

**Identification of Successful Goal Setting Strategies for
Management of Childhood Obesity: *Results from a Family-
Centered Lifestyle Intervention in Children 6 to 12 Years of Age***

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ABSTRACT

Background: Childhood obesity has grown to epidemic proportions worldwide over the past few decades. Lifestyle interventions in childhood obesity using goal setting have shown promising results. SMART goals are Specific, Measurable, Attainable, Realistic and Timely. **Objectives:** This study determined if using SMART goals in a family-based lifestyle intervention was linked to reduction in adiposity and defined the nature of SMART goals that were linked to success using the constructs from the Theory of Planned Behavior (TPB) and the Ecological Model (EM).

Methodology: Healthy overweight and obese children (n=100) from the McGill Youth Lifestyle Intervention with Food and Exercise Study (clinicaltrials.gov, NCT01290016) were randomized to either intervention group (INT) or control (CTL). INT received 5 SMART-based interventions with a dietitian over 6 mo. Height and weight were measured to compute body mass index-for-age z-scores (BAZ). SMART goals were classified using the TPB (*attitude, subjective norm, perceived behavioral control*) and the EM (*individual, family*). Groups were divided into “successful” (SUC) if BAZ maintained/decreased or “unsuccessful” (UNS) if BAZ increased over 6 mo. Differences among groups were tested using mixed model ANOVA and relationships between BAZ and SMART goals using Pearson’s correlations. **Results:** INT was 75% successful (-0.29 ± 0.22 BAZ) and 25% unsuccessful (0.29 ± 0.27 BAZ) ($p < 0.001$). The SMART goals analysis revealed that the percentage of goals classified as *subjective norm* from TPB was higher in INT-SUC compared to INT-UNS ($66.4 \pm 15.1\%$ vs $57.5 \pm 13.6\%$, $p = 0.036$). In INT overall, SMART goals classified as *subjective norm* were inversely correlated with BAZ change ($r = -0.39$, $p = 0.007$). Additionally, when SMART goals were targeting the *family* as opposed to the *individual* (child), a pattern of success was observed through an inverse correlation with BAZ change ($r = -0.28$, $p = 0.055$). **Conclusion:** We found that family-centered lifestyle interventions using SMART goals resulted in a greater proportion of successful participants compared to control. SMART goals that addressed the *subjective norm* concept from the TPB were correlated with favorable changes in BAZ after 6 mo. *Subjective norm* refers to the social pressure to perform a behavior, transmitted by those that influence an individual’s decisions. In other words, SMART goals targeting recommendations (norms) were more often associated with success. Involvement of the family also seems to have an important role to play in successful lifestyle interventions for childhood obesity.

Keywords: childhood obesity, SMART goals, lifestyle intervention, success, BMI z-score

RÉSUMÉ

Contexte: La prévalence de l'obésité infantile a pris des proportions épidémiques dans le monde au cours des dernières décennies. Les interventions visant la modification des habitudes de vie chez les enfants en surpoids ou obèses qui intègrent l'établissement d'objectifs ont démontrés des résultats prometteurs. Les objectifs SMART sont Spécifiques, Mesurables, Atteignables, Réalistes et Temporellement définis. **Objectifs:** Cette étude a pour but de 1) déterminer si l'utilisation des objectifs SMART dans le contexte d'une intervention familiale sur les habitudes de vie est relié à la réduction de l'adiposité chez les enfants et de 2) définir la nature des objectifs SMART liés au succès en utilisant les concepts de la Théorie du comportement planifié (TCP) et du Modèle Écologique (ME). **Méthodologie :** Des enfants en surpoids ou obèses (n=100) en santé de l'étude MYLIFE (McGill Youth Lifestyle Intervention with Food and Exercise Study, clinicaltrials.gov : NCT01290016) ont été assignés de façon alléatoire à un groupe intervention (INT) ou contrôle (CTL). INT a reçu 5 interventions utilisant les objectifs SMART avec une diététiste sur une période de 6 mois. La taille et le poids ont été mesurés pour calculer le score-z de l'indice de masse corporelle pour l'âge (zIMC). Les objectifs SMART ont été classifiés en utilisant la TCP (*attitude, normes sociales et auto-efficacité*) et le ME (*individu, famille*). Les groupes ont été divisés en 2 sous-groupes : succès (SUC) si le zIMC a été diminué ou maintenu et non-succès (NSUC) si le zIMC a augmenté en 6 mois. Les groupes ont été comparés en utilisant une ANOVA à modèle mixte et la relation entre le zIMC et les objectifs SMART a été déterminé avec les corrélations de Pearson. **Résultats :** INT a obtenu du succès à 75% (zIMC: -0.29 ± 0.22) et un non-succès à 25% (zIMC : 0.29 ± 0.27) ($p < 0.001$). La proportion d'objectifs SMART classifiés dans *normes sociales* de la TCP est plus grande dans le groupe INT-SUC que INT-NSUC (66.4 ± 15.1 % vs 57.5 ± 13.6 %, $p = 0.036$). Les objectifs SMART classifiés dans *normes sociales* sont inversement corrélés avec zIMC ($r = -0.39$, $p = 0.007$). De plus, lorsque les objectifs SMART englobent la *famille* en opposition à l'*individu*, une tendance au succès a été observée par le biais d'une corrélation inverse avec zIMC ($r = -0.28$, $p = 0.055$). **Conclusion:** L'intervention familiale sur les habitudes de vie intégrant les objectifs SMART a obtenu une plus grande proportion de participants succès que le groupe contrôle. Les objectifs SMART qui abordent le concept de *normes sociales* de la TCP sont corrélés avec des changements favorables du zIMC après 6 mois. Les *normes sociales* réfèrent à la pression sociale d'exercer un comportement, transmise par ceux qui influencent les décisions d'un

individu. En d'autres mots, les objectifs SMART qui abordent les recommandations (*normes*) sont plus souvent associés au succès. L'implication de la famille semble également avoir un rôle important à jouer dans le succès des interventions sur les habitudes de vie auprès des enfants en surpoids ou obèses.

Mots-clés: obésité infantile, objectifs SMART, intervention, habitudes de vie, succès, score-z de l'IMC

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LIST OF ABBREVIATIONS

AAP: American academy of pediatrics

AMDR: Acceptable macronutrients distribution ranges

BCT: Behavior change technique

BL: Baseline

BMI: Body mass index

CCHS: Canadian Community Health Survey

CFG: Canada's Food Guide

CTL: Control group

DXA: Dual-energy x-ray absorptiometry

EER: Estimated energy requirements

EM: Ecological model

FFM: Fat-free mass

INT: Intervention group

PA: Physical activity

RCT: Randomized controlled trial

SUC: Successful subgroup

TPB: Theory of planned behavior

TRA: Theory of reasoned action

UNS: Unsuccessful subgroup

US: United States

WHO: World Health Organization

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CONTRIBUTION OF AUTHORS

Hope Weiler, Tamara Cohen, Popi Kasvis and Celia Rodd are co-authors of this thesis. Hope Weiler is the principle investigator of the MYLIFE study. HW and Celia Rodd designed the study. Tamara Cohen designed the interventions, intervention tools, study forms and questionnaires. Sarah-Ève Loiselle carried out interventions with most participants from the 9 to 12.5 y group. TC carried out interventions with participants from the 6 to 8.9 y group and helped with counselling of the 9 to 12.5 y group of participants. Popi Kasvis carried out interventions for participants in the control group. TC, SL and PK assisted with all study visits, including data collection of anthropometry, food diaries and questionnaires. Catherine Vanstone was responsible for taking bloods and conducting DXA; she also provided assistance where needed.

SL was the primary author of this thesis, under the supervision of HW. SL reviewed the relevant literature, wrote the present thesis, performed statistical analyses and prepared tables and graphs for presentation of results with the help of HW. The thesis supervisor HW reviewed and edited drafts of the thesis.

1. LITERATURE REVIEW

1.1 INTRODUCTION: EPIDEMIOLOGY, CAUSES AND CONSEQUENCES OF CHILDHOOD OBESITY

Over the past three decades the prevalence of overweight and obesity among children has increased at a dramatic rate worldwide. The World Health Organization (WHO) considers childhood obesity as one of the most serious public health challenges of the 21st century [1]. Although overweight and obesity in youth have recently stabilized from 2009-2010 to 2011-2012 in the United States (US), the prevalence remains high, affecting more than 30% (of which 17% are obese) of American youth aged 2 to 19 y [2]. More specifically, for the age group 6-11 y, 34.2% are overweight and obese of which 17.7% are obese according to the Centers for Disease Control growth charts [2]. According to the 2004 Canadian Community Health Survey (CCHS), obesity is 70% higher now compared to the prevalence reported in 1978/79 for children 2 to 17 years of age [3]. For the age group 6 to 11 y, the proportion of overweight and obese literally doubled from 1978/79 to 2004, increasing from 13% to 26%. Besides, the percentage of obese children in this age group increased from 0 to 8%. A similar picture is seen among adolescents (12 to 17 y), where the proportion of overweight and obese rose from 14% to 29% [3]. More recently, the 2009 to 2011 Canadian Health Measures Survey reported that 19.7% of children aged 5 to 11 y were overweight and 13.1% were obese, based on WHO cut-offs [4]. In the province of Quebec, the prevalence of overweight and obesity among children is also of concern. In fact, about one fifth of children, more specifically, 10 to 22% of boys and 13 to 19% of girls 6 to 16 y of age are classified overweight. Furthermore, 4 to 9% of boys and girls are obese [5]. These numbers are alarming since the problem is advancing more rapidly than among adults and obese children tend to stay obese in adulthood [6]. In fact, after the age of 6, the probability of obesity in adulthood exceeds 50% for obese children [7].

Obesity is a multifactorial condition resulting from an imbalance between energy intake and expenditure [8]. This can cause a range of adverse metabolic effects, thus increasing risks of chronic diseases such as coronary heart disease, diabetes mellitus and cancers that can eventually lead to adult morbidity and mortality. [9] In addition, psycho-social issues, including

low self-esteem and risk of depression, arise. It may stigmatize the children and therefore, impact upon development of confidence and academic abilities. [10] Although genetic predisposition is important to consider [8], the dramatic increase in the prevalence of childhood overweight and obesity implicate an important role of environmental factors in its development. [11] Many researchers have therefore tried to develop treatment programs for childhood obesity. Lifestyle interventions are the cornerstone of the treatment of obesity because they target modifiable behaviors; diet, physical activity (PA) and inactivity. [12] Also called “the pandemic of the twenty-first century”, childhood obesity needs to be understood, in particular, its social and environmental contexts, in order to develop prevention and treatment methods. [13] In its 2005 report, the Institute of Medicine insisted on the seriousness, urgency and medical nature of childhood obesity as well as the need to take action. [14]

In order to have a better understanding of this problem and what work has been done to date, the following review of literature will cover the main topics related to diet, activity and behavior modification in childhood obesity. First, body composition of children will be described, then recommendations, patterns and determinants of eating and activity will be reviewed. Theoretical models will be described in depth, namely, the Theory of Planned Behavior and the Ecological Model, and how they are used to assess health behaviors. Finally, what is known about behavior change techniques (BCTs) and interventions for treating childhood obesity will be summarized.

1.2 DEFINITION OF CHILDHOOD OBESITY

The body mass index (BMI; $\text{weight}/\text{height}^2$) is widely used in adults to define obesity with values at or above the cut-off point of $30 \text{ kg}/\text{m}^2$ and overweight defined as BMI values between $25 \text{ kg}/\text{m}^2$ and $29.9 \text{ kg}/\text{m}^2$. [15] However, in children, the BMI value increases from 2 to 4 y of age to maturity, requiring the use of percentiles for age to interpret it correctly. [16] Many experts recommend using BMI to evaluate obesity among children and youths aged 2 to 19 y because it can be obtained easily and it is strongly correlated to percent body fat. [14] In 2005, the Institute of Medicine elected to define children with $\text{BMI} \geq 95^{\text{th}}$ percentile for age and

gender as obese and those with BMI \geq 85th percentile for age and gender as overweight. [14] Data available also suggest that a BMI-for-age z-score (BMI z-score) value \geq 99th percentile is associated with the presence of comorbidities, excess adiposity and persistence of obesity into adulthood. [14] In 2006, the WHO decided to release new growth curves in response to the need for a widely applicable growth reference for older children and adolescents (5 to 19 y). Therefore, the height-for-age, the weight-for-age and the BMI-for-age curves were developed, where the BMI curve matches the WHO under 5 y curve and the BMI values for overweight and obesity in adults at 19 y. [17]

Despite widespread use and reliance on BMI, the waist circumference in children provides a better estimate of visceral adipose tissue than BMI and is a good indicator of health risks. Conversely, BMI is better at estimating subcutaneous adipose tissue. [14] Waist circumference percentiles have been created for Canadian youth aged 11 to 18 y and the results show that boys have higher values than girls at every age and percentile level. [18] Percentiles of waist circumference can be used for diabetes and cardiovascular factors risk evaluation. [14] In fact, obese children with waist circumference at or above the 90th percentile have a higher risk for dyslipidemia and insulin resistance, compared to obese children with normal waist circumference. [19] Body composition is subject to change as children go through puberty. A recent study has shown that an early sexual maturation was positively associated with overweight and obesity in girls, but not in boys. In fact, compared to their counterparts, early maturing boys were thinner and early maturing girls were fatter. These results show that obesity is associated with sexual maturation in both genders, but the opposite way; the association is positive for girls, and negative for boys. [20] Besides, in a previous study, body fat content and fat-free mass (FFM) were measured in boys and girls from different Tanner's stages using dual-energy x-ray absorptiometry (DXA) and it was found that as boys go through puberty, their FFM continues to increase whereas for girls, both, FFM and body fat content increase. [21] The ideal definition of childhood obesity would be based on percentage body fat. [16] Sex-specific centile curves for body fat have been created to facilitate interpretation and percent body fat above the 98th percentile of the curve corresponds to obesity in children. [22] Using BMI only does not allow to distinguish if an increased mass results from increased fat,

lean tissue or bone. Hence, body fat reference curves for children have been created for the Caucasian population. [22] These limitations are also of issue when adiposity is remediated. It is not clear when BMI declines if it is due to proportionate losses of lean and fat tissue; only the latter is desirable.

1.3 OVERVIEW OF DIET AND ACTIVITY IN CHILDREN

1.3.1 CANADIAN RECOMMENDATIONS

According to the 2006 Canadian guidelines for obesity [23], dietary and lifestyle interventions should be undertaken to treat and manage obesity as a healthy diet and physical activity constitute the first-line treatment option. Specifically, in terms of physical activity, it is recommended to prescribe fun and recreational activities and to encourage children and adolescents to reduce sedentary activity and screen time. As per healthy diet, a dietary plan should be developed by a health professional, preferably a registered dietitian within a family-oriented behavior therapy. The guidelines also provide orientations in terms of research, in particular regarding the validation of models and tools to assess intention to change and intervention effectiveness. [23] Regarding the dietary aspect, Health Canada made specific age-group recommendations in the Eating Well with Canada's Food Guide (CFG). [24] On a daily basis, children of 4 to 8 y of age should consume 5 portions of vegetables and fruits, 4 portions of grain products, 2 portions of milk and alternatives and 1 portion of meat and alternatives. For children aged 9 to 13 y, the daily recommendations are as follows: 6 portions of vegetables and fruits, 6 portions of grain products, 3-4 portions of milk and alternatives and 1-2 portion of meat and alternatives. [24] It has been shown that an adequate consumption of fruits and vegetables is associated with a reduced risk of chronic diseases and lower risk of obesity and whole fruits should be preferred over juices. [25] Whole grain products should represent at least half of the portions of grain products. Lower fat dairy products and lean meats should be chosen. [26] In fact, the CFG recommends using small amounts of unsaturated fat to prepare food. Alternatives of meat such as legumes, tofu and fish should also be incorporated in the diet. Additionally, children and adolescents must limit their consumption of food away from home and sugar-sweetened drinks since these foods have been linked to body fatness in

Canadian youth. [26] Finally, water should be the preferred beverage. As regards of physical activity, the Canadian Society of Exercise Physiology (CSEP) published the Canadian Physical Activity Guidelines for the different age groups. [27] For children and adolescents aged 5-17 y, it is recommended that they engage in 60 minutes of moderate to vigorous physical activity every day, including vigorous intensity at least 3 days per week and activities to strengthen muscles and bones 3 days per week. Regarding sedentary behaviors, it should be minimized by limiting screen time to no more than 2 hours per day and limiting sedentary transport, extended sitting and time spent indoors. [27] In fact, television viewing has been identified as an early life risk factor for obesity in children as it may reduce energy expenditure and may contribute to impairment of the regulation of energy balance by uncoupling food intake from energy expenditure. [28]

1.3.2 EATING AND ACTIVITY PATTERNS IN CANADIAN CHILDREN

Eating Patterns

Research has shown that children who eat less than 5 portions of vegetables and fruits per day are more likely to be overweight or obese. According to the 2004 CCHS, in Canada, among those who eat less than 5 daily portions, about 19% are overweight and about 10% are obese [3]. In the province of Quebec, children aged 6 to 14 y consume on average 4 portions of fruits and vegetables per day while the recommendations for their age-group from CFG is 5 to 6 daily portions. About 2/3 of boys aged 6 to 11 eat less than the minimal recommendations for fruits and vegetables, and similar proportions are found among girls of the same age [5]. The survey also revealed that children aged 6 to 16 y are getting almost one quarter (22%) of their energy from the group “other foods” which includes food and drinks rich in sugar and fat. In terms of fat intake, boys and girls aged 6 to 11 y consume on average 31 to 33% of their energy as total fat, including about 12% as saturated fat [5], which is within but close to the higher end of the acceptable macronutrients distribution range (AMDR) for fat (25-35% of total daily energy) for this age group [29], but about ¼ of them consume more than 30% of energy as fat. According to the results from a cross-sectional study based on the 2004 CCHS, many groups of children and adolescents are consuming sweetened beverages in higher amount than recommended [30]. When looking at these data, it’s not surprising that overweight and obesity is increasing among

children and adolescent. This also supports the need for further research to establish the best strategies towards improving dietary habits.

Activity Patterns

Although some studies have demonstrated the protective effect of physical activity on childhood obesity, the 2004 CCHS data didn't show this association with children aged 6 to 11 y since there is no statistically significant difference in the proportions of overweight and obese children according to the weekly hours of physical activity. Across the 3 categories (< 7 hrs, 7 to 14 hrs, >14 hrs), there is a proportion of 17-18% of children being overweight and 8-9% being obese. [3] However, an association is seen in older boys (12-17 y) whereas sedentary boys are more likely to be obese than active boys; 16% versus 9%. Interestingly, only 13% of sedentary boys are overweight compared to 24% in the active/moderately active category. These differences were not seen among girls of this age group with about one quarter of them being overweight or obese no matter what their level of activity is. [3] Where no association was shown between physical activity and weight status among children aged 6 to 11, sedentary activities were linked to obesity risk. According to the 2004 CCHS, 36% of all children reported more than 2 hours of screen time per day. Within this group, 35% were overweight or obese compared to 18% in the group having 1 hour or less of screen time per day. [3] The report from the *Institut de la statistique du Québec* showed that the frequency "often/always" of television watching during dinner was increasing with age, starting from 37% of those who were 6-8 y to 50% of those who were 15-16 y. [5]

Overall it is clear that overweight and obesity is a growing concern in children in Canada. Improvements in diet, physical activity and inactivity patterns are required to resolve the problem. In order to establish effective programs, it is important to understand the determinants of these lifestyle habits.

1.3.3 EATING AND ACTIVITY DETERMINANTS IN CHILDREN

Eating determinants

Eating behaviors are strongly influenced by a variety of social and physical environmental factors and may interfere on the onset of obesity. Many studies have shown the important

influence that family has on children's eating practices, including attitude. [31] Preferences, availability and accessibility of food will influence choices. Children tend to choose the food that they are served the most often. Food neophobia is also identified as a predictor of fruits and vegetables consumption but it was shown that repeated exposure can overcome dislike of food. Moreover, children are more likely to eat food that is easily accessible and ready to eat. Indeed, less nutritious foods are often found to be easily accessible, convenient and at a low cost compared to healthier food. [32] Children's acceptance, preference and intake are influenced by what they see from their parents but also from their peers. [31] However, with age, the familial effect takes less importance to the benefit of other social influence outside the family. [33]

Nowadays, palatable energy-dense foods are easily accessible and available through fast-food stores, vending machines, etc. Eating in different occasions and places is acceptable and snacking energy-dense food is now more common. For meals purchased away from home, large portions are now the norm and meals from restaurants tend to contain more fat than those prepared at home. [11, 26] In fact, Gillis and Bar-Or observed that Canadian obese children and adolescents consume more servings of meat and alternatives, grain products, sugar sweetened drinks, food eaten away from home (such as take-out, restaurant, theme day and food bought at school) and potato chips than their non-obese counterpart. In a one-year cross-sectional study on 181 participants aged 4 to 16, they found significant positive correlations between percent body fat with meat and alternatives, sugar sweetened drinks and food eaten away from home [26]. Research has also shown that children with higher weight have a greater preference for fat and tend to regulate their energy intake less precisely. In fact, some studies have reported that overweight children have a greater proportion of energy coming from fat compared to their normal counterpart. [11] However, one must take into account that higher energy and fat is needed to maintain balance in overweight children. It is therefore difficult to determine whether children are overweight because they consume more energy and fat or whether they eat more because they are overweight. Birch and Davison believe that both are likely to be true. [11] Longitudinal studies have shown associations between higher dietary fat and increased weight status in children. Some authors found that girls having more than 30% of

their energy coming from fat significantly increased their BMI and skinfold thickness from 5 to 7 y of age, compared to girls having 20-30% of total energy from fat. [34]

Gender differences have also been identified in the literature regarding food preferences. A study conducted in United Kingdom on 1291 children aged 4 to 16 found that girls like more fruits and vegetables than boys and boys have a pronounced preference for fatty and sugary foods, meat, processed meat products and eggs compared to girls. [35] In a Canadian study, boys aged 6-11 y were found to have a higher sugar-sweetened beverage consumption compared to girls and other age-groups, which may put them at risk for overweight and obesity. [30] Overall, children's food preferences are not consistent with a healthy diet. [35]

Physical Activity

Lack of physical activity is known to be an important factor contributing to childhood obesity as physical activity is a key component of the energy balance. However, the relationship between physical activity and adiposity in youth is inconsistent amongst the different studies, possibly due to the different methods used to measure physical activity. [36] According to Kohl and Hobbs, there are 3 different types of influence on behavioral determinants of physical activity namely: physiological and developmental factors, environmental factors as well as psychological, social and demographic factors. [37] Therefore, understanding the determinants of physical activity is quite complex since the interaction between intrinsic and extrinsic factors must be taken into account in order to provoke behavioral changes.

A review published in 2000 the correlates of physical activity for children [38]. The authors found many variables that were associated with physical activity. Perceived barriers were a consistent negative correlation while being a male, intention to be active, preference for PA were positively associated with physical activity. In terms of environment, they found positive associations with access to facilities and programs, as well as time spent outdoors. Parent support and siblings' physical activity were also found to be associated. Unfortunately, age seems to be inversely associated with physical activity, meaning that boys and girls become less active as they age [38, 39]. In a prospective study designed to understand which determinants are involved in this decline, psychological and parents variables were identified as significant for

boys and girls. In fact, children's physical education, attitude, perceived competence, activity preferences as well as parents' physical activity and transport to the activity location are factors that were found to explain a significant proportion of the variance for both genders [39]. However, different covariates of changes were found for boys and girls, suggesting that different factors influence the decline of physical activity for both genders. For example, it was found that parents' physical activity was related to changes in physical activity for boys but not in girls.

Research has shown that overweight children, especially girls, may be more vulnerable to physical activity barriers, especially body-related barriers. A high body consciousness was reported as a main barrier in overweight children, especially among girls, compared to non-obese children in a study examining the barriers to physical activity [40]. Moreover, body awareness was found to be the unique type of barrier that differed between overweight and non-overweight boys. Resource and social barriers as well as lower level of adult support were also highly reported as significant barriers compared to their non-overweight counterpart. Parent support, especially if it's action-oriented, has been shown to influence children's activity. These findings support the need for interventions that minimize body awareness particularly for girls, promotes body acceptance and parental support. Perceived barriers can be an important determinant of physical activity in children but their perceived support and ability to overcome them has shown positive association with higher levels of physical activity intensity [40].

According to some authors, being overweight exacerbate barriers reported by all adolescents, such as low self-efficacy to overcome transportation barriers and perceived lack of athletic ability compared to peers [41]. At the interpersonal level, overweight adolescents experience a higher level of victimization and difficulty to form relationships with peers. A review of 7 studies found that self-efficacy was a strong mediator for physical activity, showing that self-efficacy should be one of the strategies used by interventions to improve physical activity [42]. Another cross-sectional study of 133 non-obese and 54 obese children in grade six also found lower levels of physical activity self-efficacy in obese children that exhibited significantly lower movement counts and daily participation in moderate and vigorous physical activity, compared

to non-obese youth [36]. The authors observed that obese children were significantly less involved in community organizations that promote physical activity and were less likely to report their father or male guardian to be active, showing that parents' physical activity is related to their child's physical activity. Thus, these findings support the hypothesis that physical inactivity is an important factor contributing to childhood obesity. In fact, some researchers have been interested in studying sedentary behaviors in children as a stronger predictor of obesity than activity itself. A small statistically significant relationship between body fatness and television watching has been found in a meta-analysis including studies on children and youth [43]. Similarly, longitudinal data showed significantly relationship between overweight and sedentary behaviors [44].

In light of these findings, it is clear that physical activity is influenced by environmental and personal factors as it's the case for eating habits. The following section focus on how behavioral models can explain and describe lifestyle changes.

1.4 BEHAVIORAL MODELS

1.4.1 THEORY OF PLANNED BEHAVIOR

The Theory of Planned Behavior (TPB) model is a behavioral intention prediction theory using a social-psychological approach to understand and predict the determinants of health-behavior. [45] The TPB is an extension of the Theory of Reasoned Action (TRA) that was designed to predict behavior from intention. [46] The construct *perceived behavioral control* was added to the original model for situations where one may not have complete volitional control over a behavior, which is one of the assumptions of the TRA. [47] The TRA also assumes that people are rational beings. [45] Thus, according to the TPB, intentions to perform behaviors can be accurately predicted from 3 constructs: the *attitude* toward the behavior, the *subjective norm* and the *perceived behavioral control*, as illustrated in Figure 1. [46] In this theory, the individual's intention to perform a behavior is the central factor and intentions are assumed to capture the motivational factors that influence a person to exert effort to perform the behavior. [46]

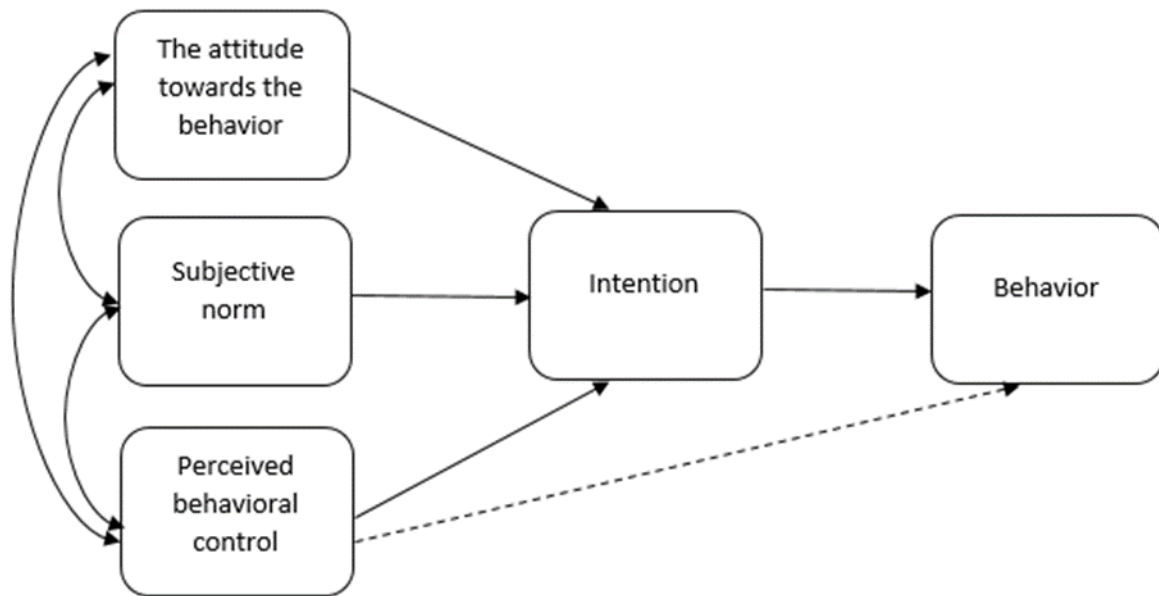


FIGURE 1 THEORY OF PLANNED BEHAVIOR (ADAPTED FROM AJZEN 1991)

The *attitude* toward the behavior is determined by the individual's beliefs about the outcomes or attributes of the behavior, weighted by the evaluation of those outcomes or attributes (how good they would be). [47] The attitude can also be described as the degree to which a person has favorable or unfavorable evaluation of the behavior in question. [46]. The attitude can be described using differential pairs of terms such as "important-not important", "enjoyable-not enjoyable", "useful-not useful", "pleasant-unpleasant", "fun-boring" and "valuable-worthless". [48] Questions about the importance of eating healthy foods can also be asked in a similar manner as "It is important for me to eat healthy foods everyday". [49] The *subjective norm* is determined by a person's normative beliefs, i.e. the perception of how importantly referent individuals approve or disapprove the behavior, weighted by the individual's motivation to comply with those referents. [47] In other words, the *subjective norm* is a social factor that refers to the person's social pressure to perform or not the behavior in question. [46] Statements such as "People important to me think that I should {perform a specific behavior}" where the participant would have to answer with a scale that goes from to strongly agree to strongly disagree are used to assess this construct. [48] Finally, the *perceived behavioral control* is determined by control beliefs, i.e. the presence or absence of facilitators and barriers to behavior performance, weighted by the individual's perceived power or the perceived impact of each condition to facilitate or inhibit the behavior which is also called self-efficacy. [47] This last predictor refers to the perceived ease or difficulty of performing the behavior, which is assumed to reflect past experience as well as anticipated impediments and obstacles. [46] A statement like "I feel that I have the ability to {perform a specific behavior} if I wish to" assessed by a scale would be an example of a question used to assess this construct. [48] Another example question would be "I have control over whether or not I eat healthily". [49] Generally, the more favorable the attitude and subjective norm are toward the behavior and the greater the perceived control is, the stronger should be the intention to perform the behavior in question. Moreover, the relative importance of each construct in the prediction of intention is expected to vary across behaviors and situations [46] or can be influenced by demographic variables such as age or gender. [48] There are evidence showing that the determinants are changing during development in children and youth. [48]

The TPB can be used in different studies to measure intention to change health related behaviors. A study [50] conducted in 310 5th and 8th graders applied the TPB was applied to study the psychological correlates of vigorous PA. The authors were able to explain 30% of the variance in PA intention from which the *attitude* represented the largest contribution, follow by the *perceived behavioral control*. In other words, when children have a sense of competency towards the activity and if it is fun/exciting, they are more likely to engage to engage in it. Their results showed that *subjective norm* didn't predict PA intention. A study [48] designed to examine the ability of the TPB to describe the determinants of PA intention in Canadian school children and adolescents aged 8 to 16 y (n=746), reported that the *perceived control* was the largest contributor to PA intention across the whole sample, followed by *attitude* and *subjective norm*. It was also found that *subjective norm* did not have a reliable contribution to predict intention in Grade 5 and 8 participants, but it made the largest relative contribution in Grade 3 participants, which shows the importance of normative beliefs at a young age. One of the weaknesses of this study is that PA behaviors were not measured per se, only physical activity intention was assessed. In 2006, Fila and colleagues published a study that examined the intention to eat healthfully among urban Native American youth aged 5 to 8 y (n= 139) using the TPB to which they added 2 new constructs: barriers and self-efficacy. [49] They found no association between intention and healthy eating behaviors for both genders. However, healthy eating behaviors were mostly predicted by *subjective norm* for boys, including influence of parents, TV and after school program. For girls, "barriers" was the strongest predictor of healthy eating behaviors, including parental support, taste and availability of food, but as they become older, they are more likely to engage in healthy eating behaviors. [49] Self-reported data were used to qualify healthy eating behaviors, which may lead to potential inaccuracies. It was also observed that girls had significantly higher mean values for intention and self-efficacy and lower mean values for barriers to eat healthy compared to boys, which is consistent with the findings from studies presented in previous sections.

The TPB has been used in many researches to understand the predictors of certain behaviors in children and adults, but there is still limited evidence on TPB and diet and activity in overweight and obese children. Nonetheless, the existing literature as shown that the TPB can predict

intentions, making it a potential model to help understanding behaviors that lead to success in the management of childhood obesity. However, the TPB cannot explain alone all the behaviors related to obesity because it doesn't take into account the environment of the child but the ecological model does.

1.4.2 ECOLOGICAL MODEL

The Ecological Model (EM) refers to the interaction between the individual and its environment, that is, the physical and sociocultural surrounding. The EM provides a comprehensive framework for integrating other theories, along with the consideration of the environment. [47] A general principle arising from the EM is that it usually takes a combination of both, the individual level and environmental level to achieve changes in health behaviors. In fact, the core concept of the EM is that behavior has multiple levels of influences, including intrapersonal, interpersonal, organizational, community and policy. [47] This model provides a comprehensive framework for understanding the multiple and interacting determinants of health behaviors, that's why they can be used to develop interventions that target mechanisms of change at several levels of influence. [47]

Different versions of the EM have been proposed in the literature. As mentioned earlier, the development of childhood obesity involves multiple factors from different contexts interacting with each other. Davison and Birch proposed an EM adapted for childhood obesity. [51] According to these authors, the child's ecology includes the family and the school which are embedded in a larger context including community and society. In addition, the child's particular characteristics, such as gender and age, interact with its environment's characteristics and influence development. The EM of the development of childhood overweight is illustrated in Figure 2. [51] According to this model, child behavioral patterns, namely dietary intake, physical activity and sedentary behavior, are risk factors for overweight. Hence, the development of these risk factors is shaped by parenting style and family characteristics. Finally, characteristics of school environment, community, society and demographic influence the child weight status as a result of their influence on parenting practices and family characteristics as well as child's eating and activity behaviors. [51]

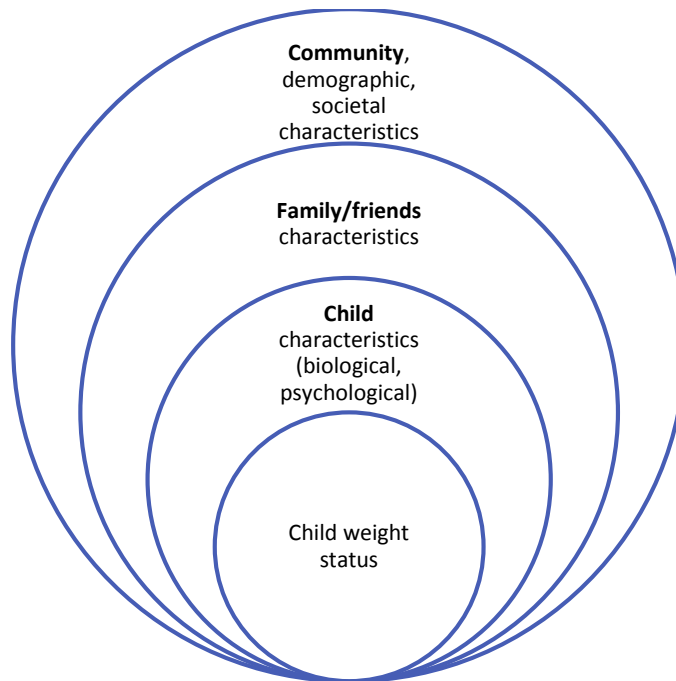


FIGURE 2 ECOLOGICAL MODEL FOR CHILDHOOD OBESITY (ADAPTED FROM DAVISON & BIRCH 2001 AND GLANTZ 2008)

The EM is a very comprehensive model that allows to take into account the interactions found among the complex set of factors that influence child risk of obesity, notably with regards to diet and physical activity. [52] The social ecology theory, along with the TPB, have both been identified as the most promising avenues for research on diet and physical activity behavior changes in regard to obesity. [52]

1.4.3 BEHAVIOR CHANGE TECHNIQUES

It is important to develop interventions that support health-behavior changes in order to increase the impact on health, but there needs to be an understanding of mechanisms of behavior change to accomplish that. [53] Hardeman and colleagues [53] presented the development and application of a causal modelling approach to develop theory-based interventions, because without theoretical basis, literature on behavior change intervention would not be helpful for a new situation. [54] Causal processes that underlie a behavioral intention can be tested within RCTs examining the effectiveness of the intervention. [54] A simple generic model (Figure 3) links the BCT (how to change the behavior) to behavior determinant (what predicts the behavior), to behavior, psychological and biochemical variables that are ultimately linked to health outcomes. [53] Of course, this model will be tailored for each application, depending on the population, context and health outcomes. Within the causal approach from Hardeman et al., the first step is to identify behavioral determinants that are identified from theories (e.g. attitude, subjective norm and perceived behavioral control from TPB) so that BCTs can be directed at these behavior change determinants. [54] Another part of the process is to map BCTs on to the proposed behavioral determinants, because different techniques will address different determinants. Michie et al. [54] have attempted to create an extensive list of BCTs and definitions and to identify the links between these techniques and the theory-based behavioral determinants. A comprehensive taxonomy of BCTs to help people change their physical activity and healthy eating behaviors called CALO-RE has been developed and updated recently. [55] This taxonomy addresses the poor reporting of interventions, the great diversity in terminology and the low replicability. The CALO-RE taxonomy was used in a systematic review of prevention and management childhood obesity behavior change interventions in order to identify effective BCTs. [56] Effectiveness ratios were calculated and 6

BCTs achieved a 100% effectiveness ratio in obesity management interventions: individual information, environment restructuring, role model, stress management, communication skills and practice. General information was the only technique identified as uniquely non-effective. A concrete application of the theory-based BCTs was done in a pilot study on the prevention of obesity in children. [57] Goal-setting, self-efficacy and readiness for change were the constructs used within a community-based obesity prevention program designed for 5th and 6th graders and their family. The main outcome was that techniques were successfully adapted for 11-12 years old children into games, worksheets and helpful acronyms that satisfied the targeted population. [57] The following section gives an overview of the evidence that we have to our disposal regarding interventions for treating childhood obesity.

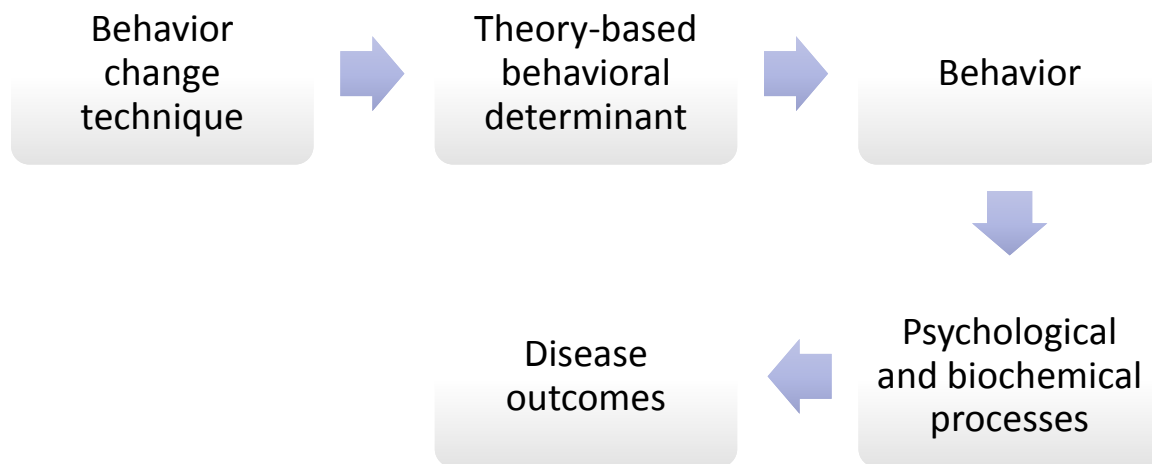


FIGURE 3 GENERIC CAUSAL MODELLING APPROACH PROPOSED BY HARDEMAN ET AL. 2005 (ADAPTED FROM MICHIE ET AL. 2008)

1.5 LIFESTYLE INTERVENTIONS FOR CHILDHOOD OBESITY

1.5.1 FAMILY-BASED INTERVENTIONS

Parents have a great influence on their children's diet in many ways and the role played by the family is important in the treatment of childhood obesity. A recent qualitative study about a weight-loss program for children identified engagement of parents in the program as well as a supportive environment as factors of success [58]. In fact, parents play a cornerstone role in motivating their child and providing an environment that facilitates behavior changes in terms of diet and physical activity. However, the degree of success of the outcomes has been associated with the parenting style, more specifically the authoritative style. [58] From another point of view, Golan believes that targeting parents exclusively results in better outcomes than parents attending sessions with the child [59]. In fact, Golan published in 2006 results showing that interventions involving parents only yielded to better results in terms of weight status, compared to interventions with child-only or both parents and child [59]. The superiority of the parents-only group was also shown in a 7-year follow up where the parents-only group had a greater reduction in mean percent overweight than the child-only group [60]. The recent HIKCUPS RCT involving prepubertal overweight and obese children (n=165) demonstrated that a child-centered physical activity program and a parent-centered dietary-modification program, both in isolation and combined, were efficacious in decreasing BMI z-score at 1-year follow-up, but the 2 groups including the dietary component showed a greater reduction (Diet -0.39 (-0.51, -0.27 95% CI); Activity -0.17 (-0.28, -0.06 95% CI) and Diet + Activity -0.32 (-0.42, -0.22) [61]. Participants were divided in 3 groups and the 2 programs that involved the dietary component with parents resulted in a greater decrease in BMI z-score, leading one to believe that the focus on parental behavior change strategies, including problem-solving, goal-setting, role modeling and positive reinforcement, may have resulted in parents taking greater responsibility [61]. Despite discrepancies found in the literature, one key message remains: parents are undoubtedly an important factor in the success of childhood obesity treatment [61]. However, very few studies address specifically the goals set with the children and their parents leading to success throughout the lifestyle intervention process. A review published in a journal of Princeton University stated that parents play a critical role in the prevention of

childhood obesity, and that this role is changing at the different stages of the child's development [62]. The lack of a parental component in some school-based programs could be one of the reasons contributing to their poor success. The authors concluded that intervention in childhood obesity should involve and work directly with parents to make healthful changes at home and to support healthy eating and physical activity [62].

In order to establish the benefits of including a family component in weight-loss interventions, meta-analysis of RCT have been conducted. Although some studies have shown inconsistent results in the past, a meta-analysis published in 2007 including 16 studies involving parents showed that family-behavioral weight-loss treatment for children can be effective [63]. Intervention containing a family-behavioral component produced larger effect sizes compared to other treatment and control groups. However, these interesting results didn't provide information about which aspects of family-behavior treatments were responsible for the desired outcomes.

A survey conducted among pediatricians, pediatric nurses and registered dietitians showed that those who are able to use counseling techniques to guide the families were the most likely to successfully help the families [64]. However, the health care professionals surveyed generally did not feel proficient in behavioral counseling. These results demonstrate a need to improve training of health professionals that are working with overweight and obese children and their family.

Qualitative studies can provide useful input regarding specific key components leading to success for interventions. However, these results are not statistically linked to the outcomes. On the other hand, RCTs that have been done so far have not identified specific goal strategies leading to success, as they rather focus on more general BCTs.

1.5.2 COMPONENTS OF SUCCESSFUL INTERVENTIONS

Several fundamental principles for obesity treatment have been identified in the literature. The family involvement is one of them, as demonstrated previously. In fact, the American Academy of Pediatrics (AAP) Experts acknowledge the commitment of parents to be important as they serve as role model, authority figures and behavioralists to mold their children's habits [65].

Secondly, interventions must be individualized to each patient. A single rigid approach is unlikely to meet each individual's needs [66]. Motivational interviewing is a client-centered counselling style that helps clients to explore and resolve ambivalence by evaluating their motivation level to change a behavior. This approach helps directing the intervention and discussion towards the right focus in order to promote change [14]. Thirdly, BCTs have been used in behavioral interventions. Several BCTs have been identified such as goal setting, positive reinforcement, self-monitoring, stimulus control and problem solving are good examples of behavioral strategies [55, 67-69]. The list of BCTs to help people change physical activity and healthy eating behaviors, the CALO-RE taxonomy, updated in 2011, contains 40 items [55]. Some evidence also suggest that strategies attempting to reduce unhealthy behaviors seem to be more effective than those attempting to increase healthy behaviors, but a meta-analysis on behavioral interventions to prevent pediatric obesity found only small beneficial changes on the targeted behaviors and no significant effect on BMI compared to control [69].

We believe that a particular attention should be given to goal setting since this technique targets clearly defined behaviors, is easy for children to understand and can be expressed under the form of a contract. Indeed, goal-related contracting may increase the ownership over the goal in question and help the children maintain focus [68]. In addition, a study showed that high adherence to self-regulatory/goal-setting skills predicted positive weight outcomes after 2-years among participants who were part of a behaviorally focused maintenance treatment following a 20-week family-based behavioral weight loss treatment [70]. Goals set with children should be small and easily attainable in order to increase the feeling of self-efficacy, which may motivate them to maintain their efforts and reduce disappointment and perception of failure [67]; but on the contrary, unrealistic goals could be detrimental [68]. In fact, the use of goal setting is recommended by the Canadian clinical practice guidelines for the management of obesity in adults and children [23]. Successful goal setting can be achieved using the acronym SMART, which refers to Specific, Measurable, Attainable, Realistic and Timely, as also suggested by Health Canada in their *Eat well and be active educational toolkit* [71]. Experts recommend

that 2 to 3 specific changes in diet or activity at a time should be set with the clinician and that these changes should be small and gradual [72].

A list of evidenced based lifestyle behaviors to treat pediatric obesity has been created by the AAP Experts [65]. The specific eating, physical activity and sedentary behaviors include: limiting sugar-sweetened beverage, consume 5 or more servings of fruits and vegetables, decrease television viewing or screen time to 2 hours or less per day, be physically active 1 hour or more each day, prepare more meals at home, eat family meals at the table, have a healthy breakfast every day, involve the whole family in lifestyle changes, allow the child to self-regulate his meals, limit eating out at the restaurant, pack a lunch for school, switch to skim milk and increase consumption of calcium, eat a diet rich and fiber and low in energy-dense food [65]. The AAP suggests that overweight and obese children and their families should focus on these basic lifestyle eating and activity habits. However, it is not clear which of these behaviors are more effective in decreasing adiposity. A qualitative analysis with the participants from family-based lifestyle intervention was conducted by interviewing parents and children 6 to 12 months after the 3-month intervention period [73]. Children were questioned about specific ongoing changes in food choices and their most frequent answers were listed as follows: smaller portions, drinking more water, eating healthier, drinking less soda, eating less fast food, making better choices when eating out, trying new fruits and vegetables, snacking less and improving snack choices [73]. These results suggest that many behavior changes lasted after the intervention period. This qualitative data provide some insight into the successful changes but these behaviors have not been linked statistically to the desired health outcomes.

2. RATIONALE AND OBJECTIVES

Rationale

The literature supports the use of family-based lifestyle interventions but it's not clear yet which specific behavior change techniques are linked to success. Only general behavior change techniques have been linked statistically to outcomes and only showed modest beneficial changes. Moreover, evidenced-based behavior change techniques have been recommended but none was linked with children's preferences. More specific behaviors have been identified in qualitative studies but were not statistically linked to adiposity, diet or activity outcomes. Components of successful interventions have been identified in the literature and the SMART goal approach is a promising strategy. There is a current gap of knowledge in the literature regarding the nature of nutrition and activity preferred goals leading to success in the lifestyle intervention for overweight and obese children. Because childhood obesity is multifactorial, there is a need to understand which behavioral and environmental components are involved in successful outcomes. However, limited research has been conducted using the Theory of Planned Behavior and the Ecological Model to gain better understanding of lifestyle change determinants in children.

Objectives and Hypotheses

The general purpose of the present study is to investigate whether there is a link between lifestyle goal-setting strategies and obesity within a combined behavioral-environmental framework. The specific objectives of this study are as follow:

1. The first objective is to determine if using SMART goals in a family-based lifestyle intervention for overweight and obese children is associated with reduction in adiposity.

Hypothesis: Based on current evidence, it is hypothesized that participants in the SMART-based intervention will be more successful in reducing adiposity, through changes in diet and activity.

2. The second objective is to describe the nature of successful goal-setting strategies using a mixed behavioral-environmental model that combines the constructs from the Theory of Planned Behavior and the Ecological Model as a theoretical framework.

Hypothesis: Based on previous research using the Theory of Planned Behavior to measure physical activity intention, the hypothesis is that perceived behavioral control will show the strongest correlations with successful results, followed by subjective norm. We also hypothesize that goals involving parents will be linked with success.

3. MANUSCRIPT

3.1 INTRODUCTION

Childhood obesity has reached epidemic proportions worldwide over the past few decades. In Canada, about one quarter of adults are obese according to measured data from the 2008 Canadian Community Health Survey (CCHS) and this proportion goes up to 62.1% when obesity is combined with overweight [74]. Despite the recent stabilization of childhood and adults overweight and obesity in the US, this problem is alarming because the prevalence remains high [2]. Nowadays, it's almost one third (31.5%) of Canadian children aged 5 to 17 years old that are considered overweight or obese according to the 2009-2011 CCHS [4]. Obesity at a young age is of concern because it has been linked to many adverse health and psychological outcomes such as chronic diseases, low self-esteem and reduced quality of life that can track into adulthood [8, 13, 75]. Obesity is a challenging and complex problem that requires a multifactorial intervention. The two most common causes are felt to be genetics and environment. Although genetic factors can have an influence on predisposition to obesity, general rising prevalence indicates that environmental factors are more likely to underlie the obesity epidemic [8]. In North America, the obesogenic environmental features have multiplied over the years including easy access to energy-dense food and drinks, development of sedentary technology-based activities, change in built environments and social norms, leading children to be more sedentary and eat more poorly [76]. The family environment has also changed and is characterized by hectic lifestyle, decreased frequency of family meals, increased frequency of meals away from home and excessive inactivity, especially from increased television viewing [8]. In fact, according to the 2007-2009 Canadian Health Measure Survey (CHMS), only 7% of children aged 5 to 11 years old meet the daily recommendations of 60 minutes of moderate and vigorous physical activity (PA) [77]. The 2004 CCHS revealed that among children aged 2 to 17 years old, only 16.8% of overweight children were eating fruits and vegetables at least 5 times or more per day, and that proportion was even lower (6.4%) in obese children [3]. This specific paper by Shields reported daily frequency of fruits and vegetables consumption and not daily portions. In another report about Canadians' eating habits based on the CCHS, it was shown that among children aged 4 to 8 y, 71% did not meet

the minimum of 5 daily portions of vegetables and fruits recommended in the 1992 Canada's Food Guide. [78] For the 9 to 13 y age groups, it was 62% and 68% of boys and girls respectively, who did not meet these recommendations. Diet and activity are modifiable lifestyle factors that have been targeted by weight loss interventions, and according to a 2009 Cochrane systematic review, combined behavioral lifestyle interventions can produce a significant reduction in overweight in children and adolescents [79]. However, which type of treatment program should be used is unclear. There is a need to find strategies that will lead to success.

Interventions in childhood obesity aim to change behaviors in order to achieve long term success. Several BCTs have been created and a taxonomy of BCTs was developed in order to standardize terminology in scientific studies [55]. Michie et al. published in 2008 a paper that describes methods for developing a list of BCTs and link them to theoretical constructs using a causal modelling approach [53, 54]. In fact, these BCTs typically come from an underlying theory or model to understand behaviors [52, 54]. In a publication reviewing several theories and models and their application to obesity prevention, the Theory of Planned Behavior and Social Ecology were identified as the most promising avenues [52]. The TPB suggests that behavior can be predicted from intention which is determined by 3 variables: attitude, subjective norm and perceived behavioral control [46]. Social Ecology, also known as *Ecological Model*, explain changes in an individual while taking into account the context or niche in which this individual is embedded. In the case of a child, his immediate ecological niche corresponds to his family [51]. BCTs (*how* to change behaviors) are targeted at behavioral determinants (*what* predicts behaviors) that are identified from behavioral constructs in order to explain the mechanism of change [54]. Eleven key determinants of behavior change have been identified and include items such as skills, self-efficacy, intention, attitude, social influences, environment and action planning [54]. Among the techniques that have been found useful in changing each behavioral determinants we find skills, capabilities, motivation/goals and action planning and social influence among others [54]. The BCT "goal/target specified" was linked to 3 construct domains: skills, motivation and goals and action planning [54]. Goal setting has been used in varied interventions including childhood obesity prevention and management programs [56,

80]. The SMART (specific, measurable, attainable, realistic and timely) goal approach is a well-known technique derived from the BCT “goal setting” and is currently applied by Health Canada, the Government of Ontario and Dietitians of Canada [71].

Despite advancing research, there is still little information about how to develop theory-based interventions and which BCTs should be included in childhood obesity interventions to maximize success. More specifically, little is known regarding the inclusion of SMART goals in childhood obesity programs and what should be the nature of these goal setting strategies. Therefore, the aims of this study are 1) to determine if using SMART goals in a family-based intervention is associated with reduction in adiposity in overweight and obese children and 2) to define the nature of family-based SMART goals that were linked to success using the theoretical constructs of the Theory of Planned Behavior and the Ecological Model.

3.2 METHODS

3.2.1 PARTICIPANTS

The participants were recruited from the greater Montreal area through Canada Post mailings, school boards, pediatrician referrals, newspapers and radio advertising. This sample of participants was selected from the McGill Youth Lifestyle Intervention with Food and Exercise (MYLIFE) study. The MYLIFE study was conducted from January 2011 to February 2014 at the Mary Emily Clinical Nutrition Research Unit, Sainte-Anne-de-Bellevue, Quebec. The detailed MYLIFE study protocol has been published elsewhere [81]. Ethical approvals were obtained from McGill Faculty of Medicine Institutional Review Board and English Montreal Public School Boards. The inclusion criteria were as follows: between 6.0 and 12.9 years of age at the onset of the program, have a body mass index (BMI) over the 85th percentile for age and sex according to the World Health Organization (WHO) cut-off criteria, speaking English or French and be otherwise healthy. Written parental consent and children written assent were provided at the first visit. Participants were randomized to either a lifestyle intervention group receiving 5 individualized counseling sessions over the first 6 mo with a registered dietitian about nutrition and physical inactivity/activity or a control group receiving the same counseling sessions at the

end of the study. Regardless of their group, they were followed during a period of one year on a 3-month basis for a total of 5 study visits (baseline, 3, 6, 9 and 12 mo). The MYLIFE study was initially designed for the 6 to 8.9 y age group and includes 3 study groups: control, standard intervention based on the recommendations from the Canada's Food Guide (CFG) and modified intervention (with an augmented consumption of milk and milk products to 4 portions instead of 2). In May 2012 a second study for children aged 9 to 12.9 y with 2 study groups: control and standard intervention, was launched. For the purpose of this study, only participants in control and standard intervention groups were included and data from baseline and 6-mo time points were selected for the analysis.

3.2.2 RANDOMIZATION

Children aged 6 to 8.9 y were stratified by gender and BMI z-score (overweight or obese) and children aged 9 to 12.9 y were stratified according to gender and pubertal development using the Tanner stages [82, 83]. Participants were informed of their study groups at the end of their baseline visit and all other staff members (except for interventionist dietitians) were blinded.

3.2.3 STUDY PROTOCOL

Parents or caregivers, usually mothers, assisted in screening of participants over the phone. Information was confirmed at the first visit to which participants arrived at the research unit fasted since 12 hours for blood sampling. Age was documented and weight and height were measured to confirm inclusion criteria.

Participants and their parents were asked to complete a 3-day food diary the week prior to the baseline visit during which they were also asked to complete questionnaires (physical activity level, eating behaviour, socio-demographics, etc.). At baseline visit, dual-energy x-ray absorptiometry (DXA) and anthropometry assessments were completed. All groups also received a general education about nutrition and physical activity. Then participants were seen at 3, 6, 9 and 12 months of study to obtain new diaries and physical activity questionnaires, as well as provide anthropometry and body composition measurements. Table 1 illustrates the components of the MYLIFE study design that are applicable for the present study, with the shaded cells representing the time-points used for data analysis.

TABLE 1 STUDY DESIGN

	BASELINE	3-MONTH	6-MONTH
Anthropometry	✓	✓	✓
Body composition (DXA scan)	✓	✓	✓
3-day food diary of 24-h recall	✓	✓	✓
Physical activity questionnaire	✓	✓	✓
Questionnaire (socio-demographics)	✓		
General education	✓		

Adapted from Cohen et al. 2013

The intervention group had five 1.5 hour lifestyle counseling visits at the end of months 1 through 5, followed by every 3 months as well as a debriefing at 12-mo. Families therefore received a total of 7.5 hours of counseling between baseline and 6-mo visits. The control group received the exact same lifestyle counseling sessions at the end of the 12-mo study.

Interventions were individualized, family-centered and focused on nutrition education, physical activity and behavior change. Each intervention included 5 components: education, nutrition intervention and evaluation, physical activity intervention, sedentary behaviour intervention, overcoming barriers and goal setting (SMART goals). The purpose of education was to increase self-efficacy and therefore perceived behavioral control through increasing nutrition knowledge. This allowed participants and their family to make healthy choices and adopt healthy behaviors. Each session had a specific education topic, details the counseling sessions were published elsewhere [81]. For example, session 2 was dedicated to learn how to read the food labels and identify healthy choices using a teaching document by Health Canada [84]. During the nutrition evaluation part, the dietitian completed a 24-h recall with the child and parents that revealed strengths and weaknesses in the child's diet in order to personalize and adapt the intervention according to family's needs. Children were also evaluated on their understanding of healthy food choices, based on the concept of the traffic light diet [85], that separate the food into 3 general categories: "go to foods" (green), "food that are healthy but when eaten too much become unhealthy" (yellow) and "sometimes foods" (red). Physical activity was discussed at every session where the family was asked about the amount practiced by the child and informed about the recommendations from the Canadian Society of Exercise Physiology guidelines [27] as well as FITT principle (frequency, intensity, time and type) [86]. Likewise, sedentary activities were discussed at every session. Children were asked how much time they were spending in front of a screen, which includes computer, phone, television or other electronic devices, and were informed of the recommendations [87]. The dietitian discussed strategies to decrease screen time when necessary. Barriers and situations that could prevent the child from adopting healthy lifestyle choices (also called "tricky situations") such as holidays, rainy days and birthday parties were addressed and strategies to overcome them were discussed. At the end of each intervention, three SMART goals (nutrition or physical

activity) were set by the child with the guidance of the dietitian under the form of a contract signed by the participant. The SMART system describes goals as specific (what?), measurable (how much and how often?), attainable (how?), realistic (can I do it?) and timely (when?). This system is used in the “Eat Well and Be Active Educational Toolkit” from Health Canada (website: <http://www.hc-sc.gc.ca/fn-an/food-guide-aliment/educ-comm/toolkit-trousse/plan-3a-eng.php>). [71] Goal setting is a valid tool with children and is a strategy used in different treatment programs [65, 66]. This individualized approach allows participants to change their lifestyle at their own rhythm and take control over their goals. At the following intervention visit, the dietitian reviewed the previous goals to go over achievements and barriers and new goals were set. Supplementary table 2 illustrates an example of a SMART goal set by a child and his family and written under the form of a behavioral contract. The first column represents the 5 components described by the acronym SMART, the 2nd column displays the questions that are asked by the dietitian in order to fulfill each component and the 3rd column represents examples of answers that are obtained from the children with the agreement and collaboration of their parents.

3.2.4 MEASUREMENTS

Demographics and Home Setting

At baseline visit, parents were asked to complete a demographic questionnaire “the Family Health Questionnaire” (FHQ) that contains questions adapted from the Canadian Community Health Survey (CCHS) [88] in order to capture information such as education, ethnicity, family income, family lifestyle (nutrition and activity practices and beliefs) and environment characteristics. These data helped to characterize the study population and generalizability. This information is important to describe both groups and guide the diet and activity interventions using environment-based resources. Parental intention and perceived behavioral control regarding physical activity were also assessed and are a proxy of their child’s intention and perceived behavioral control. Parents were asked at baseline: *“How committed are you to participating regularly in family physical activity over the next month?”* and *“If you were motivated, how confident are you that you could participate in regular family-based physical activity over the next month?”* using a 7-point scale going from “extremely uncommitted” to

“extremely committed” [81, 89]. These validated questions were taken from a pilot intervention study on family physical activity planning and were based on previous work using the TPB [89].

Anthropometry

Weight was measured using a calibrated balance-beam scale (Detecto, Missouri, USA) to the nearest 0.1 lb and was converted to kg. Standing height was measured using a wall-mounted stadiometer (Seca 214, Hamburg, Germany) with a precision of 0.1 cm. Body mass index (BMI) was calculated using weight in kg divided by height squared in meters (kg/m^2) and BMI z-scores were derived using the WHO AnthroPlus software (version 1.0.4, Geneva, Switzerland) [90]. Waist circumference (WC) was measured to the nearest 0.1 cm at the umbilicus [91]. The waist circumference is a reliable tool to assess adiposity because it provides a better estimate of visceral adipose tissue measured with MRI compared to BMI. [14, 92] Height and weight growth velocity was calculated using the difference between measurements at 6-mo and at baseline divided by the difference expressed in year between baseline and 6-month visit [93, 94].

Body composition assessment

Whole body composition was assessed using dual-energy x-ray absorptiometry (DXA) at each visit with a Hologic 4500A fan beam densitometer (APEX software version 13.3; Discovery Series, Bedford, MA). For this test, children wore light clothing (shorts, T-shirt) or if their clothes had any metal components, they were asked to change into standardized clothing provided by the facility. The whole body scan provides total body fat (g and %) but does not distinguish subcutaneous from visceral fat depots. The body composition parameters used for the present analysis are as follow: total body percent fat, fat mass and lean mass.

Physical activity

Physical activity was assessed using a modified version (unpublished) of the Physical Activity Questionnaire – Older Children (PAQ-C) that was validated (n=30 using a 7-day activity diary, a pedometer and an accelerometer, unpublished) [95]. This questionnaire is valid for Canadian children. Questions regarding duration and intensity of the activities were added (using the Canada Fitness Survey for 7 y of age and older) to allow metabolic equivalent (MET) calculation.

The PAQ-C reflects the past week and captures activity in general, at school, after school and during weekends. At each visit, parents were asked to complete the questionnaire. A MET (unit describing the energy expenditure of a specific activity) for each activity was based on the Compendium of Energy Expenditure for Youth [96].

Dietary intake

Parents were asked to complete a 3-day food diary prior to each visit and bring it when they come at the research unit or mail it, to be reviewed by a dietitian. They had to record food and beverages during 3 non-consecutive days including 2 weekdays and 1 weekend day. When food diaries were not available for the follow up visits, the dietitian would do a 24-hour recall with the participants. Nutrient analysis was conducted using Nutritionist Pro software (Axxya System LLC., Stafford, USA) that uses the Canadian Nutrient File 2010b. When food items could not be found in the software database, nutritional facts were taken directly from the food label. All food diaries and recalls were reviewed by registered dietitians before analysis. An average of the 3 days from the food diaries only was used to estimate the average dietary daily intakes. Data analysis includes specific nutrients (proteins, carbohydrates, lipids, sugar and fibres) and total energy intake.

3.2.5 SMART GOALS CLASSIFICATION

In order to describe the nature of SMART goals set by the families during lifestyle interventions, each goal was assessed and coded using several descriptors. A similar coding method was also used by Martin and colleague to a larger scale with childhood obesity interventions, but in this case, interventions were coded with BCTs from the CALO-RE taxonomy [56]. First, each goal was labeled as “diet” for goals targeting food intake or “activity” for goals targeting physical activity or sedentary activity. Goals were also described according to if they were “positive” when aiming to increase a healthy behavior or “negative” when aiming to decrease an unhealthy behavior. This classification was added following the results from a systematic review and meta-analyses of RCTs on behavioral interventions, concluding that strategies attempting to reduce unhealthy behaviors seem to be more effective than those promoting positive behaviors in children [69]. Then, all SMART goals were classified using the three constructs from the TPB

(attitude, subjective norm and perceived control). In order to do so, we developed a classification method to ensure consistency and reproducibility (Table 4) that is based on the TPB's definition. The attitude corresponds to someone's beliefs about the likely outcomes of the behavior and the evaluation of these outcomes; subjective norm corresponds to beliefs about the normative expectations of others and motivation to comply with these expectation; and perceived behavioral control corresponds to beliefs about the presence of factors that may facilitate or impede performance of the behavior and the perceived power of these factors. [46] Every goal was first identified to one of the following types: "new", "increase or decrease" or "repeat" which correspond to the three possibilities when setting goals: are we working on a new goal or new behavior that was never targeted before, are we trying to increase or decrease a behavior that was already addressed previously (e.g. in a previous goal) or are we maintaining the same goal to continue work on it? Afterward, based on the definition of each construct, one or more constructs were attributed to each type of goals, considering all possible combinations. In other words, a SMART goal could be attributed to one, two or three constructs. A description statement was provided to describe the potential situation in each construct for each type of goal. The researcher had to first identify the type of goal and secondly find the most appropriate combination of constructs among those available for the chosen type.

Furthermore, each goal was classified using one of the two levels (individual or family) of the Ecological Model used for the study. A goal was classified "individual" when the achievement depended only on the child. When a family member was involved in the goal at any degree without being a limiting factor, the goal was still considered "individual". For example, if a goal was to eat more yogurt for PM snack and that the parents indicated they could readily provide this food item, they would not be considered as a limiting factor even if they are involved in the purchase of the yogurt. However, when the accomplishment of the goal depended on a family member (who was not likely to accommodate the request) and the child, it was considered as a "family" goal. In other words, if the designated family member doesn't change his behavior, the child won't achieve this specific goal. For example, if a goal was to go for a 15 min walk every day after supper with a parent, if the parent who commits to this goal is not available and the child is not allowed to go alone for safety reasons, it is a limiting factor. Finally, 8 categories

were created to classify each goal within one of them only. The categories represented the 5 food groups from the CFG (fruits and vegetables, grain products, milk & alternatives, meat & alternatives, other foods), the activity aspect (physical activity or sedentary activity) and a miscellaneous category for all other goals (e.g. eating behavior, healthy choices, eating out, portion control, etc.). Supplementary table 3 is a summary table for SMART goals classification used for the analysis.

3.2.7 STATISTICS

Sample size calculation and participant diagram

For this secondary analysis, we used the t-test calculation as the preferred way to estimate sample size, a power of 80% ($\beta=0.20$) and a significance level $\alpha=0.05$ (two-sided). We found that a sample of 35 children in each group (CTL and INT) would be appropriate to detect a mean change of BMI z-score of -0.2 (SD 0.3) with a standardized effect size of 0.67, based on calculations from the original protocol [81, 97]. BMI z-score change is the variable of interest for sample size calculation because it allows to distinguish successful and unsuccessful participants, which is linked to the primary outcome. Although less commonly used, the correlation coefficient technique to calculate sample size is also appropriate in this study since one of the main outcomes is to test the association between 2 variables. This sample size calculation yielded to a total sample size of 85 participants when aiming to detect a significant correlation coefficient (r) of 0.3, based on a previous study using the TPB to predict physical activity. [97-99] No dropout rate will be added to this calculation since participants were already recruited. The present study included a total of 100 participants, 51 in the control group and 49 in the intervention group, which is a greater number than both sample size estimation techniques described above. The progress through the phases of this randomized trial is illustrated by the flow diagram, based on CONSORT guidelines [100] (Supplementary figure 1). The group “Intensive Intervention” from the 6 to 8.9 y age group was not used in the present analysis (as mentioned previously), hence no details about follow up and analysis are provided. Only one participant was excluded from the final analysis because no data was available for SMART goal analysis.

Main outcomes

The primary outcome variable of this study is the BMI z-score change from baseline to 6-mo. In fact, the analysis of SMART goals is based on comparisons between successful and unsuccessful participants from the intervention group that are identified using change in BMI z-score. This technique has been used previously to identify predictors of success of an outpatient therapy in obese children and adolescents [101]. Therefore, BMI z-score change between baseline and 6-mo was used as the determining variable to separate unsuccessful and successful participants. In fact, BMI z-score is an easy measure to obtain for clinicians (as opposed to percent body fat that requires more equipment) and it is known as a good indicator of adiposity with a reduced within-child variability when increased fatness compared to BMI [102]. It is also the standard of following obesity status in children recommended by the American Academy of Pediatrics [103]. Children were considered unsuccessful (UNS) when they increased their BMI z-score over 6 months (change > 0) and successful (SUC) when they maintained or decreased their BMI z-score over 6 months (change ≤ 0). BMI z-score change is a key variable to test both objectives. It allows to determine the success of SMART-based intervention and to determine the nature of successful SMART goals. Secondary outcomes include the 3 constructs of the TPB (attitude, subjective norm and perceived control) as well as the 2 levels of the EM (individual and family). Other outcomes include change in food intake, PA and sedentary activity and their association with success. Lifestyle categories were also used to further describe the SMART goals.

Statistical analysis

Descriptive statistics were performed for each time point (baseline and 6-month) with variables expressed as mean ± standard deviation, absolute values or frequency (percentage) where appropriate. Normality and homogeneity of data distribution were tested and data was log transformed when not normal. Mixed model analysis of variance (ANOVA) or chi-square test were used to detect differences between control and intervention and also among all subgroups (CTL-UNS, CTL-SUC, INT-UNS and INT-SUC) with ethnicity, family income and mother's education level as covariates. Repeated measures mixed model ANOVA was used to determine whether there were significant changes for the different variables over time. For all

ANOVAs covariates included age, puberty (Tanner stage), ethnicity, as well as education and income of the family.

Dietary data was obtained through 3-day food diaries that were filled out by a parent with or without the help of their child, collected at baseline and 6-mo visits. Participants were asked to record all food and beverages during 3 non-consecutive days including 2 weekdays and 1 weekend day. All food diaries were reviewed by a registered dietitian and nutrient analysis was performed using the software Nutritionist Pro™ (Redmond, WA, USA) that uses the Canadian Nutrient File 2010b. An average of the 3 days was used to estimate daily intake of energy, proteins, carbohydrates, fat, fibers and total sugar (i.e. naturally occurring and added). Energy requirements were calculated using the Institute of Medicine's equation for estimated energy requirements (EER) that requires age, sex, height, weight and physical activity level [104]. Sedentary and low active were used as level of physical activity to avoid overestimation of energy requirements. Nutrients were also reported as percentage of total energy.

For activity data (physical activity and screen time), the PAQ-C was analyzed at baseline and 6-mo. Each activity was assigned with a metabolic equivalent (MET) unit reflecting one of the 3 levels of intensity (light, medium and high) for children and was multiplied by minutes of activity per day and the amount of days per week. Each participant obtained a score that is expressed as MET-min/week, which can be converted in kilocalories/kilogram/day (kcal/kg/d) by dividing the value obtained by 7 (re: 7 d/wk) times 24 (re: 24 h/d) [105]. Screen time was calculated using the hours spent watching television plus the hours spent playing video games sitting (excluding active video games such as dance mat) and was expressed in hours/week.

SMART goal descriptors were expressed as percent of total goals (number of goals coded as a descriptor/ total goals *100) and differences between INT-UNS and INT-SUC subgroups were tested using mixed model ANOVA, using age, number of visits as well as commitment and confidence of the family to engage in PA at baseline as covariates. Pearson's partial correlation were used to test the association between SMART goals descriptors and BMI z-score change (normally distributed), controlling for age and sex. Relationships between BMI z-score change and main descriptors (TPB and EM) was also tested using simple regression analysis. Multiple

regression and stepwise regression were also used to see the relationship between BMI z-score change (dependent variable) and main descriptors, including age, sex and all SMART goal descriptors as independent variables. Pearson's partial correlations as well as simple linear regression were performed to test the association between the main descriptors and changes in diet and activity.

For descriptive statistics ANOVAs, compound symmetry was selected as the covariance structure since it provided the best fit for the model and allowed to meet convergence criteria. Statistical significance was determined using a probability of 0.05. Statistical analysis was performed using SAS version 9.3 (SAS Institute, Cary, NC) and all graphs were produced using GraphPad Prism version 5.01 (GraphPad Software, La Jolla, CA).

3.3 RESULTS

3.3.1 DEMOGRAPHICS, ANTHROPOMETRICS, BODY COMPOSITION, DIET AND ACTIVITY

A total of one hundred children (55 girls and 45 boys) aged 6.0 to 12.9 y participated in this study. There were 51 participants in the control group (CTL) aged 9.36 ± 1.87 y and 49 participants in the intervention group (INT) aged 9.53 ± 1.93 y, the age was not different among groups. Families from CTL and INT were not different at baseline in terms of demographics (Supplementary table 5). Of the participants, 76% were white, 52% of mothers had a university education, 30% of families had a yearly income above 75,000\$ (Canadian) and 83% lived with both parents. At baseline, 55% of parents were very or extremely committed and 51% were very or extremely confident in their commitment to engage in physical activity.

In terms of anthropometry and body composition, CTL and INT were not different at baseline and 6-mo follow up (Table 2). Height z-score was 0.94 ± 0.96 for CTL and 1.11 ± 1.00 for INT ($p=0.318$), showing that participants from both groups were over the 50th percentile for height. Height increased significantly for both groups from baseline to 6-mo with a similar height velocity, but the height z-score did not change significantly during this period. At baseline, the average BMI-for-age z-scores for CTL and INT were 3.00 ± 0.93 and 3.16 ± 1.14 , respectively. Ninety-six percent of the participants were over 2.00 and considered obese. At 6-mo, the

average BMI z-score for both groups was not lower than at baseline (2.93 ± 0.81 for CTL and 3.02 ± 0.93 for INT). INT BMI z-score did not decline more than CTL over 6-mo (-0.15 ± 0.34 vs -0.06 ± 0.25 , $p = 0.687$). Waist circumference was not different among groups at baseline and 6-mo and there was no significant change over 6 months. In terms of percent body fat, CTL and INT were both well above the healthy range for their age at baseline with means of 38.00 ± 4.07 % and 37.75 ± 5.24 %, respectively and no significant change by 6-mo. Fat mass did not increase more in CTL than INT (CTL: 1292.49 ± 1710.97 g vs INT: 668.85 ± 1483.49 g). Finally, while differences in lean mass at baseline and 6 mo were not evident, CTL values were significantly higher at 6-mo vs baseline, which was not the case for INT with a p value of 0.085.

In terms of diet, CTL and INT were not different at baseline and 6-mo, and there was no difference among groups for the change between the 2 time points (Table 2). Participants from both groups had a similar energy intake at baseline (CTL: 1706.7 ± 358.8 kcal/d, INT: 1644.1 ± 405.8 kcal/d) with CTL having an intake corresponding to 89.2 ± 23.7 % of estimated energy requirements and 84.9 ± 21.6 % of estimated energy requirements achieved for INT, for a sedentary physical activity level. All percent of energy for macronutrients (protein, carbohydrates and fat) fell within the AMDR of the Institute of Medicine. [29] The average fibre intake at baseline was 16.5 ± 4.7 g/d for CTL and 15.6 ± 4.3 g/d for INT. For total sugar, CTL consumed on average 86.2 ± 32.7 g/d and INT consumed 89.2 ± 32.7 g/d at baseline, which corresponds to about 21.5 teaspoons/d and 22 teaspoons/d of sugar respectively.

For physical activity and screen time, groups were not different at BL, 6-mo and did not change significantly over time. At baseline, the estimated amount of physical activity was 6667.3 ± 4402.7 METs-min/wk (which corresponds to an average of 15.9 kcal/kg/d) for CTL and 7390.9 ± 5293.8 METs-min/wk (which corresponds to an average of 17.6 kcal/kg/d) for INT. Both groups seem to have increased over time but the difference was not significant. Participants from CTL reported on average 6.7 ± 2.7 hours/week of screen time and INT reported 7.4 ± 2.2 hours/week at baseline. Although INT decreased more than CTL over 6 mo, the difference was not significant.

TABLE 2 BASELINE AND 6-MO ANTHROPOMETRICS, BODY COMPOSITION, DIET AND ACTIVITY CHARACTERISTICS

VARIABLES	BASELINE VISIT		6-MO FOLLOW UP		CHANGE FROM BL TO 6-MO	
	CONTROL	INTERVENTION	CONTROL	INTERVENTION	CONTROL	INTERVENTION
<i>Sample size</i>	<i>N = 51</i>	<i>N = 49</i>	<i>N = 51</i>	<i>N = 49</i>	<i>N = 51</i>	<i>N = 49</i>
Time, mo	-	-	-	-	6.4 ± 0.7	6.4 ± 0.6
Height, cm	140.1 ± 11.8	142.4 ± 12.9	143.42 ± 12.0*	145.6 ± 12.8*	3.28 ± 1.28	3.11 ± 1.21
Height z-score	0.94 ± 0.96	1.11 ± 1.00	0.92 ± 0.94	1.09 ± 1.05	-0.02 ± 0.24	-0.02 ± 0.17
Height velocity, cm/yr	-	-	-	-	0.51 ± 0.21	0.49 ± 0.18
Weight, kg	51.93 ± 15.54	55.44 ± 16.62	55.47 ± 16.50	58.17 ± 16.83	3.55 ± 2.36	2.74 ± 2.72
Weight velocity, kg/yr	-	-	-	-	0.56 ± 0.38	0.42 ± 0.41
BMI, kg/m ²	25.85 ± 4.18	26.71 ± 3.98	26.37 ± 4.15	26.87 ± 3.75	0.52 ± 1.10	0.16 ± 1.15
BMI z-score	3.00 ± 0.93	3.16 ± 1.14	2.93 ± 0.81	3.02 ± 0.93	-0.06 ± 0.25	-0.15 ± 0.34
Waist circumference, cm	87.2 ± 11.4	89.0 ± 10.9	89.2 ± 11.1	89.8 ± 11.2	1.99 ± 3.67	0.83 ± 2.98
Fat mass, %	38.00 ± 4.07	37.75 ± 5.24	37.82 ± 4.20	37.11 ± 5.20	-0.19 ± 1.83	-0.72 ± 1.70
Fat mass, g	20034.68 ± 7132.77	21142.73 ± 7481.91	21343.29 ± 7655.90	21725.52 ± 7942.40	1292.49 ± 1710.97	668.85 ± 1483.49
Lean mass, g	30593.08 ± 8306.72	32996.64 ± 9759.49	32859.25 ± 9039.76*	34696.31 ± 9953.31	2271.46 ± 1331.40	1997.76 ± 1432.43
<i>Sample size (FD)</i>	<i>N = 21</i>	<i>N = 29</i>	<i>N = 20</i>	<i>N = 22</i>	<i>N = 13</i>	<i>N = 15</i>
Energy, kcal	1706.7 ± 358.8	1644.1 ± 405.8	1699.4 ± 447.9	1703.5 ± 451.1	0.5 ± 330.8	-134.0 ± 366.6
Energy, % requirements (sedentary) †	89.2 ± 23.7	84.9 ± 21.6	87.4 ± 28.2	86.6 ± 31.6	-4.2 ± 18.4	-8.2 ± 17.4
Energy, % requirements (low active) †	76.5 ± 20.3	72.9 ± 18.6	75.0 ± 24.2	74.3 ± 26.9	-3.6 ± 15.8	-7.1 ± 14.9

Protein, g	78.5 ± 18.3	71.0 ± 16.2	77.5 ± 20.5	76.4 ± 18.8	-2.3 ± 17.0	-2.4 ± 15.2
Protein, % of energy	18.6 ± 3.2	17.7 ± 3.2	18.5 ± 2.8	18.4 ± 3.7	-0.4 ± 4.3	0.8 ± 3.3
Carbohydrate, g	220.5 ± 50.8	221.7 ± 57.0	226.0 ± 68.5	226.3 ± 66.2	18.0 ± 61.3	-18.7 ± 48.8
Carbohydrate, % of energy	51.6 ± 6.2	54.1 ± 5.8	52.8 ± 4.9	53.0 ± 5.2	3.7 ± 5.5	-1.0 ± 7.3
Lipid, g	57.9 ± 15.6	55.1 ± 20.5	55.4 ± 15.9	56.6 ± 17.9	-5.9 ± 15.0	-6.6 ± 24.3
Lipid, % of energy	30.4 ± 3.8	29.6 ± 6.2	29.4 ± 4.4	29.7 ± 3.8	-2.9 ± 5.4	-0.3 ± 7.9
Fibre, g	16.5 ± 4.7	15.6 ± 4.3	15.2 ± 4.2	17.2 ± 6.1	0.2 ± 5.3	-0.1 ± 3.8
Total sugar, g	86.2 ± 32.7	89.2 ± 32.7	89.3 ± 38.9	89.9 ± 31.8	15.1 ± 29.3	-2.4 ± 30.3
Total sugar, % of energy	20.1 ± 6.6	21.3 ± 4.6	20.7 ± 6.4	21.1 ± 4.8	3.7 ± 6.4	0.9 ± 6.0
Sample size	<i>N</i> = 43	<i>N</i> = 44	<i>N</i> = 38	<i>N</i> = 36	<i>N</i> = 38	<i>N</i> = 36
PAC-Q, METs-min/week	6667.3 ± 4402.7	7390.9 ± 5293.8	8119.2 ± 4635.1	9843.1 ± 6850.1	1490.8 ± 5517.1	1964.8 ± 5398.2
Screen time, h/week	6.7 ± 2.7	7.4 ± 2.2	6.5 ± 2.5	6.7 ± 2.5	-0.1 ± 2.2	-0.9 ± 2.5

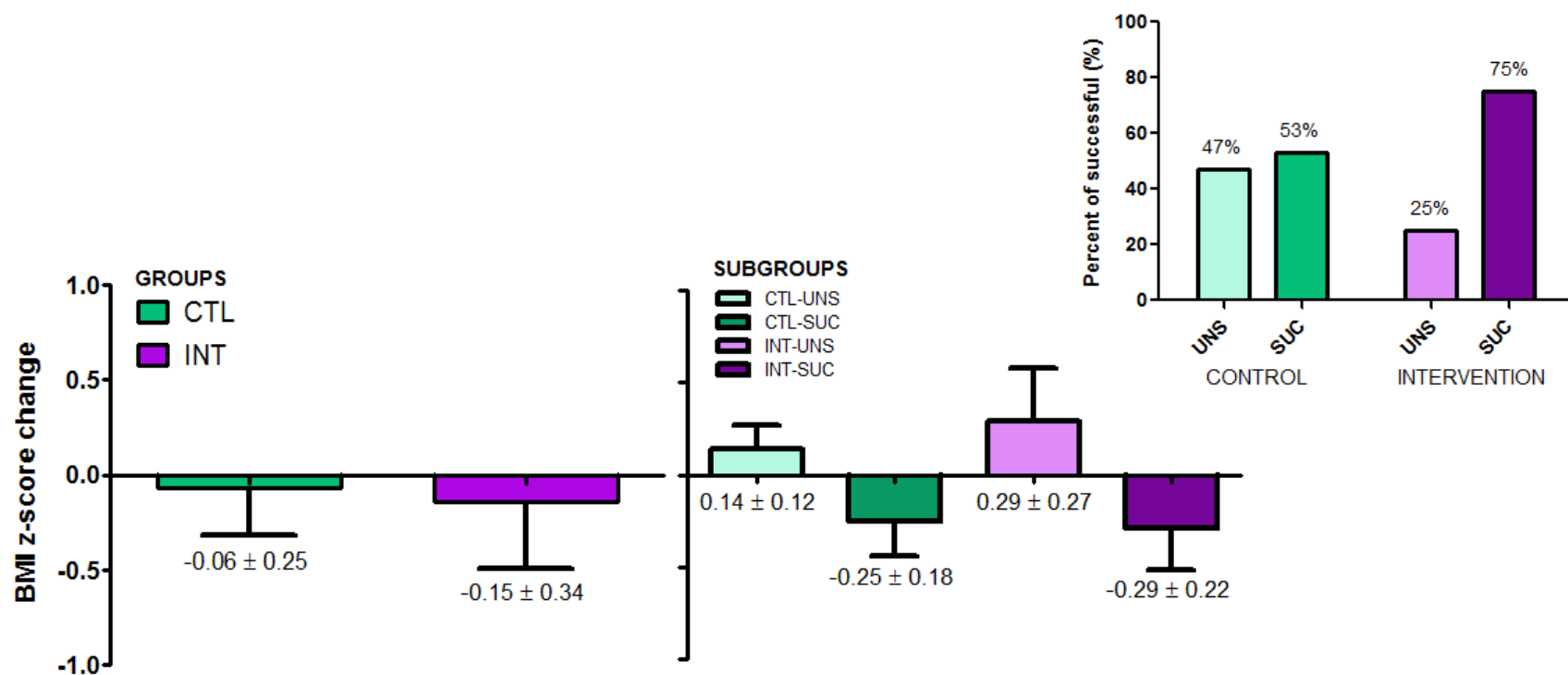
Data is reported as mean ± SD.

† Using the appropriate age, weight and height for each time-point.

* *P* < 0.05 for within-group difference at 6-mo, compared to BL.

No significant differences were found between groups for change from BL to 6-mo.

FIGURE 1 CHANGE IN BMI Z-SCORE FROM BASELINE TO 6-MO FOR GROUPS AND SUBGROUPS



When dividing CTL and INT into successful and unsuccessful subgroups, significant differences at baseline and between the 2 time-points are seen (Table 3). First, the proportion of participants in each subgroup is different; 75% of INT was SUC against 25% for UNS ($p < 0.001$). In CTL, the proportion of SUC was less than INT but not significantly higher than UNS; 53% vs 47%, respectively ($p = 0.780$) (Figure 1). A significant p value ($p = 0.019$) from the chi square test of differences of association between UNS or SUC classification and study groups (CTL or INT) indicate a significant association, i.e., participants in INT are more likely to be SUC. Another interesting fact about CTL is that there was a higher proportion of girls in UNS versus SUC ($p = 0.014$), but this difference was not seen in INT. There was no difference in terms of height and height z-score among subgroups at baseline and between the 2 time-points. Weight was greater in SUC of both groups but weight gain was significantly smaller over 6 months in INT, along with weight velocity. BMI and BMI z-score were also higher in SUC at baseline but decreased significantly more than UNS over 6 months in both groups, whereas UNS participants actually increased BMI z-score over time. Waist circumference followed the same pattern as weight, that is; higher at baseline in SUC from both groups with a significantly smaller increase from baseline to 6-mo compared to UNS in both groups. Percent body fat, fat mass and lean mass were all higher in SUC at baseline compared to UNS. However, although there seems to be positive patterns over 6 months, only fat mass from CTL-SUC increased significantly less than UNS. Among INT subgroups, at 6-mo, UNS and SUC were not different in terms of percent body fat, but lean mass was significantly higher in SUC (UNS: 33665.68 ± 8894.35 , SUC: 35049.68 ± 10267.54 , $p = 0.025$) and this difference was not observed in CTL.

For diet, there was no difference in terms of energy, macronutrient, fibre and sugar intake among subgroups at baseline (Table 4). Physical activity and screen time were not different either at baseline. At 6-mo, most of the diet and activity variables did not differ between subgroups and were not different from baseline. Subgroups showed a difference in terms of carbohydrates and sugar when looking at the change between baseline and 6-mo (data not shown). In fact, INT-SUC decreased the amount of carbohydrates in grams and in percent of total daily energy over 6 mo, while CTL-SUC increased it (INT-SUC: -20.7 ± 51.4 g CTL-SUC: 30.1 ± 66.1 g, $p = 0.023$) (INT-SUC: -2.1 ± 6.7 % CTL-SUC: 5.0 ± 6.4 %, $p = 0.030$). This significant

difference among these 2 subgroups was also reflected in total sugar intake in grams and percent of energy: INT-SUC decreased over time while CTL-SUC increased (INT-SUC: -5.9 ± 30.9 g CTL-SUC: 26.9 ± 18.7 g, $p= 0.001$) (INT-SUC: -0.3 ± 5.5 % CTL-SUC: 6.3 ± 5.0 %, $p= 0.022$). CTL-SUC was also significantly higher than CTL-UNS in sugar intake in gram and percent of energy at 6-mo. The change between the 2 time points was also significantly different among these 2 subgroups with CTL-UNS achieving more favorable changes (CTL-UNS: 1.3 ± 33.1 g, $p= 0.002$) (CTL-UNS: 0.6 ± 6.5 %, $p= 0.026$). No significant difference are seen between INT subgroups.

TABLE 3 ANTHROPOMETRY AND BODY COMPOSITION FOR SUBGROUPS AT BASELINE AND CHANGE FROM BASELINE TO 6-MO

VARIABLES	CONTROL		P-value	INTERVENTION		P-value
	UNSUCCESSFUL	SUCCESSFUL		UNSUCCESSFUL	SUCCESSFUL	
Participants, n (%)	24 (47%)	27 (53%)	<0.001	12 (25%)	37 (75%)	<0.001
Sex- female, n (%)	18 (75%)	11 (41%)	0.014	6 (50%)	20 (54%)	0.807
BASELINE						
Height, cm	140.4 ± 13.8	139.9 ± 9.8	0.826	141.7 ± 10.9	142.7 ± 13.5	0.117
Height z-score	0.95 ± 0.85	0.93 ± 1.05	0.701	0.45 ± 0.77	1.33 ± 0.97	0.136
Weight, kg	49.49 ± 17.56 ^a	54.09 ± 13.11	0.056	49.72 ± 12.54	57.29 ± 17.34 ^b	0.005
BMI, kg/m ²	24.27 ± 4.19 ^a	27.26 ± 3.63 ^b	0.001	24.30 ± 2.99 ^a	27.49 ± 3.94 ^b	<0.001
BMI z-score	2.53 ± 0.66 ^a	3.42 ± 0.93 ^b	0.002	2.36 ± 0.50 ^a	3.42 ± 1.17 ^b	<0.001
Waist circumference, cm	84.8 ± 12.3 ^a	89.7 ± 10.0 ^b	0.029	83.9 ± 9.2 ^a	90.6 ± 10.8 ^b	0.001
Fat mass, %	36.91 ± 3.44	38.97 ± 4.34	0.047	36.23 ± 6.15	38.24 ± 4.81	0.062
Fat mass, g	18620.76 ± 7624.50 ^a	21291.50 ± 6408.56 ^b	0.009	18255.13 ± 5648.52 ^a	22079.25 ± 7759.2 ^b	0.003
Lean mass, g	29728.35 ± 9590.26 ^a	31361.74 ± 6879.45	0.074	30651.33 ± 7849.20	33757.28 ± 10187.96 ^b	0.005
CHANGE FROM BL TO 6-MO						
Time, mo	6.28 ± 0.55	6.56 ± 0.74	0.113	6.49 ± 0.68	6.33 ± 0.63	0.671
Height, cm	2.9 ± 1.2	3.6 ± 1.3	0.563	2.8 ± 1.1	3.2 ± 1.2	0.395
Height z-score	-0.03 ± 0.22	-0.01 ± 0.26	0.374	-0.07 ± 0.16	-0.01 ± 0.17	0.472
Height velocity, cm/yr	20.09 ± 8.45	25.56 ± 9.35	0.405	20.08 ± 8.97	21.94 ± 9.17	0.501
Weight, kg	4.80 ± 2.15 ^a	2.44 ± 1.95 ^b	0.004	5.42 ± 2.06 ^a	1.87 ± 2.32 ^b	<0.001
Weight velocity, kg/yr	33.04 ± 15.45 ^a	17.59 ± 13.85 ^b	0.012	38.03 ± 15.74 ^a	13.42 ± 17.28 ^b	0.001
BMI, kg/m ²	1.29 ± 0.69 ^a	-0.16 ± 0.94 ^b	<0.001	1.64 ± 0.83 ^a	-0.32 ± 0.77 ^b	<0.001
BMI z-score	0.14 ± 0.12 ^a	-0.25 ± 0.18 ^b	<0.001	0.29 ± 0.27 ^c	-0.29 ± 0.22 ^b	<0.001
Waist circumference, cm	3.3 ± 3.7 ^a	0.9 ± 3.3	0.006	2.5 ± 1.1	0.3 ± 3.2 ^b	0.029
Fat mass, %	0.54 ± 1.45	-0.87 ± 1.88	0.239	-0.11 ± 1.51	-0.93 ± 1.71	0.179
Fat mass, g	2150.46 ± 1428.11 ^a	500.52 ± 1562.15	0.032	1535.97 ± 1039.55	371.56 ± 1496.20 ^b	0.063
Lean mass, g	2385.02 ± 1147.49	2166.65 ± 1473.29	0.158	3014.35 ± 1578.30	1649.21 ± 1193.93	0.100

Data is reported as mean ± SD. Within row, different superscripts indicate p < 0.05. Participants and sex differences were tested using χ^2 .

TABLE 4 DIET AND ACTIVITY FOR SUBGROUPS

VARIABLES	CONTROL		P-value	INTERVENTION		P-value
	UNSUCCESSFUL	SUCCESSFUL		UNSUCCESSFUL	SUCCESSFUL	
BASELINE						
Sample size	N = 9	N = 12		N = 6	N = 23	
Energy, kcal	1843.7 ± 328.7	1603.9 ± 345.9	0.848	1362.2 ± 469.4	1717.6 ± 352.1	0.636
Energy, % requirements (sedentary)	95.8 ± 19.1	84.3 ± 25.5	0.858	77.0 ± 24.5	86.9 ± 20.4	0.994
Energy, % requirements (low active)	82.0 ± 16.5	72.3 ± 21.9	0.859	66.0 ± 21.1	74.7 ± 17.5	0.984
Protein, g	82.8 ± 18.6	75.3 ± 17.3	0.688	60.0 ± 14.9	73.9 ± 15.3	0.120
Protein, % of energy	17.9 ± 2.3	19.2 ± 3.6	0.877	18.6 ± 3.9	17.5 ± 2.9	0.714
Carbohydrate, g	237.0 ± 38.8	208.2 ± 54.9	0.638	178.6 ± 45.3	232.9 ± 54.3	0.223
Carbohydrate, % of energy	51.9 ± 6.5	51.5 ± 5.9	0.662	53.9 ± 5.1	54.2 ± 5.9	0.717
Lipid, g	63.1 ± 17.5	54.0 ± 30.5	0.862	48.1 ± 29.7	56.9 ± 16.8	0.503
Lipid, % of energy	30.4 ± 4.2	30.5 ± 3.4	0.359	29.1 ± 8.3	29.7 ± 5.5	0.115
Fibre, g	17.3 ± 4.4	15.9 ± 4.8	0.810	13.6 ± 3.7	16.1 ± 4.3	0.610
Total sugar, g	98.2 ± 34.7	77.3 ± 27.9	0.154	58.9 ± 22.4	97.1 ± 30.2	0.262
Total sugar, % of energy	21.7 ± 8.2	19.0 ± 4.9	0.338	17.1 ± 2.8	22.4 ± 4.3	0.216
Sample size	N = 21	N = 22		N = 9	N = 35	
PAC-Q, METs-min/week	6738.6 ± 3276.3	6599.2 ± 5256.5	0.943	5411.9 ± 2190.7	7899.9 ± 5721.1	0.338
Screen time, h/week	6.3 ± 2.4	7.1 ± 3.0	0.309	8.2 ± 1.4	7.2 ± 2.4	0.999
6 MO FOLLOW UP						
Sample size	N = 9	N = 11		N = 3	N = 19	
Energy, kcal	1861.5 ± 571.6	1782.5 ± 387.2	0.339	1346.6 ± 191.3	1814.8 ± 477.8	0.173
Energy, % requirements (sedentary)	93.9 ± 21.8	90.5 ± 28.9	0.205	56.9 ± 8.3	92.9 ± 35.1	0.304

Energy, % requirements (low active)	80.5 ± 18.9	77.6 ± 24.8	0.202	65.9 ± 9.7	79.7 ± 29.8	0.297
Protein, g	90.7 ± 28.5	73.7 ± 10.8	0.388	56.7 ± 1.4	80.2 ± 19.9	0.035
Protein, % of energy	19.8 ± 2.7	16.9 ± 2.6	0.024	17.1 ± 2.0	18.1 ± 3.9	0.499
Carbohydrate, g	244.2 ± 76.2	250.2 ± 67.8	0.139	194.1 ± 25.5	241.6 ± 72.2	0.288
Carbohydrate, % of energy	52.4 ± 2.8	55.6 ± 4.5	0.206	57.8 ± 0.6	53.0 ± 5.7	0.309
Lipid, g	59.9 ± 20.6	55.4 ± 13.3	0.358	42.1 ± 10.0	60.1 ± 18.8	0.344
Lipid, % of energy	28.8 ± 4.3	28.1 ± 4.0	0.583	27.8 ± 2.7	29.6 ± 4.2	0.990
Fibres g	15.4 ± 4.3	15.3 ± 4.5	0.661	17.5 ± 1.2	17.5 ± 7.3	0.893
Total sugar, g	98.5 ± 36.8	104.4 ± 40.5	0.033	83.2 ± 11.6	96.9 ± 33.8	0.405
Total sugar, % of energy	20.9 ± 2.6	23.7 ± 8.5	0.024	24.7 ± 0.1	21.4 ± 5.1	0.255
Sample size	<i>N</i> = 19	<i>N</i> = 19		<i>N</i> = 5	<i>N</i> = 31	
PAC-Q, METs-min/week	7239.6 ± 3241.1	8998.8 ± 5560.0	0.184	8854.0 ± 3653.8	10002.6 ± 7221.8	0.859
Screen time, h/week	6.3 ± 2.5	6.8 ± 2.6	0.860	8.1 ± 1.9	6.4 ± 2.6	0.105

Data is reported as mean ± SD.

No significant differences were found between groups or subgroups at baseline and 6-mo follow up.

3.3.2 SMART GOALS ANALYSIS

Description

Table 5 summarizes the classification that was used to code each SMART goal. Firstly, there was no difference in the amount of SMART goals in one subgroup versus the other. The maximum number of SMART goals was 15, which corresponds to 3 goals multiplied by 5 visits. Participants of both subgroups attended a similar amount of visits and therefore, set a similar amount of SMART goals. In general, a higher proportion of goals, about 60%, were targeting the “diet” aspect and were aiming to increase a healthy behavior, but no differences were found among subgroups. The Theory of Planned Behavior (TPB) classification revealed a significant difference between UNS and SUC regarding the *subjective norm* construct. In fact, there was a higher proportion of goals that addressed this concept in SUC compared to UNS (68.6% vs 57.5%, $p=0.033$). No statistical differences were found for the 2 other constructs (attitude and perceived control) of TPB, neither for the 2 items from the Ecological Model (EM) (individual and family). In terms of lifestyle categories, the activity aspect, gathering physical activity and screen time, represented together 39.5% of all goals but the majority targeted physical activity (35.8%) over sedentary activity (3.7%). The diet aspect represented 60.5% of all goals, but goals addressing one of the 5 groups of CFG represented 46.5% of all goals, with ‘fruits & vegetables’ being the most popular, followed by ‘grain products’ and ‘other foods’. The ‘miscellaneous’ category which includes eating behaviors and healthy choices represented 14.3% of all goals. Subgroups were not different for all lifestyle categories.

TABLE 5 CLASSIFICATION OF SMART GOALS

CLASSIFICATION		UNSUCCESSFUL (n=12)	SUCCESSFUL (n=37)	P-VALUE
Visits, n		4.7 ± 0.7	4.4 ± 0.9	0.436
Total amount of SMART goals, n		13.8 ± 2.2	13.1 ± 2.8	0.437
<i>Type of goal</i>				
Diet		60.6	60.5	0.996
Activity		39.4	39.5	0.996
<i>Type of behavior</i>				
Increase healthy behavior		69.6	66.9	0.832
Decrease unhealthy behavior		30.4	33.1	0.832
<i>Theory of Planned Behavior</i>				
Attitude		36.3	30.0	0.122
Subjective norm		57.5	68.6	0.033
Perceived control		83.2	83.4	0.759
<i>Ecological Model</i>				
Individual		70.4	64.1	0.676
Family		29.6	35.9	0.534
<i>Lifestyle behaviors</i>	ALL			
Physical activity	35.8	36.5	35.6	0.823
Screen time	3.7	2.9	4.0	0.410
Fruits & vegetables	15.3	19.8	13.9	0.303
Grain products	11.4	11.2	11.5	0.674
Milk & alternatives	8.9	9.3	8.8	0.893
Meat & alternatives	1.1	0	1.4	0.154
Other foods	9.5	9.3	9.5	0.905
Miscellaneous	14.3	11.0	15.3	0.399

Data is represented as % of total goals.

Relationship between SMART goals and success

Figure 2 represents the association between the 3 constructs of the TPB (blue circles) as well as the 2 items from the EM (green circles) with success (maintained or decreased BMI z-score over 6 mo). For the TPB, the only construct that was significantly correlated to success was the *subjective norm* ($r = 0.41$, $p = 0.005$). In other words, when choosing more often goals targeting *subjective norm* there is a positive association with BMI z-score change. For the EM, Figure 2 demonstrates that when choosing more often goals targeting the family as opposed to the participant alone (individual), there seems to be a pattern of success, and the correlation is close to significant ($r = 0.28$, $p = 0.055$). Goals including one or more members of the family of the participant tend to be associated with success than individual-based goals. There was no significant correlation between BMI z-score change and descriptors of type of goal (diet or physical activity) and type of behavior (decrease unhealthy or increase healthy).

The association between *subjective norm* and favorable changes in BMI z-score is also brought out by a simple regression between these 2 variables (Figure 3) that shows an inverse relationship with an adjusted R-square of 0.1690 ($\beta = -0.01$, $p = 0.002$). This relationship demonstrates that the higher the proportion of goals targeting *subjective norm*, the more the BMI z-score change will decrease. In fact, *subjective norm* accounts for about 17% of the variance of BMI z-score change in this model. Moreover, similar results were observed with multiple and stepwise regressions (Supplementary table 6) even after including other parameters in the model. The multiple regression model ($p = 0.046$) generated an R-square of 0.3082, meaning that approximately 31% of the variability in the dependant variable (change in BMI z-score) is accounted by the variables in the model that controlled for age, sex and all descriptors of SMART goals (Supplementary table 4). The coefficient indicates that a decrease of 0.01 in BMI z-score is expected for every unit increase in proportion of goals classified as *subjective norm*. As for the stepwise regression, 2 variables were kept in the final model: *subjective norm* and *family*. The coefficient and standard error for *subjective norm* are exactly the same as those obtained with the multiple regression. The coefficient of *family* implies that for each unit increase in proportion of goals classified as *family*, a decrease of 0.005 in BMI z-score is anticipated.

The next step of this analysis was to investigate any association between the constructs from TPB and EM with changes in diet and activity over 6 mo. None of the diet and activity variables correlated with *attitude*, *perceived control*, *individual* or *family*. A significant correlation was found with 2 of the diet variables and *subjective norm*. In fact, *subjective norm* was negatively correlated with carbohydrate ($r = -0.74$, $p = 0.006$) and sugar ($r = -0.62$, $p = 0.033$), both expressed in percent of total daily energy. Simple linear regressions (Figure 4) demonstrated significant inverse relationships between the percentage of energy from carbohydrates ($r^2 = 0.5548$, $p = 0.0022$) and sugar ($r^2 = 0.2909$, $p = 0.0466$) and the percentage of *subjective norm* goals. The negative correlation between *subjective norm* and screen time ($r = -0.35$, $p = 0.057$) was almost significant. A simple linear regression was performed to illustrate the association of *subjective norm* and the decrease in screen time (Supplementary figure 2). Although non-significant, this regression ($r^2 = 0.1087$, $p = 0.065$) shows a trend of decrease in screen time with an increasing proportion of SMART goals classified as *subjective norm*. Physical activity was also not significantly correlated with *subjective norm* ($r = 0.19$, $p = 0.322$), but the simple linear regression illustrated a positive trend ($r^2 = 0.1117$, $p = 0.062$) (Supplementary figure 2).

In the light of these results, the classification of SMART goals into 8 lifestyle categories was revisited according to the 2 variables that seem to have the strongest influence on success, i.e. *subjective norm* and *family*. Figure 5 demonstrates that overall, the majority of goals for both variables are directed at diet as opposed to activity (physical activity and screen time), representing 68% of *subjective norm* goals and an even higher proportion (84%) in goals involving the *family*. When looking at the breakdown of lifestyle behavior categories, the 3 most popular among goals classified as *subjective norm* were *physical activity* (26%), *fruits & vegetables* (16%) and *miscellaneous* (16%). Regarding goals classified as *family*, the most popular categories were *fruits & vegetables* (25%), *grain products* (17%) as well as *physical activity* and *miscellaneous* (equal proportion of 16%). The least often targeted category was *screen time*, representing 6% of *subjective norm* goals and 0% of *family* goals.

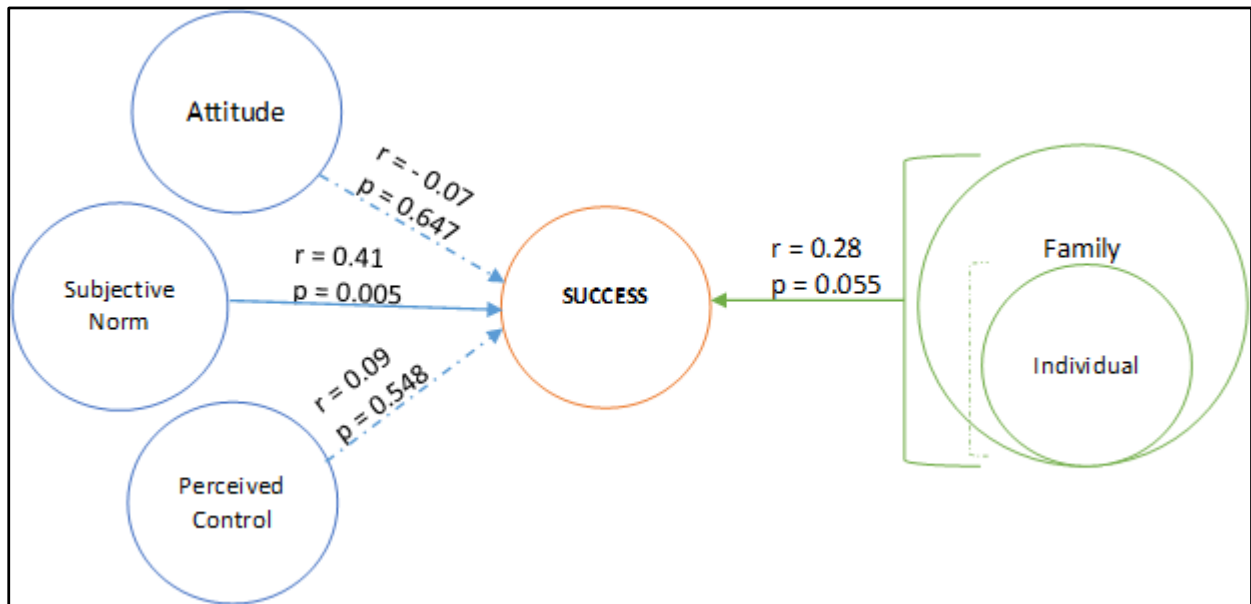


FIGURE 2 CORRELATION BETWEEN TPB/EM AND SUCCESS

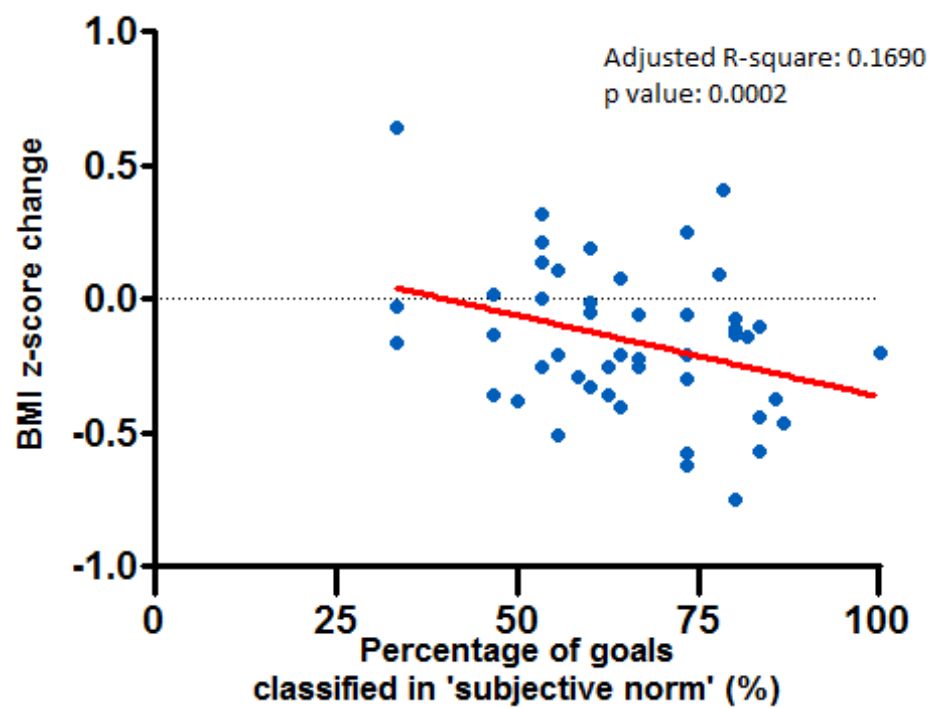


FIGURE 3 SIMPLE REGRESSION BETWEEN SUBJECTIVE NORM AND BMI Z-SCORE

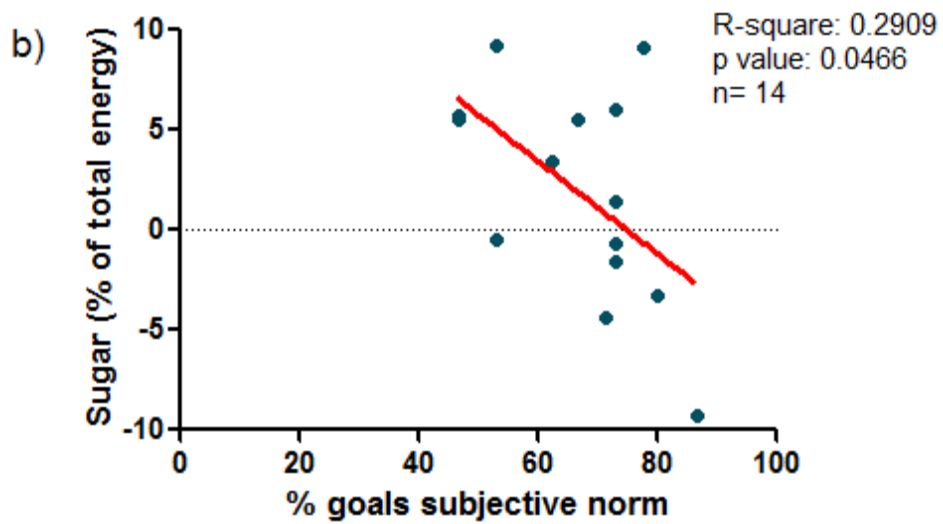
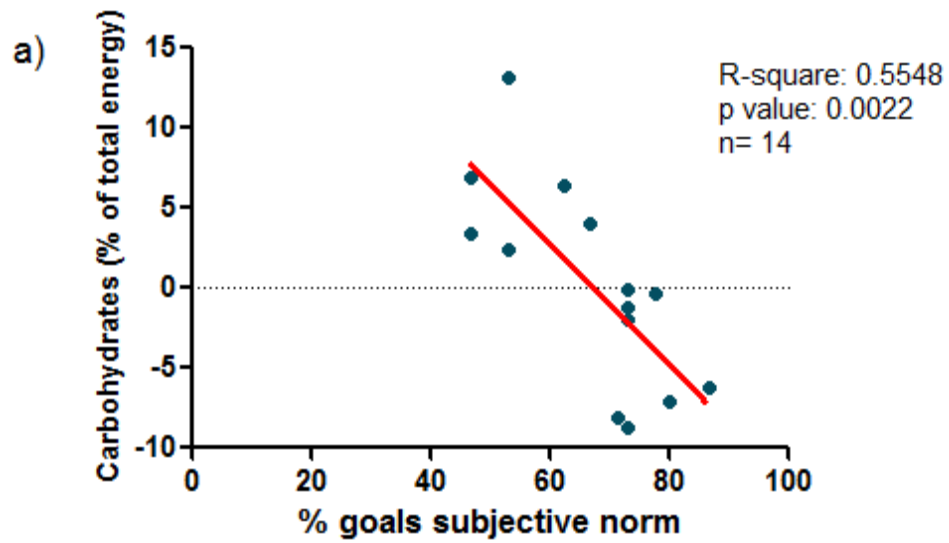
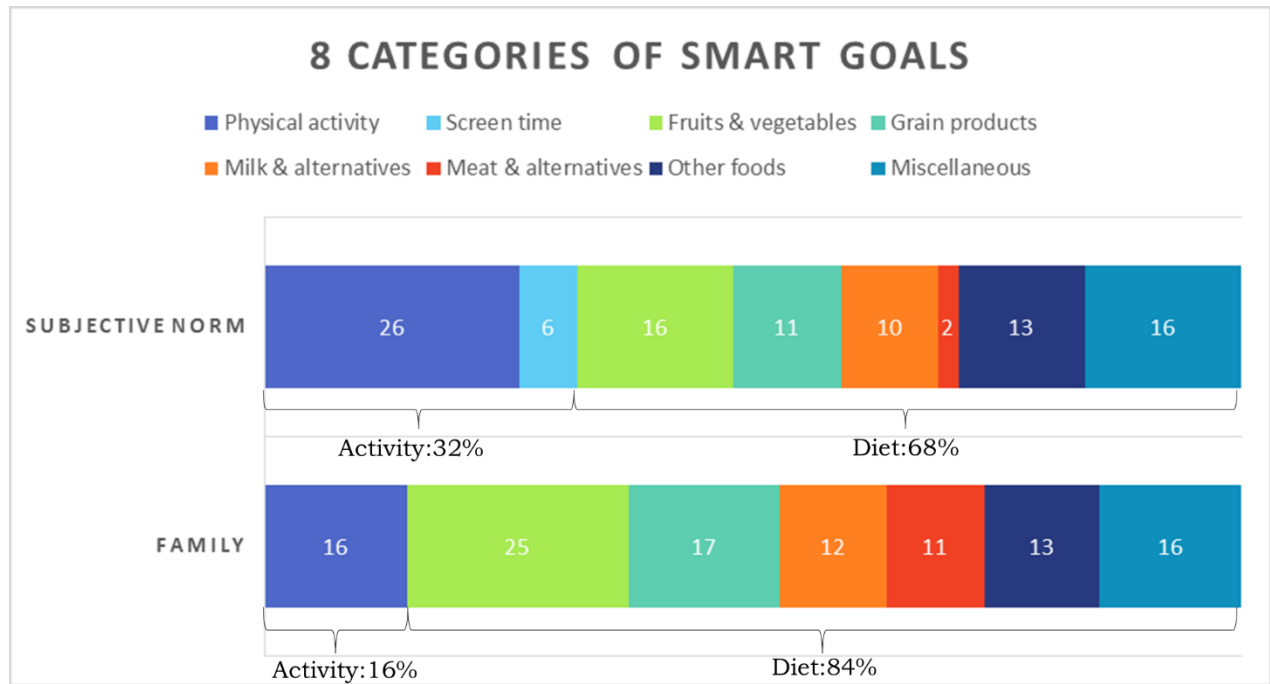


FIGURE 4 RELATIONSHIP BETWEEN DIET AND SUBJECTIVE NORM

FIGURE 5 PROPORTION OF 'SUBJECTIVE NORM' AND 'FAMILY' SMART GOALS IN EACH LIFESTYLE CATEGORIES



3.3.3 DISCUSSION

By assessing the proportion of unsuccessful and successful participants in each group, it was possible to determine that SMART-based family-centered lifestyle intervention had significantly more successful participants than control group, thus providing some evidence for the inclusion of SMART goal approach in intervention aiming at management of childhood obesity.

Furthermore, goals have been described using the Theory of Planned Behavior and the Ecological Model in order to characterize SMART goals set by successful participants. It appears that goals targeting the construct *subjective norm* from the TPB were associated with favorable changes in BMI z-score over 6 mo. SMART goals targeted at the *family* as opposed to the child alone also seem to have a higher chance of success. These findings indicate that participants need to be reminded of the recommendations (norms) regarding diet and activity and that family support has a positive role in their success.

The results from our study showed that there was a higher proportion of successful participants in INT compared to CTL (UNS: 53%, SUC: 75%, $p=0.019$). This demonstrates that participants who followed an intervention program including individualized family-centered lifestyle counseling using SMART goals with a registered dietitian were more successful in maintaining or decreasing BMI z-score within a 6-mo period than those who only received a short education session at baseline, showing an association between INT and success. However, the mean change in BMI z-score over 6-mo was not different between groups. The Academy of Nutrition and Dietetic published their position in 2013 regarding the interventions for the treatment of pediatric overweight and obesity and recommended behavioral strategies such as goal setting to promote healthy lifestyles in clinical setting [106]. A review examining the use of goal-setting strategies in dietary behavior change with children found only 3 studies that provided details about the goal-setting components, but all 3 reported successful interventions [107]. A qualitative study conducting interviews with obese adolescents following a weight management program revealed that the participants who reported success were those who set concrete goals and broke down larger goals into smaller and more manageable ones, with the help of a coach, family member, nutritionist or physician [108]. In Scottish men, the Camelon weight management group intervention using SMART goals for weight loss, physical activity and

alcohol consumption, yielded to a proportion of 44.3% of men who achieved 5 to 10% weight loss in 12 weeks [109]. The HIKCUPS study, which is a RCT of physical activity and dietary modification program for overweight and obese children involving 165 children found that 2 of the 3 study groups that included a parent-centered dietary modification intervention with SMART goals yielded a greater BMI z-score reduction compared to the study group targeting activity in isolation [61, 110]. Although SMART goals were utilized on adults in the 2 studies mentioned above, the results are consistent with our findings in children. Nonetheless, inconclusive evidence were found regarding goal setting in a systematic review on effective BCTs in childhood obesity interventions [56]. Our results also showed that there was a higher proportion of girls in CTL-UNS compared to CTL-SUC, an observation that was also made in a weight management study among obese adolescents, where more girls reported no success than success (58.3% vs 41.7%) in changing weight-related behaviors [108].

On the other hand, our data show that a little bit more than half CTL was successful; this could be attributed to different reasons that have not been tested such as recruitment bias, baseline education session, level of motivation, stage of change, family status (single parent) [101]. Interestingly, when dividing participants into UNS and SUC subgroups, we observed that many adiposity parameters (such as weight, BMI, BMI z-score, waist circumference, percent body fat and fat mass) were higher at baseline in SUC of both groups CTL and INT. Generally, all these parameters changed favorably over 6-mo for SUC compared to UNS, suggesting that it may be easier to decrease adiposity in few months for those who are severely obese. This observation has been validated in a study identifying predictors of weight loss after an obesity treatment for children where adjusted BMI explained a substantial part of the variance ($R^2=0.17$, $p<0.001$) in weight loss (the higher the adjusted BMI, the greater the total weight loss) [111]. This notion could help understanding why 53% of CTL was SUC. In fact, CTL-SUC participants had significantly higher weight, BMI, BMI z-score, waist circumference and fat mass compared to CTL-UNS at baseline. However, when comparing the average energy intake, physical activity and screen time among subgroups, this phenomenon is not seen. Even if no difference were seen among subgroups, it is possible that the combined effect of these 3 variables changing in a

positive direction added up to better success in SUC groups. Although a higher proportion of girls was found in CTL-UNS, sex differences were not found among weight loss predictors [111].

The analysis of 3-day food diaries revealed that on average, participants consumed less energy than their estimated energy expenditure for sedentary and low active physical activity levels. However, children are known to misreport food intake, usually in the direction of under-reporting, because they have limited ability to cooperate to dietary assessment, especially when they are under 7 years old [112]. On the other hand, the ability of parents to accurately recall their child's food intake seems accurate, but they are not reliable reporters of their child's food intake out-of-home [112]. While all protein, carbohydrate and lipid intakes are within the AMDR, the average fibre intake at each time point is lower than the DRI value of 25 to 31 g/d recommended for this age group [29]. The proportion of energy from total sugar at each time point is slightly over the recommendation from Health Canada in the 2014 label modification proposal, which states that total sugars should not correspond to more than 20% of energy [113]. However, the current values from both groups are over the 2014 position statement from the Heart and Stroke Foundation and the 2014 WHO draft sugar guidelines that recommend an individual's daily total free sugar intake should not exceed 10% of total daily energy intake but a reduction below 5% of energy would have additional benefits [114, 115]. Nevertheless, the total daily sugar intake doesn't allow to distinguish added sugar or free sugar (113,114) from intrinsic sugar (for example, sugar naturally occurring in fruits or milk). Therewith, the sugar intake values could be inaccurate due to the constant changes in formulation for commercial, multi-ingredient foods, which make the added sugar values changing constantly. In fact, the United States Department of Agriculture (USDA) removed the added sugar content of selected foods from its database because of the rapid changes of the estimates [116]. Ultimately, dietary data could be imprecise because of missing food diaries, half of the sample did not have a food diary at baseline and even less at 6-mo follow up (n=50 at baseline and n=44 at 6-mo).

When UNS and SUC were compared in terms of SMART goals descriptors, there was no difference in terms of type of goals (diet or activity) and type of behaviors (increase healthy behavior or decrease unhealthy behavior) among subgroups. Overall, we found diet goals

(60.5%) to be targeted more often than activity goals (39.5%), which is consistent with the results from a review of meta-analyses of randomized trials on behavioral interventions to prevent childhood obesity, which stated that most RCTs targeted dietary behaviors slightly more often than physical activity. [69] This review also found that strategies attempting to reduce unhealthy behaviors seem to be more effective than those promoting healthy behaviors, but this trend was not observed in the present study. [69] On the other hand, in an intervention targeting parents' dietary habits, it was observed that increasing fruits and vegetables (a healthy behavior) also led to a reduction in high fat/high sugar food (unhealthy behavior) for both, parents and their children, but a reduction in high fat/high sugar intake didn't lead to an increased consumption of fruits and vegetables, suggesting that increasing a healthy behavior might have a double effect. [117]

When the relationship between SMART goals and success was tested, the results revealed that one of the constructs of the TPB, the *subjective norm*, was strongly associated with success, described earlier as a maintenance or decrease in BMI z-score from baseline to 6-mo. The concept of *subjective norm* refers to the normative expectations from others and motivation of the individual to comply with these expectations, in other words, it is the perceived social pressure to perform a behavior. [46] According to the classification method developed for the purpose of this analysis, when a SMART goal was attributed to *subjective norm*, it could be combined with one or two of the other constructs of the TPB depending on the situation, but it was always in the situation of a new behavior or a behavior that needed to be increased or decreased. A SMART goal was classified as *subjective norm* when the recommendations or guidelines related to the chosen goal were addressed during the intervention. In the intervention, it corresponded to when participants and family needed to be taught or reminded about the normative behaviors regarding diet, physical activity or sedentary activity. Many families needed to be reminded about what were the norms or guidelines regarding many aspects of their lifestyle. For example, many participants and their family members did not realized that they were eating too many portions of grain products or not enough fruits and vegetables. Another situation where *subjective norm* was addressed was with activity; parents often did not realized or needed to be reminded that their child should do more moderate to

intense physical activity and decrease screen time. There are numerous potential reasons (e.g. barriers, unfavorable attitude and unacceptance towards the norm) why families needed frequent reminders about these norms but they were not investigated in this study. Therefore, this association reveals that not only families need to be educated about the current national recommendations, but they also need to be reminded and supported to achieve them. An Australian study found that 45.5% of parents with primary school-aged children were concerned that their child eats too much junk food, but interestingly, not knowing what foods to provide was identified as a factor that makes healthy eating difficult [118]. A study that applied the TPB to healthy eating behaviors in urban Native American youth found *subjective norm* as the best predictor of healthy eating in boys, along with family, while girls' eating behavior was mostly predicted by barriers. [49] Another longitudinal study with 279 adolescents found that perceived social norms play a role in decision making about eating and activity and should be included as potential target in future interventions despite its lack of predictive utility found in previous literature. [119]

Although gender differences were observed when identifying barriers for physical activity among obese adolescents, a qualitative study showed that self-satisfied participants expressed self-efficacy and at the opposite, dissatisfaction was associated with unrealistic goals. [108] It is obvious that barriers need to be addressed in order to be able to achieve a goal. Overcoming barriers and giving strategies was represented by the construct *perceived behavioral control*. Despite the importance of this aspect in the intervention, we did not see any association with success. However, the influence of this construct might have been hidden by the nature of the intervention. In fact, barriers and tricky situations were addressed at every intervention and the SMART goal approach also already reinforces *perceived control* through *attainable* and *realistic* components. In a study mentioned earlier about with 677 Canadian school children (Grade 3, 5, 8, 11), it was found that for the total sample, *perceived behavioral control* made the largest contribution in predicting physical activity intention, followed by *attitude* and *subjective norm*. [48] *Perceived behavioral control* was also identified as a strong component to predict the variance in intentions regarding food choices, along with *attitude* in adolescents from England. [120]

In the present study, we did not find any association between *attitude* and success, which suggests that participants and families already had favorable opinions about healthy eating, physical activity and related outcomes, which was expected given the design of the study. In a study trying to understand soft drink consumption among female adolescents aged 13-18 y, *attitude* was found to be the strongest predictor of intention to drink soda. [121]

With respect to the Ecological model, we found a small association very close to significant between success and family involvements in SMART goals realization. This finding is consistent with the current literature, associating parenting styles and family characteristics to the development of obesity risk factors. [51] There are multiple ways by which parents can shape their children's dietary practice such as knowledge and modelling. Their support is therefore essential for achieving healthy lifestyle habits and has been shown beneficial in pediatric obesity treatment. [122] A meta-analysis published in 2006 found that family-behavioral treatments was an effective strategy for weight loss in children. [63] The authors report that parent involvement is beneficial because they have significant control over food purchases, meal planning and preparation and may have influence over variables like portion sizes and modeling. [63] A review including 16 studies published in 2008 concluded that family involvement is beneficial for pediatric obesity treatment. [122] Also in 2008, a systematic review of randomized trials for treatment of pediatric obesity found evidence of small to moderate treatment effect of combined lifestyle intervention on BMI that was stronger with parental involvement, particularly to children 8 y.o. or younger. [103] A more recent meta-analytic review also supports parent involvement in the treatment of youth who are overweight, which accounts for 20% of the variance in weight-related outcomes according to the authors. [123] In addition to our results, there are numerous evidence in favor of parental involvement in interventions for prevention and management of childhood overweight and obesity. Therefore, targeting the family as opposed to the child alone seems to be the most promising approach to successful behavioral lifestyle interventions.

The 2 variables (*subjective norm* and *family*) with the strongest relationship with success were found to be majorly composed of diet-related goals overall, as observed for all goals. However, when breaking down the 2 general categories of *diet* and *activity* into 8 lifestyle categories,

physical activity represented the lifestyle category with the highest proportion among *subjective norm* goals. Moreover, a non-significant positive association was observed between *subjective norm* and the amount of physical activity. A cross-sectional study conducted with 677 Canadian children and youth examined the relative contribution of the 3 predictors of the TPB across age groups and *subjective norm* made the largest contribution to predicting physical activity intention in Grade 3 participants (average age of 8.2y) only, but the authors believe that this finding highlights the relative importance of normative beliefs of physical activity participation at a young age. [48] A review of the correlates of physical activity and sedentariness found a positive association between self-efficacy and parental support (among others) and physical activity in children 4 to 12 y. [124] For adolescents, attitude, self-efficacy, goal orientation/motivation, family influence and friend support were identified as correlates, showing that self-efficacy is a constant correlates across ages and that social pressure or influence might have a stronger association with age. [124] Although screen time was one of the least popular lifestyle categories to be targeted when setting goals according to our results (which is consistent with the findings of Kamath et al. about sedentary activities [69]) it was negatively correlated with *subjective norm*. A possible explanation for this is that recommendations about screen time were always addressed with participants at each intervention session but were not necessarily incorporated into a SMART goal. Therefore, participants could have apply it on their own by being exposed to the recommendations, but it could also be decreased unconsciously if other activities are replacing sedentary behaviors. However, 2 reviews didn't find any association between sedentary behavior and physical activity, suggesting that sedentary behaviors don't replace physical activity and vice versa [124]. On the other hand, a study on 2143 Australian children aged 6-7 y showed an association between television viewing with less physical activity and snacking (ex: sweet drinks, chips, baked goods, chocolate) [125]. Moreover, a small significant relationship between TV viewing and body fatness among children and youth was found in a meta-analysis [43]. We did not find a correlation between physical activity or screen time and carbohydrates or sugar consumption but goals identified with *subjective norm* were strongly associated with a decrease in carbohydrates and sugar intake. A study using NHANES data and the Healthy Eating Index (HEI)

– 2005 to determine the diet quality also found that lower television viewing was associated with higher HEI-2005 scores (i.e. healthy diet) among children and adults. [126] Among *family goals, fruits and vegetables* was the most frequent lifestyle category. A study exploring parental influence on girls' fruits and vegetables consumption found that the strongest predictor was parental fruits and vegetables consumption (21.5% of variance), but that pressure to eat may discourage fruits and vegetables consumption intake in young girls. [127] In 3960 9-13 years old boys recruited from 9 European countries, active parental encouragement and availability at home was related to self-reported vegetables intake in those who were overweight, in contrast to normal weight boys [128]. These combined results highlight the importance of parental eating habits and approach.

3.4 SUPPLEMENTARY TABLES AND FIGURES

3.4.1 TABLES

SUPPLEMENTARY TABLE 1 NUTRITION AND ACTIVITY RECOMMENDATIONS BY AGE GROUP

AGE GROUPS	DIET (CFG PORTIONS)	PHYSICAL ACTIVITY	SEDENTARY BEHAVIOURS
6-8 y	Veg and fruits: 5 Grain products: 4 Milk and alt: 2 Meat and alt: 1	60 min of moderate to vigorous activity daily including 3 d/wk of vigorous activity and 3 d/wk of muscles & bones strengthening	Screen time: Maximum 2 hours/d
9-12 y	Veg and fruits: 6 Grain products: 6 Milk and alt: 3-4 Meat and alt: 1-2		

SUPPLEMENTARY TABLE 2 EXAMPLE OF A **SMART** GOAL

COMPONENTS	DESCRIPTIONS	EXAMPLES
Specific	What do you want to do?	“Eat more vegetables”
Measurable	How much and how often are you going to do it?	“Eat 1 portion of vegetables at lunch”
Attainable	How will you do it?	“Mom will put carrots and dip in lunchbox”
Realistic	Can you do it?	“Yes, I like carrots”
Timely	When will you do it?	“Monday to Friday ”

SUPPLEMENTARY TABLE 3 CLASSIFICATION OF SMART GOALS WITH THE THEORY OF PLANNED BEHAVIOR

Types of goals	Theory of Planned Behavior			Description of each construct
	Attitude	Subjective Norm	Perceived Control	
New goal (starting a new action that was never done before)	1*	1	1	A When it's a new goal, we might have to work on the attitude of the participant towards the goal, so that he has a favorable/positive opinion about it (think that it's fun, that he will like it or beneficial for health).
	0	1	1	SN When it's a new goal, we work on the subjective norm because the participants don't usually know about the recommendations (or if they knew it, we have to remind them because they are not applying it right now).
	1	0	1	PC The participant has accepted to do this goal but has never done it so we are working on improving his perception/awareness of control by giving tips and ideas on how to perform this goals and address barriers in order to improve self-confidence/ self-efficacy.
Increase or decrease a goal or a behavior that has already been targeted previously	1	1	0	A Can work on the attitude to make it more acceptable, to find other ways to make the participant enjoy the goal or to convince about the benefits. (Ex: find another activity or recipe)
	1	0	0	SN Subjective norm might have to be reinforced or reminded in order to achieve better the goal. The participant is doing it but not reaching the recommendations yet. Will not be discussed if was explained in a previous session.
	0	1	0	PC When it's the same goal, the participant is already doing it, so he already knows that he is able to do it (he has proven it). Therefore, there is no need to reinforce their perception of control. Unless we are providing tips/tools to make it easier to perform and increase the perception of control or we are challenging the participant (activity that he knows but never did as much). <i>Exceptions:</i> If there is a loss of control on eating such as bingeing or if we start a new activity that the participant has never performed before in his life (but the main goal is the same). <i>Note:</i> For this type, PC will not be exclusive or associated with attitude
	0	1	1	

Types of goals	Theory of Planned Behavior			Description of each construct
	Attitude	Subjective Norm	Perceived Control	
Repeat of the same goal (to continue working on it)	1	0	1	A To continue the same goal, we might have to reinforce the positive attitude towards the goal. Maybe give other suggestions in order to improve the acceptability (in terms of enjoyment/taste/benefits). Ex: recipes, other activity
	1	0	0	SN When it's the exact same goal, the participant already know about the recommendations. So there is no need to emphasis on this, this matter was already explained in a previous counselling session.
	0	0	1	PC The perceived control can be an issue because the participant has tried to perform the activity and didn't succeed, so we might have to address barriers and increase his perception of control.

* 1: included, 0: not included

SUPPLEMENTARY TABLE 4 SUMMARY OF SMART GOALS CLASSIFICATION

CLASSIFICATION	CHOICES	PARAMETER
Type of goal	Diet Activity	OR
Type of behavior	Positive: increase healthy Negative: decrease unhealthy	OR
Theory of Planned Behavior	Attitude Subjective norm Perceived control	AND/OR
Ecological model	Individual Family	OR
Categories	Fruits and vegetables Grain products Milk & alternatives Meat & alternatives Other foods (treats) Physical activity Sedentary activity Miscellaneous	OR

SUPPLEMENTARY TABLE 5 BASELINE DEMOGRAPHIC CHARACTERISTICS OF FAMILIES

Variables	All	Control	n	Intervention	n	P value*
Age, years	9.53 ± 1.93	9.36 ± 1.87	51	9.53 ± 1.93	49	0.571
Sex, female	55 (55%)	29 (57%)	51	26 (53%)	49	0.703
Ethnicity, white	76 (76%)	39 (76%)	51	38 (78%)	49	0.898
Mother education, university level	49 (52%)	28 (56%)	50	21 (47%)	45	0.604
Family income, > 75,000\$/y	25 (30%)	12 (27%)	44	13 (34%)	38	0.265
Family description, dual parents	82 (83%)	43 (84%)	51	39 (81%)	48	0.686
Commitment to engage in PA, very or extremely committed	52 (55%)	27 (55%)	49	24 (52%)	46	0.735
Confidence to engage in PA, very or extremely confident	48 (51%)	24 (49%)	49	24 (52%)	46	0.436

Data is represented as n (%). Age is reported as mean ± SD.

* P value test the difference between control and intervention using a chi-square test.

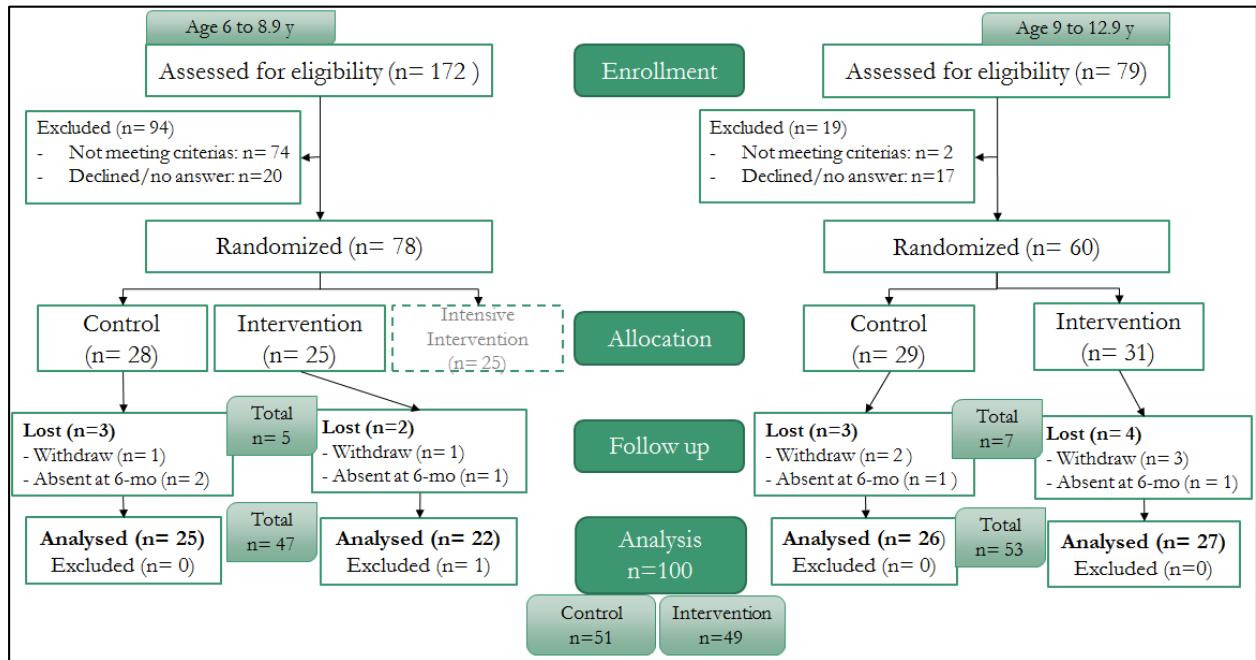
SUPPLEMENTARY TABLE 6 MULTIPLE REGRESSION

Multiple regression*					
Variables	Coefficient	Standard error	Adjusted R-square	Model R-square	P value
Subjective norm	-0.01	0.003	0.1698	0.3082	0.009
Stepwise regression*					
Variables	Coefficient	Standard error	Partial R-square	Model R-square	P value
Subjective norm	-0.01	0.003	0.1863	0.1863	0.002
Family	-0.005	0.002	0.0650	0.2513	0.052

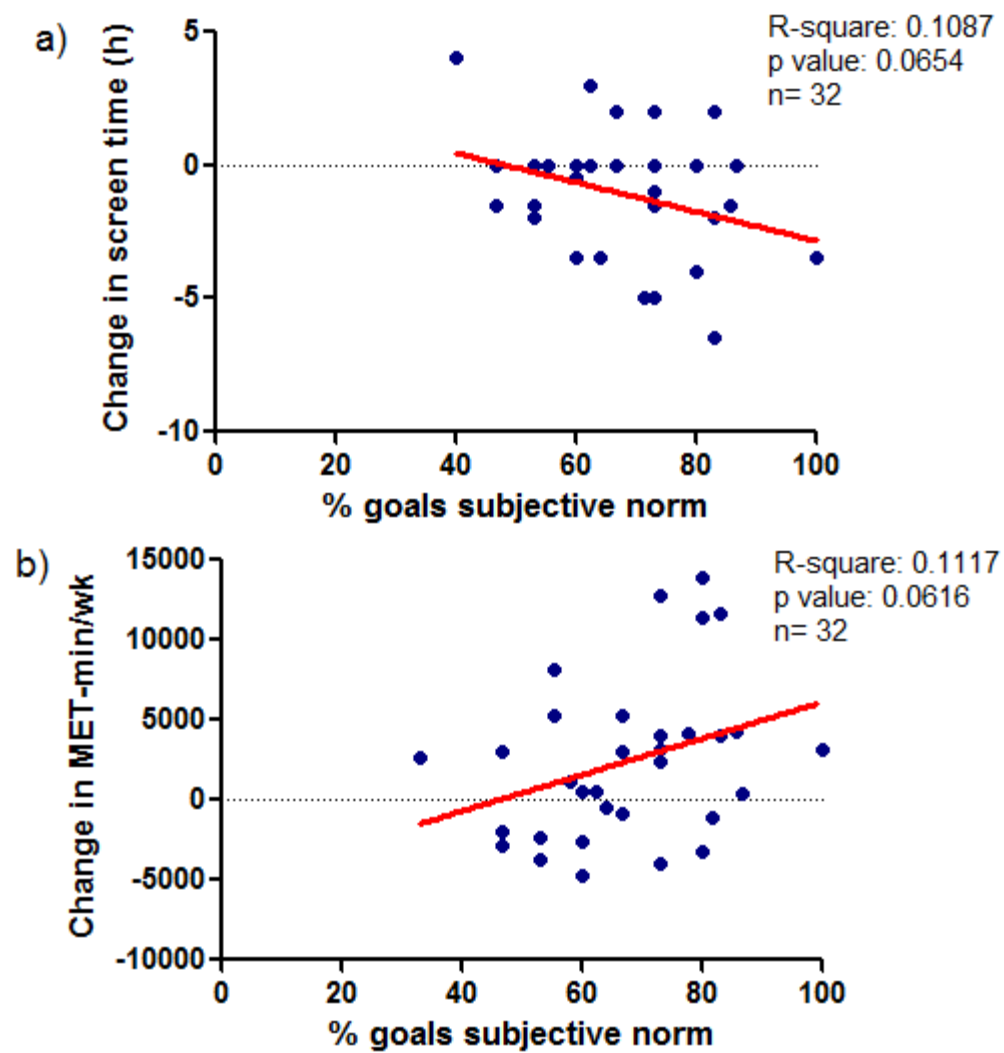
Only significant variables are shown.

*Independent variables include age, sex, all other classification descriptors (TPB, EM, type of goal, type of behavior)

3.4.2 FIGURES



SUPPLEMENTARY FIGURE 1 PARTICIPANTS FLOW DIAGRAM



SUPPLEMENTARY FIGURE 2 RELATIONSHIP BETWEEN ACTIVITY AND SUBJECTIVE NORM

4. EXTENDED DISCUSSION

4.1 SUMMARY OF FINDINGS

The present study assessed the relationship between success in change in BMI z-score and SMART goals, by defining them using the Theory of planned behavior and the Ecological model, in a group of 100 overweight and obese children. Firstly, we found that 5 family interventions with a registered dietitian incorporating SMART goals resulted in greater proportion of successful participants at reducing BMI z-score over 6 months in compared to control, although no significant difference was found in change of BMI z-score between CTL and INT.

Furthermore, SMART goals that addressed the *subjective norm* construct, which refers to the perceived social pressure to perform a behavior, from the Theory of Planned Behavior were associated with positive changes in BMI z-score from baseline to 6-mo. We found that carbohydrate and sugar intakes were inversely correlated to the proportion of goals addressing *subjective norm*. Moreover, physical activity was the most often targeted lifestyle behavior by this concept and the correlation coefficient was almost significant between these 2 variables. Since SMART goals were chosen by participants, this could mean that they feel the need to be reminded about the recommendations and set goals that aim at achieving them in order to succeed. Screen time was an unpopular goal among participants, but the correlation with *subjective norm* goals was close to significant, suggesting that it was probably more easily incorporated as a behavior change.

In addition, our results revealed a non-significant trend favoring success associated with *family* involvement in SMART goals. The associations tested in our study were close to significant. We found that one quarter of goals that involved the *family* were aiming at increasing fruits and vegetable intake. This pattern shows that participants might succeed better with parental support, especially with respect to fruits and vegetables consumption.

4.2 STRENGTHS AND LIMITATIONS

To our knowledge, this study is unique at attempting to describe the SMART goals that are associated with success in the context of a lifestyle intervention for childhood obesity. The analysis was grounded on evidence-based theories and the classification of SMART goals according to the different constructs was performed in a standardized manner, which allows easy replication. The accuracy of SMART goals classification into the TPB and EM could also be a weakness since the study was not designed for this purpose. There were no specific questions asked to the participants to assess the different constructs. However, the information used to proceed to this classification was from the intervention chart, which is known to be objectively reported. The use of a second reviewer to classify independently all goals with the descriptors would have allowed to validate the reproducibility of the classification method. Another strength of the study is that all interventions were conducted by a registered dietitian and the intervention design was evidence and theoretically based. The study also used objectively measured (as opposed to self-reported) height, weight and body composition and physical activity as well as dietary data were captured using validated methods. Furthermore, puberty stage was also assessed objectively.

One of the limitations of this study is the performance bias, which is expected in this type of research. In fact, participants were recruited through physician referrals and advertising so they are suspected to be more motivated to make changes than the average population and are aware of the treatment strategy when reading the consent form. Also, this kind of intervention cannot be blinded so participants from the control group might be tempted to start making changes on their own even without intervention. Despite the adequacy of the sample size according to calculation, the analysis of SMART goals was underpowered since it was performed only on INT which corresponds to half of the sample. Although some associations were found, these may have been stronger and other variables may have been significant with more participants. This is even more evident with the analysis of diet and physical activity where data were missing, which reduced even more the sample size. Since the outcomes were measured right at the end of the intervention period, maintenance of success and evolution in diet and physical activity behavior were not assessed. Screen time was probably

underestimated since the questionnaire did not include questions about computer use and mobile devices (e.g. smart phones, tablets, etc.). Also, choices of answers were used to assess television or video game weekly time in the questionnaire, which might not reflect the reality (the highest possible answer was “more than 5 h/wk). Physical activity was measured using a validated questionnaire for children, but it might have been underestimated since some evidence shows that energy expenditure varies with pubertal status, which was not taken into account in calculations [105]. A real-time recording of physical activity (e.g. accelerometer) would have been even more precise than the questionnaire. Nevertheless, the associations between existing variables indicate that the measures were sufficient to detect changes and relationships.

4.3 CONCLUSION

To our knowledge, this study is the first that aimed to describe SMART goals using behavioral and ecological models in order to identify the nature of goals that are linked to success in the context of a family-centered lifestyle intervention with overweight and obese children. This study provides insight into successful goal setting strategies that should be adopted to increase the effectiveness of interventions. Lifestyle intervention using SMART goal approach appears to be more effective than a single education session to improve adiposity in children. The success of interventions was mainly ascribed to SMART goals that addressed *subjective norm* from the Theory of Planned Behavior, which refers to the social pressure to perform a behavior transmitted by those who influence someone’s decision. This theoretical work helps to better understand mechanisms underlying the effects of social pressure on youth’s eating and activity behaviors.

In the present study, it was found that SUC participants from CTL and INT had a greater adiposity compared to UNS; the fact that a higher weight and BMI is associated with greater weight loss has been verified in a previous study and highlights the importance of setting realistic weight loss goals while taking into account initial weight status. [111] National tools such as *Eating Well with the Canada’s Food Guide* and the *Activity Guide* are very useful to

educate families about the recommendations but are not sufficient to change behaviors. BCTs like goal setting have shown to be part of successful interventions. The purpose of goal setting is to make an overarching goal concrete and to do so, it must be specific, measurable, attainable, realistic or relevant and time-framed (SMART). [129] Some qualitative evidence suggest that obese children should be encouraged to set achievable, non-weight related, short term goals in order to achieve the long term goal of losing weight; the achievement of such goals will make them feel that they are progressing in the right direction. [130] Our results and other studies have shown that intervention lasting only a few months can produce significant change, but many health care providers feel unprepared to implement lifestyle treatments. [123] Medical professionals also feel unprepared to discuss health-related behavior change with patients, which raises the importance of training in theory-based behavior change techniques to treat obesity. [131]

Of course, proper training of health care providers according to the latest evidence is crucial in a society where the rate of childhood obesity is growing like it is the case for Canada and United States. The present results could be translated to a practical point of view; this research indicates that *subjective norm* – the belief that individuals that are important to the child think that he or she should be active or should eat healthy according to the recommendations – plays an important role in the success of participants in a lifestyle intervention program, along with the support from *family*. This information provides some insights to understanding theoretical mechanisms involved in lifestyle behavior change to help intervention designers and practitioners developing programs and future research on behavior change techniques. At last, this study provides some answers to a question that is asked by many researchers in the field of childhood obesity that is, what are the specific components and the nature of successful childhood obesity interventions. Identifying which types of behavior change techniques lead to success will help developing cost-effective interventions, policies and guidelines to support obesity management in children.

4.4 FUTURE DIRECTIONS

The present study used the Theory of Planned Behavior constructs for a description purpose only. There are currently very few studies that tested the ability of this theory to predict health-related behavior change in children, especially diet-related behaviors. Studies measuring TPB constructs during intervention would allow to understand better the factors that influence intentions in children. There are also very few studies that describe what are the specific problematic areas for this population, in order to know where to intervene. Goal setting, more specifically SMART goals, has been shown to be a behavior change technique that can be used in interventions but more research is needed to support the inclusion of this behavior change technique into programs. The exact contribution of goal setting to successful interventions is still unknown; testing interventions with and without goal setting strategies would allow to answer this question. [107, 132] Another component for which we know an association with successful treatments of pediatric overweight is parental support and involvement. However, the extent and the type of involvement remain unclear; we don't know if an active or supportive participation is better. More effective programs will not be designed until there is a better understanding of nutrition and activity behaviors [52]. Moreover, future studies should use a behavior-specific taxonomy such as the CALO-RE taxonomy not only to refine the descriptions of behavior change techniques but also to improve reporting, aiding replication and allow comparisons. [56]

A recent study from the Center for Disease Control found that many children have a misperception of their own weight status. In fact, a majority of overweight boys and girls believed that they are about the right weight, suggesting that they may be exposed to overweight and obese people in their immediate social environment. [133, 134] An accurate perception of weight status has been linked to greater motivation to change lifestyle behaviors, therefore, current evidence suggest to target misperception to increase intervention effectiveness. [134] It would be interesting to investigate how overweight and obese children and families perceive their lifestyle. Our findings suggest that families needed to be educated and reminded about the recommendations, this could be a matter of perception as well. Can we increase the success of lifestyle intervention in overweight and obese children by targeting

normative behavior and further involving family? We know that tobacco control became a successful public health movement because of shifts in social norms and a variety of policy initiatives among other things. [135] Tobacco control holds many parallels with the actual obesity epidemic. In the light of the results obtained in the present study and what we have learned from tobacco, maybe it is time for the governments to put the record straight in terms of normative behaviors for children and their family and mobilize the society with successful strategies targeting the industry in order to ensure the health of future generations.

SMART goals are a promising avenue to achieve behavior change in children, but since numerous factors contribute to obesity, it is unlikely that a single technique would lead to success for all obese children. [103] Therefore, a multidisciplinary and multimodal approach using evidence-based interventions and techniques seems to be the best option, but requires more attention and long-term impact assessment. [103]

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