



Evaluating 12 Years of Implementing a Multidisciplinary Specialist Child and Adolescent Obesity Treatment Service: Patient-Level Outcomes

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Introduction: Childhood obesity is a chronic disease that requires multidisciplinary and specialist intervention to address its complex pathophysiology, though access to treatment is limited globally. Evaluating the impact of evidence-based interventions implemented in real-world clinical settings is essential, in order to increase the translation of research into practice and enhance child health outcomes. In Ireland, the National Model of Care for Obesity highlighted the need to develop and improve healthcare services for children and adolescents with obesity.

Aims: This study aims to evaluate the impact of a family-based, Tier 3 multi-disciplinary child and adolescent obesity outpatient service (www.w82go.ie) on standardized body mass index (BMI-SDS).

Methods: Following referral by pediatricians, patients were assessed by a pediatric multidisciplinary team (physiotherapist, dietician, and psychologist) and personalized obesity treatment plans were developed. Anthropometric and demographic information were recorded at baseline and final visit. Descriptive statistics were used to explore distribution, central tendency and variation in the demographic data, change in BMI-SDS over time was assessed using a *t*-test, and multiple linear regression analysis was used to investigate the association of demographic factors on the change in BMI-SDS.

Results: The overall mean BMI-SDS reduction across the whole cohort ($n = 692$) was -0.17 (95% CI = $-0.20, -0.13$; $P < 0.001$). Younger age at admission and longer duration of treatment were associated with greater BMI-SDS reduction but there was no significant association between change in BMI-SDS and any of the other parameters (deprivation score, treatment type, sex, obesity category at admission or presence of comorbid condition).

Conclusion: Engagement in a specialist Tier 3 pediatric obesity service was associated with reductions in BMI-SDS in children and adolescents with obesity.

Keywords: pediatric [MeSH], multidisciplinary, obesity treatment, complex interventions, family-based therapy, personalized treatment

INTRODUCTION

Obesity and overweight compromise the health and wellbeing of children worldwide, with global prevalence estimated at 240 million children affected, the majority in low and middle income countries and with greater burden borne by those living in disadvantage (1, 2). Childhood obesity affects children across diverse demographics and environments, often causing challenges to their health and wellbeing that persist into adulthood (3, 4). **Figure 1** depicts the range of health complications and impairments that present in children and adolescents with obesity and the related adult conditions where risk is increased with obesity during childhood (5–31).

There is evidence that interventions to improve nutrition, physical fitness and emotional health can lead to positive changes in behavior, diet, and physical activity. Multi-component interventions are proven more effective than single interventions at reducing body size and improving health-related quality of life in children and adolescents with obesity (32, 33). Multicomponent interventions are the first-line treatment for child and adolescent obesity with additional pharmacotherapy and surgical intervention required in more severe cases (3, 4).

Childhood obesity has increased in Ireland consistent with global trends, and Ireland now ranks 10th in the EU for overweight and obesity in children aged 6–9 years (34). In little more than a generation, obesity among children in Ireland has increased 10-fold to affect around 9% of children in 2016 (2). 2018 trends suggest that the prevalence of childhood obesity in Ireland was plateauing (35) however, the prevalence for children living in disadvantage continued to rise. In turn, the leveling off of obesity prevalence previously seen at the population may be reversed due to the impact of the COVID-19 pandemic on child health and growth. For example, in England the findings of the National Child Measurement Programme (NCMP) for the 2020/2021 school year estimate that obesity prevalence increased from 9.9 to 14.4% and from 21 to 25.5% between 2019/20 and 2020/21 in children aged 4–5 years and 10–11 years respectively. Childhood obesity disproportionately affects low income families, and in Ireland, the prevalence of morbid obesity is 1.8% in the general population (7-year-old children) and 3.2% for those in disadvantage (36). Based on recent census this equates to approximately 21,000 children with severe obesity (37). Provision of clinical services to treat childhood obesity is important since multiple obesity-related health complications and comorbidities emerge in childhood (see **Figure 1**) such that children present to general pediatric and other pediatric specialities for evaluation and management (38). In addition, clinical services are required in line with Article 24 of the United Nations Convention on the Rights of the Child (access to healthcare). Treating childhood obesity is also important as obesity and related complications can track into adulthood, with ongoing consequences for the health and wellbeing of the individual, for future health services and for the Irish economy.

In Ireland, a Tier 3 (tertiary level) clinical service for the assessment and treatment of obesity in children and adolescents exists in Children's Health Ireland (CHI) at Temple Street The W28GO Child and Adolescent Obesity Service

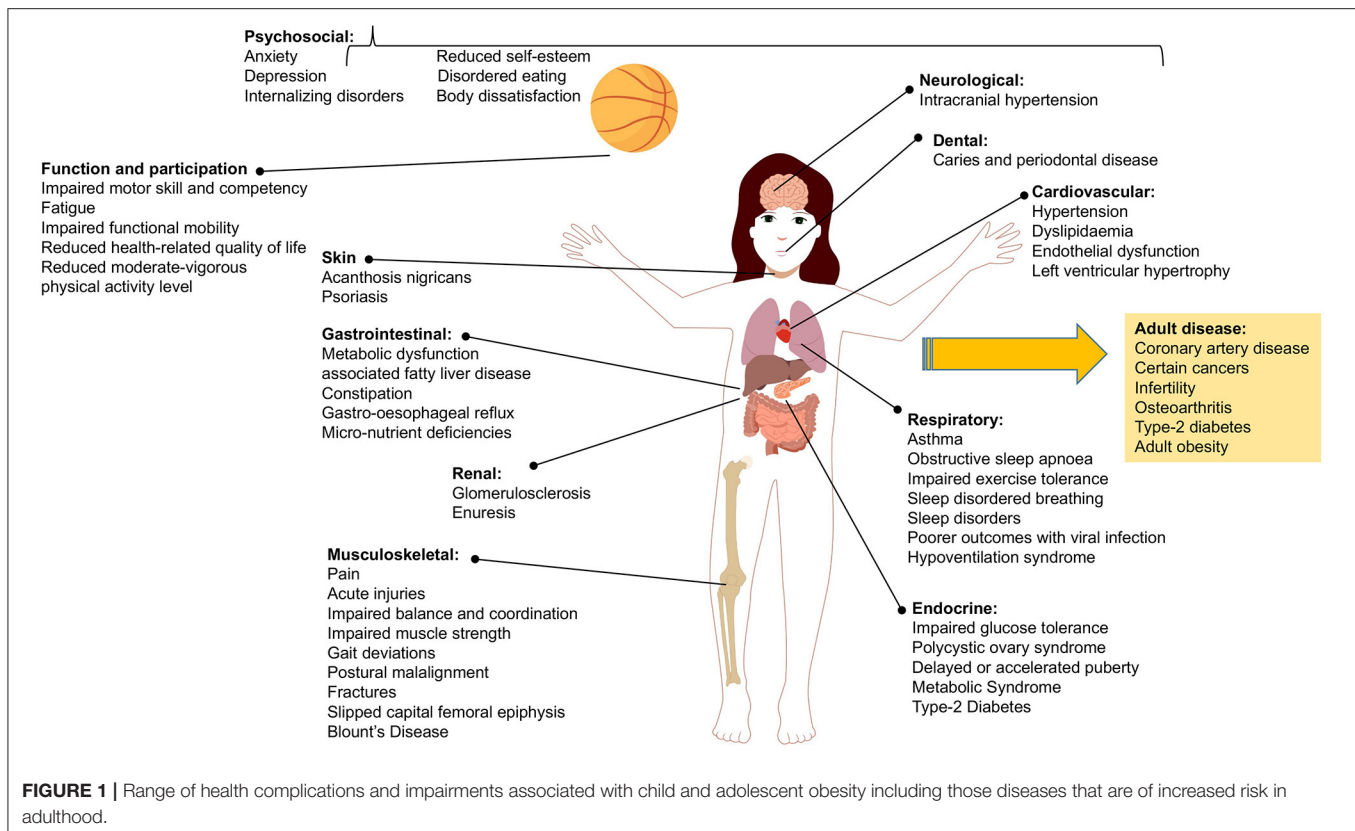
(www.w82go.ie) is a family-based, multi-disciplinary obesity service for individuals with obesity under 16 years of age. The service was developed based on international guidelines on treatment of childhood obesity (39, 40) and to date, process- and patient-level outcomes are positive (41). The service is a center of excellence accredited as a Pediatric Center for Obesity Management by the European Association for the Study of Obesity and has partial funding from the HSE/Department of Health with capacity to see approximately 120 new patients and 250 return patients each year. In 2021 a National Model of Care for the Management of Overweight and Obesity was launched in Ireland which highlighted the need to increase access to childhood obesity services and to evaluate the health impacts of such interventions (42). To support integrated care and early intervention for children with obesity, it is essential to evaluate existing obesity interventions. Building an understanding of the health impacts of existing obesity interventions will support and enhance development and implementation of new interventions throughout primary, secondary and tertiary care. Preliminary data exist regarding the impacts of obesity treatment in pediatric healthcare in Ireland (41, 43–47) however it is unknown whether children from varied demographic or medical backgrounds have different outcomes from treatment for obesity.

This study aimed to explore the impact of the W82GO service on BMI-SDS and whether change in BMI-SDS differed between socioeconomic groups, sex, those with co-morbid conditions or the type of treatment offered.

MATERIALS AND METHODS

The participants of this study were all children and adolescents (<16 years) referred with a diagnosis of clinical obesity (BMI >98th percentile for age and sex) to the Tier 3 W82GO Child and Adolescent Weight Management Service at CHI at Temple Street, Dublin, Ireland. The service does not exclude children with disability or co-morbid diagnoses and as such any child referred by a hospital consultant (pediatric physician or surgeon) were included in the analysis. Audit approval (CA21-06-02) was granted by the hospital in order to explore routinely collected health data. The data for all children and adolescents presenting to the service between 2008 and 2019 were included in the study.

Following referral by pediatric physicians and surgeons, patients were assessed by a pediatric MDT (dietician, physiotherapist, psychologist and medical social worker) and a personalized treatment plan was developed and delivered as either individual care, group care or a combination of these (combined). Treatment involved delivery of a complex intervention incorporating nutrition therapy, exercise therapy, behavioral support and psychological/family therapy. Behavior change techniques were embedded in the intervention in line with clinical guidelines and the intervention was offered as a group programme or *via* individual outpatient appointments. Further description of the clinical service and intervention is available elsewhere (46) but briefly up to 24 clinical treatment sessions were offered to patients incorporating practical education related to nutrition (e.g., understanding



food labeling and portion sizes, and learning how to shop in a supermarket), physical activity, fitness and function (e.g., improving fundamental motor skill and physical fitness, and supervised physical activity sessions) and behavior change (e.g., goal setting, self monitoring, stimulus control). In addition, education and advice addressed additional areas supporting behavior change (see **Table 1**). It was not possible to standardize the intervals between clinic visits as they are dependent on the multiple factors related to the individual (e.g., severity of obesity and related complications, distance from the clinic, parental availability and motivation, and treatment intensity recommended by the multidisciplinary team (MDT)).

Anthropometric (weight, height, body mass index (BMI) and BMI-SDS) on UK90 child growth charts (48), demographic information (sex and socioeconomic position [SEP] estimated with Pobal score, (data.gov.ie/dataset/pobal-hp-deprivation-index), and medical history were recorded at baseline. All anthropometric measurements and questionnaires related to physical activity, psychosocial health, sleep, quality of life and nutritional intake were administered by trained clinical staff. Body weight was measured using an electronic scale (SECA, Vogel & Halke, Hamburg, Germany) and height to the nearest 0.1 cm with a stadiometer (SECA, Vogel & Halke) in light clothing and without shoes. These measures were measured in triplicate and used to calculate BMI (weight kg/height m²), expressed as a standardized score (BMI-SDS) according to age- and sex-specific UK reference

data (49). Children are classified as having obesity if they plot above the 98th centile for BMI on relevant sex and age adjusted growth charts (12), and as having morbid obesity if they plot above the 99.6th BMI centile on age and sex-adjusted charts. The presence of a diagnosed co-morbid condition was assessed by review of medical records and common co-morbid conditions included: epilepsy, psoriasis, asthma, dyspraxia, intellectual disability (ID), attention deficit hyperactivity disorder (ADHD), and autistic spectrum disorder (ASD).

Descriptive statistics were used to explore distribution, central tendency and variation in the demographic data collected during the baseline assessment of the patients. The change in BMI-SDS between baseline and the children's last visit to the clinic was assessed using a *t*-test, and multiple linear regression analysis was used to investigate the association of demographic factors on the change in BMI-SDS. The power of the regression model was 0.98 (assuming $P = 0.05$, $n = 662$, and predictor degrees of freedom = 12), which indicates that it is extremely likely to detect a change in SDS-BMI of 0.05 or more, should such an effect exist. Plots of residuals and fitted values were used to visually assess the assumptions of the multiple linear regression model that the regression errors were normally distributed, independent and with constant variance. Collinearity between the predictor variables was assessed using variance inflation factors, that did not exceed 1.5 for any of the predictors in the reported model. All analyses were performed using R version 3.6.2 and $P < 0.05$ was considered to represent statistical significance.

TABLE 1 | Example components included in complex intervention for obesity treatment.**Evidence-based intervention strategies and targets**

Education and information on the benefits of a healthy lifestyle (68–72)
Practical education and support for appropriate portion sizes (73)
Supporting reduced intake of sugar-sweetened drinks (74)
Facilitating attentive/mindful eating (75, 76)
Facilitating new cooking skills (77)
Supporting increased fruit and vegetable intake (78)
Supporting increased fiber intake (79)
Supporting reduced saturated fat intake (80, 81)
Supporting reduced frequency of take-away foods (82)
Supporting increased hydration (83)
Supporting swap of refined carbohydrates for those with a lower glycemic index (84)
Supporting removal of electronic distractions when eating and sleeping (85–87)
Supporting increased chewing of food and decrease rate of eating (88, 89)
Supporting increased sleep duration (90)
Supporting reduced time spent using television and screens (91)
Encouraging muting of television advertisements (92)
Facilitating practice of physical tasks and activities to increase self-efficacy (93)
Supporting increased levels of moderate-to-vigorous physical activity toward 60 min per day (94, 95)

RESULTS

There were 1,097 children referred to the Tier 3 W82GO Service between 2008 and 2020. Of these, 856 (78%) attended an initial assessment appointment, and 692 (81% of attendees) returned for one or more follow-up appointments. There were 29 participants dropped from the regression model at this point due to missing values in one or more variables. The number of follow-up appointments ranged from 1 to 24. Most children (47%) attended individual appointments only, 42% attended a combination of group and individual appointments (combined), and 10% attended only group appointments. Most children remained in the W82GO Service for more than 1 year (median = 401, IQR = 474). There were 86 children 16 years or older on discharge from the clinic.

Mean age at baseline was 11 years, (SD = 6.5), 51% of children were female and 49% male. Most children (80%) had morbid obesity and the overall mean BMI-SDS was 3.17 (sd=0.62) at the baseline assessment appointment (Table 2). The Pobal deprivation index showed the distribution was skewed toward disadvantage, and 8% of the children were classed as very disadvantaged (Figure 2). In addition to obesity, 24% of children had one or more co-morbid conditions, including epilepsy, psoriasis, asthma, dyspraxia, ID, ADHD or ASD (Table 2).

The mean BMI-SDS change across the whole cohort on discharge was -0.17 (95% CI = -0.20 , -0.13 ; $P < 0.001$). Most children (64%) had lower BMI SDS after treatment, 34% gained and 2% had no change (Figure 3). Younger age at admission

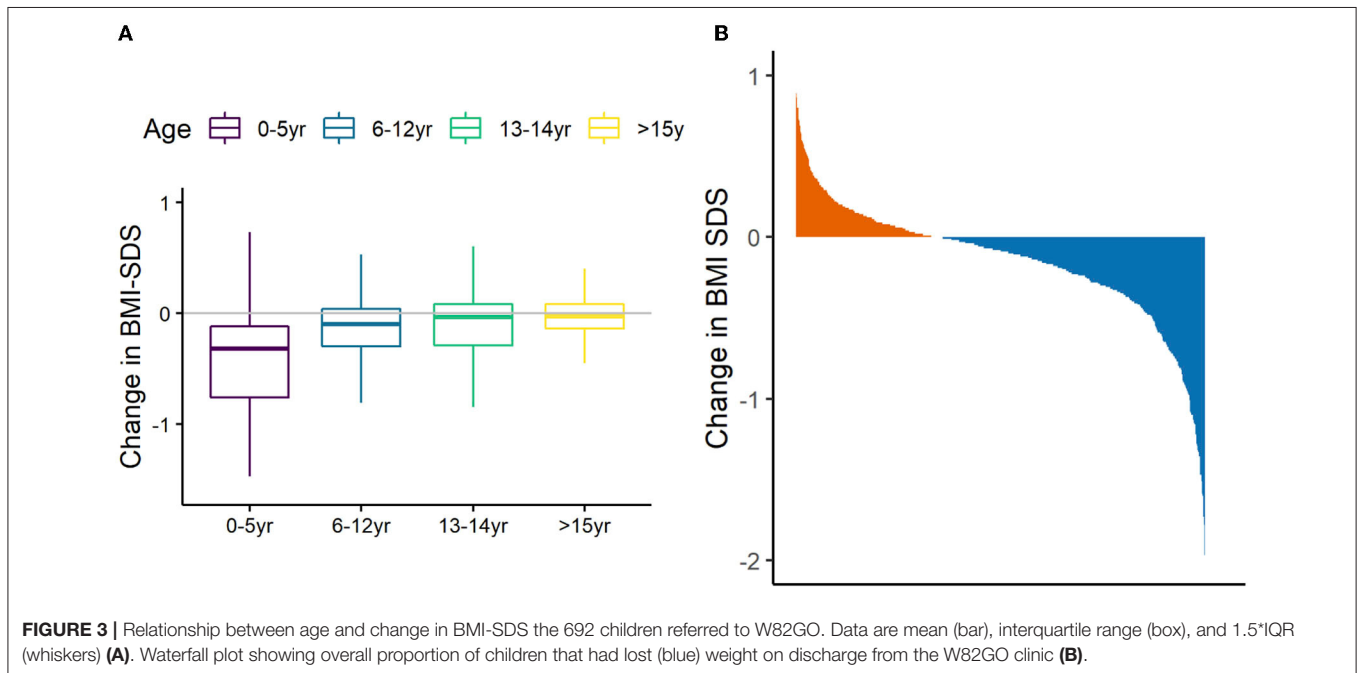
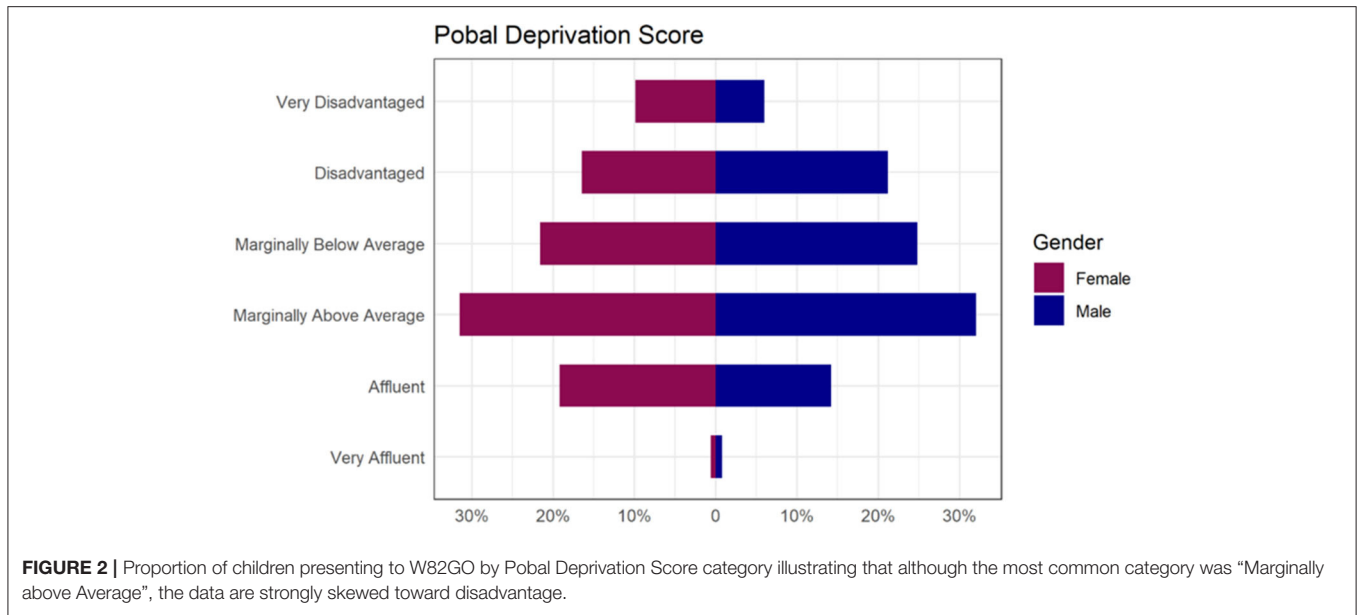
was associated with greater reduction in BMI SDS ($\beta = 0.03$, 95% CI = 0.02, 0.04, $P < 0.001$). Table 3 describes regression analysis where longer treatment duration was associated with greater reduction of BMI SDS ($\beta = -0.01$; 95% CI = -0.14 , -0.06 ; $P < 0.001$). There was no significant association between reduction in BMI SDS and any of the other parameters (Pobal score, treatment type, sex, comorbid condition).

DISCUSSION

The results of this study demonstrate that engagement in a Tier 3 specialist pediatric obesity service was associated with a significant reduction in BMI-SDS in children with obesity in Ireland. Reduction in BMI-SDS was greater in younger children, and in children with longer treatment durations, but was not affected by sex, treatment type (group/individual), obesity category on admission, comorbid conditions, or SEP. In agreement with other reports of multidisciplinary childhood obesity interventions, there was extensive between-subject variability in the response to treatment, and in the parameters recorded at baseline.

Most children reduced BMI-SDS when engaged with the W82GO Service, but the absolute changes in BMI-SDS were moderate (mean BMI-SDS reduction = 0.17). These data were collected in a clinical service setting, and the findings are directly applicable to the clinical cohort and treatment challenges of childhood obesity in the Irish health service. The BMI-SDS reduction we report for the W82GO service is comparable to other European multi-disciplinary interventions. For example, the changes in BMI-SDS are similar to those reported in a 2018 systematic review of Tier 3 pediatric weight management interventions from the UK (50), and to a shorter term (10-week) community-based intervention in the UK (MEND) which reported a mean 0.18-unit reduction in BMI-SDS when applied in 9,563 children (51). Furthermore, systematic reviews of randomized controlled trials of multidisciplinary interventions in childhood obesity reported a mean reduction in BMI-SDS of 0.13 units in 2,399 participants of 20 trials (32), and a reduction of 0.20 in 12 trials (50). Therefore, our findings of moderate reduction in BMI-SDS in most patients over the 12 years of implementing W82GO are consistent with the findings from similar interventions reported elsewhere.

There was a significant association between age at admission and reduced BMI SDS in this study, suggesting that children referred to the W82GO Service at a younger age had greater improvements in BMI-SDS. Previous studies have reported inconsistent associations between the success of multidisciplinary interventions in obesity and age at admission (51–53). This may reflect differences between children and adolescents including their stage of development, the length of time exposed to the state of obesity (which makes treatment more intractable) or the differing treatment approaches used for children at different stages of development. Parents may have more success at modifying the home environment of



younger children, compared to adolescents where social and peer influence may be stronger. In agreement with other studies of multidisciplinary obesity interventions (52, 53), there was no association between sex and BMI-SDS reduction in our study.

There is extensive evidence that obesity is associated with SEP with higher prevalence typically reported in children in disadvantaged categories (54). Recent population-level data in the UK from 1.2 million children of comparable age, sex and ethnicity to W82GO clearly shows a strong and linear relationship between obesity and SEP (54). In contrast,

“marginally above average” was the most common Poblal deprivation category of the children in this study, suggesting that those attending W82GO do not represent the children in Ireland with the highest risk of obesity, and that families living with severe deprivation may either not be referred as often to the service or may fail to attend the service. As such, considerations regarding how the service engages and supports families living in disadvantage is warranted. There are no stratified data on the prevalence of obesity by SEP in Irish children, (55, 56) but previous studies have reported increased prevalence of obesity in schools in disadvantaged

TABLE 2 | Demography and clinic presentation data for study participants.

	Age < 6 years (N = 70)	Age 6–12 years (N = 349)	Age > 12 (N = 270)	Total (N = 692)
Gender				
Female	40 (57 %)	175 (50 %)	142 (53 %)	359 (52 %)
Male	30 (43 %)	174 (50 %)	128 (47 %)	333 (48 %)
Weight (kg)				
Mean (SD)	31.13 (± 11.28)	59.40 (± 16.81)	93.62 (± 19.45)	69.90 (± 27.11)
Height (cm)				
Mean (SD)	112.5 (± 11.49)	143.3 (± 11.93)	164.6 (± 8.306)	148.4 (± 19.07)
BMI (kg/m²)				
Mean (SD)	24.07 (± 3.196)	28.23 (± 4.197)	34.36 (± 5.510)	30.18 (± 5.855)
BMI SDS				
Mean (SD)	3.749 (± 0.9853)	3.087 (± 0.5337)	3.130 (± 0.5226)	3.174 (± 0.6259)
BMI percentile				
Mean (SD)	99.79 (± 0.5330)	99.67 (± 0.9103)	99.70 (± 0.6447)	99.69 (± 0.7819)
Pobal category				
Very affluent	0 (0 %)	3 (1 %)	2 (1 %)	5 (1 %)
Affluent	15 (21 %)	58 (17 %)	42 (16 %)	115 (17 %)
Marginally above average	24 (34 %)	115 (33 %)	80 (30 %)	220 (32 %)
Marginally below Average	11 (16 %)	77 (22 %)	72 (27 %)	161 (23 %)
Disadvantaged	15 (21 %)	64 (18 %)	51 (19 %)	131 (19 %)
Very disadvantaged	4 (6 %)	28 (8 %)	23 (9 %)	55 (8 %)
Body size category				
Morbid obesity	62 (89 %)	274 (79 %)	219 (81 %)	556 (80 %)
Obesity	5 (7 %)	65 (19 %)	40 (15 %)	110 (16 %)
Overweight	3 (4 %)	6 (2 %)	6 (2 %)	15 (2 %)
Treatment category				
Individual	58 (83 %)	143 (41 %)	125 (46 %)	327 (47 %)
Mixed	12 (17 %)	173 (50 %)	108 (40 %)	294 (42 %)
Group	0 (0 %)	33 (9 %)	37 (14 %)	71 (10 %)
BMI SDS change				
Mean (SD)	−0.5150 (± 0.7863)	−0.1527 (± 0.4525)	−0.08938 (± 0.3283)	−0.1692 (± 0.4834)
Comorbidities				
Epilepsy	0 (0 %)	6 (2 %)	8 (3 %)	14 (2 %)
Asthma	5 (12 %)	39 (16 %)	37 (12 %)	81 (14 %)
Autism	0 (0 %)	10 (4 %)	3 (1 %)	13 (2 %)
ADHD	0 (0 %)	9 (4 %)	3 (1 %)	12 (2 %)
Intellectual disability	0 (0 %)	5 (2 %)	10 (3 %)	15 (3 %)
Dyspraxia	0 (0 %)	7 (3 %)	7 (2 %)	14 (2 %)
Psoriasis	0 (0 %)	1 (0 %)	4 (1 %)	5 (1 %)

areas in Ireland (57). Children from lower SEP are more likely to drop out of obesity interventions (51) and less likely to sustain reductions in obesity once treatment has ended (58). However, it is unknown as to whether they are more or less likely to be referred for treatment in the first instance. The

TABLE 3 | Multiple linear regression analysis of the association between change in SDS-BMI and demographic parameters.

Predictors	Change in BMI-SDS		
	Estimates	CI	P-Value
Age	0.03	0.02 to 0.04	<0.001
Body size category	0.06	−0.03 to 0.16	0.199
ref = Morbid Obesity			
Obesity			
Overweight	0.07	−0.17 to 0.31	0.564
Gender	−0.01	−0.08 to 0.06	0.827
Ref = Female			
Male			
Treatment category	0.03	−0.09 to 0.15	0.613
ref = Group			
Individual			
Mixed	0.10	−0.03 to 0.22	0.131
Pobal category	0.18	−0.23 to 0.60	0.394
Ref = very affluent			
Affluent			
Marginally above average	0.21	−0.20 to 0.62	0.314
Marginally below average	0.19	−0.22 to 0.60	0.370
Disadvantaged	0.23	−0.19 to 0.64	0.291
Very disadvantaged	0.19	−0.23 to 0.62	0.380
Treatment duration (years)	−0.10	−0.14 to −0.06	<0.001
Comorbidity	−0.02	−0.10 to 0.07	0.689
Observations	663		
R ²	0.135		

Bold values are statistically significant predictors.

strong relationship between SEP and childhood obesity should be a primary consideration for all interventions targeted at prevention and treatment of childhood obesity. Development of Irish childhood obesity services should specifically target recruitment and retention of children in lower SEP categories to address inequality and the greater burden of risk. In addition, social and community-based integrated care will be essential for such high risk and vulnerable groups.

There are many reports describing the efficacy of multidisciplinary childhood obesity interventions, but comparisons between studies are precluded by the diverse range of recruitment/referral processes, clinical settings, training of clinical staff, demography, focus and delivery of therapies, and timing and duration of treatment. Perhaps the only consistency across these studies is the use of BMI-SDS to monitor response to treatment. BMI-SDS is a simple, quantitative measure of body size that facilitates comparison across growth intervals, yet despite its almost universal application, BMI-SDS poorly represents the metabolic, physical, and psychological pathology of obesity. In terms of quantification of body size, BMI-SDS is not an optimal predictor of adiposity in children with severe obesity, which defines a large proportion of children treated at obesity clinics (59). Furthermore, there is no consensus on the change in BMI-SDS that is associated with clinically significant changes

in body fat or health outcomes at a population level. A recent meta-analysis proposed that a reduction in BMI-SDS of more than 0.6 units is required to ensure reduced body fat (60), and >1.0 , >1.2 , and >0.7 for meaningful reductions in systolic blood pressure, low density lipoproteins and triglycerides, respectively (61). Despite these significant limitations, BMI-SDS is a low-cost, quick and easy to use metric employed to assess the efficacy of childhood obesity interventions (62). Future research should be directed toward development of holistic parameters that can assess the impact of obesity on child health and wellbeing and that can be used to reliably define and monitor 'success' in the evaluation of treatment interventions. We suggest that BMI-SDS be supplemented with measures of nutritional status, physical fitness, mental health, and musculoskeletal function rather than BMI SDS alone. Such additional parameters target the functional limitations that obesity imposes on children, and quantify improvements in quality of life that are not represented by the commonly used metrics of BMI, weight or BMI-SDS. Though our service integrates such measures as part of routine care, this paper did not focus on the outcomes related to quality of life, fitness, mental health or function and it is warranted to include this in future studies undertaken with the service.

Our findings must be interpreted in the context of numerous limitations. It was not possible to standardize treatment schedules between individuals, nor to compare patients to an untreated control group which could be considered unethical (63, 64). Consequently, the data are observational, and the possibility that changes in BMI-SDS were affected by factors other than the W82GO Service cannot be excluded. Nevertheless, the changes in BMI-SDS that we report are comparable to those reported in previous studies of multidisciplinary childhood obesity interventions (33, 50, 60). It is a limitation of this study that it was not possible to standardize the timing or reasons for discharge from the clinic. There was no long-term (>24 months) follow-up in this analysis, and it is not known if the observed changes in BMI-SDS treatment were maintained once patients left the service.

This study tracks the progress of 692 children through the W82GO Service of Children's Health Ireland at Temple Street, and this large sample size and the longitudinal design are strengths. It is also a strength of this study that none of the parameters in this study were self-reported, all measurements were collected by clinical staff and indexed to UK and Ireland reference parameters for SEP and growth. This retrospective analysis of 12 years of multidisciplinary intervention for childhood obesity demonstrated moderate reductions in BMI-SDS in most children. There was extensive between-subject variability in the response to treatment, and in the parameters recorded at baseline, reflecting the multi-dimensional pathophysiology of childhood obesity, and supporting the W82GO approach of personalized intervention. Future research should focus on exploring whether children engaged in the service experienced change in other health outcomes including blood pressure, physical fitness, emotional-

or mental-health outcomes or quality of life. In addition, further investigation is required to understand why some children do not respond to the intervention and how future interventions can optimally manage diverse phenotypes of obesity.

The Irish government commitments to address obesity include the development and implementation of a national integrated service model for the health and social care of those with obesity "including specialist services on an equitable geographic basis for both children and adults" (65). Multicomponent clinical services such as the W28GO Service are recommended in the RCPI Expert Report addressing obesity treatment (66) and further development of the W28GO Service is planned as part of the Model of Care for the Management of Overweight and Obesity developed by the National Clinical Programme for Obesity (67).

Clinical services such as W82GO and research studies indicate that childhood obesity has a multifactorial etiology that is driven by genetic, social, pathological and lifestyle-related factors. Future childhood obesity services should reflect this complexity by incorporating multidisciplinary interventions and considering systemic clinical outcomes in addition to changes in BMI-SDS.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The study was reviewed and approved by the Clinical Audit Committee of Children's Health Ireland at Temple Street. Written informed consent from the participant's legal guardian/next of kin was not required due to the audit of routinely collected and anonymised clinical data.

AUTHOR CONTRIBUTIONS

GO'M led the development of the clinical intervention, study design, and managed and directed the study. All authors made significant contributions to data collection. Data analysis was completed by GO'M and CW. All authors contributed to writing and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fnut.2022.895091/full#supplementary-material>

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