (0.0)	
Two Parent Household, n (%)**	204 (84.3)	150 (88.2)	54 (75.0)	**0.01**

Bold p-values are significant at $p < 0.05$.

*Demographic characteristic was compared across studies using a two-sample t-test.

**Demographic characteristic was compared across studies using Pearson's chi-squared test.

***Demographic characteristic was compared across studies using Fisher's exact test.

†Uncategorized race/ethnicity data are presented in Supplementary Table 1.

Table 2. Child zBMI and child self-reported quality of life scores at T1, stratified by demographics.

Demographics (N)	**Child zBMI**	**HRQOL: Total**	**HRQOL: Physical**	**HRQOL: Emotional**	**HRQOL: Social**	**HRQOL: School**	**WSQOL: Total**	**WSQOL: Self**	**WSQOL: Social**	**WSQOL: Environment**
Child Sex										
Male (104)	2.23 ± 0.36	72.0 ± 16.8	75.3 ± 19.2	65.4 ± 21.5	74.5 ± 20.3	71.2 ± 22.0	75.3 ± 21.2	60.5 ± 30.1	80.0 ± 21.2	75.0 ± 33.0
Female (138)	2.11 ± 0.40	73.4 ± 13.5	76.8 ± 16.3	65.4 ± 22.1	74.7 ± 18.9	74.6 ± 16.9	74.8 ± 17.0	58.9 ± 28.2	81.0 ± 16.4	69.2 ± 31.8
*p**	**0.028**	0.92	0.76	0.97	0.94	0.58	0.28	0.55	0.46	0.071
Child Race/Ethnicity										
Non-Hispanic White (148)	2.11 ± 0.38	71.3 ± 15.5	75.1 ± 18.2	63.3 ± 22.8	73.3 ± 20.1	71.8 ± 19.7	73.9 ± 18.6	58.4 ± 28.5	79.4 ± 18.6	72.3 ± 31.7
People of Color (93)	2.24 ± 0.39	74.9 ± 14.0	77.7 ± 16.5	68.7 ± 19.9	76.4 ± 18.3	74.9 ± 18.7	77.4 ± 18.1	62.2 ± 29.2	83.1 ± 17.3	71.4 ± 33.0
*p**	**0.005**	0.096	0.35	0.083	0.28	0.19	0.15	0.31	0.11	0.95
Parent Education										
Did not graduate college (100)	2.19 ± 0.41	72.3 ± 14.9	76.3 ± 17.8	66.7 ± 21.5	72.9 ± 20.5	71.1 ± 18.9	74.9 ± 18.3	58.9 ± 30.0	79.9 ± 17.7	74.2 ± 31.6
Graduated college or higher (141)	2.13 ± 0.37	73.0 ± 15.1	76.0 ± 17.5	64.5 ± 22.2	75.7 ± 18.7	74.4 ± 19.6	75.5 ± 18.6	60.4 ± 28.0	81.5 ± 18.5	70.4 ± 32.5
*p**	0.12	0.83	0.73	0.43	0.39	0.099	0.69	0.75	0.38	0.32
Household Income										
< $50,000 (47)	2.16 ± 0.41	73.5 ± 14.0	75.9 ± 17.6	70.4 ± 20.9[b]	74.8 ± 19.4	71.4 ± 18.0	75.1 ± 18.3	59.0 ± 30.9	80.2 ± 17.9	76.6 ± 30.0
$50,000 - $99,999 (73)	2.23 ± 0.35	69.2 ± 16.2	72.7 ± 18.8	59.7 ± 24.4[a]	71.9 ± 20.1	70.4 ± 20.3	71.7 ± 19.6	55.6 ± 29.1	78.0 ± 21.2	64.6 ± 34.0
≥ $100,000 (113)	2.10 ± 0.39	75.3 ± 13.6	79.1 ± 15.0	67.2 ± 20.1[ab]	76.3 ± 19.0	76.6 ± 16.8	76.7 ± 17.8	61.5 ± 27.8	82.4 ± 16.2	73.5 ± 31.9
*p***	0.090	0.057	0.12	**0.035**	0.30	0.057	0.22	0.32	0.63	0.078

Bold p-values are significant at $p < 0.05$.

*Wilcoxon rank-sum test

**Kruskal Wallace test

[ab] Groups that are *not* significantly different from each other (Bonferroni-adjusted $p < 0.05$) if the Kruskal Wallace test was significant.

Table 3. Parent proxy-reported quality of life scores at T1, stratified by demographics.

Demographics (N)	HRQOL: Total	HRQOL: Physical	HRQOL: Emotional	HRQOL: Social	HRQOL: School	WSQOL: Total	WSQOL: Self	WSQOL: Social	WSQOL: Environment
Child Sex									
Male (104)	68.0 ± 14.7	72.5 ± 19.3	61.5 ± 17.6	67.8 ± 20.2	67.8 ± 18.9	46.4 ± 21.8	26.0 ± 23.2	56.5 ± 23.2	36.5 ± 33.6
Female (138)	70.6 ± 14.9	71.8 ± 21.0	63.9 ± 18.0	70.6 ± 18.4	75.7 ± 17.3	47.1 ± 18.8	25.5 ± 22.2	59.2 ± 19.9	29.7 ± 28.2
*p**	0.16	0.98	0.16	0.30	**0.001**	0.54	0.96	0.21	0.18
Child Race/Ethnicity									
Non-Hispanic White (148)	69.3 ± 15.8	71.9 ± 20.8	62.7 ± 18.2	69.0 ± 20.4	72.2 ± 18.2	45.6 ± 19.6	24.9 ± 21.4	57.0 ± 21.0	29.9 ± 30.3
People of Color (93)	69.9 ± 13.5	72.5 ± 19.5	63.1 ± 17.5	69.9 ± 17.2	72.4 ± 18.9	48.5 ± 20.9	26.3 ± 24.1	59.8 ± 22.1	36.4 ± 30.7
*p**	0.97	0.99	0.92	0.88	0.80	0.33	0.86	0.32	0.083
Parent Education									
Did not graduate college (100)	68.4 ± 15.9	70.0 ± 20.9	63.8 ± 18.6	67.8 ± 21.6	71.0 ± 19.1	45.4 ± 21.6	25.8 ± 24.6	56.5 ± 22.1	29.5 ± 30.9
Graduated college or higher (141)	70.3 ± 14.1	73.5 ± 19.7	62.2 ± 17.4	70.4 ± 17.4	73.2 ± 18.0	47.6 ± 19.0	25.3 ± 20.8	59.2 ± 20.9	34.5 ± 30.2
*p**	0.31	0.19	0.37	0.41	0.41	0.16	0.74	0.26	0.15
Household Income									
< $50,000 (47)	66.9 ± 13.6[a]	70.9 ± 18.1[ab]	60.0 ± 19.2	66.1 ± 18.6[ab]	68.0 ± 18.5	45.8 ± 20.0	23.7 ± 23.9	57.8 ± 19.4[ab]	30.3 ± 32.9
$50,000 - $99,999 (73)	66.0 ± 16.0[a]	65.6 ± 22.1[a]	62.2 ± 18.3	65.6 ± 20.3[a]	71.1 ± 19.0	43.2 ± 20.0	25.7 ± 22.2	53.2 ± 21.1[a]	27.7 ± 27.2
≥ $100,000 (113)	73.0 ± 13.7	76.8 ± 18.7[b]	64.4 ± 16.7	73.2 ± 18.3[b]	75.3 ± 17.4	49.2 ± 19.4	25.1 ± 21.7	61.6 ± 21.1[b]	35.7 ± 31.1
*p***	**0.004**	**0.001**	0.34	**0.014**	0.072	0.082	0.75	**0.030**	0.20

Bold p-values are significant at $p < 0.05$.

*Wilcoxon rank-sum test

**Kruskal Wallace test

[ab] Groups that are *not* significantly different from each other (Bonferroni-adjusted $p < 0.05$) if the Kruskal Wallace test was significant.

Table 4. zBMI and child self-reported quality of life values and change across timepoints.

Measure	T1*	T2*	T3*	T1-T2 Change**	T1-T2 p-value***	T2-T3 Change**	T2-T3 p-value***	T1-T3 Change**	T1-T3 p-value***
zBMI	2.2 ± 0.4	1.8 ± 0.6	1.8 ± 0.6	-0.33 (-0.37, -0.29)	**<0.0001**	0.05 (0.02, 0.08)	**0.0013**	-0.28 (-0.33, -0.23)	**<0.0001**
HRQOL: Total	72.8 ± 15.0	78.9 ± 14.0	80.4 ± 13.5	5.4 (3.5, 7.3) †	**<0.0001**	1.5 (-0.3, 3.4)	0.0992	6.9 (4.7, 9.1) †	**<0.0001**
HRQOL: Physical	76.2 ± 17.6	82.2 ± 14.0	83.5 ± 12.6	4.6 (2.4, 6.7)	**<0.0001**	1.3 (-0.7, 3.2)	0.205	5.8 (3.2, 8.5)	**<0.0001**
HRQOL: Emotional	65.4 ± 21.8	75.2 ± 19.3	74.6 ± 18.9	9.5 (6.3, 12.6) †	**<0.0001**	-0.9 (-3.7, 2.0)	0.5458	9.3 (6.0, 12.6) †	**<0.0001**
HRQOL: Social	74.6 ± 19.5	80.8 ± 19.3	82.1 ± 18.6	6.4 (3.4, 9.4)	**<0.0001**	1.8 (-1.0, 4.6)	0.2026	8.0 (4.7, 11.3)	**<0.0001**
HRQOL: School	73.1 ± 19.3	75.4 ± 18.4	79.6 ± 18.1	1.6 (-0.9, 4.1)	0.2037	4.0 (1.5, 6.6)	**0.0024**	5.1 (2.6, 7.6)	**0.0001**
WSQOL: Total	75.0 ± 18.9	83.2 ± 16.4	82.8 ± 17.7	6.8 (4.3, 9.3)	**<0.0001**	0.2 (-2.0, 2.4)	0.8782	6.3 (3.2, 9.5)	**0.0001**
WSQOL: Self	59.6 ± 29.0	74.3 ± 24.8	73.5 ± 25.8	12.7 (8.5, 16.9)	**<0.0001**	-1.0 (-5.0, 3.0)	0.6348	11.7 (6.5, 17.0)	**<0.0001**
WSQOL: Social	80.6 ± 18.6	87.0 ± 15.3	86.6 ± 16.8	5.3 (2.8, 7.8)	**0.0001**	0.3 (-2.0, 2.5)	0.8105	4.8 (1.7, 8.0)	**0.0026**
WSQOL: Environment	71.7 ± 32.4	78.2 ± 27.7	79.1 ± 25.4	4.9 (0.6, 9.1)	**0.0246**	1.7 (-2.0, 5.5)	0.3631	6.0 (1.1, 10.8)	**0.016**

*Values for each timepoint presented as mean ± SD

**Change presented as mean (95% CI)

***Significant change between timepoints was tested using paired t-tests.

†PedsQL change values that are greater than the minimum clinically important difference;[50] there is no reported MCID for the YQOL-W

Bold p-values are significant at $p < 0.05$

Table 5. Percentage of participants whose HRQOL scores exceeded the minimal clinically important difference between timepoints

Measure	T1-T2	T2-T3	T1-T3
		Child Self-Report	
HRQOL: Total	53.0%	34.7%	55.6%
HRQOL: Physical	39.9%	24.5%	41.8%
HRQOL: Emotional	51.2%	21.1%	45.8%
HRQOL: Social	43.5%	25.9%	49.7%
HRQOL: School	31.5%	31.3%	41.2%
		Parent Proxy-Report	
HRQOL: Total	59.9%	28.4%	60.8%
HRQOL: Physical	45.9%	18.2%	44.4%
HRQOL: Emotional	55.8%	20.9%	54.9%
HRQOL: Social	53.5%	31.8%	54.2%
HRQOL: School	45.0%	28.8%	40.1%

Table 6. Parent proxy-reported quality of life values and change across timepoints.

Measure	T1*	T2*	T3*	T1-T2 Change**	T1-T2 p-value***	T2-T3 Change**	T2-T3 p-value***	T1-T3 Change**	T1-T3 p-value***
HRQOL: Total	69.5 ± 14.9	79.0 ± 13.5	78.4 ± 14.8	8.5 (6.7, 10.3)†	**>0.0001**	-0.9 (-2.7, 0.9)	0.3363	7.5 (5.5, 9.6)†	**<0.0001**
HRQOL: Physical	72.1 ± 20.2	82.6 ± 16.3	80.5 ± 18.8	9.0 (6.4, 11.5)†	**>0.0001**	-2.6 (-5.3, 0.2)	0.0687	6.1 (3.0, 9.2)	**0.0001**
HRQOL: Emotional	62.8 ± 17.8‡	74.7 ± 16.8	73.8 ± 17.8	11.4 (8.9, 13.8)†	**>0.0001**	-2.0 (-4.4, 0.4)	0.0978	9.8 (7.3, 12.2)†	**<0.0001**
HRQOL: Social	69.4 ± 19.2	78.8 ± 19.3	79.8 ± 18.7	8.7 (5.7, 11.7)	**>0.0001**	1.3 (-1.4, 4.0)	0.3539	10.3 (7.6, 13.1)†	**<0.0001**
HRQOL: School	72.3 ± 18.4	77.6 ± 17.8	78.6 ± 17.6	4.6 (2.1, 7.1)	**0.0004**	0.9 (-1.6, 3.4)	0.4791	4.9 (2.1, 7.6)	**0.0006**
WSQOL: Total	46.8 ± 20.1	65.1 ± 21.8	65.1 ± 22.6	16.9 (14.2, 19.5)	**>0.0001**	-0.3 (-2.8, 2.2)	0.8234	16.7 (13.8, 19.7)	**<0.0001**
WSQOL: Self	25.7 ± 22.6	47.3 ± 26.6	46.0 ± 29.1	20.4 (16.7, 24.0)	**>0.0001**	-1.6 (-5.4, 2.2)	0.4113	19.3 (15.2, 23.5)	**<0.0001**
WSQOL: Social	58.0 ± 21.3	73.2 ± 21.2	74.1 ± 21.3	13.8 (11.1, 16.4)	**>0.0001**	0.5 (-1.9, 2.9)	0.6883	14.3 (11.3, 17.2)	**<0.0001**
WSQOL: Environment	32.7 ± 30.8	59.9 ± 32.5	58.3 ± 32.4	25.1 (20.7, 29.6)	**>0.0001**	-1.6 (-5.7, 2.6)	0.4504	23.5 (18.5, 28.5)	**<0.0001**

*Values for each timepoint presented as mean ± SD

**Change presented as mean (95% CI)

***Significant change between timepoints was tested using paired t-tests.

†PedsQL change values that are greater than the minimum clinically important difference;[50] there is no reported MCID for the YQOL-W

‡PedsQL score below the cut off score for impaired HRQOL;[50] there is no reported cut off score for the YQOL-W

Bold p-values are significant at $p < 0.05$

Table 7. Comparison of child and parent quality of life scores at each timepoint.

	T1				T2			
Score	Pearson's r	Pearson's r p-value	Mean Difference*	Paired t-test p-value	Pearson's r	Pearson's r p-value	Mean Difference*	Paired t-test p-value
HRQOL: Total	0.439	**< 0.0001**	3.2 (1.2, 5.2)	**0.002**	0.357	**< 0.0001**	-0.0 (-2.4, 2.3)	0.98
HRQOL: Physical	0.457	**< 0.0001**	4.0 (1.5, 6.6)	**0.002**	0.303	**0.0001**	-0.5 (-3.2, 2.2)	0.72
HRQOL: Emotional	0.308	**< 0.0001**	2.6 (-0.4, 5.6)	0.09	0.236	**0.002**	0.6 (-2.8, 3.9)	0.75
HRQOL: Social	0.391	**< 0.0001**	5.2 (2.4, 7.9)	**0.0002**	0.302	**0.0001**	2.1 (-1.4, 5.6)	0.23
HRQOL: School	0.430	**< 0.0001**	0.9 (-1.6, 3.5)	0.47	0.34	**< 0.0001**	-1.8 (-5.0, 1.3)	0.26
WSQOL: Total	0.317	**< 0.0001**	28.1 (25.2, 31.0)	**< 0.0001**	0.355	**< 0.0001**	18.2 (14.9, 21.6)	**< 0.0001**
WSQOL: Self	0.186	**0.004**	33.7 (29.4, 38.0)	**< 0.0001**	0.255	**0.0008**	27.2 (22.5, 32.0)	**< 0.0001**
WSQOL: Social	0.327	**< 0.0001**	22.4 (19.5, 25.4)	**< 0.0001**	0.347	**< 0.0001**	13.8 (10.6, 17.1)	**< 0.0001**
WSQOL: Environment	0.244	**0.0001**	38.9 (34.0, 43.9)	**< 0.0001**	0.334	**< 0.0001**	18.5 (13.2, 23.8)	**< 0.0001**

Bold p-values are significant at $p < 0.05$

*Mean difference presented as mean (95% CI). Mean is child score minus parent score, such that the value presented is the average amount that the child self-reported scores exceeded the parent proxy-reported scores.

Table 7 continued.

	T3			
Score	**Pearson's r**	**Pearson's r p-value**	**Mean Difference***	**Paired t-test p-value**
HRQOL: Total	0.340	**< 0.0001**	2.0 (-0.6, 4.6)	0.13
HRQOL: Physical	0.192	**0.0171**	3.0 (-0.2, 6.3)	0.07
HRQOL: Emotional	0.345	**< 0.0001**	0.8 (-2.5, 4.2)	0.63
HRQOL: Social	0.378	**< 0.0001**	2.3 (-1.0, 5.6)	0.18
HRQOL: School	0.392	**< 0.0001**	1.1 (-2.0, 4.3)	0.49
WSQOL: Total	0.463	**< 0.0001**	17.7 (14.3, 21.2)	**< 0.0001**
WSQOL: Self	0.343	**< 0.0001**	27.4 (22.3, 32.6)	**< 0.0001**
WSQOL: Social	0.426	**< 0.0001**	12.5 (9.1, 15.9)	**< 0.0001**
WSQOL: Environment	0.413	**< 0.0001**	20.8 (15.6, 26.0)	**< 0.0001**

Bold p-values are significant at $p < 0.05$

*Mean difference presented as mean (95% CI). Mean is child score minus parent score, such that the value presented is the average amount that the child self-reported scores exceeded the parent proxy-reported scores.

Table 8. Multiple regression: change in child zBMI as a predictor of child self-reported quality of life.

		Regression			
Child QOL Scores (n)*	**Pearson's r** (p-value)**	**β**	**95% CI**	**Robust SE**	**p-value**
HRQOL: Total (166)	-0.169 (**0.030**)	-5.86	-12.73, 1.01	3.48	0.094
HRQOL: Physical (166)	-0.118 (0.13)	-3.64	-10.43, 3.16	3.44	0.292
WSQOL: Total (166)	-0.273 (**0.0003**)	-10.08	-16.77, -3.40	3.38	**0.003**
WSQOL: Self (167)	-0.222 (**0.004**)	-12.13	-24.22, -0.05	6.12	0.049
WSQOL: Total (Maintenance) (140)***	-0.057 (0.50)	-4.43	-15.2, 6.34	5.45	0.418

*Models use the listed QOL score at T2 as the dependent variable, change in zBMI from T1-T2 as the main predictor, and the listed QOL score at T1 as an adjustment variable

**Pearson's r between the listed QOL score at T2 and change in zBMI from T1-T2

***This model used change in zBMI from T2-T3 as the main predictor to assess maintenance

Bold p-values are significant at $p < 0.005$

Table 9. Multiple regression: change in zBMI as a predictor of parent proxy-reported quality of life.

		Regression			
Parent QOL Scores (n)*	**Pearson's r (p-value)**	**β**	**95% CI**	**Robust SE**	**p-value**
HRQOL: Total (166)	-0.268 (**0.0005**)	-9.13	-14.21, -4.05	2.57	**0.0005**
HRQOL: Physical (166)	-0.315 (**0.0001**)	-13.79	-19.62, -7.96	2.95	**< 0.0001**
WSQOL: Total (168)	-0.483 (**< 0.0001**)	-28.38	-36.23, -20.54	3.97	**< 0.0001**
WSQOL: Social (168)	-0.436 (**0.0001**)	-23.99	-31.72, -16.26	3.91	**< 0.0001**

*Models use the listed outcome at T2 as the dependent variable, change in zBMI from T1-T2 as the main predictor, and the listed outcome at T1 as an adjustment variable

Bold p-values are significant at $p < 0.005$

Supplementary Table 1. Uncategorized responses to race/ethnicity questions for SHIFT and FOCUS participants.

Race/Ethnicity	SHIFT (n = 170)	FOCUS (n = 72)
Child, n (%)		
Non-Hispanic White	103 (60.6)	45 (62.5)
Black/African-American	5 (2.9)	4 (5.6)
Asian	5 (2.9)	2 (2.8)
Native Hawaiian/Pacific Islander	1 (0.6)	0 (0.0)
Multiracial	32 (18.8)	n/a*
Other	0 (0.0)	12 (16.7)
Hispanic White	16 (9.4)	4 (5.6)
Hispanic Multiracial	6 (3.5)	n/a*
Hispanic Other	1 (0.6)	5 (6.9)
Missing	1 (0.6)	0 (0.0)
Parent, n (%)		
Non-Hispanic White	120 (70.6)	55 (76.4)
Black/African American	7 (4.1)	4 (5.6)
Asian	7 (4.1)	2 (2.8)
Native Hawaiian/Pacific Islander	1 (0.6)	0 (0.0)
Multiracial	11 (6.5)	n/a*
Non-Hispanic Other	0 (0.0)	3 (4.2)
Hispanic White	8 (4.7)	5 (6.9)
Hispanic Black/African American	1 (0.6)	0 (0.0)
Hispanic American Indian/Alaskan Native	1 (0.6)	0 (0.0)
Hispanic Multiracial	1 (0.6)	n/a*
Hispanic Other	1 (0.6)	3 (4.2)
Missing	12 (7.1)	0 (0.0)

*Multiracial was included as a response option in SHIFT but not in FOCUS. Categories were collapsed for analyses to prevent misclassification (Table 1).

References

1. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007-2008 to 2015-2016. *JAMA*. 2018;319(16):1723-1725. doi:10.1001/jama.2018.3060
2. Ogden CL, Carroll MD, Lawman HG, et al. Trends in Obesity Prevalence Among Children and Adolescents in the United States, 1988-1994 Through 2013-2014. *JAMA*. 2016;315(21):2292-2299. doi:10.1001/jama.2016.6361.Trends
3. National Center for Health Statistics. *Health, United States, 2018*. Hyattsville, MD; 2019. doi:https://dx.doi.org/10.15620/cdc:100685
4. Fryar CD, Carroll MD, Ogden CL. *Prevalence of Overweight, Obesity, and Severe Obesity Among Children and Adolescents Aged 2–19 Years: United States, 1963–1965 Through 2015–2016*. Hyattsville, MD; 2018. https://www.cdc.gov/nchs/data/hestat/obesity_child_15_16/obesity_child_15_16.htm.
5. Cote A, Harris K, C P, Sandor G, Devlin A. Childhood obesity and cardiovascular dysfunction. *J Am Coll Cardiol*. 2013;62(15):1309-1319. doi:10.1016/j.jacc.2013.07.042
6. Mohanan S, Tapp H, McWilliams A, Dulin M. Obesity and asthma: Pathophysiology and implications for diagnosis and management in primary care. *Exp Biol Med*. 2014;239(11):1531-1540. doi:10.1177/1535370214525302
7. Narang I, Mathew J. Childhood Obesity and Obstructive Sleep Apnea. *J Nutr Metab*. 2012;2012:8. doi:https://doi.org/10.1155/2012/134202
8. Halfon N, Larson K, Slusser W. Associations between obesity and comorbid mental health, developmental, and physical health conditions in a nationally representative sample of US children aged 10 to 17. *Acad Pediatr*. 2013;13(1):6-13. doi:10.1016/j.acap.2012
9. Simmonds M, Llewellyn A, Owen CG, Woolacott N. Predicting adult obesity from childhood obesity: A systematic review and meta-analysis. *Obes Rev*. 2016;17(2):95-107. doi:10.1111/obr.12334
10. Gordon-Larsen P, The N, Adair L. Longitudinal trends in obesity in the United States from adolescence to the third decade of life. *Obesity*. 2010;18(9):1801-1804. doi:10.1038/oby.2009.451
11. Singh AS, Mulder C, Twisk JWR, Van Mechelen W, Chinapaw MJM. Tracking of childhood overweight into adulthood: A systematic review of the literature. *Obes Rev*. 2008;9(5):474-488. doi:10.1111/j.1467-789X.2008.00475.x
12. Umer A, Kelley GA, Cottrell LE, Giacobbi Jr. P, Innes KE, Lilly CL. Childhood obesity and adult cardiovascular disease risk factors: A systematic review with meta-analysis. *BMC Public Health*. 2017;17(1):1-24. doi:10.1186/s12889-017-4691-z
13. Wang Y, Min J, Khuri J, Li M. A systematic examination of the association between parental and child obesity across countries. *Adv Nutr*. 2017;8(3):436-448. doi:10.3945/an.116.013235
14. Mead E, Brown T, Rees K, et al. Diet, physical activity and behavioural interventions for the treatment of overweight or obese children from the age of 6 to 11 years. *Cochrane Database Syst Rev*. 2017;6:476. doi:10.1002/14651858.CD012651
15. Spear BA, Barlow SE, Ervin C, et al. Recommendations for treatment of child and adolescent overweight and obesity. *Pediatrics*. 2007;120 Suppl:S254-S288. doi:10.1542/peds.2007-2329F
16. Mockus DS, Macera CA, Wingard DL, Peddecord M, Thomas RG, Wilfley DE. Dietary self-monitoring and its impact on weight loss in overweight children. *Int J Pediatr Obes*. 2011;6(0):197-205. doi:10.3109/17477166.2011.590196
17. Saelens BE, McGrath AM. Self-Monitoring Adherence and Adolescent Weight Control Efficacy. *Child Heal Care*. 2003;32(2):137-152.

18. Whitlock E, O'Connor E, Williams S, Beil T, Lutz K. Effectiveness of weight management interventions in children: a targeted systematic review for the USPSTF. *Pediatrics*. 2010;125(2):e396-418. doi:10.1542/peds.2009-1955
19. Grossman DC, Bibbins-Domingo K, Curry SJ, et al. Screening for obesity in children and adolescents us preventive services task force recommendation statement. *JAMA*. 2017;317(23):2417-2426. doi:10.1001/jama.2017.6803
20. Centers for Disease Control and Prevention. *Measuring Healthy Days Population Assessment of Health-Related Quality of Life*. Atlanta, GA; 2000.
21. Karimi M, Brazier J. Health, Health-Related Quality of Life, and Quality of Life: What is the Difference? *Pharmacoeconomics*. 2016;34(7):645-649. doi:10.1007/s40273-016-0389-9
22. Braet C, Mervielde I, Vandereycken W. Psychological aspects of childhood obesity: A controlled study in a clinical and nonclinical sample. *J Pediatr Psychol*. 1997;22(1):59-71. doi:10.1093/jpepsy/22.1.59
23. Sutaria S, Devakumar D, Yasuda SS, Das S, Saxena S. Is obesity associated with depression in children? Systematic review and meta-analysis. *Arch Dis Child*. 2019;104(1):64-74. doi:10.1136/archdischild-2017-314608
24. Morrison K, Shin S, Tarnopolsky M, Taylor V. Association of depression & health related quality of life with body composition in children and youth with obesity. *J Affect Disord*. 2015;172:18-23. doi:10.1016/j.jad.2014.09.014
25. Tsiros M, Olds T, Buckley J, et al. Health-related quality of life in obese children and adolescents. *Int J Obes*. 2009;33:387-400. doi:10.1038/ijo.2009.42
26. Hayden-Wade H, Stein R, Ghaderi A, Saelens B, Zabinski M, Wilfley D. Prevalence, characteristics, and correlates of teasing experiences among overweight children vs. non-overweight peers. *Obes Res*. 2005;13(8):1381-1392.
27. Wille N, Erhart M, Petersen C, Ravens-Sieberer U. The impact of overweight and obesity on health-related quality of life in childhood – results from an intervention study. *BMC Public Health*. 2008;8(421). doi:10.1186/1471-2458-8-421
28. Guyatt GH, Feeny DH, Patrick DL. Measuring Health-related Quality of Life. *Ann Intern Med*. 1993;118(8):622-629.
29. Patrick DL, Skalicky AM, Edwards TC, et al. Weight loss and changes in generic and weight-specific quality of life in obese adolescents. *Qual Life Res*. 2011;20(6):961-968. doi:10.1007/s11136-010-9824-0
30. Gopinath B, Baur LA, Burlutsky G, Mitchell P. Adiposity adversely influences quality of life among adolescents. *J Adolesc Heal*. 2013;52(5):649-653. doi:10.1016/j.jadohealth.2012.11.010
31. Sawyer MG, Harchak T, Wake M, Lynch J. Four-year prospective study of BMI and mental health problems in young children. *Pediatrics*. 2011;128(4):677-684. doi:10.1542/peds.2010-3132
32. Parkinson KN, Adamson AJ, Basterfield L, Reilly JK, Le Couteur A, Reilly JJ. Influence of adiposity on health-related quality of life in the Gateshead Millennium Study cohort: longitudinal study at 12 years. *Arch Dis Child*. 2015;100(8):779-783. doi:10.1136/archdischild-2014-307498
33. Williams JW, Canterford L, Hesketh KD, et al. Changes in body mass index and health related quality of life from childhood to adolescence. *Int J Pediatr Obes*. 2011;6(2-2):442-448. doi:10.3109/17477166.2010.526226
34. Militello LK, Kelly S, Melnyk BM, Smith L, Petosa R. A Review of Systematic Reviews Targeting the Prevention and Treatment of Overweight and Obesity in Adolescent Populations. *J Adolesc Heal*. 2018;63(6):675-687. doi:10.1016/j.jadohealth.2018.07.013
35. Edwards TC, Patrick DL, Skalicky AM, Huang Y, Hobby AD. Perceived body shape, standardized body-mass index, and weight-specific quality of life of African-American, Caucasian, and Mexican-American adolescents. *Qual Life Res*. 2012;21(6):1101-1107. doi:10.1007/s11136-011-0019-0

36. Davis E, Nicolas C, Waters E, et al. Parent-proxy and child self-reported health-related quality of life: using qualitative methods to explain the discordance. *Qual Life Res*. 2007;16(5):863-871. doi:10.1007/s11136-007-9187-3
37. Hoedjes M, Makkes S, Halberstadt J, et al. Health-related quality of life in children and adolescents with severe obesity after intensive lifestyle treatment and at 1-year follow-up. *Obes Facts*. 2018;11(2):116-128. doi:10.1159/000487328
38. Fullerton G, Tyler C, Johnston CA, Vincent JP, Harris GE, Foreyt JP. Quality of life in Mexican-American children following a weight management program. *Obesity*. 2007;15(11):2553-2556. doi:10.1038/oby.2007.306
39. Yackobovitch-Gavan M, Nagelberg N, Phillip M, Ashkenazi-Hoffnung L, Hershkovitz E, Shalitin S. The influence of diet and/or exercise and parental compliance on health-related quality of life in obese children. *Nutr Res*. 2009;29(6):397-404. doi:10.1016/j.nutres.2009.05.007
40. Finne E, Reinehr T, Schaefer A, Winkel K, Kolip P. Changes in self-reported and parent-reported health-related quality of life in overweight children and adolescents participating in an outpatient training: Findings from a 12-month follow-up study. *Health Qual Life Outcomes*. 2013;11(1):13. doi:10.1186/1477-7525-11-1
41. Rank M, Wilks DC, Foley L, et al. Health-related quality of life and physical activity in children and adolescents 2 years after an inpatient weight-loss program. *J Pediatr*. 2014;165(4):732-737.e2. doi:10.1016/j.jpeds.2014.05.045
42. Saelens BE, Lozano P, Scholz K. A randomized clinical trial comparing delivery of behavioral pediatric obesity treatment using standard and enhanced motivational approaches. *J Pediatr Psychol*. 2013;38(9):954-964. doi:10.1093/jpepsy/jst054
43. Centers for Disease Control and Prevention. Defining Childhood Obesity. https://www.cdc.gov/obesity/childhood/defining.html. Published 2018. Accessed January 22, 2020.
44. Centers for Disease Control and Prevention. Defining Adult Overweight and Obesity. https://www.cdc.gov/obesity/adult/defining.html. Published 2017. Accessed January 22, 2020.
45. Saelens BE, Scholz K, Walters K, Simoni JM, Wright DR. Two Pilot Randomized Trials To Examine Feasibility and Impact of Treated Parents as Peer Interventionists in Family-Based Pediatric Weight Management. *Child Obes*. 2017;13(4):314-323. doi:10.1089/chi.2016.0233
46. Epstein LH, Squires S. *The Stoplight Diet for Children: An Eight-Week Program for Parents and Children*. Boston, MA: Little Brown & co; 1988.
47. National Health and Nutrition Examination Survey (NHANES). NHANES 2017-2018 Procedure Manuals. https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/manuals.aspx?BeginYear=2017. Published 2017.
48. Varni JW, Seid M, Rode CA. The PedsQL™: Measurement Model for the Pediatric Quality of Life Inventory. *Med Care*. 1999;37(2):126-139.
49. James W Varni, Seid M, Kurtin P. PedsQL™ 4.0: Reliability and Validity of the Pediatric Quality of Life Inventory™ Version 4.0 Generic Core Scales in Healthy and Patient Populations. *Med Care*. 2001;39(8):800-812. https://www.jstor.org/stable/3767969.
50. Varni JW, Burwinkle TM, Seid M, Skarr D. The PedsQL™ 4.0 as a pediatric population health measure: Feasibility, reliability, and validity. *Ambul Pediatr*. 2003;3(6):329-341. doi:10.1367/1539-4409(2003)003<0329:tpaapp>2.0.co;2
51. Varni JW, Seid M, Knight TS, Uzark K, Szer IS. The PedsQL™ 4.0 Generic Core Scales: Sensitivity, Responsiveness, and Impact on Clinical Decision-Making. *J Behav Med*. 2002;25(2):175-193. doi:10.1023/A:1014836921812
52. Morales LS, Edwards TC, Flores Y, Barr L, Patrick DL. Measurement properties of a multicultural

weight-specific quality-of-life instrument for children and adolescents. *Qual Life Res*. 2011;20(2):215-224. doi:10.1007/s11136-010-9735-0
53. Kuczmarski RJ, Ogden CL, Grummer-strawn LM, et al. *Advance Data*. Vol 314. Hyattsville, MD; 2000.
54. Taveras E, Marshall R, Sharifi M, et al. Comparative Effectiveness of Clinical-Community Childhood Obesity Interventions: The Connect for Health Randomized Controlled Trial. *J Am Med Assoc*. 2017;171(8):100–106. doi:10.1001/jamapediatrics.2017.1325.Comparative
55. Quinlan NP, Kolotkin RL, Fuemmeler BF, Costanzo PR. Psychosocial outcomes in a weight loss camp for overweight youth. *Int J Pediatr Obes*. 2009;4(3):134-142. doi:10.1080/17477160802613372
56. Wong WW, Barlow SE, Mikhail C, et al. A residential summer camp can reduce body fat and improve health-related quality of life in obese children. *J Pediatr Gastroenterol Nutr*. 2013;56(1):83-85. doi:10.1097/MPG.0b013e3182736f70
57. Poeta LS, Duarte MDFDS, Giuliano IDCB, Mota J. Interdisciplinary intervention in obese children and impact on health and quality of life. *J Pediatr (Rio J)*. 2013;89(5):499-504. doi:10.1016/j.jped.2013.01.007
58. Hofsteenge GH, Weijs PJM, Delemarre-Van De Waal HA, De Wit M, Chinapaw MJM. Effect of the Go4it multidisciplinary group treatment for obese adolescents on health related quality of life: A randomised controlled trial. *BMC Public Health*. 2013;13(1):1. doi:10.1186/1471-2458-13-939
59. Hayes M, Baxter H, Müller-Nordhorn J, Hohls JK, Muckelbauer R. The longitudinal association between weight change and health-related quality of life in adults and children: a systematic review. *Obes Rev*. 2017;18(12):1398-1411. doi:10.1111/obr.12595
60. Jalali-Farahani S, Abbasi B, Daniali M. Weight associated factors in relation to health-related quality of life (HRQoL) in Iranian adolescents. *Health Qual Life Outcomes*. 2019;17(1):1-10. doi:10.1186/s12955-018-1074-9
61. van der Heijden LB, Feskens EJM, Janse AJ. Maintenance interventions for overweight or obesity in children: a systematic review and meta-analysis. *Obes Rev*. 2018;19(6):798-809. doi:10.1111/obr.12664
62. Khairy SA, Eid SR, El Hadidy LM, Gebril OH, Megawer AS. The health-related quality of life in normal and obese children. *Egypt Pediatr Assoc Gaz*. 2016;64(2):53-60. doi:10.1016/j.epag.2016.05.001
63. Killedar A, Lung T, Petrou S, Teixeira-Pinto A, Tan EJ, Hayes A. Weight status and health-related quality of life during childhood and adolescence: effects of age and socioeconomic position. *Int J Obes*. 2020;44(3):637-645. doi:10.1038/s41366-020-0529-3
64. Williams J, Wake M, Hesketh K, Maher E, Waters E. Health-related quality of life of overweight and obese children. *J Am Med Assoc*. 2005;293(1):70-76. doi:10.1001/jama.293.1.70
65. Zeller MH, Modi AC. Predictors of health-related quality of life in obese youth. *Obesity*. 2006;14(1):122-130. doi:10.1038/oby.2006.15
66. Schwimmer JB, Burwinkle TM, Varni JW. Health-Related Quality of Life of Severely Obese Children and Adolescents. *J Am Med Assoc*. 2003;289(14):1813-1819. doi:10.1001/jama.289.14.1813
67. Alcantara J, Ohm J, Alcantara J. Comparison of pediatric self reports and parent proxy reports utilizing PROMIS: Results from a chiropractic practice-based research network. *Complement Ther Clin Pract*. 2017;29:48-52. doi:10.1016/j.ctcp.2017.08.003
68. Galloway H, Newman E. Is there a difference between child self-ratings and parent proxy-ratings of the quality of life of children with a diagnosis of attention-deficit hyperactivity disorder (ADHD)? A systematic review of the literature. *ADHD Atten Deficit Hyperact Disord*. 2017;9(1):11-29. doi:10.1007/s12402-016-0210-9

69. Rajmil L, López AR, López-Aguilà S, Alonso J. Parent-child agreement on health-related quality of life (HRQOL): A longitudinal study. *Health Qual Life Outcomes*. 2013;11(1):10. doi:10.1186/1477-7525-11-101
70. Evensen E, Wilsgaard T, Furberg AS, Skeie G. Tracking of overweight and obesity from early childhood to adolescence in a population-based cohort - the Tromsø Study, Fit Futures. *BMC Pediatr*. 2016;16(64):1-11. doi:10.1186/s12887-016-0599-5