Evaluation of Exercise Program for Overweight and Obese Pediatric Participants in a Single Tertiary Center in Singapore

Title

Evaluation of exercise programme for overweight and obese paediatric patients in a single tertiary centre

Introduction

The prevalence of childhood obesity has been rising in recent years. In Singapore, the proportion of overweight children aged 6 to 18 years increased from 11% in 2013 to 13% in 2017[i]. Childhood obesity is associated with multiple adverse health outcomes, including increased risk of cardiovascular[ii], endocrinological[iii], respiratory[iv], and orthopaedic[v] conditions. For example, obesity has been associated with increased insulin resistance, impaired glucose tolerance, dyslipidaemia and increase in blood pressure. There is also an association between childhood obesity and psychological comorbidities including depression, anxiety, and behavioural disorders[vi]. Beyond the negative implications on the individual, childhood obesity also has long-term implications for the healthcare system, as many of the obesity-related chronic conditions persist into adulthood[vii]. It is thus necessary to intervene early in the battle against childhood obesity, to prevent the adverse downstream effects at both the individual and national level.

One of the well-known and significant contributors to paediatric obesity is physical inactivity and sedentary behaviour[viii]. Exercise and physical activity are thus essential in the management of paediatric obesity. Exercise strategies are broadly classified into aerobic exercise, resistance training and a combination of both. Aerobic exercise has been shown in many studies to be effective in reducing fasting insulin levels, insulin resistance[ix], and body fat percentage[x] as well as improving blood lipid levels in obese adolescents. Aerobic exercise generally involves moderate- to vigorous-intensity physical activity such as running or cycling, for a sustained period of a least 30-60 minutes. Both local and international guidelines, including the 2020 World Health Organization (WHO) guidelines on physical activity and sedentary behaviour, recommended for children and adolescents to spend at least an average of 60 minutes of moderate- to vigorous-intensity physical activity per day[xixii]. Resistance training has also been shown to reduce body fat percentage, improve blood lipid levels and insulin resistance in the adult population[xiii], although there is presently limited evidence in children and adolescents.

There have been various weight management programs and strategies developed at both the primary and tertiary care levels around the world. One study in California studied the effectiveness of a family-based weight management program in the primary care setting, which involved using motivational interviewing (MI) and cognitive behavioural therapy to optimize participant self-efficacy[xiv]. The study showed that almost 70% of participating children were able to reduce or maintain Body Mass Index (BMI) after only 6 months, compared to 45% to 58% in control groups. Another randomized controlled trial conducted in New Haven, Connecticut[xv] studied the impact of a weight management program on BMI, percentage body fat, blood pressure and biochemical markers such as cholesterol levels and fasting plasma glucose. The program consisted of twice weekly high intensity exercise led by exercise physiologists, combined with once weekly nutrition and behaviour modification classes. At the end of the 1-year program, there was a significant decrease in BMI, total body fat, and total cholesterol levels in program participants, compared to the control group.

We audited the results of the exercise programme used in the weight management of overweight and obese paediatric patients in KK Women's and Children's Hospital (KKH), in Singapore, a tertiary paediatric centre.

Methods

Study setting and patient selection

We collected data from all the participants who were enrolled in our weight management programme in Singapore Sport and Exercise Medicine Centre at KK Women's and Children's Hospital (SSMC@KKH) from 2017 to 2022. Demographic data included age, gender, and race. Anthropometric data included height, weight, BMI and blood pressure. Participants were recruited to the weight management programme based on doctor's referral. Confidentiality was maintained according to institutional regulations. Ethics approval was not required as this study was an institutional audit.

Pre-exercise evaluation

All participants were required to undergo a fitness assessment on their first visit at SSMC@KKH. Anthropometric values such as body weight, height, and BMI were measured and calculated using an automated BMI machine (Avamech B1000-LAN) at every visit. Blood pressure was taken using an automated device (GE Dinamap Procare DPC300N-EN) to get a baseline reading and ensure safety before starting any physical activity.

In addition to the fitness assessment, participants and their parents/guardians received physical activity counselling from a Clinical Exercise Physiologist. They were advised to reduce sedentary activities, get sufficient sleep, and perform at least 60 minutes of physical activity each day. Physical activity and fitness goals were discussed and set as well. For participants who expressed interest and commitment in the programme, a package of 4, 8 or 12 sessions with a recommended frequency of once per week was offered.

Exercise programme

The exercise programme (Fitness Superstars) consisted of group sessions of 90 minutes each and were supervised by a Clinical Exercise Physiologist. As part of the programme, participants were educated about the importance of living an active and healthy lifestyle, as well as work on improving their body composition, fitness level, and confidence in performing physical activities. To ensure a safe environment for them to exercise, pre and post blood pressure were taken and exercise intensity was monitored using a chest strap heart rate monitor (Polar H10). Sports and games were included as a way to promote social interaction and enjoyment during exercise. Table 1 shows an example of a 90-minute group exercise session.

Table 1. Session content of the "Fitness Superstars" exercise programme at SSMC@KKH

COMPONENTS	DETAILS	INTENSITY	DURATION
WARM-UP	Machine: Treadmill, Stationary Bicycle, Elliptical, Fluid Rower	Light (60-69% HR Max)	10 minutes

	Dynamic Movements • Forward Runs to Side Shuffles • Backwards Runs to V-Shuffles • High Knee Cross Touch to Leg Swings • Walk and Scoop • Knee Hugs to Quadriceps Stretch • Giant Wide Steps to Squat • Knee Turn In to Reverse Lunge with Side Reach • Multi-Hip to 3-Point Calf Stretch • Seated Lower Body Stretches	Moderate (70-79% HR Max)	10 minutes
CARDIORESPIRATORY FITNESS **- "HUFF AND PUFF"**	Machine: Treadmill, Stationary Bicycle, Elliptical, Fluid Rower	Moderate-High (70-89% HR Max)	20 minutes
CIRCUIT EXERCISES **- "TO THE BEAT"**	Set A: 2-3 sets/rounds • Up and Go • Fast Foot Ladder • Standing Board Jump • Burpees on the Move • High Knee Hurdles • Hop - Gallop - Skip Set B: 2-3 sets of 30 seconds each • Soccer Step Ons • Sole Roll • Dribbling Forward and Backwards • Soccer Step Over • Lateral Step and Body Feint • Step Tap	Moderate-High (70-89% HR Max)	40 minutes
CORE FUN!	2 sets of 15-20 repetitions • Alternate Hand and Leg • Rotational Abdominal Crunch • Single Leg Balance Reverse Bridge Right and Left • Reverse Bridge March	Light (60-69% HR Max)	10 minutes

Outcomes

Several variables were transformed prior to analysis. First, the BMI category was collapsed from four (A, B, C, D) to two, where the category of Not severely overweight included those in the acceptable weight and overweight category, and severely overweight which included those in XXX. Second, the variables of BMI, weight and height were transformed into change scores between all pairs of consecutive visits ($visit_n - visit_{n-1}$). This enabled us to statistically model the outcomes of the change in BMI and weight between visits.

Statistical analysis

All statistical analyses were performed using R (version 4.3.0) and the R package *mgcv* [23]. The primary outcomes we studied were the change in weight and BMI between two consecutive visits. The outcomes were modelled after the linear effects of sex (male or female) and ethnicity (Chinese, Malay, Indian, Eurasian); the smooth effects of gap between

visits (weeks) with a different shape for each level of BMI category, age, difference in height between consecutive visits, and a subject specific random effect; using Generalized Additive Modelling (GAM) [23]. GAM was used instead of traditional statistics like linear regression as we hypothesised that the effects of BMI and weight changes across the values of our covariates may be nonlinear. The typical approach for statistical inference using GAMs is visualizing the 95% confidence interval (CI) of the predicted mean values of the outcome at the given values of each covariate. Herein, we report the predicted mean weight and BMI difference between two consecutive visits given the following values of the covariates: visit gap of one week up to 12 weeks, BMI categories (not severely vs severely overweight), and age from six to 12 years old. A statistically significant result can be inferred from a non-zero crossing of the 95%CI.

Results

Patient demographics and baseline characteristics

In total, we collected data from 166 participants who participated in our weight management programme from 2017 to 2022. For the purposes of the analysis, we only included participants aged 6- to 15-years-old, inclusive. After excluding those who were below 6-years-old and above 15-years-old, there were a total of 123 participants whose data we included in our analysis.

The average age of participants was 11.67 years old. The gender of participants was distributed evenly, with 41% (n=50) female and 59% (n=73) male. In terms of race, 51% (b=63) were Chinese, 15% (n=18) were Indian, 29% (n=36) were Malay and 4.9% (n=6) were others.

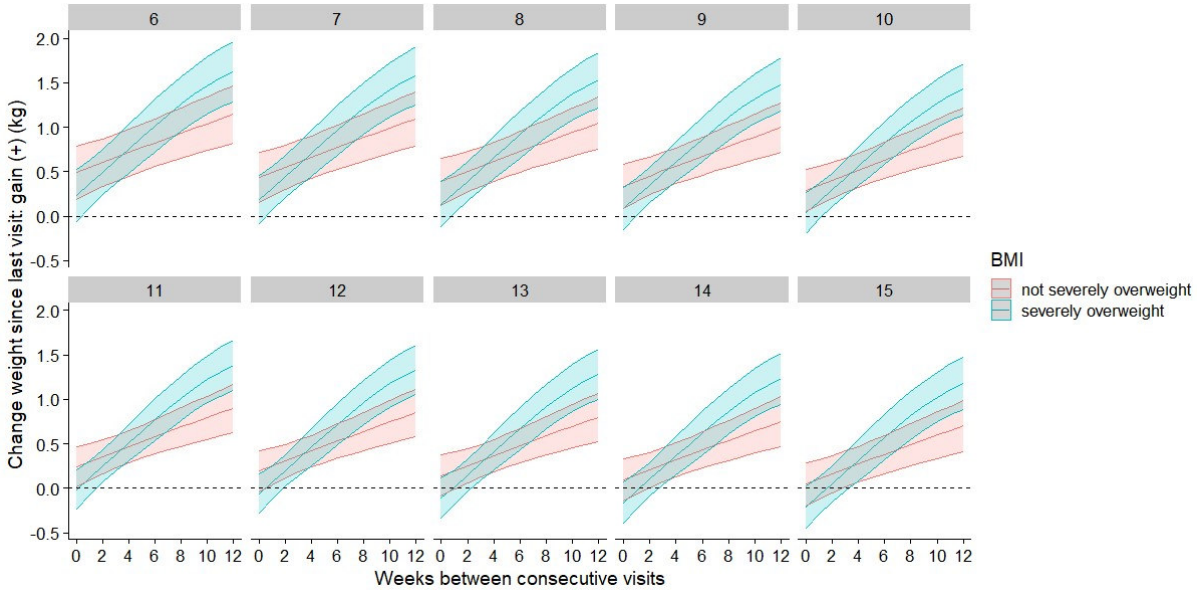
The BMI of participants were plotted on weight- and gender-specific centile charts from Singapore Health Promotion Board[xvi]. Participants were divided into 2 main BMI categories: obese (BMI ≥97th percentile) and overweight (BMI 90th to 97th centile). 76% (n=94) of the participants were in the obese category whereas 24% (n=29) of them were overweight. The average BMI of participants at first visit was 30.82.

Table 2. Participant demographics

CHARACTERISTIC	N = 123[1]
Sex	
female	50 / 123 (41%)
male	73 / 123 (59%)
Race	
Chinese	63 / 123 (51%)
Indian	18 / 123 (15%)
Malay	36 / 123 (29%)
Others	6 / 123 (4.9%)
BMI	30.82 (4.97)
Category	
not severely overweight	29 / 123 (24%)
severely overweight	94 / 123 (76%)
Height	154.09 (14.00)
Weight	74.62 (21.19)
Systolic Blood Pressure (SBP)	113.95 (11.27)
Diastolic Blood Pressure (DBP)	64.10 (9.20)
Age	11.67 (2.66)

Comparing change in weight between consecutive visits

Figure 1. Change in weight between consecutive visits



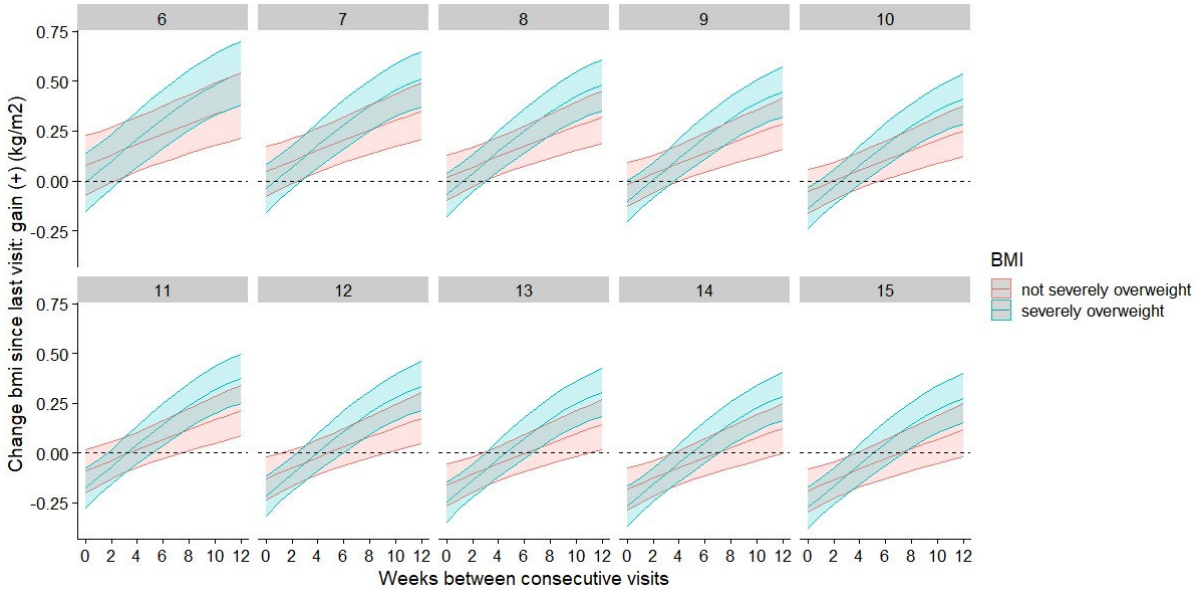
Overall, there was a gain in weight across all age groups for both obese and overweight categories. This is except for a small group of participants, such as the 15-year-old obese participants, who showed weight loss up to 2 weeks between consecutive visits. The older patients in general demonstrated weight loss for the more frequent visits as compared to their younger counterparts.

The obese participants demonstrated either weight loss, or less weight gain, compared to the overweight participants for shorter visit intervals. Taking the 15-year-old group for example: at 2 weeks between consecutive visits, obese participants on average maintained their weight, whereas the overweight participant showed weight gain. However, the trend is the opposite at longer visit intervals. For every age group, past a certain number of weeks between visits, the obese participants demonstrated greater weight gain as compared to the overweight participants. For example, when we look at the 15-year-old group again, for 3 weeks or more between consecutive visits, the obese participants gained more weight as compared to the overweight participants.

Can you write something descriptive about the results like I did for BMI? Here you can mention the weight. I believe you have the results on excel right?

Comparing change in BMI between consecutive visits

Figure 2. Change in BMI between consecutive visits



The change in BMI between visits depended on the gap between visits, the BMI index at baseline, and baseline age of the individuals. A decrease in BMI between visits required that the maximum gap between visits to be ≤ 3 years (Figure). Also, a decrease in BMI between visits were only found in individuals ≥ 10 years old (Figure). The greatest decrease in BMI (-0.273, 95%CI -0.378 to -0.168) between visits were found in 15 year old individuals who were severely overweight and the gap between visits were within a week (Figure). From gaps ranging from 1 to 3 weeks, the age group and BMI category which benefited most was those 15 years of age who were classified as severely overweight (1 week gap: - 0.219, 95%CI -0.313 to -0.125; 3 week gap: -0.111, 95%CI -0.205 to -0.017) (Figure). The group which would benefit the least as a function of visit gaps were those 12 years and not severely overweight (<1 to 1 week gap), 12 years and severely overweight (2 week gap), and 14 years and not severely overweight (3 week gap) (Figure).

As paediatric patients are expected to gain both height and weight with age, we also analysed the change in BMI between consecutive visits. As can be seen from figure 2, a large proportion of participants showed a decrease in BMI despite the gain in weight shown in the corresponding graphs in figure 1. In other words, the weight gain of these participants was compensated by the increase in height, thus leading to an overall decrease in BMI. This observation is more evident in the older participants as compared to younger ones. Taking the 15-year-old group for example, participants showed a decrease in BMI up to an interval of 5 weeks between visits for the obese group and an interval of 7 weeks between visits for the overweight group. In contrast, in the 6-year-old group, participants showed either no change in BMI (obese group) or gain in BMI (overweight group) even if the sessions were less than a week apart.

Like the trend observed before for weight, the obese group tended to show a greater reduction in BMI as compared to the overweight participants when the interval between visits was shorter. Conversely, the longer the number of weeks between visits, the more the obese participants tended to show a greater increase in BMI as compared to the overweight participants.

Discussion

In this clinical audit, we studied the change in both weight and BMI between consecutive visits. Overall, the trends showed that the shorter the interval between consecutive visits, the more

likely it was for participants to maintain or lose both weight and BMI. This is in line with existing studies, which show that a higher frequency of exercise is associated with a more significant reduction in weight and BMI[xvii]. The 2017 US preventive services task force recommendation (USPSTF) statement[xviii] showed that intensive behavioural intervention, defined as more than or equal to 26 contact hours in children and adolescents 6 years and older over a period of 2 to 12 months, can result in significant improvement in weight and BMI for up to 12 months, whereas less intensive interventions show inadequate evidence of effectiveness. The behavioural interventions studied in the USPSTF statement comprised multiple components including family- and groups-based sessions, counselling about healthy eating and decreasing sedentary behaviour, as well as supervised physical activity sessions run by exercise physiologists[xix]. Similarly, in our weight management programme, sessions were also led by exercise physiologists. As part of the programme, participants were also educated about the importance of living an active lifestyle prior to taking part in the exercise sessions.

Although participants in our programme were recommended to attend the sessions once weekly, the results of the audit showed that a significant proportion ultimately did not adhere to this frequency, with some attending as infrequently as 12-weekly. Plausible reasons for the lack of adherence to the recommend frequency include competing commitments such as school, especially during examination seasons, or the inconvenience of travelling, for those who live far away from the hospital or those who have no available caregiver to bring them for the sessions. Barlow et al studied parent reasons for nonreturn to a multidisciplinary weight management clinic[xx]. Out of the 85 parents who were surveyed, commonly cited reasons included: child would miss too much school (28%), programme was too far from home (23%), scheduling conflicts (21%) and insurance does not cover care (21%). As this present audit did not investigate specific reasons for lack of adherence to the program, we recommend that future studies focus on how to improve attendance in weight management programmes, given the clear trend that shorter visit intervals greatly increase the chances for BMI reduction.

Our clinical audit also found that older participants lost weight and BMI more easily than their younger counterparts for the same interval between visits. The results showed that the older the participant, the greater the tendency to either maintain or lose BMI, even up to visit intervals of 7 weeks. This could be explained by the different levels of motivation in older participants when compared to their younger counterparts. A study by Brown et al which examined motivations for weight loss in children and adolescents found that older children (aged 12-15) had significantly greater odds compared to younger children of more frequently attempting to lose weight by reducing food intake, exercising, and eating fewer sweets or fatty foods[xxi]. Several studies have identified the main motivation for weight loss in adolescents, especially adolescent girls, to be appearance reasons[xxii xxiii xxiv]. In obese adolescents, who may be motivated by appearance rather than the desire for better health, it is therefore crucial to monitor for unhealthy weight loss behaviours that can pose a threat to the health of the adolescent[xxv]. On the other hand, for younger children, parental involvement has been proven to be positively associated with weight management strategies[xxvi]. Hence for younger children, more emphasis can be placed on parental supervision of dietary and lifestyle habits at home.

Lastly, our study also found that at shorter visit intervals, the obese participants were more likely to have reductions in BMI compared to the overweight participants. This finding has also been demonstrated in previous clinical trials[xxvii] and cohort studies[xxviii] in which higher BMI predicted greater weight loss. However, conversely, our results showed that at longer visit intervals, the obese participants were more likely to increase their BMI as compared to the overweight participants. This is suggestive that individuals with a higher baseline BMI

demonstrate greater weight fluctuations over time. A cohort study by Gulliford et al which studied the BMI of a population over a 9-year period showed that although reductions in BMI were seen more frequently among those with a higher baseline BMI, these decreases were more likely to be followed by subsequent increases rather than further decreases or stability in BMI[xxix]. Other studies have also reported more instability in weight trajectories among patients with higher BMIs[xxx]. Fluctuations in weight have been associated with a higher risk of morbidity and mortality compared to stable obesity[xxxi]. It is therefore essential for weight management programmes to focus on consistent weight loss in the long-term. This is particularly so for the obese patients, who are predisposed to greater fluctuations in weight. Putting in place measures to ensure more frequent attendance may be imperative in ensuring consistent and healthy weight loss.

Conclusion

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