EFFECT OF ADHERENCE TO A WEB-BASED BEHAVIOURAL MODIFICATION INTERVENTION ON HEALTH BEHAVIOURS AND REDUCTION IN OVERWEIGHT/OBESITY AMONG ADOLESCENTS

by

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Abstract

PURPOSE: The purpose of this study was to: 1) investigate whether adherence to components of a web-based weight management intervention have an effect on health behaviours (moderate-to-vigorous physical activity (MVPA), sedentary behaviour, and dietary quality) and change in body mass index (BMI) z-score of adolescents; and 2) to examine how health behaviours mediate the relationship between adherence to components of the intervention and change in BMI-z-score.

METHOD: A total of 158 overweight/obese adolescents and their parents participated in an 8-month web-based weight management intervention. Path analysis was used to examine the effect of adherence to intervention components on health behaviours associated with obesity (MVPA, sedentary behaviour, and dietary quality) and change in BMI z-score at 4 and 8 months and to test for mediation effects. Adherence assessed the percentage of content viewed and number of weeks of self-monitoring of physical activity (steps), sedentary time, and dietary intake. MVPA and sedentary behaviour were assessed with accelerometers and self-reported questionnaires. Three self-administered 24-hour dietary recalls were used to compute a dietary quality index.

RESULTS: Adolescents viewed 49% and 39% of the web content at 4 and 8 months, respectively. They self-monitored their steps, sedentary time, and dietary intake for 7.5, 2.0, and 3.9 weeks during the first four months and 10.9, 2.7, and 5.6 weeks for the duration of the intervention period (8 months), respectively. The amount of content adolescents' viewed had a significant direct effect on their dietary quality at both 4 and 8 months (Standardized Coefficient (SC)=0.19, p=0.09 and SC=0.24, p=0.01, respectively) and a significant direct

effect on change in BMI z-score at 8 months (SC=0.26, p=0.01). None of the health behaviours mediated the effect of adherence to intervention on change in BMI z-score.

CONCLUSION: The study highlights that viewing more content was associated with improved dietary quality and greater reduction in BMI z-score but use of the self-monitoring tools did not explain these changes. Health behaviours could not explain the underlying process of the intervention. Finding ways to maintain adolescents engaged with the intervention is necessary given its effects on health outcomes.

Preface

This statement is to certify that the identification and design of the thesis project, data analyses, interpretation of results, and writing of the manuscript was carried out by the candidate, Benajir Shams, under the supervision of Dr. Louise C. Mâsse. The other two members in the thesis committee were Dr. Chris Richardson and Dr. Mariana Brussoni. This research used the secondary data of MySteps® study which was conducted under the supervision of Dr. Louise C. Mâsse and with the help of other research staffs at British Columbia's Child and Family Research Institute (CFRI).

MySteps® study was approved by the Behavioural Research Ethics Board at the University of British Columbia (#H08-01638) and the Office of Research Ethics at the University of Waterloo (#16429).

Table of Contents

List of Tables

List of Figures

List of Symbols & Abbreviations

BC	British Columbia
BMI	Body Mass Index
BMI-SDS	Body Mass Index-Standard Deviation Score
BMI z-score	Body Mass Index z-score
CCHS	Canadian Community Health Survey
CFI	Comparative Fit Index
CFRI	Child and Family Research Institute
CHMS	Canadian Health Measure Survey
CI	Confidence Interval
CVD	Cardiovascular Disease
HEI	Healthy Eating Index
KG	Kilogram
MET	Metabolic Equivalent
MVPA	Moderate-to-Vigorous Physical Activity
NHANES	National Health and Nutrition Examination Survey
PACE	Patient-Centered Assessment and Counselling for Exercise
PACE+	Patient-Centered Assessment and Counselling for Exercise plus Nutrition
PAR	Physical Activity Recall
RCT	Randomized Controlled Trial
RMSEA	Root Mean Square Error of Approximation
RR	Relative Ratio
SC	Standardized Coefficient
SD	Standard Deviation
SE	Standard Error
SRMR	Standardized Root Mean Square Residual
TV	Television
US	United States
USDA	United States Department of Agriculture
VG	Video Games
WHO	World Health Organization
cm	Centimeter
df	Degree of Freedom
m^2	Meters squared
R^2	R-squared
χ^2	Chi-squared
%	Percentage

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Dedication

To My Parents

Chapter 1. Introduction

Global prevalence of adolescent overweight and obesity is high.[1] In the United States (U.S.) 34.5% of adolescents (12-19 years) are overweight or obese,[2] while in Canada the prevalence is 30.1% for adolescents aged 12-17 years.[3] The increase in childhood and adolescent obesity is a recent phenomenon in Canada with rates having tripled from 1978 to 2004.[4] The growing trend of childhood obesity in developed countries is perhaps more related to the urbanized lifestyle[5] than to genetic factors associated with obesity.[6] Physical activity,[7;8] sedentary,[9;10] and dietary behaviours[11-14] have all been related to obesity in adolescents. Unfortunately, many Canadian adolescents do not meet current recommendations for health behaviours associated with reduction in obesity.[15;16] Only 7% of Canadian adolescents meet the recommended level of physical activity which is to perform 60 minutes of moderate-to-vigorous physical activity (MVPA) daily.[15] Only 30% of adolescents spend less than two hours per day in front of a screen in their free time.[15] In addition, fewer than half of the adolescents consume the recommended amount of fruits and vegetable as well as milk and dairy alternatives.[16] Strategies are needed to help adolescents become more active, limit their sedentary behaviour, and improve their dietary quality in order to decrease adolescent obesity.

Research on behavioural modification interventions targeting weight loss in adolescents is limited.[17] Web-based behavioural modification interventions may be particularly effective in adolescents because of their wide acceptance of the technology.[18] However, participant adherence to such interventions has been reported to be only 50% or less.[19] Adherence, which is measured by the extent to which participants comply with the intervention components,[20] is related to the efficacy of an intervention.[21] Higher adherence to

interventions has been shown to reduce obesity[22;23] and improve health behaviours[24] among adolescents. Longer and more frequent participations were associated with greater reduction in body mass index (BMI)[22] and BMI-standard deviation score (SDS)[23] among children and adolescents of 6-16 years and 7-17 years in two behavioural modification interventions, respectively. Patrick et al. found that adolescents (11-15 years) who completed greater number of counselling calls met a greater amount of dietary and sedentary behaviour guidelines.[24] Based on the evidence described here it is suggested that adherence to intervention components might have an effect on improving health behaviours and thus, reducing obesity in adolescents.

The underlying mechanism through which targeted health behaviours contribute to the effectiveness of an obesity treatment intervention through behavioural modification has not been studied widely.[25] Mediation analysis can be used to determine whether the effect of the intervention is mediated through changes in the behaviours targeted by the intervention or not, as well as to measure the extent of the mediation effect.[26] Understanding how behavioural modification interventions work will provide insight about which component of the intervention seems more effective.[25] In the past, most weight-loss studies have used mediation analyses to examine the mediating effect of psychosocial characteristics (e.g. self-efficacy) on health behaviours and weight status[27;28] and primarily examined this among adults.[29;30] Findings from few studies provide evidence that the health behaviours targeted by the intervention mediate the outcome of the intervention.[30;31] For example, one randomized controlled trial (RCT) suggested that step counts and dietary behaviour regarding vegetable consumption of females (44-50 years) mediated the effect of the intervention on their weight loss at 12- and 24-month.[30] Lubans et al. reported that step counts taken by overweight and

obese adult men mediated the relationship between their weight loss and the effect of a 3-month in-person intervention primarily designed to improve parent-child co-activity.[31] However, this study reported that daily steps taken by children (9-12 years) did not mediate the effect of the intervention on their weight loss.[31] Future interventions should target health behaviours that have been proved to mediate intervention outcome for better result. However, mediation analyses of adolescents' health behaviour on their obesity reduction have not been studied rigorously. Therefore, this study aimed to address the following research questions:

1. "Does adherence to components of a web-based familial obesity treatment intervention have an effect on reducing BMI z-score and improving health behaviours (amount of MVPA, sedentary behaviour, and dietary quality) among 12 to 17 years old adolescents?"
2. "Do adolescent health behaviours (amount of MVPA, sedentary behaviour, and dietary quality) mediate the effect of adherence to intervention components on their change in BMI z-score?"

   The findings of this study will improve understanding of the intervention components of a web-based behavioural management intervention that result in improved intervention outcomes. Results from the mediation analyses will improve understanding of the underlying mechanism of obesity reduction for adolescents taking part in intervention. Overall, the study findings can be used as evidence base for development and implementation of future web-based behavioural modification interventions.

Chapter 2. Literature Review

2.1 Prevalence of Obesity in Youth

Obesity is the third highest contributor to the burden of mortality in relation to other non-communicable diseases in high and middle income countries.[32] About 155 million school age children are overweight and obese worldwide.[1] In the U.S. more than 34% of children (12-19 year) are overweight and obese.[2] Canada is facing an unprecedented increase in childhood obesity as the prevalence has tripled from 1978 to 2004.[4] As reported in the 2009-2011 Canadian Health Measure Survey (CHMS) 2009-11, about 30.1% of Canadian children aged 12-17 years are overweight and obese based on World Health Organization (WHO) cut-points for BMI.[3] Interestingly, the proportion of overweight and obese children is similar for 12-17 years boys and girls (18.9% vs. 20.9% of boys and girls are overweight and 10.7% vs. 9.6% of boys and girls are obese, respectively).[3]

In children, the increased levels of obesity has been linked to an increased prevalence of type-2 diabetes,[33] as well as other health problems including asthma,[34] sleep apenea,[35] metabolic disorders,[36] cardiovascular disease risk,[37] low self-esteem,[38] and psychological problems.[39] Long term health problems associated with childhood obesity include being overweight and obese in adulthood, cardiovascular diseases, metabolic syndromes, some forms of cancer (i.e., breast cancer, prostate cancer), and premature mortality.[40;41] In addition obesity tracks into adulthood and the consequences (metabolic syndromes, cardiovascular diseases, cancer) are even worse in later life.[40] Obese children should be exposed to intervention for treatment at the earliest possible.[42] The health problems associated with the early onset of obesity also increase medical expenses across the lifespan[43] with significant

economic consequences.[44] The increasing prevalence of childhood obesity and its toll on the mental, physical, and economic well-being has led to the prioritization of research that facilitates the early detection and treatment.

2.2 Health Behaviours of Canadian Adolescents: Recommendation and Prevalence

The majority of Canadian adolescents are not meeting current guidelines for MVPA and sedentary behaviour.[15] In addition, more than half of adolescents do not consume the recommended amount of fruit, vegetable, milk or dairy alternatives, and meat or meat alternatives.[16] This section describes the recommendations and prevalence for these health behaviours.

2.2.1 Moderate and Vigorous Physical Activity and Sedentary Behaviours

Table 2.1 summarizes the MVPA and screen time recommendations according to the Canadian Physical Activity and Sedentary Behaviour Guidelines[45] for adolescents aged 12-17 years.

Table 2.1: Recommended level of Moderate-to-Vigorous Physical Activity (MVPA) and sedentary behaviour for Adolescents (12-17 years)

	Daily Recommendations
Moderate-to-Vigorous Physical Activity	At least 60 minutes of moderate-to-vigorous intensity physical activity (MVPA) in a day is recommended for adolescents aged 12-17 years.[45]
Sedentary Behaviour	Limiting recreational screen time to two hours or less in a day is recommended for adolescents aged 12-17 years; also suggesting that any less time spent in prolonged sitting time, indoor time, and limiting the use of sedentary mood of transport is more advantageous for their health.[45]

Research indicates that few Canadian adolescents meet the Canadian Physical Activity Guidelines and this is particularly true for girls as they engage in less MVPA than boys. For example, only 7% of boys and 5% of girls aged 11-14 years and only 6% of boys and 2% of girls aged 15-19 years accumulate 60 minutes of MVPA on at least six days of the week (as measured by accelerometry).[15] Both boys and girls tend to reduce their MVPA as they get older.[15] Among children aged 11-14 years, girls and boys accumulate 59 and 53 minutes of MVPA per day, respectively and among 15-19-year old adolescents, girls and boys accumulate 39 and 47 minutes of MVPA per day, respectively.[15] Interestingly, MVPA does not vary by weight status among girls aged 6-19 years (48 minutes vs. 44 minutes in a day for overweight/obese and normal weight, respectively).[15] In contrast, among boys of the same age, MVPA decreases with increasing weight status (65, 51, and 44 minutes for normal weight, overweight and obese children, respectively).[15]

Only 31% of Canadian adolescents aged 12-17 years meet the recommended sedentary time limit regardless of their gender, age, or weight status.[15] For example, according to the 2007-09 CHMS data (based on accelerometry data), boys (6-19 years) who are obese, overweight, and normal weight spend 536, 524, and 500 minutes per day in sedentary activities respectively.[15] Girls (6-19 years) who are obese, overweight, and normal weight spend 544, 515, and 524 minutes per day in sedentary activities, respectively.[15] Considering the inadequate physical activity levels along with an overabundance of sedentary behaviours, strategies are needed to help Canadian adolescents become more active.

2.2.2 Dietary Intake

Table 2.2 summarizes the Canada's Food Guide[46] recommendation for adolescents.

Table 2.2: Dietary Recommendations for Adolescents

	Daily Recommendations	
	9-13 years	14-18 years
Fruits & Vegetables	6 servings for both girls and boys	7 and 8 servings for girls and boys, respectively
Grain	6 servings for both girls and boys	7 and 8 servings for girls and boys, respectively
Meat & Alternatives	3 to 4 servings for both girls and boys	3 to 4 servings for both girls and boys
Milk & Alternatives	6 servings for both girls and boys	6 and 7 servings for girls and boys, respectively

Canadian adolescents' dietary intake of fruits and vegetables, milk and dairy alternatives, and grain are less than optimal. Among 9-13 year old adolescents, almost 68% of girls and 62% of boys do not consume at least five servings of fruits and vegetables per day and it decreases slightly by 14-18 years of age (63% of girls and 53% of boys).[16] The majority of 10-16 year olds (61% of boys and 83% of girls) do not consume at least three servings of milk and dairy alternatives daily.[16] Among 14-18 year old adolescents, 33% of girls and 6% of boys do not consume at least five servings of grain products.[16] However, adolescents mostly fulfill the recommended levels for meat and alternatives consumption. Boys and girls aged 9-18 years consume at least seven and five servings of meat and meat alternatives daily, respectively.[16]

When compliance with dietary guidelines is assessed with the Healthy Eating Index (HEI), a dietary score ranges from one to 100, the dietary quality of most adolescents appears inadequate. The HEI, originally developed by the U.S. Department of Agriculture (USDA)[47]

has been adapted for evaluating the extent to which a person meets Canada's Food Guide recommendations.[16] The HEI score integrates both the diet components that should be taken in greater amount (eight components; e.g., total vegetable and fruit, whole fruit, dark green and orange vegetables, total grain products, whole grains, milk and alternatives, meat and alternatives, and unsaturated fats) and those that should be taken in smaller amounts (three components; e.g., saturated fats, sodium, and "other" foods which include solid fat, alcohol, and sugar). The total score for these diet components are referred to as HEI. Higher HEI score represents better dietary quality. Among 9-13 year Canadian adolescents, 91% of boys and 92% of girls have an HEI between 50 and 80 suggesting their diet requires improvement.[16] Notably, only about 3% of the adolescents of that age have a HEI greater than 80 which is referred as having a diet of "good" quality.[16] As adolescents get older (14-18 years), 73% of boys and 74% of girls have a HEI between 50 and 80.[16] Among girls of the same age, only 3% have a HEI greater than 80; whereas no boys of this age reach that threshold.[16] These findings indicate that the dietary quality of Canadian adolescents is poor and highlight the need for developing interventions that improve their dietary quality.

2.3 Behavioural Factors Associated with Obesity Treatment

Risk factors for childhood obesity are complex and multi-factorial,[48] with research supporting the involvement of genetic, metabolic, environmental, and behavioural components.[49] The worldwide increase in childhood obesity in developed countries suggests a link between obesity and the modernized lifestyle that has evolved in recent decades, especially changes in food intake and physical activity levels.[5] Evidence from a number of cross-sectional and prospective observational studies indicate that levels of physical activity, sedentary behaviours, and dietary intake are associated with obesity among children and

adolescents.[50;51] The following section will review the evidence on the relationship between obesity with physical activity level, time spent in sedentary behaviours, and dietary quality among children and adolescents.

2.3.1 Physical Activity

Evidence linking low levels of physical activity with overweight and obesity in children and adolescents comes from both cross-sectional and prospective studies.[7;8] A systematic review suggested that less physical activity is significantly associated with elevated BMI and obesity among children aged 2-19 years in 11 out of 16 cross-sectional studies.[7] The remaining five studies reported no association between physical activity and obesity and an inverse association between physical activity and BMI.[7] Janssen et al.'s review reported evidence from both observational and experimental studies.[8] The review found a dose-response relationship between physical activity and obesity in 14 out of 31 observational studies.[8] In the review, 4 out of 31 observational studies suggested that increased physical activity is associated with obesity reduction; with more robust associations in studies that utilize objectively measured physical activity.[8] Similarly, more than half of the experimental studies (17 out of 24) of the review reported that increased levels of physical activity is associated with lower levels of obesity.[8] Based on this evidence, it appears that physical activity has a potential influence on levels of obesity in children and adolescents.

2.3.2 Sedentary Behaviour

Today's adolescents often engage in numerous sedentary activities in the form of recreational screen time, including mostly - watching television (TV) or movies and using a computer for recreation. Many studies have identified these screen-related sedentary behaviours as

important factors associated with the development of overweight and obesity among children and adolescents (2-18 year).[9;10;52] In a recent systematic review, 36 out of 46 cross-sectional studies found a positive association between overweight/obesity and time spent in sedentary activities.[52] Although studies examined different aspects of sedentary behaviours (e.g. watching TV, using the computer, playing video games (VG), and sitting) associations were predominantly observed with TV watching.[52] Longitudinal studies from the review reported that higher time spent in watching TV resulted in greater weight gain in 16 out of 28 studies, and watching TV along with playing VG and using a computer recreationally resulted in greater weight gain in three out of the 28 studies.[52] The review also suggested that reducing time spent watching TV, playing VG, and using a computer recreationally decreased BMI in one out of four intervention studies.[52] A meta-analysis of 25 RCTs revealed that less time spent watching TV or movies, playing VG, using the computer recreationally, and sitting are associated with lower BMI in children less than 18 years.[9] A systematic review by Tremblay et al. found seven out of eight RCTs, seven out of 10 intervention studies, 19 out of 33 longitudinal studies, and 94 out of 119 cross-sectional studies had a positive association between time spent watching TV and overweight/obesity in children aged 5-17 years.[10] In this review, six observational studies reported a dose response relationship indicating an increased risk of obesity with more TV watching.[10] Additionally, a meta-analysis of six RCTs found that BMI decreased significantly with less TV watching.[10] Together, these findings indicate that reducing sedentary time may contribute to reduction in obesity among adolescents.

2.3.3 Dietary Quality

The type and amount of food that adolescents consume play a crucial role in the development of obesity. Evidence from both cross-sectional[11-13] and longitudinal studies[14] suggest that high intake of fat and energy dense foods are associated with obesity among children and adolescents. Evidence from longitudinal studies indicate that low intake of dietary fiber is linked with greater risk of obesity in children.[14] Several cross-sectional studies reported that low intake of vegetables and fruits are associated with higher obesity.[11-13] High intake of sugar sweetened beverages was linked with higher obesity in a systematic review of cross-sectional, prospective, and interventional studies among children less than 19 years.[53]

In addition, dietary quality measured with the HEI is associated with obesity.[20;54;55] Given that the HEI is still in its early stage, literature to support its association with obesity is mostly limited to adults. Evidence suggests that an HEI score less than 50 is associated with obesity among American adults (National Health and Nutrition Examination Survey [NHANES] 1988-94;[20] 2003-2004, and 2005-2006[54]). An increase in the HEI score (Canadian version) was associated with decrease in BMI among obese participants, especially for women (CHMS 2004).[55] Likewise, higher HEI (locally adapted) score was associated with lower BMI in adults in Sau Paulo, Brazil.[56] However, HEI (calculated with the 2010 USDA food guidelines) was not associated with weight status of children aged 12 years in Puerto Rico.[57] Despite the fact that the extent of success in reducing childhood (<18 years) obesity through dietary modifications is still debatable,[58] in light of the evidence discussed it appears that improving dietary quality may reduce obesity among children and adolescents.

2.4 Determinants of Obesity

Development of obesity is associated with gender, age, and socio economic status (SES).[59] Body composition depends on both age and gender and the relationship is interlinked.[60] The gender specific difference in body fat accumulation starts with the onset of puberty in adolescence.[61] According to Ogden et. al., BMI of U.S. adolescents (12-19 years) increases with age in males, but not in females.[2] However, proportion of body fat is higher in females than males.[62] National level data shows that prevalence of high BMI varies with age and gender.[63] According to the 2006 population data, Mexican male adolescents (12-19 years) had higher prevalence of high BMI than females.[63] In 2003-2006, U.S. adolescents (12-19 years) had higher prevalence of high BMI than pre-school (2-5 years) and school aged children (6-11 years).[63]

The relationship between adolescent obesity and SES is different in different countries.[64] For both boys and girls, higher SES is associated with higher rate of childhood obesity in developing countries.[64] Whereas the scenario is opposite in developed countries.[64] Due et. al. reported that in 21 out of 24 high income European and North American countries, high SES was significantly associated with lower rate of overweight in adolescents.[65] However, middle income countries showed a mixed effect of SES on overweight and obesity.[65]

Income and education levels are related to the prevalence of overweight and obesity in adolescents. According to 2004 Canadian Community Health Survey (CCHS), BMI of Canadian boys (2-19 years) was mostly the same across their family income levels.[63] However, BMI of Canadian girls of the same age varied with their family income levels.[63] In girls, higher BMI was significantly lower in families with the highest income quantile.[63] In

terms of relation with education level, both boys and girls showed a trend of lower rate of overweight with increasing education level in the household (2004 CCHS).[63]

2.5 Efficacy of Childhood Obesity Treatment Intervention

Childhood obesity can be treated with behavioural modification intervention. A Cochrane review recently examined 54 behavioural interventions of which six incorporated dietary interventions only, 12 incorporated physical activity interventions only, and 36 incorporated both physical activity and dietary interventions.[17] From the meta-analysis of 23 studies in the review, the authors concluded that 19 interventions were efficacious in treating childhood obesity at 6-month and 12-month.[17] Importantly, this review highlighted greater reduction in BMI-SDS is observed at both 6-month and 12-month when a familial component is incorporated in these lifestyle interventions.[17] Similarly, positive impact of familial involvement in the behavioural modification intervention in reducing childhood obesity was suggested by other reviews.[66-68] Furthermore, it is important to note that the majority of the studies (37 out of 54) target children less than 12 years of age which highlights a potential gap in information on the efficacy of such interventions among adolescents.[17]

2.5.1 Potential of Web-based Intervention in Reducing Childhood Obesity

Web-based intervention is defined by Barak et al.[69] (p.-5) as "a primarily self-guided intervention program that is executed by means of a prescriptive online program operated through a website and used by consumers seeking health related assistance." Web-based technologies are increasingly being used to deliver lifestyle interventions to adolescents because of recent advances in technology and their wide acceptance among adolescents.[18] Previously established interventions are being delivered via a digital platform either solely

(via internet sites, social media, phone, and emails) or as a part of conventional methods (print and in-person). Preliminary evidence suggested that such web-based interventions reduce obesity and improve health behaviours.[19;23;66-68;70;71] For example, Nguyen et al.'s review suggested that BMI and/or BMI z-score of adolescents (12-18 years) was improved at the end of intervention in three internet based obesity treatment studies with duration ranging from 14-16 weeks.[66] A systematic review by Chen et al.[70] reported that technology-based (web-based and videogame-based) interventions reduced obesity (six out of 14 studies) among adolescents aged 12-18 years.[70] In addition, technology-based interventions have the potential to improve dietary behaviour (five out of seven studies), to increase physical activity level (six out of 11 studies), and to reduce sedentary activities (two out of three studies) among adolescents.[70] Whittmore et al.'s systematic review of school-based obesity prevention programs for adolescents (12-18 years) found that web-based interventions resulted in improved dietary habit (three out of eight), increased physical activity (two out of eight) and decreased BMI (two out of eight) compared to control group.[19] Whittmore et al. also reported that adolescents taking part in web-based intervention achieved increased physical activity compared to those in print-based intervention group (one out of two studies).[19] A systematic review by An et al. showed a reduction in obesity in six out of eight RCTs suggesting that web-based interventions have the potential to treat obesity.[67] These RCTs were16 weeks to two years in duration and conducted among overweight and obese children and adolescents (8-18 years).[67] In summary, these reviews suggest that behavioural modification intervention delivered via the web show some efficacy in treating adolescent obesity as well as in improving their behaviours associated with obesity though more research is needed in this area.

2.6 Importance of Adhering to Behavioural Modification Intervention to Treat Obesity and Improve Health Behaviours

Adherence, defined as the extent to which a person follows and complies with all the intervention components, is emerging as an important area to address as lack of adherence to behavioural modification interventions limit their efficacy [21] In previous studies, adherence has been measured as 'compliance',[22;23] 'intervention dose',[24] and 'attendance'.[72] To date, adherence to intervention and its relation with health outcomes has been mainly studied in the context of adherence to medication and its association with chronic diseases.[73] These studies mostly suggested that more adherent participants had reduced disease conditions.[73] Few studies support that non-medical behavioural adherence can prevent several chronic diseases, including diabetes mellitus[74;75] and cardiovascular diseases.[76;77] To date, only a few researchers have focused their research efforts on understanding the role of adherence to intervention components on reducing obesity, in particular.[21]

Studies have suggested that increased adherence, measured as attendance and completion of program requirements, results in greater reduction in obesity and improvement in health behaviours among children.[22-24;72] For example – completing more counselling calls (at least nine out of 11 calls) was associated with a higher likelihood of meeting the dietary guidelines (fat consumption, and fruit and vegetable servings) and sedentary behaviour guidelines among 11-15 year old girls who completed a 12-month computer-based family intervention aimed at increasing MVPA, decreasing sedentary time, increasing intake of fruits and vegetables, and reducing fat intake.[24] However this effect was not found among boys of the same age.[24] Additionally, completion of counselling calls did not increase physical activity level for both boys and girls.[24] Rice et al. reported that in a 12-month behavioural

modification intervention that incorporated training and counselling on physical activity and dietary habits, children aged7-17 years who attended 25 weeks or more had greater reduction in BMI as compared to those who had a lower attendance.[22] In another study, obese children (6-16 years) who completed intervention sessions in less than 60 days of interval had a greater BMI-Standard Deviation Score (SDS) compared to those who attended intervention sessions in an interval of 60-120 days. (-0.19 for <60 days vs. -0.11 for ≤120 days).[23] Wadden et al. revealed that weight loss was significantly higher among adolescent girls (12-16 years) whose mothers attended a greater number of intervention sessions (nine or more out of 16) compared to girls whose mothers' attended less than nine sessions, or girls who attended the sessions by themselves.[72] This study was a 16-week group-based obesity treatment education program aimed at improving dietary habits and physical activity levels of adolescents.[72]

Adherence to self-monitoring is another area that has been investigated in relation to reducing obesity[78] and improving health behaviours.[79;80] In one study, self-monitoring of daily food intake was associated with greater reduction in BMI z-score among overweight adolescents who participated in a 14-week web-based behavioural modification intervention.[78] In Michie et al.'s systematic review, a meta regression of 122 experimental and quasi-experimental studies found that self-monitoring explained 13% of the heterogeneity among the health behaviour modification interventions conducted in adults.[79] The study suggested that self-monitoring either alone or along with other techniques increased level of physical activity and improved dietary behaviour of adults.[79] In Olander et al.'s systematic review, a meta-analysis of 42 studies found that self-monitoring resulted in increased level of physical activity among obese adults.[81] Among overweight and obese

adolescent girls aged 12-17 years, self-monitoring and in-person intervention sessions were associated with more family meals and less consumption of fast food.[80] However, the study did not identify whether the improvement to dietary behaviour was attributed with the self-monitoring or as a result of attending the in-person meeting. Overall, it appears that self-monitoring of behaviours impacts the outcomes of behavioural modification interventions.

Adolescents are less adherent in maintaining any recommended health related activities (e.g., medication, health behaviour, exercise, diet, and appointment) than both adults and children.[73] Interestingly, they become more engaged when exposed to web-based technologies.[19] At the same time, web-based behavioural modification intervention face lower adherence (close to 50%).[82] Web-based interventions have great potential to engage adolescents considering its wide acceptance[18] and to be implemented in larger population considering its cost-effectiveness.[82] However, few have focused on adherence to web-based behavioural modification interventions targeted at adolescents and their families pointing to the need for further research in this area.

2.7 Mediation Effect of Health Behaviours on Reducing Obesity

Identifying the mediation or indirect effect of obesity related health behaviours (physical activity, sedentary behaviour, and dietary intake) can help elucidate how and to what extent obesity can be reduced through following intervention instructions and performing the desired behaviours.[31] This insight can guide for developing more effective targeted behavioural modification interventions.[83] Mediation analyses have been reported to be very important to improve the design of obesity treatment interventions by exploring the possible underlying mechanism of behaviour change.[84] Until now, researchers have mainly studied

whether change in health behaviours or BMI as a result of participating in an intervention is mediated via change in the psychosocial processes (self-efficacy) targeted by the intervention.[27;28] In contrast, few studies have examined whether reduction in BMI is mediated by a change in the targeted health behaviours.[29;30] Hollis et al.'s RCT among 44-50 year old normal and overweight females showed that the effect of completing a motivational interview on weight loss was mediated by their level of physical activity (step counts) at 12-month and dietary behaviour (vegetable consumption) at both 12- and 24-month.[30] However, consumption of fruits and vegetables, dairy, meat and alternatives, whole grain, sugary and high fat foods, meal frequency, amount of MVPA, and sitting time did not mediate the reduction in weight at both 12- and 24-month.[30] One RCT by Lubans et al. reported that health behaviours (step counts, portion size, energy consumption, alcohol consumption, and fat intake) did not mediate the effect of an intervention on BMI reduction among overweight and obese adult males (18-60 years) at 6-month.[29] Another study by Lubans et al. found that the relationship between weight loss of overweight and obese men (mean age 40.6 years) and the effect of a 3-month duration in-person intervention primarily designed to improve parent-child co-activity was mediated via their daily step counts.[31] However, this study reported that the effect of the intervention on the weight loss of children aged 9-12 years was not mediated by their daily step counts.[31] The health behaviours targeted by the behavioural intervention are expected to mediate the effect of these interventions but the extent to which these impact levels of obesity has yet to explore, particularly among adolescents.

2.8 Rationale and Objectives

Few studies have examined how adherence to different components of a family-based behavioural modification intervention delivered on the web impacts the health outcomes of

overweight and obese adolescents. To address this gap, the present study conducted a secondary analysis of data that was collected for the MySteps® study – an 8-month web-based behaviour modification intervention targeted at overweight and obese adolescents (12-17 years) and their families. Primarily, this study focused on the relationship between adherence to the components of the MySteps® intervention and increase in physical activity, reduction in sedentary time, improvement in dietary quality, and reduction in BMI z-score. For this study, adherence measured the extent to which participants viewed the content of the MySteps® program on the web and how much they reported using the self-monitoring tools to track their behaviours with the program (e.g., self-monitoring their steps, amount of screen time, and dietary intake). Furthermore, this study examined whether the link between adherence and the reduction in BMI z-score was mediated through change in MVPA, sedentary behaviour, and dietary quality. The specific aims and hypotheses for this study were:

Aim 1: To determine whether higher adherence to the intervention components (amount of content viewed, and utilization of the self-monitoring tools to track steps taken, amount of sedentary time, and dietary intake) has a direct effect on reduction in BMI z-scores from baseline to 4-month and 8- month of exposure to the intervention. (Path A in figure 2.1)

Hypothesis for Aim 1: Adolescents who had higher adherence to the intervention components (higher percentage of content viewed, and higher use of the self-monitoring tools to track steps, sedentary time, and dietary intake) will have a greater reduction in BMI z-score at 4-month and 8-month than adolescents with lower levels of adherence to the intervention components.

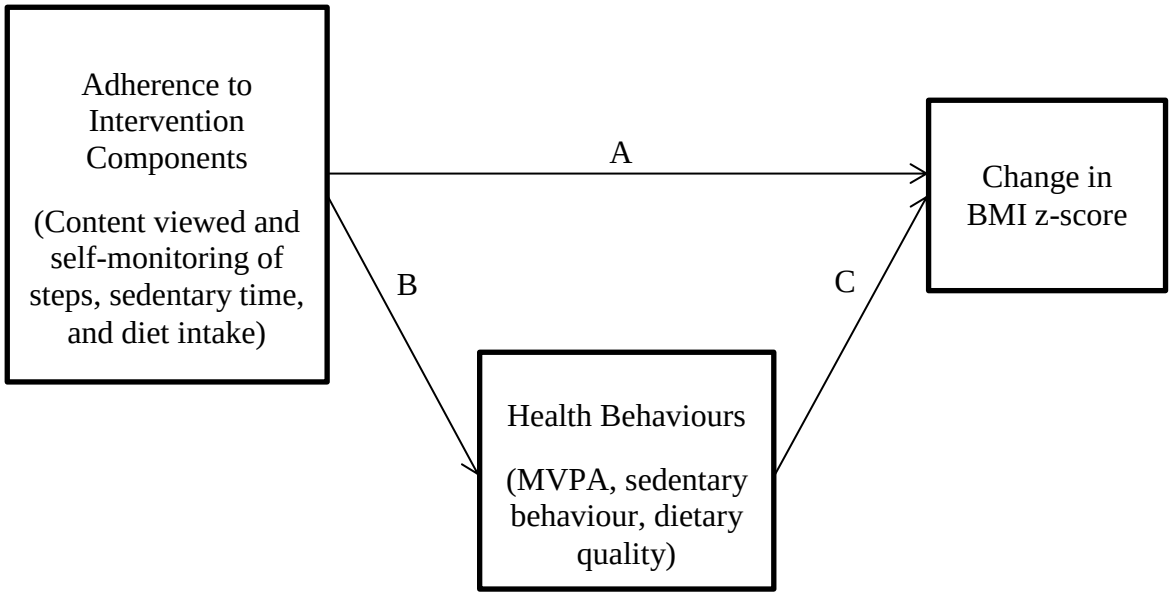
Aim 2: To determine whether higher adherence to the intervention components (amount of content viewed, and utilization of the self-monitoring tools to track steps taken, sedentary time, and dietary intake) has a direct effect on obesity-related health behaviours (MVPA, sedentary behaviour, and dietary quality) from baseline to 4-month and 8-month of exposure to the intervention. (Path B in figure 2.1)

Hypothesis for Aim 2: Adolescents who have higher adherence (higher percentage of content viewed, and higher use of the self-monitoring tools to track steps, sedentary time, and dietary intake) were expected to have higher MVPA, lower sedentary behaviour, and higher dietary quality score at 4-month and 8-month of exposure to the intervention.

Aim 3: To determine whether change in the health behaviours associated with obesity (MVPA, sedentary behaviour, and dietary quality) mediate the effect of adherence to the intervention components (amount of content viewed, and use of the self-monitoring tool to track steps taken, sedentary time, and dietary intake) on BMI z-score reduction at 4-month and 8-month. (Path B and C in figure 2.1)

Hypothesis for Aim 3: The effect of adherence to the intervention components (amount of content viewed, and use of the self-monitoring tools to track steps taken, sedentary time, and dietary intake) on BMI z-score reduction will be fully mediated by adolescent's health behaviours (MVPA, sedentary behaviour, and dietary quality) at 4-month and 8-month.

Figure 2.1 : Association between adherence to the intervention components and change in BMI z-score through health behaviours



Chapter 3. Methods

The present study was a secondary data analysis of the adolescents who participated in MySteps® study which was conducted from December 2010 to March 2013 in Vancouver, Canada. The study protocol for the MySteps® study was approved by the University of British Columbia and the University of Waterloo research ethics boards. The MySteps® study utilized a single group pre-post design to examine individual and familial determinants of adherence to behavioural modification intervention. The primary goal of the MySteps® study was not to test the efficacy of the behavioural modification intervention but to examine predictors of adherence; therefore, the study used an intervention that had some level of efficacy in treating adolescent obesity.[85] The following sections will discuss the efficacy of the MySteps® intervention, participants of the study, recruitment of participants, and the study protocol.

3.1 MySteps® Intervention

MySteps® was an 8-month web-based behaviour modification intervention designed to reduce levels of overweight/obesity among adolescents by developing their skills for increasing MVPA, decreasing sedentary time, and improving dietary quality. MySteps® targeted both the adolescents and their parents. Parents were expected to change the familial environment as well as provide the support for their adolescents to change their health behaviours. The MySteps® intervention evolved from the PACE (Patient-centered Assessment and Counselling for Exercise) intervention which was developed and tested in the research context for over two decades.[86;87] Initially, PACE was a paper-based intervention that aimed at increasing levels of physical activity in adults.[86;87] In later years,

PACE became PACE+ (Patient-centered Assessment and Counselling for Exercise plus Nutrition) as it included a nutrition component and included a focus on adolescents.[88] The latest adolescent version was delivered via the web and it added a component for the parents which helped the parents to initiate environmental changes to support their adolescents change health behaviours.[88] The PACE + intervention improved health behaviours of adolescents in primary care settings in both a prospective cohort study[89] and a RCT.[24] Adolescents showed 18% increase in fruit and vegetable consumption, 12% decrease in fat consumption, and 17% increase in moderate intensity physical activity level in a 4-month prospective study.[89] However, adolescents did not improve their vigorous intensity physical activity.[89] Adolescents who selected to improve their moderate physical activity showed significant improvement for that behaviour and adolescents who selected to reduce their fat consumption or increase their fruit and vegetable consumption improved these behaviours but effects were borderline significant.[89] An RCT of the 12-month PACE+ intervention conducted among 11-15 year old adolescents (27.4% of whom were overweight or obese) found that girls were significantly more likely to meet the guidelines for saturated fat intake (RR=1.33; 95% CI: 1.01-1.68) and boys were more likely to meet the physical activity guideline (RR=1.47; 95% CI: 1.19-1.75) as compared to their counterparts in the control group.[24] However, adolescents did not achieve any decrease in their BMI z- score at 12-month.[24]

MySteps® intervention adopted the components of PACE+ intervention which is an interactive computer program supplemented with telephone counselling and motivational emails. Similar to PACE+, it incorporated physical activity and diet related content, encouraged participants to select particular behaviour to improve, and encouraged parental

involvement. The health guidelines presented in the U.S. version of the intervention were converted to the Canadian context. For example - the dietary guidelines of MySteps® study were based on Canada's Food Guide instead of the food pyramid. The physical activity guideline of MySteps® study promoted 60 minutes of MVPA per day for adolescents instead of 30 minutes per day. In addition, MySteps® intervention provided local examples of fast foods and physical activity opportunities which were adopted to reflect the Canadian context.[90] The PACE+ intervention was adapted to the Canadian context because it fulfills the Canadian Clinical Practice Guidelines of pediatric obesity management.[85] In addition, the PACE+ intervention was consistent with the two theoretical perspectives known to mediate behaviour change, namely the Transtheoritical Model of Behaviour Change[91] and Social Cognitive Theory.[92]

3.2 Participants

Overweight and obese adolescents and one of their parents were recruited to participate in the MySteps® study. Inclusion was limited to adolescents who: were 12-17 years of age, were overweight and obese as defined by the WHO cut-points;[93] had access to internet in their home, resided in the metropolitan area of Vancouver (British Columbia (BC)), were not planning to move within the study period, and were fluent in English. Adolescents with co-morbidities requiring medical attention, disabilities limiting their level of physical activity, a history of psychiatric problems or substance abuse, type-1 diabetes, and adolescents who were either on medication that could affect their weight status or were participating in another weight-loss intervention were ineligible. Initially, 160 adolescents and one of their parents were enrolled into the MySteps® study. The analytic sample was reduced to 158 as one mother unexpectedly died and one adolescent had surgery. Among those participants 104

(65.82%) completed the first 4-month evaluation and 96 (60.76%) completed the 8-month evaluation. (Consort diagram shown in appendix)

3.3 Recruitment

Study participants were mainly recruited through newspaper advertisements and selective referral invitations. About 62% of the participants were recruited via newspaper advertisement; 5% were recruited through parenting magazines, Facebook, and craigslist advertisement; 15% were recruited from referrals of the Centre for Healthy Weights Program in BC; 13% were recruited from the referrals of the BC Children's Endocrinology and Diabetes Clinic; and 5% were recruited by word of mouth. To reach a broad segment of the population paid advertisements were printed out in all of the free local newspapers which were circulated at subway stations, bus terminals, major retailers, and fast food shops. Invitations to referral families were sent via mail.

3.4 Protocol

Adolescents and their parents were initially contacted via telephone to assess their eligibility. Eligible families made two initial visits to the BC Child & Family Research Institute (CFRI) evaluation centre. At their first in-person visit, they signed consent forms and went through the baseline assessment (description given below). Both adolescents and parents were tutored in using the MySteps® website at their second visit which was one or two weeks after their baseline assessment. Onwards both adolescents and parents accessed the MySteps® website from their home. At 4-month, which marked the end of the first phase of the intervention, participants visited the CFRI evaluation center for another assessment. They continued using the program for another four months at which point they returned for their 8-month

assessment. At each evaluation, parents and adolescents were each given an honorarium of $20 cash for taking part in the assessments.

During each of the three in-person assessments (baseline, 4-month, and 8-month), adolescents were surveyed about their physical activity, sedentary behaviour, and dietary intake. Their anthropometric measurements which included height and weight were measured by trained staff members. To measure their dietary intake, participants completed a self-administered 24-hour dietary recall which was administered online. To help ensure the representativeness of the dietary recall, participants were also asked to complete two more 24-hour dietary recalls from their home, including a weekday and a weekend day. In addition, adolescents were fitted with an accelometer to monitor their physical activity and sedentary time during the following eight days. They were instructed to wear the monitor over their right or left hip under their cloth during their waking hours and to record their wearing time and sleep time in a log book.

Adolescents were instructed to login to the MySteps® website every week. During the first four months, adolescents received new topics related to the benefits of adopting healthier behaviours, a challenge to perform a particular healthy behaviour (e.g., reducing intake of sugar sweetened beverages, performing more physical activity, or cutting down screen time) and instructions to develop a skill (e.g., goal setting, identifing supporting factors, making action plans to overcome barriers). Each week, the adolescents had to read about four to five pages, which required about 30 minutes of their time. At the end of the first four months, adolescents chose the behaviour(s) they intended to improve during the next four months. During this period, they received weekly topics related to the behaviour they had chosen. During the entire intervention, the parent website covered complementary topics which

talked about their role in supporting and encouraging their adolescents to perform healthy behaviours. Parents were prompted to provide healthy food choices at home, set limits for particular behaviours (e.g. TV time) and communicate constructively with their adolescents.

Adolescents were provided with a list of activities grouped into three categories: 1) green light activities (aerobics, jogging, skiing, snowboarding, playing basketball etc.), 2) yellow light activities (yoga, fishing, playing baseball, walking the dog, washing the car, etc.), and 3) red light activities (chatting online, sitting or laying around, watching TV or movies, playing video games or computer games etc.). Adolescents and their parents were given pedometers to self-monitor their steps. Adolescents were asked to wear the pedometer during the day and were prompted by the program to monitor their steps on weeks 2, 4, 6, 8, 12, and 16. Adolescents were expected to report the number of steps they took in the program by filling out the "weekly steps tracking log". Adolescents were asked to monitor their sedentary behaviours (red light activities) on week 14 using the "chilling sheet'.

Adolescents were encouraged to learn about the stop light diet which categorizes foods into three groups: red, green, and yellow light food. The red light food refers to food high in calories and fat or low in vitamins, minerals, and fiber (e.g., french fries, regular soda, spare ribs). The yellow light food refers to food lower in calories and fat or higher in vitamins, minerals, and fiber compared to red light food (e.g., diet soda, turkey bacon, microwave popcorn, pudding, turkey burger, hummus). The green light food refers to food lowest in calories and fat and highest in vitamins, minerals, and fiber compared to the other two food groups (e.g., fish, fruits, beans, vegetables, chicken breast, salsa, air popped popcorn). Adolescents were prompted by the program to monitor their daily consumption of foods

(types of beverages, fruits and vegetables, fast foods, and protein intake) on weeks 3, 5, 7, and 9 using the “weekly food tracking sheet”.

Adolescents recieved motivational counselling calls support by trained staff on weeks 2, 4, 8, 12 , and 16. These calls, which lasted five to 10 minutes, aimed to support adolescents in achieving their weekly goals which they had recorded on the website. Participants who had not logged-in that particular week discussed the benefits of participating in the intervention and their barriers to participating. Both adolescents and parents received weekly email reminders and tips from the health counsellors. Intervention activities and the assessments are presented in table 3.1.

Table 3.1 : MySteps® intervention activities and assessments for adolescents

	First Four Months																	Last Four Months														
	Weeks																	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Intervention Components																																	
Types of Content Viewed	D	P	D	P	D	P	D	P	D	D	D	P	D	S	D	P		Each week adolescents selected the behaviour (D, P, or S) they wished to work on															
Self-monitored Steps																		If chosen															
Self-monitored Sedentary Time																		If chosen															
Self-monitored Diet Intake																		If chosen															
Completed Counselling Calls																																	
Assessments																																	
Demographic Questionnaire	Baseline Assessment																4-Month Assessment																8-Month Assessment
Wore Accelerometer for measuring MVPA time and Percent time Sedentary																																	
Answered 7-day Physical Activity Recall for measuring self-reported MVPA time *																																	
Answered Screen Behaviour Questionnaire for measuring self-reported Screen Time																																	
Completed the online 24-hour Dietary Recall for measuring Dietary Quality ♦																																	

D= Dietary content, P= Physical activity content, S=Sedentary content

*= Adolescents were fitted with the accelerometer during assessment which they were supposed to wear on the following eight days

♦= Adolescents completed the three online 24-hour Dietary Recalls

▢ indicates that adolescents took part in the activites or assessment at the particular time

3.5 Measures

3.5.1 Adherence

Adherence to the MySteps® intervention was measured by assessing the percent of content adolescents viewed and the number of times they used the self-monitoring tools to track their steps, sedentary time, and dietary intake.

Content Viewed: Adolescents were expected to view a total of 161 pages of which 83 were in the first four months and 78 were in the last four months. Content viewed at 4 months and at 8 months were assessed by calculating the percentage of total webpages that adolescents accessed from baseline to 4-month and from baseline to 8-month.

Self-Monitoring: During the first four months of the intervention, adolescents were prompted to monitor their steps on six weeks, their time spent in sedentary activities on one week, and their dietary intake (type of beverages consumed, fruits and vegetables intake, fast foods consumption, protein intake) on four weeks. In addition, adolescents were able to monitor all these behaviours every week if they chose to. In the last four months of the intervention self-monitoring was less prescriptive as during this phase of the intervention adolescents selected which behaviour they wanted to work on. The number of weeks the adolescents monitored their steps, sedentary time, and dietary intake during the first four months of the intervention and the entire duration of the intervention served to measure utilization of MySteps® self-monitoring tools at four months and eight months.

3.5.2 Change in Body Mass Index Z-Score (BMI z-score)

Height for each adolescent was measured twice with a stadiometer (Hohltain, United Kingdom) to the nearest 0.1 cm and if the two estimates differed more than 0.5 cm, both were taken again. An average height (nearest 0.1 cm) for each adolescent was then estimated. Weight was measured twice with a calibrated scale (model 597K, Health-O-Meter, McCook, IL) to the nearest 0.1 kg. For estimates that differed more than 0.7 Kg, both measures were repeated. An average weight (nearest 0.1 kg) for each adolescent was estimated. BMI was calculated by dividing one's average weight in Kilogram (Kg) by his/her average height in meters squared (m^2). Age- and sex- specific BMI z-scores at baseline, 4 months, and 8 months were then estimated by using a STATA macro developed by WHO according to the growth standard for 5-19 years-old children and adolescents.[94] Change in BMI z-score at 4 months was calculated by subtracting the 4-month BMI z-score from the baseline value and change in BMI z-score at 8 months was calculated by subtracting the 8-month BMI z-score from the baseline value.

3.5.3 Health Behaviours

MySteps® intervention assumed that adolescents would reduce their BMI z-score if they increased their levels of MVPA, reduced their sedentary behaviour, and improved their dietary quality. MySteps® intervention aimed to achieve these changes in health behaviours by having adolescents view the program content and self-monitor their health behaviours. Level of MVPA was assessed with accelerometry and with the 7-day Physical Activity Recall (PAR) interview. Similarly, sedentary behaviour was assessed with accelerometry and with a self-reported questionnaire that asked about screen time behaviour. Finally, dietary

quality was assessed with a self-administered 24-hour Dietary Recall. These measures are described below.

Moderate-to-Vigorous Physical Activity (MVPA) measured by Accelerometry: To objectively access MVPA, the GT3X and GT3X+ (Actigraph Pensacola, FL) accelerometers were used. To get the counts from the accelerometers, the data were processed using a STATA macro which utilized a previously established protocol.[95;96] Acceleration data which was collected in 10 second epochs was first aggregated into two minute intervals to account that activities performed by children are often not continuous but interrupted. Accelerometer data were considered valid if adolescents wore the accelerometer for 10 or more hours a day (63% of awaken time assuming eight hours of sleep) and for three days of the week. Lack of activity for 60 minutes was counted as non-wear time.[95]

Within any two minute epoch, accelerometry count $\geq$ 2296 per minute was considered as the cut-point for MVPA.[97] All counts above this cut-point were aggregated to calculate total minutes of MVPA during the assessment week.[98] Total MVPA time was divided by the number of days the accelerometer was worn to determine average minutes of MVPA at baseline, 4 months, and 8 months.

MVPA measured by 7-day Physical Activity Recall (PAR): A 7-day PAR, adapted from the Stanford Five-City Project,[99] was administered to the participants to record the duration (minutes) and the intensity (leisure, moderate, or very hard) of activities performed for at least 10 minutes in duration in the previous seven days. To help participants report the intensity of their activities, adolescents were asked to indicate whether the activity was performed at a leisure pace (walking at a relaxed pace) or at a moderate pace (walking fast or

at a brisk pace) or at a very hard pace (equivalent to running or jogging very hard). A couple of probing questions were asked to maximize the completeness of data. To capture the intensity of the activities, metabolic equivalent (MET, where 1 MET is the amount of energy expended at resting) were assigned to each activity based on the Compendium of Energy Expenditures for Youth.[100] Self-reported MVPA time was defined as the average minutes per day spent performing activities that were ≥ to 4 MET.[97;101;102] Time spent in MVPA was computed by summing all the activities above this point. The total minutes in a week was divided by seven to obtain average minutes of MVPA per day. Self-reported MVPA values were computed for the baseline, 4-month, and 8-month assessments.

Percent of Sedentary Time measured with Accelerometry: The accelerometer data (see description above) was also used to compute the percent of time when adolescents were sedentary. Accelerometry counts ≥0 and ≤100 per minute was used as the cut-point to determine sedentary behaviour.[103] In the analyses, percent of sedentary time was used which was computed by dividing the total minutes of sedentary time by the amount of time the adolescents wore the accelerometer. Similar to the physical activity data, three days of valid accelerometer data were needed to compute percent of sedentary time at baseline, 4 months, and 8 months.

Screen Time measured with Questionnaire: Screen time was assessed by using the questions which were developed and validated in overweight adults by Rosenberg et al.,[104] as well these questions were used in previous research among adolescents.[105] Adolescents were asked how much time they spent watching TV or spent sitting using a computer for fun (not for work or school). Separate questions were asked for each activity. Adolescents were asked how much time they spent on these activities last Saturday and on the most recent weekday.

Average screen time per day was computed by multiplying the amount of screen time reported on Saturday by two and by multiplying the same time reported on the previous weekday by five. Then the screen time on weekdays and weekend days were summed and dividing this number by seven resulted in computing an average screen time per day. Baseline, 4-month, and 8-month values were computed.

Dietary Quality measured by 24-Hour Dietary Recalls: Dietary quality of adolescents were assessed with the Canadian Healthy Eating Index (HEI).[47] The HEI score was derived from the 24-hour dietary recalls which were self-reported using the web-based program developed by the University of Waterloo.[106] The web-based diet-recall tool has been validated in an ethnically diverse sample of children (11-14 years) against a dietitian-administered dietary recall.[106] To ensure the utmost accuracy of the type and the amount of food intake, a database containing more than nine hundred common foods (items and brands) and pictures of serving sizes were provided. Amount of nutrient intake per day was estimated from the 24-hour recall by using the Food Processor software package (version 8.0, ESHA Research, Salem, OR, 2002) that uses the 2007 Canadian Nutrient File.[107]

To estimate HEI scores, all food reported in the 24-hour dietary recall were grouped into eleven components. Eight of the components are recommended to be present in greater amounts (total vegetable and fruit, whole fruit, dark green and orange vegetables, total grain products, whole grains, milk and alternatives, meat and alternatives and unsaturated fats) and three components are present in smaller amounts (saturated fat, sodium, and "other" foods which include solid fat, alcohol and sugar). The criteria for recommended amounts of food consumed used the age and sex specific recommendation of Canada's Food Guide.[46] A score for each of the eleven food groups was assigned according to Canadian HEI[47] and a sum of

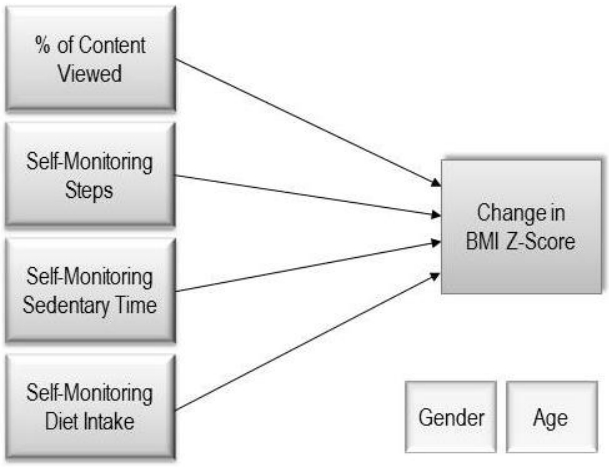
the scores for these eleven food components was referred to as HEI score for that day. An average of the three HEI scores derived from the three 24-hour dietary recalls (one collected at the evaluation center and two collected at home including one weekday and one weekend day) reported by the adolescents at each evaluation point was then calculated to assess their dietary quality at baseline, at 4 months, and at 8 months.

3.6 Data Analysis

Path analysis, a statistical method for conducting multiple regression analyses simultaneously[108] was used to answer all the research questions. Path analysis is typically represented in the form of a hypothesized model.[108] Path analysis can be used either to build parsimonious model or to provide estimates of magnitude and significance of the hypothesized paths in the model.[108] Hypothesized paths can include both direct and indirect paths.[108] Path analysis is used to identify if a hypothesized mediating variable has any effect on the relationship between an independent and a dependent variable.[108]

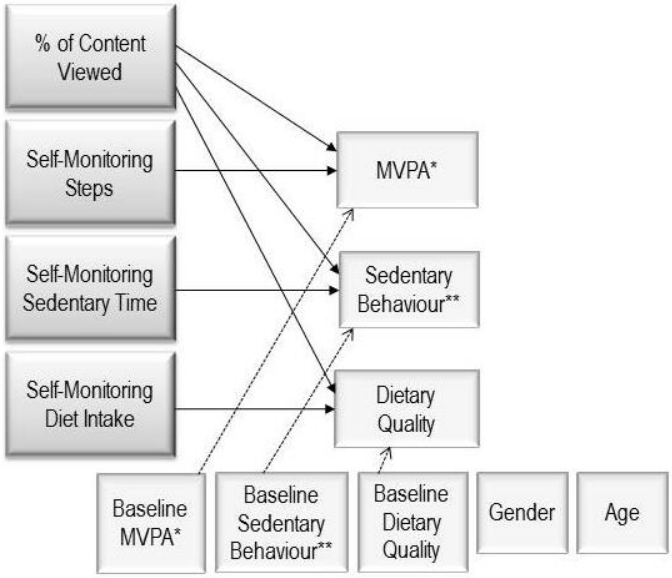
To address aim 1, two separate models were run to examine whether adherence to the components of the intervention had a direct effect on change in BMI z-score at 4 months and at 8 months. The dependent variable for these analyses was change in BMI z-score. The independent variables in both models were percentage of content viewed and number of weeks adolescents self-monitored their steps, sedentary time, and dietary intake. Both models included adolescents age and sex as covariates. Figure 3.1 shows the hypothesized model for aim 1.

Figure 3.1: Direct effect of adherence to intervention on change in BMI z-score



To address aim 2, in total four separate models (two models using health behaviours at 4 months as dependent variables and two models using health behaviours at 8 months as dependent variables) were run to examine whether adherence to the components of the intervention had a direct effect on the health behaviours (i.e., amount of MVPA, sedentary behaviour, and dietary quality) at 4 months and 8 months. There were two models at each time point (4-month and 8-month) as the MVPA and sedentary behaviours were either measured with accelerometry or with questionnaire (accelerometry measures of MVPA time and percent of sedentary time versus self-reported measures of MVPA time and screen time). In all models dietary quality was computed from the three 24-hour dietary recalls. The independent variables for all models were percentage of content viewed and number of weeks adolescents self-monitored their steps, sedentary time, and dietary intake. All paths in each model were adjusted for adolescents' age and sex and corresponding health behaviours at baseline. Figure 3.2 depicts a general model for aim 2.

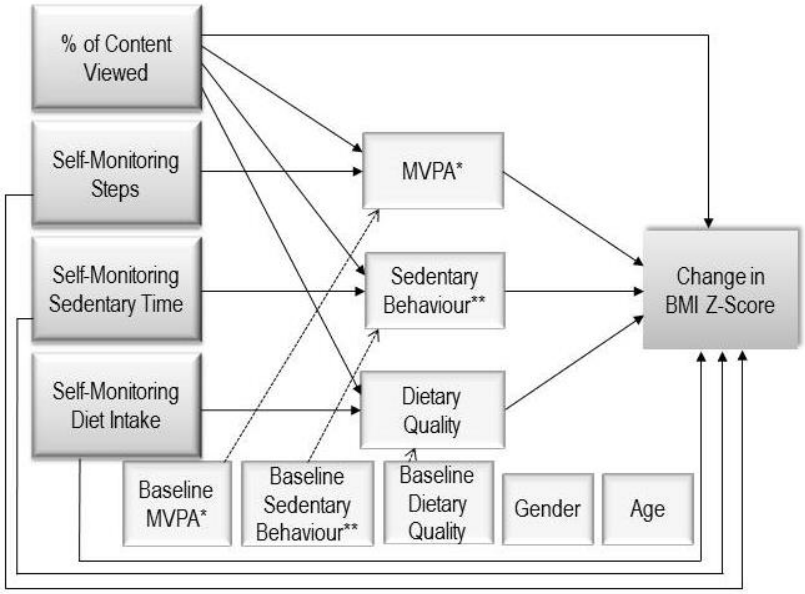
Figure 3.2 : Direct effect of adherence to intervention on health behaviours



MVPA=Moderate-to-vigorous physical activity
MVPA*=Accelerometry measured MVPA time / self-reported MVPA time
Sedentary behaviour**=Accelerometry measured % of sedentary time / self-reported screen time

To address aim 3, in total four separate models (two models with dependent variable as change in BMI z-score at 4 months, and two models with dependent variable as change in BMI z-score at 8 months) were run. Similarly, there were two models at each time point (4-month and 8-month) as the MVPA and sedentary behaviours were either measured with accelerometry or with questionnaire but dietary quality was computed from the three 24-hour dietary recalls, so there was a model for measured and self-reported health behaviours. These models assessed whether any effect of the intervention on change in BMI z-score at 4 and 8 months were mediated by change in the health behaviours. The independent variables in all models were percentage of content viewed and number of weeks adolescents self-monitored their steps, sedentary time, and dietary intake. All paths in each model were adjusted for adolescents' age and sex and their corresponding health behaviours at baseline. A general model for aim 3 is presented in figure 3.3.

Figure 3.3 : Direct and indirect effect (via health behaviours) of adherence to intervention on change in Body Mass Index (BMI) z-score



MVPA=Moderate-to-vigorous physical activity
MVPA*=Accelerometry measured MVPA time / self-reported MVPA time
Sedentary behaviour**=Accelerometry measured % of sedentary time / self-reported screen time

Bivariate scatter plots and residual plots for the hypothesized models were evaluated (using STATA) which showed that all the assumptions of linear regression were met. The path analyses were conducted using the Mplus® software version 7.0.[109] Mplus® estimates models in which some variables have missing values by using full information maximum likelihood (FIML) method.[110] FIML uses all available information to estimate model and provides unbiased estimates as long as the data is missing at random.[110] Fit indices traditionally used with path analysis works better when the aim is to build a parsimonious model. It includes the Root Mean Square Error of Approximation (RMSEA) [cut point for mean RMSEA= 0.05[111], lower and upper bound of 90% confidence interval (CI) of RMSEA ≤ 0.05[111] and ≤ 0.10[111], respectively], Comparative Fit Index (CFI) [cut point: ≥ 0.95[112]], and Standardized Root Mean Square Residual (SRMR) [cut point: ≤ 0.05[113]]. However, this

study aimed to test specific hypotheses which may not always result in testing the most parsimonious model. As a result, we used incremental r-squared to determine whether adding the independent variables to the covariate model resulted in a meaningful increase in the percentage of the variance explained by the model. For all models, an incremental r-square of 5% was arbitrarily considered meaningful. Magnitude (Standardized Coefficient (SC)) of a path and p-value associated with it were taken into account to explain the significance of the path. However, the p-value is more liberal and does not always say much about the relationship between variables.

To assess whether or not a hypothesized behaviour mediated the effect of adherence to a component of the intervention on change in BMI z-score, three parameters had to be fulfilled primarily. Firstly, the path between an independent variable (the components of intervention) and dependent variable (change in BMI z-score) had to be significant. Secondly, the path between an independent variable (the component of intervention) and a mediator (health behaviour) had to be significant. Thirdly, the path between a mediator (health behaviour) and dependent variable (Change in BMI z-score) had to be significant.[114] In all cases, significance was examined by examining both the p-value and the percentage of variance explained (see rationale above).

Mediation can occur if there is a direct effect of the intervention on BMI z-score and its effect is suspected when the addition of the mediator to the model suppress or eliminate the direct effect. If mediation occurs, the magnitude of its effect can be estimated from the combined model using the following equation: [115]

$Z = a \times b / \sqrt{(a^2 \times Sa^2 \times + a^2 \times Sb^2)}$, in which a= path coefficient from the intervention to mediator, b= path coefficient from the mediator to outcome, Sa^2 = the standard error of a, Sb^2 = standard error of b.

Chapter 4. Results

4.1 Demographic Characteristics of Adolescents and Parents

Table 4.1 presents the demographic characteristics of the adolescents and their parents (N=158), as well as their BMI z-score and health behaviours. Adolescents were on average 13 years of age. Around 58% of them were females. The majority of their parents were married. Parents were primarily female and on average 46 years of age. About half of the parents had no university degree and the sample included a mix of income levels.

As shown in the table 4.1, adolescents were mostly obese (mean BMI z-score 2.68). Adolescents accumulated approximately half of the recommended MVPA time (60 minutes/day) as measured by accelerometry and self-reported to accumulate about 44 minutes of MVPA per day. However, adolescents spent 62% of their accelerometry wear time in sedentary activities. They exceeded the recommended amount of screen time per day (≤120 minutes/day) by close to an hour. Adolescents had an inadequate dietary quality, which averaged 64%.

Table 4.1 : Demographic characteristics of adolescents and their parents and Body Mass Index (BMI) z-score and health behaviours (objectively measured and self-reported Moderate-to-Vigorous Physical Activity (MVPA), objectively measured percent of sedentary time, self-reported screen time, and dietary quality) at baseline

		%	Mean +/- SD [Range]
Demographic Characteristics			
Child Age (Year) N=158			13.2 +/- 1.8 [11 – 16]
Child Gender N=158	Female Male	57.6% 42.4%	
Parent Age (Year) N=158			45.8 +/- 6.2 [31 – 66]
Parent Gender N=158	Female Male	84.8% 15.2%	
Household Income N=153	≤$60,000 $60,001-$100,000 >$100,001	34.0% 34.6% 31.4%	
Parent Education N=156	High School or less Trade Certificate⁄Diploma Bachelor degree Above Bachelor degree	17.3% 38.5% 19.9% 24.4%	
Parent Marital Status N=156	Married Common-Law Single⁄Widowed⁄Separated⁄Divorced	66.7% 5.2% 28.2%	
Ethnicity N=155	White East⁄Southeast Asian South Asian Aboriginal Other	47.7% 14.8% 12.9% 8.4% 16.1%	
Obesity Status and Health Behaviours			
Body Mass Index Z-Score N =158			2.68 +/- 0.82 [1.14 - 6.01]
Measured MVPA (min/day) N =128			34.4 +/- 20.9 [2.8 - 119.0]
Self-Reported MVPA (min/day) N = 145			44.0 +/- 39.3 [1.4 - 254.3]
Measured Sedentary Time (%/day) N =128			62.0 +/- 8.6 [36.8 - 83.9]
Self-Reported Screen Time (min/day) N = 157			177.3 +/- 140.4 [10.7 - 677.1]
Dietary Quality Score (%) N=156			64.0 +/- 8.7 [39.1 - 83.8]

SD=Standard deviation, %=Percentage

Among the 158 adolescents who enrolled in the intervention, 104 (65.8%) completed the 4-month assessment and 96 (60.76%) completed the 8-month assessment. Those who completed the 4-month assessment were not significantly different from those who did not complete it with respect to their age (χ^2=6.35, p=0.27), gender (χ^2=0.09, p=0.76) and parent's education level (χ^2=5.8, p=0.12). Similarly, the 8-month completers were not significantly different from those who did not complete the assessment with respect to their age (χ^2=5.36, p=0.37), gender (χ^2=0.01, p=0.92), and parent's education level (χ^2=2.9, p=0.40). However, 4-month completers and 8-month completers were significantly different from those who did not complete these assessments in terms of their parent's income level (χ^2=8.45, p=0.02 at 4-month and χ^2=6.62, p=0.04 at 8-month). Adolescents from families with higher income level mostly completed 4-month assessment and 8-month assessment compared to those from lower income level families. (Data not shown)

4.2 Adherence to the Intervention Components

Table 4.2 describes adherence to the intervention components at 4-month and 8-month for adolescents who completed these assessments. Adolescents viewed approximately half of the web contents during the first four months. For the 8-month duration of the intervention, they viewed 39% of the content. They predominantly self-monitored their steps for about 7.5 weeks in the first four months and for 10.9 weeks for the 8-month duration of the intervention. They self-monitored their sedentary time and dietary intake less frequently than physical activity. They self-monitored their sedentary time for 2 weeks at 4months and 2.7 weeks at 8months and self-monitored their dietary intake for 3.9 weeks at 4months and 5.6 weeks at 8months.

Table 4.2: Adherence to intervention components (percent of content viewed, self-monitoring of steps, sedentary time, and diet intake) among the completers at 4 months and 8 months

	4-Month N = 104	8-Month N = 96
	Mean (SD) Range	Mean (SD) Range
% of Content Viewed	49.24 (31.80) (0 – 100)	39.31 (27.34) (0 – 90.61)
Self-monitoring Steps (No. of weeks)	7.46 (6.23) (0 – 16)	10.85 (10.75) (0 – 33)
Self-monitoring Sedentary Time (No. of weeks)	2.00 (3.35) (0 – 16)	2.74 (5.51) (0 – 32)
Self-monitoring Diet Intake (No. of weeks)	3.86 (5.73) (0 – 17)	5.64 (9.22) (0 – 33)

SD=Standard deviation, %=Percentage

4.3 Descriptive Change in BMI Z-Score and Health Behaviours

Adolescents had a wide range of variation with respect to their adherence to the intervention. Table 4.3 describes adolescents' change in BMI z-score and health behaviours by levels of

adherence at the 4- and 8-month assessments. Examination of the descriptive data highlights the following:

Adolescents who viewed more content and self-monitored their steps, sedentary time, and dietary intake more often had greater reduction in BMI z-score at both 4 and 8 months. In general, adolescents who adhered to the intervention components had better health behaviours – they accumulated more MVPA, were less sedentary, and had higher dietary quality scores. However, not all behaviours improved. In fact, measured MVPA decreased with increased percent of content viewed and increased self-monitoring of steps. In addition, percent of sedentary time increased with increased self-monitoring of sedentary time.

Table 4.3 : Descriptive change in Body Mass Index (BMI) z-score and health behaviours (objectively measured and self-reported Moderate-to-Vigorous Physical Activity (MVPA), objectively measured percent of sedentary time, self-reported screen time, and dietary quality) by level of adherence to the intervention at 4months and 8months

	% of Content Viewed [a]		Self-monitoring Steps [b]		Self-monitoring Sedentary Time [c]		Self-monitoring Diet Intake [d]	
	Low	High	Low	High	No	Yes	No	Yes
	Mean (n)	Mean (n)	Mean (n)	Mean (n)	Mean (n)	Mean (n)	Mean (n)	Mean (n)
4-Month								
Change in BMI Z-Score N=104	.03 (52)	.05 (52)	.01 (52)	.04 (52)	.01 (50)	.07 (54)	.01 (51)	.07 (53)
Measured MVPA (min/day) N=63	33.17 (28)	34.17 (35)	33.14 (26)	34.14 (37)				
Self-Reported MVPA (min/day) N=97	43.22 (46)	40.53 (51)	38.44 (47)	44.97 (50)				
Measured Sedentary Time (%/day) N=63	62.07 (28)	63.68 (35)			63.31 (21)	62.79 (42)		
Screen Time (min/day) N=104	138.79 (52)	127.17 (52)			152.19 (50)	115.20 (54)		
Dietary Quality (%) N=103	61.51 (52)	65.00 (51)					61.71 (50)	64.68 (53)
8-Month								
Change in BMI Z-Score N=96	.04 (48)	.13 (48)	.09 (47)	.08 (49)	.06 (42)	.10 (54)	.08 (45)	.09 (51)
Measured MVPA (min/day) N=51	36.86 (22)	31.56 (29)	34.98 (18)	33.22 (33)				
Self-Reported MVPA (min/day) N=85	44.24 (42)	51.30 (43)	55.5 (42)	40.31 (43)				
Measured Sedentary Time (%/day) N=51	63.27 (22)	62.86 (29)			62.69 (20)	63.26 (31)		
Screen Time (min/day) N=96	136.16 (48)	130.18 (48)			143.47 (42)	125.16 (54)		
Dietary Quality (%) N=94	60.95 (46)	64.77 (48)					61.94 (43)	63.71 (51)

n=Number of children, %=Percentage

[a] = <49%=low, ≥49%=high at 4-month; <21%=low, ≥21%=high at 8-month

[b] = <5.5 weeks=low, ≥ 5.5 weeks=high at 4-month; 0=no, ≥1=yes at 8- month

[c] = 0=no, ≥1=yes at both 4- and 8- month

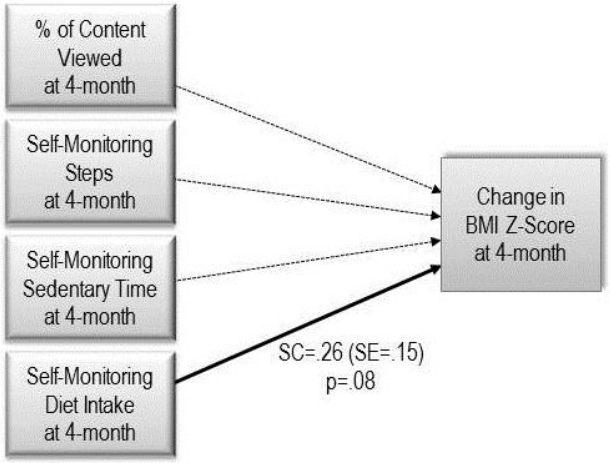
[d] = 0=no, ≥1=yes at both 4- and 8- month

4.4 Results from the Path Analysis Testing the Hypothesized Models

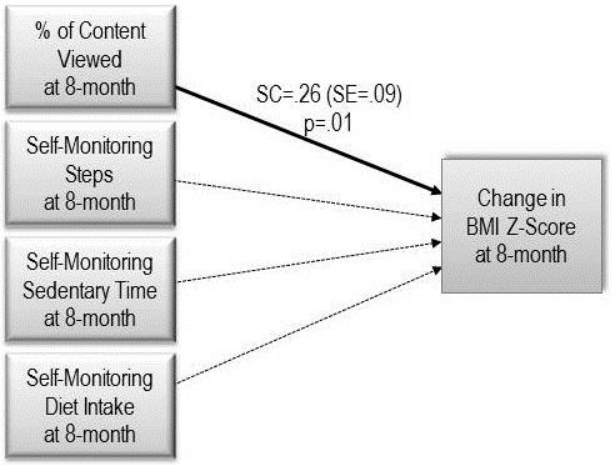
4.4.1 Effect of Adherence to the Intervention Components on Change in BMI-z-score

Figure 4.1 presents the models that show the direct paths between the intervention components (percent of content viewed and self-monitoring of steps, sedentary time, and dietary intake) and change in BMI-z-score at 4 months (top model) and at 8 months (bottom model). Full data for these models are shown in table 4.4. Self-monitoring of dietary intake had a borderline direct effect on adolescents' change in BMI z-score at 4 months (standardized coefficient (SC) =0.26, p=0.08). However, the amount of content that adolescents viewed had a significant direct effect on their change in BMI z-score at 8 months (SC=0.26, p=0.01). The 4- and 8-month models explained 5.1% and 9.6% of the total variation in BMI z-score, respectively after the effects of the covariates (gender and age) were accounted for.

Figure 4.1 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on change in Body Mass Index (BMI) z-score at 4 months (top model) and at 8 months (bottom model) (N=158)



[χ^2(df=8)=7.28, RMSEA=.00, 90% CI: .00-.09, CFI=1.00; SRMR=.03]



[χ^2(df=8)=7.71, RMSEA=.00, 90% CI: .00-.09, CFI=1.00; SRMR=.04]

Footnote:
SC=Standardized coefficient, SE=Standard error (shown for paths with significant/borderline significant effects)
Gender and age were entered as covariates for all paths (not shown)
χ^2=Chi-square estimate of standardized model, RMSEA=Root mean square error of approximation, CI=Confidence interval, CFI=Comparative fit index, SRMR=Standardized root mean square residual

Table 4.4 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on change in Body Mass Index (BMI) z-score at 4 months and 8 months

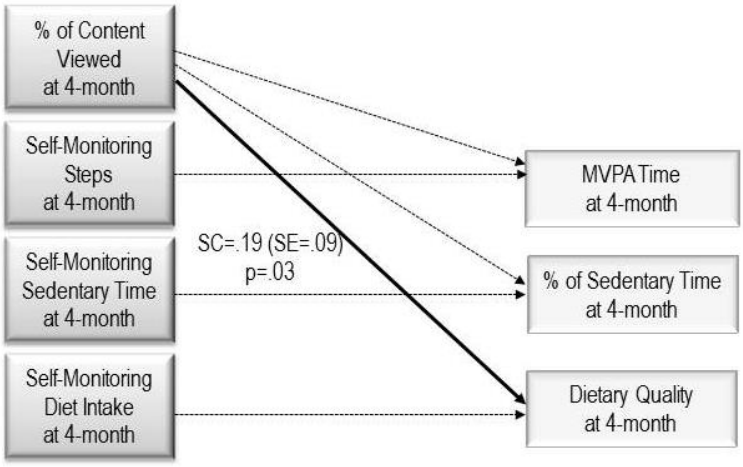
		4-Month (N=158)	8-Month (N=158)
		Change in BMI-Z-Score	Change in BMI-Z-Score
		SC (SE) p-value	SC (SE) p-value
Independent Variables	% of Content Viewed	0.06 (0.10) 0.56	0.26 (0.09) 0.01
	Self-monitoring Steps	0.04 (0.13) 0.76	0.16 (0.13) 0.23
	Self-monitoring Sedentary Time	- 0.18 (0.12) 0.14	- 0.09 (0.11) 0.45
	Self-monitoring Diet Intake	0.26 (0.15) 0.08	- 0.10 (0.15) 0.51
Covariates	Gender	0.04 (0.10) 0.66	0.04 (0.10) 0.73
	Age	- 0.03 (0.10) 0.75	- 0.13 (0.10) 0.17

SC=Standardized coefficient, SE=Standard error

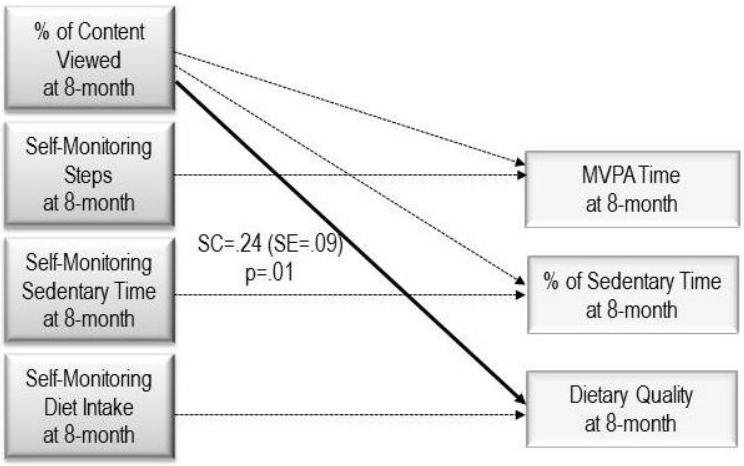
4.4.2 Effect of Adherence to the Intervention Components on Health Behaviours

Figure 4.2 shows the models that test the direct effect of the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and dietary intake) on all the health behaviours (objectively measured MVPA time and percent of sedentary time and dietary quality). The amount of content that adolescents viewed had a significant direct effect on their dietary quality at both 4 months (SC=0.19, p=0.03) and 8 months (SC=0.24, p=0.01). However, the percent of content viewed had no effect on objectively measured MVPA time and percent of time spent in sedentary activities at both 4 and 8 months. Adherence to the intervention components explained 2.4% and 7.3% of the variation in dietary quality at 4 and 8months, respectively after the effects of the covariates (gender, age, and corresponding health behaviour at baseline) were accounted for. However, self-monitoring of steps, sedentary time, and dietary intake had no effect on any of the corresponding heath behaviour at both 4 and 8 months. At 4 months, the boys had significantly lower dietary quality than the girls (Table 4.5). Data for all paths included in these models are shown in Table 4.5.

Figure 4.2 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on the health behaviours (objectively measured Moderate-to-Vigorous Physical Activity (MVPA) and percent of sedentary time, and dietary quality) at 4 months (top model) and 8 months (bottom model) (N=158)



[χ^2(df=10)=29.21, RMSEA=.05, 90% CI: .00-.04, CFI=.89; SRMR=.01]



[χ^2(df=20)=35.12, RMSEA=.07, 90% CI: .03-.11, CFI=.83; SRMR=.07]

Footnote:
SC=Standardized coefficient, SE=Standard error (shown for paths with significant effects)
Gender and age were entered as covariates for all paths, as well as baseline MVPA, percent of sedentary time, and dietary quality for each corresponding health behaviour; in which age was correlated with percent of sedentary time at baseline (SC=0.47, SE=0.07, p=0.00 in the top model, SC=0.47, SE=0.07, p=0.00 in the bottom model) (data not shown for non-significant paths)
χ^2 = Chi-square estimate of standardized model, RMSEA=Root mean square error of approximation, CI=Confidence interval, CFI=Comparative fit index, SRMR=Standardized root mean square residual

Table 4.5 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on the health behaviours (objectively measured Moderate-to-Vigorous Physical Activity (MVPA) and percent of sedentary time, and dietary quality) at 4 months and 8 months

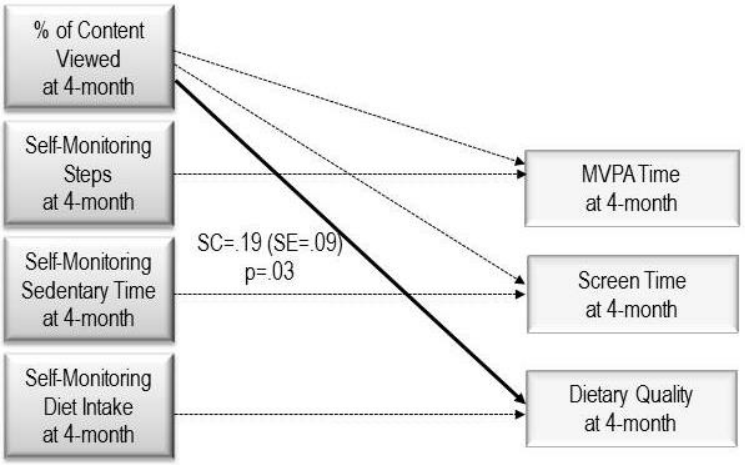
		4-Month (N=158)			8-Month (N=158)		
		Observed MVPA Time	Observed % Sedentary Time	Dietary Quality	Observed MVPA Time	Observed % Sedentary Time	Dietary Quality
		SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value
Independent Variables	% of Content Viewed	0.06 (0.13) 0.63	- 0.04 (0.09) 0.64	0.19 (0.09) 0.03	- 0.02 (0.11) 0.85	- 0.01 (0.11) 0.92	0.24 (0.09) 0.01
	Self-monitoring Steps	0.03 (0.13) 0.79	-	-	- 0.05 (0.10) 0.65	-	
	Self-monitoring Sedentary Time	-	- 0.03 (0.06) 0.62	-	-	0.05 (0.08) 0.53	
	Self-monitoring Diet Intake	-	-	- 0.06 (0.08) 0.45	-		- 0.11 (0.08) 0.14
Covariates	MVPA Time at Baseline	0.27 (0.14) 0.06	-	-	0.65 (0.09) 0.00	-	-
	% Sedentary Time at Baseline	-	0.69 (0.08) 0.00	-	-	0.69 (0.09) 0.00	-
	Dietary Quality at Baseline	-	-	0.44 (0.08) 0.00	-	-	0.24 (0.09) 0.01
	Gender	0.05 (0.14) 0.73	0.01 (0.09) 0.89	- 0.18 (0.09) 0.04	0.03 (0.11) 0.79	- 0.03 (0.11) 0.80	- 0.17 (0.09) 0.05
	Age	- 0.10 (0.12) 0.39	0.09 (0.10) 0.40	- 0.01 (0.09) 0.87	0.01 (0.11) 0.90	0.04 (0.13) 0.80	- 0.13 (0.09) 0.15

SC=Standardized coefficient, SE=Standard error

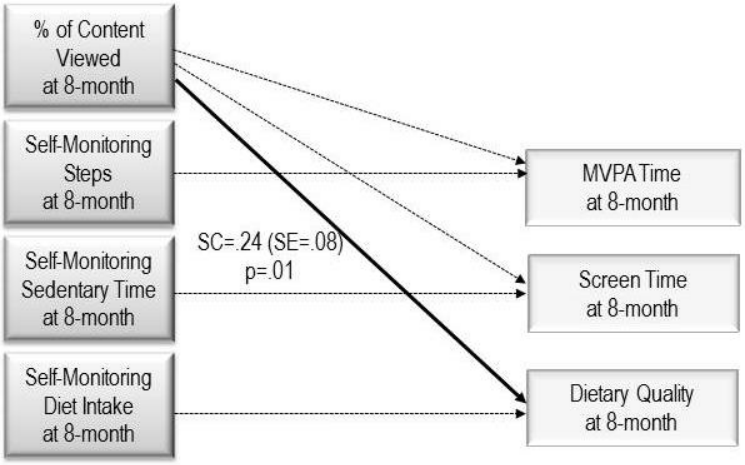
Age was correlated with percent of sedentary time at baseline (SC=0.47, SE=0.07, p=0.00 at 4-month, SC=0.47, SE=0.07, p =0.00 at 8-month)

To estimate the direct effect of the components of intervention on the self-reported health behaviours, hypothesized model for aim 2 (Figure 3.2) were run using self-reported MVPA, screen time, and dietary quality. These models (Figure 4.3) showed similar results as it was found for models presented in figure 4.2 in which accelerometry measured MVPA time and sedentary time were used instead of self-reported data. The amount of content that adolescents viewed had a significant direct effect on dietary quality at both 4 months (SC=0.19, SE=0.09, p=0.03) and 8 months (SC=0.24, SE=0.08, p=0.01). The adherence variable explained 2.3% and 7.4% of the variation in dietary quality at 4 and 8 months, repectively after the effects of the covariates (gender, age, and corresponding health behaviour at baseline) were accounted for. However, self-monitoring of steps, sedentary time, and diet intake did not improve the corresponding health behaviours. Table 4.6 presents data for all paths that were included in the models. At 4 months, the boys had a significant lower level of dietary quality than the girls (Table 4.6).

Figure 4.3 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on the health behaviours (self-reported Moderate-to-Vigorous Physical Activity (MVPA), screen time, and dietary quality) at 4 months (top model) and 8 months (bottom model) (N=158)



[χ^2(df=20)=40.59,RMSEA=.08, 90% CI:.04-.12, CFI=.68; SRMR=.06]



[χ^2(df=20)=34.01, RMSEA=.07, 90% CI:.02-.10, CFI=.85; SRMR=.05]

Footnote:
SC=Standardized coefficient, SE=Standard error (shown for paths with significant effects)
Gender and age were entered as covariates for all paths, as well as baseline MVPA, screen time, and dietary quality for each corresponding health behaviour; in which age was correlated with baseline screen time (SC=0.28, SE=0.07, p=0.00 in the top model, SC=0.28, SE=0.07, p=0.00 in the bottom model) (data not shown for non-significant paths)
χ^2=Chi-square estimate of standardized model, RMSEA=Root mean square error of approximation, CI=Confidence interval, CFI=Comparative fit index, SRMR=Standardized root mean square residual

Table 4.6 : Direct effect of adherence to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on the health behaviours (self-reported Moderate-to-Vigorous Physical Activity (MVPA), screen time and dietary quality) on change in Body Mass Index (BMI) z-score at 4 months and 8 months (N=158)

		4-Month (N=158)			8-Month (N=158)		
		Self-reported MVPA Time	Self-reported Screen Time	Dietary Quality	Self-reported MVPA Time	Self-reported Screen Time	Dietary Quality
		SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value
Independent Variables	% of Content Viewed	- 0.02 (0.11) 0.84	0.00 (0.08) 0.98	0.19 (0.09) 0.03	- 0.03 (0.10) 0.75	0.03 (0.07) 0.72	0.24 (0.08) 0.01
	Self-monitoring Steps	0.15 (0.10) 0.11	-	-	- 0.07 (0.09) 0.45	-	
	Self-monitoring Sedentary Time	-	- 0.07 (0.07) 0.36	-	-	- 0.05 (0.06) 0.37	
	Self-monitoring Diet Intake	-	-	- 0.04 (0.08) 0.62	-		- 0.12 (0.08) 0.11
Covariates	Baseline MVPA Time	0.17 (0.10) 0.09	-	-	0.44 (0.09) 0.00	-	-
	Baseline Screen Time	-	0.55 (0.09) 0.00	-	-	0.73 (0.06) 0.00	-
	Baseline Dietary Quality	-	-	0.42 (0.08) 0.00	-	-	0.46 (0.09) 0.00
	Gender	0.03 (0.10) 0.74	0.08 (0.08) 0.33	- 0.18 (0.09) 0.03	0.05 (0.10) 0.64	- 0.08 (0.07) 0.30	- 0.17 (0.09) 0.05
	Age	- 0.08 (0.10) 0.46	0.00 (0.09) 0.99	- 0.02 (0.09) 0.84	- 0.09 (0.10) 0.42	- 0.05 (0.08) 0.56	- 0.12 (0.09) 0.17

SC=Standardized coefficient, SE=Standard error

Age was correlated with baseline screen time (SC=0.28, SE=0.07, p=0.00 at 4-month, SC=0.28, SE=0.07, p=0.00 at 8-month)

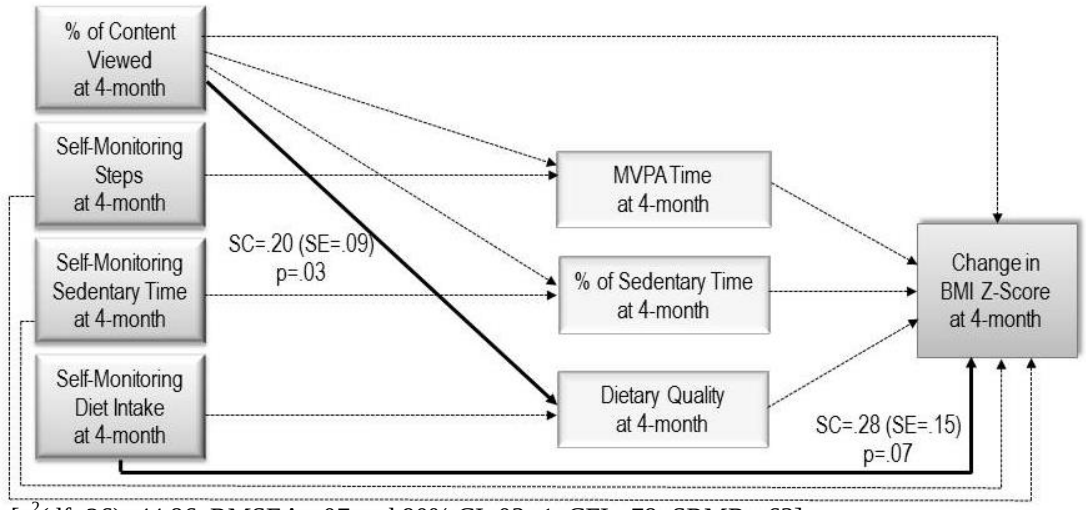
4.4.3 Mediating Effect of the Health Behaviours

Figure 4.4 shows the models in which both the direct and indirect paths (via the health behaviours) among the adherence variables and change in BMI-z-score at 4 months (top model) and 8 months (bottom model) were entered (full data shown in Table 4.7). Self-monitoring of dietary intake had a borderline significant direct effect on change in BMI z-score at 4 months (SC=0.28, SE=0.15, p=0.07). In addition, at 4 months the percent of content viewed had a significant direct effect on dietary quality (SC=0.20, SE=0.09, p=0.03). The percent of content viewed at 8 months had a significant direct effect on change in BMI z-score (SC=0.26, SE=0.10, p=0.01), as well as a significant direct effect on dietary quality (SC=0.23, SE=0.08, p=0.01). The other health behaviours (measured MVPA and sedentary time) had no impact on change in BMI z-score at both 4 and 8 months. These results indicate that the direct effect of adherence on change in BMI z-score was not mediated by any of the health behaviours. Overall, the adherence variables explained 5.4% and 7.8% of the variation in BMI z-score change at 4 and at 8 months, respectively after the effects of the covariates (gender, age, and corresponding health behaviour at baseline) were accounted for. At 4 months, the boys had a significant lower level of dietary quality than the girls (Table 4.7).

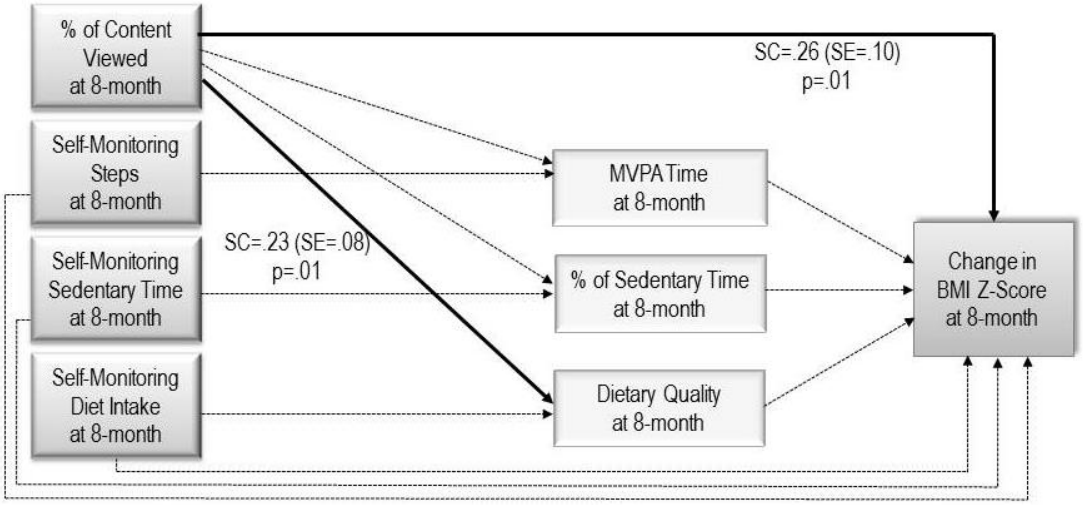
As discussed in method section, the process of identifying mediation effect has several parameters. At 4 months, the first parameter (significant effect of independent variable on dependent variable) was not fulfilled and at 8 months the third parameter (significant effect of mediator on dependent variable) was not fulfilled. So, it was concluded that the hypothesized health behaviours had no mediation effect at both at 4 and 8 months.

Figure 4.4 : Direct and indirect effects of adhering to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, and diet intake) on change in

Body Mass Index (BMI) z-score via objectively measured Moderate-to-Vigorous Physical Activity (MVPA), percent of sedentary time, and dietary quality at 4 months (top model) and 8 months (bottom model) (N=158)



[χ^2(df=26)=44.86, RMSEA=.07 and 90% CI:.03-.1, CFI=.78; SRMR=.63]



[χ^2(df=26)=48.34, RMSEA=.07, 90% CI:.04-.11, CFI=.76; SRMR=.07]

Footnote

SC=Standardized coefficient, SE=Standard error (shown for paths with significant/borderline significant effects)

Gender and age were entered as covariates for all paths, as well as baseline MVPA, percent of sedentary time, and dietary quality for each corresponding health behaviour; in which age was correlated with percent of sedentary time at baseline (SC=0.47, SE=0.07, p=0.00 in the top model and SC=0.47, SE=0.07, p=0.00 in the bottom model) (data not shown for non-significant paths)

χ^2=Chi-square estimate of standardized model, RMSEA=Root mean square error of approximation, CI=Confidence interval, CFI=Comparative fit index, SRMR=Standardized root mean square residual

Table 4.7 : Direct and indirect effect of adherence (percent of content viewed and self-monitoring of steps, sedentary time, diet intake) on Body Mass Index (BMI) z-score change via objectively measured Moderate-to-Vigorous Physical Activity (MVPA), percent of sedentary time, and dietary quality at 4 months and 8 months (N=158)

		4-Month (N=158)				8-Month (N=158)			
			Mediating Variables		Dependent Variables		Mediating Variables		Dependent Variables
		Observed MVPA Time	Observed % Sedentary Time	Dietary Quality	Change in BMI-Z-Score	Observed MVPA Time	Observed % Sedentary Time	Dietary Quality	Change in BMI-Z-Score
		SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value
Independent Variables	% of Content Viewed	0.11 (0.13) 0.39	- 0.04 (0.09) 0.67	0.20 (0.09) 0.03	0.05 (0.10) 0.60	- 0.02 (0.11) 0.87	0.00 (0.10) 0.99	0.23 (0.08) 0.01	0.26 (0.10) 0.01
	Self-monitoring Steps	0.01 (0.13) 0.94	-	-	0.04 (0.13) 0.79	- 0.06 (0.10) 0.51	-	-	- 0.11 (0.13) 0.42
	Self-monitoring Sedentary Time	-	- 0.04 (0.07) 0.57	-	- 0.18 (0.12) 0.14	-	0.05 (0.08) 0.51	-	- 0.11 (0.11) 0.33
	Self-monitoring Diet Intake	-	-	- 0.05 (0.08) 0.57	0.28 (0.15) 0.07	-	-	- 0.13 (0.08) 0.10	- 0.07 (0.15) 0.67
Mediating Variables	MVPA Time	-	-	-	- 0.16 (0.12) 0.17	-	-	-	0.09 (0.14) 0.52
	% of Sedentary Time	-	-	-	0.03 (0.13) 0.84	-	-	-	0.24 (0.15) 0.11
	Dietary Quality	-	-	-	0.02 (0.10) 0.89	-	-	-	0.03 (0.11) 0.78
Covariates	MVPA Time at Baseline	0.35 (0.13) 0.01	-	-	-	0.69 (0.08) 0.00	-	-	-
	% Sedentary Time at Baseline	-	0.71 (0.08) 0.00	-	-	-	0.69 (0.09) 0.00	-	-
	Dietary Quality at Baseline	-	-	0.41 (0.09) 0.00	-	-	-	0.46 (0.09) 0.00	-
	Gender	0.02 (0.13) 0.89	0.02 (0.09) 0.84	-0.19 (0.09) 0.03	0.06 (0.10) 0.54	0.02 (0.11) 0.88	- 0.03 (0.11) 0.79	- 0.17 (0.09) 0.05	0.06 (0.11) 0.60
	Age	-0.09(0.12) 0.44	0.07 (0.11) 0.50	- 0.02 (0.09) 0.79	- 0.05 (0.11) 0.62	- 0.01 (0.11) 0.90	0.05 (0.12) 0.66	- 0.12 (0.09) 0.17	- 0.22 (0.12) 0.06

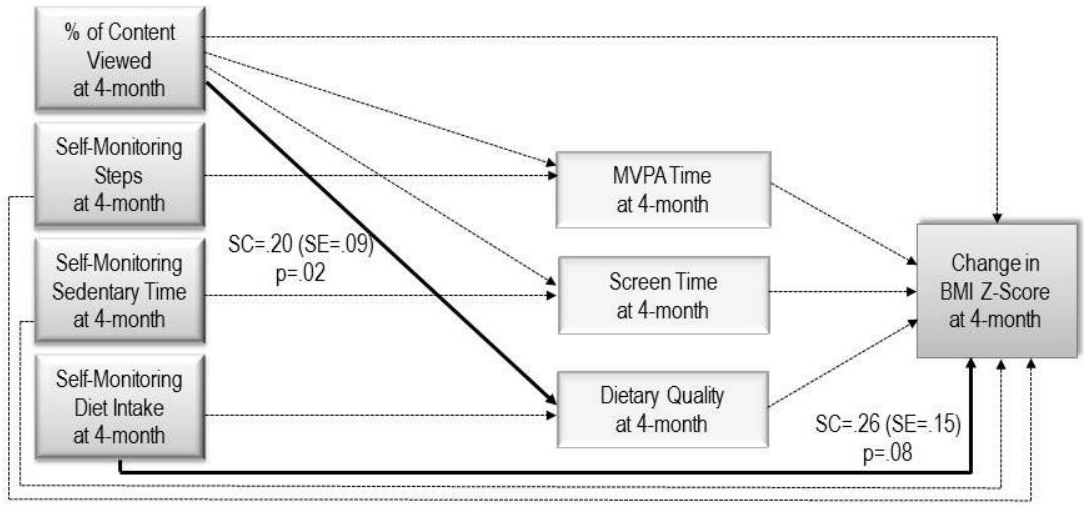
SC=Standardized coefficient, SE=Standard error

Age was correlated with percent of sedentary time at baseline (SC=0.47, SE=0.07, p=0.00 at 4-month; SC=0.47, SE=0.07, p=0.00 at 8-month)

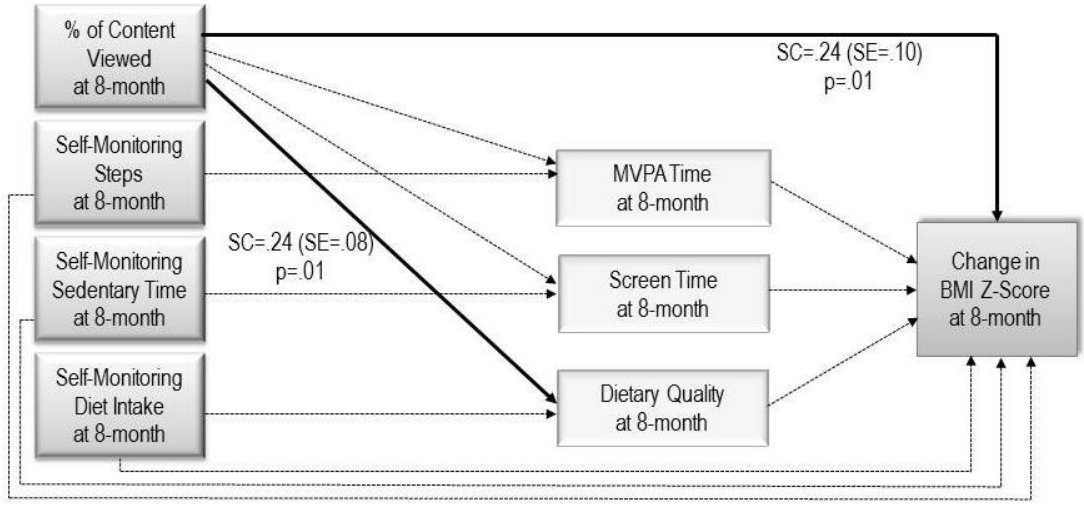
Figure 4.5 shows the models in which self-reported MVPA time and screen time were entered instead of using their respective objectively measured values. Similar to the previous models which included objective measurements, none of the health behaviours mediated the effect of the intervention components on change in BMI z-score at 4 and 8 months (full data shown in Table 4.8). All effects remain the same as observed in Figure 4.3. Adherence to the intervention components explained 4.3% and 8.2% of the variance in BMI z-scores at 4 and 8 months, respectively after the effects of the covariates (gender, age, and corresponding health behaviour at baseline) were accounted for. At 4 months, the boys had a significant lower level of dietary quality than the girls (Table 4.8).

As discussed in method section, the process of identifying mediation effect depends on three parameters. At 4 months, the first parameter (significant effect of independent variable on dependent variable) was not fulfilled and at 8 months the third parameter (significant effect of mediator on dependent variable) was not fulfilled. So, it was concluded that the hypothesized health behaviours had no mediation effect both at 4 and 8 months.

Figure 4.5 : Direct and indirect effects of adhering to the intervention components (percent of content viewed, and self-monitoring of steps, sedentary time, diet intake) on change in Body Mass Index (BMI) z-score via self-reported Moderate-to-Vigorous Physical Activity (MVPA), screen time, and dietary quality at 4 months (top model) and 8 months (bottom model) (N=158)



[χ^2(df=26)=49.72, RMSEA=.08, 90% CI:.04-.11, CFI=.63; SRMR=.06]



[χ^2(df=26)=40.20, RMSEA=.06, 90% CI:.02-.09, CFI=.86; SRMR=.06]

Footnote:
SC=Standardized coefficient, SE=Standard error (shown for paths with significant/borderline significant effects)
Gender and age were entered as covariates for all paths, as well as baseline MVPA time, screen time, and dietary quality for each corresponding health behaviour; in which age and baseline screen time was correlated (SC=0.28, SE=0.07, p=0.00 in the top model, SC=0.28, SE=0.07, p=0.00 in the bottom model) (data not shown for non-significant paths)
χ^2=Chi-square estimate of standardized model, RMSEA=Root mean square error of approximation, CI=Confidence interval, CFI=Comparative fit index, SRMR=Standardized root mean square residual

Table 4.8 : Direct and indirect effects of adhering to the intervention components (percent of content viewed and self-monitoring of steps, sedentary time, diet intake) on change in Body Mass Index (BMI) z-score via self-reported Moderate-to-Vigorous Physical Activity (MVPA) and screen time, and dietary quality at 4 months and 8 months (N=158)

		4-Month (N=158)				8-Month (N=158)			
		Mediating Variables			Dependent Variable	Mediating Variables			Dependent Variable
		Self-reported MVPA Time	Self-reported Screen Time	Dietary Quality	Change in BMI-Z-Score	Self-reported MVPA Time	Self-reported Screen Time	Dietary Quality	Change in BMI-Z-Score
		SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value	SC (SE) p-value
Independent Variables	% of Content Viewed	- 0.02 (0.10) 0.86	0.01 (0.08) 0.94	0.20 (0.09) 0.02	0.05 (0.10) 0.61	- 0.04 (0.10) 0.71	0.03 (0.07) 0.69	0.24 (0.08) 0.01	0.24 (0.10) 0.01
	Self-monitoring Steps	0.15 (0.10) 0.11	-	-	0.04 (0.13) 0.76	- 0.07 (0.09) 0.45	-	-	0.18 (0.13) 0.17
	Self-monitoring Sedentary Time	-	- 0.07 (0.07) 0.94	-	- 0.19 (0.12) 0.13	-	- 0.06 (0.06) 0.32	-	- 0.09 (0.11) 0.45
	Self-monitoring Diet Intake	-	-	- 0.05 (0.08) 0.56	0.26 (0.15) 0.08	-	-	- 0.13 (0.08) 0.10	- 0.09 (0.15) 0.54
Mediating Variables	MVPA Time	-	-	-	0.08 (0.10) 0.44	-	-	-	0.15 (0.10) 0.12
	Screen Time	-	-	-	0.14 (0.10) 0.17	-	-	-	0.05 (0.11) 0.65
	Dietary Quality	-	-	-	0.05 (0.10) 0.60	-	-	-	0.04 (0.11) 0.70
Covariates	Baseline MVPA Time	0.19 (0.10) 0.07	-	-	-	0.44 (0.09) 0.00	-	-	-
	Baseline Screen Time	-	0.57 (0.08) 0.00	-	-	-	0.74 (0.06) 0.00	-	-
	Baseline Dietary Quality	-	-	0.41 (0.09) 0.00	-	-	-	0.46 (0.09) 0.00	-
	Gender	0.04 (0.10) 0.69	0.08 (0.08) 0.36	- 0.18 (0.09) 0.03	0.03 (0.10) 0.79	0.05 (0.10) 0.61	- 0.08 (0.07) 0.28	- 0.17 (0.09) 0.05	0.03 (0.10) 0.81
	Age	- 0.08 (0.12) 0.43	- 0.01 (0.09) 0.91	- 0.02 (0.09) 0.80	- 0.04 (0.10) 0.66	- 0.09 (0.10) 0.39	- 0.05 (0.08) 0.52	- 0.12 (0.09) 0.17	- 0.11 (0.10) 0.30

SC=Standardized coefficient, SE=Standard error

Age was correlated with baseline screen time (SC=0.28, SE=0.07, p=0.00 at 4-month, SC=0.28, SE=0.07, p=0.00 at 8-month)

Chapter 5. Discussion

The purpose of this study was to determine whether adherence to the intervention components (viewing content and self-monitoring) had an effect on adolescents' health behaviours and their BMI z-score. In addition, this study aimed to better understand the mediating effect of the health behaviours associated with obesity on this process.

Adherence to the intervention components explained a meaningful amount of variation in change in BMI z-score, where the total amount of variance explained was 5.1% at 4 months and 9.6% at 8 months. In addition, adherence to the intervention components only had a significant effect on one of the health behaviours targeted by the intervention, namely dietary quality. The intervention components explained at least 2.3% of the total variance at 4 months and at least 7.3% at 8 months. Specifically, the study found that the amount of content viewed had a direct effect on reducing BMI z-score at 8 months, as well as on their dietary quality at both 4 and 8 months. Self-monitoring of steps, sedentary time, and diet intake had no effect on reducing BMI z-score, and on MVPA, percent of sedentary time, screen time, and dietary quality at both 4 and 8 months. None of the health behaviours mediated the effect of adherence to the intervention components on BMI z-score reduction. Last but not the least; boys had lower dietary quality compared to that of girls.

These findings suggest that the amount of content viewed had an effect on dietary quality and reduced BMI z-score of adolescents. However, the self-monitoring tools integrated in the MySteps® program did not appear to be effective. Surprisingly, change in any of the health behaviours did not mediate the effect of the percent of content viewed had on reducing BMI z-score among adolescents.

5.1 Effect of Adherence on Behaviours and Change in BMI z-score

5.1.1 Viewing Content of the Intervention

The effect of viewing program content on changing health behaviours and BMI z-score reduction are described in this section.

Effect on Health Behaviours: The amount of content that adolescents viewed had a direct effect on their dietary quality at both 4 and 8 months; but had no effect on MVPA time (objectively measured and self-reported), percent of sedentary time (objectively measured), and screen time (self-reported). Previously, Patrick et al.'s study reported similar association between dietary behaviours of adolescent girls with adherence to the PACE+ intervention.[24] Similar to this study, Patrick et al. found no association between adherence to intervention and measured MVPA time.[24] In contrast, the PACE+ study found that girls decreased their sedentary time with increase in adherence to the intervention; which was not observed in our study.[24] However, the PACE+ intervention measured adherence to intervention as the number of counselling calls that adolescents completed.[24] PACE+ did not take into account the amount of content adolescents viewed as was done in this study which may explain the discrepancies with this study.

In this study, the amount of content viewed was associated with change in dietary quality and not the other health behaviours targeted by the program. Among the three targeted behaviours of MySteps® intervention, dietary behaviour related topics alone covered approximately half of the MySteps® program (8 out of 16 weeks) during the first four months. The other half focused predominantly on physical activity but incorporated content related to sedentary behaviours. As the intervention had a greater emphasis on dietary

behaviours, it may partly explain the findings. At least in the first four months of the program having more weeks focused on dietary behaviours appeared to influence the outcomes of the program. However, in the last four months of the program adolescents viewed personalized content based on the behaviour they selected to improve. The amount of topics regarding different dietary behaviours is unknown but perhaps being exposed to dietary topics early on had a lasting effect on their behaviours as shown in this study. Alternatively, adolescents may have selected more dietary topics in the last four months as they enjoyed more these topics in the first four months. In future administration of the MySteps® program, it may be important to determine whether there is sufficient focus on physical activity and sedentary behaviours to improve these behaviours.

Effect on Changing BMI Z-Score: The amount of content viewed had a direct effect on reducing BMI z-score of adolescents at 8 months, but not at 4 months. However, Patrick et al.'s study did not report an association between BMI z-score with adherence to the intervention as PACE+ did not achieve a significant reduction in BMI z-score among adolescents at 12 months.[24] Though MySteps® evolved from PACE+, these studies measured adherence differently. MySteps® measured the amount of content adolescents viewed whereas PACE+ focused on the number of counselling calls that adolescents completed.[24] Therefore, our findings are not comparable and it explains the discrepancies. However, similar to our study findings, previous literatures reported that increased participation[22] was associated with greater reduction in obesity in overweight and obese children and adolescents.

Our study findings highlight that exposure to the MySteps® intervention was related to reduction in BMI z-score only when adolescents were exposed to it for a longer period of

time (8 months). Furthermore, the findings suggest that the changes in health behaviours that adolescents adopted had to be sustained for a period of time in order to change BMI z-score. Perhaps it explains why a significant reduction in BMI z-score was not found at 4 months. It may take a certain amount of time to reduce BMI z-score of adolescents who are participating in a behavioural modification intervention. Furthermore, it should be noted that stopping the increase in BMI z-score is also important as we know that without treatment obese adolescents typically see a continued increase in their BMI z-score.[116]

5.1.2 Using the Self-Monitoring Strategies

Effect on Health Behaviours: This study found that self-monitoring of steps, sedentary time, and dietary intake while volunteering in a behavioural modification intervention had no significant effect on these health behaviors at both 4 and 8 months. However, previous literatures suggest different relationships between self-monitoring and behaviour change which contradicts our study findings.[79;80] Studies conducted in adults showed that self-monitoring is important to integrate in health behaviour modification intervention.[79] DeBar et al. found that overweight adolescent girls (12-17 years) who used the self-monitoring tool and attended the in-person intervention significantly decreased their consumption of fast food as compared to those who received only paper or web-based materials.[80] It appears that on average the adolescents followed the instructions. It is somewhat unclear as to why this study did not find an association between utilization of the self-monitoring tools and change in the health behaviours when other studies have found a positive relationship between self-monitoring and adopting healthy behaviours.[80-82]

In our study, self-monitoring was assessed by the number of weeks adolescents reported

using the MySteps® forms to track their behaviours. Adolescents self-monitored their health behaviours as prompted by the MySteps® program. Specifically, adolescents who completed the 4-month assessment monitored their steps for 7.5 weeks, their sedentary time for 2.0 weeks, and their dietary intake for 3.9 weeks when the program prompted them to self-monitor for 6, 1, and 4 weeks, respectively. However, the adolescents had alternative ways of self-monitoring their behaviours which was not captured by the MySteps® program. For example, adolescents were provided with a pedometer. It is likely that the adolescents used the pedometer to track their behaviours but did not record this information in the MySteps® program. This may especially be true on the weeks MySteps® prompted adolescents to focus on their dietary intake and prompted the adolescents to use the dietary tracking form. They could be wearing their pedometers that week but only used the dietary intake form as instructed by the program. MySteps® alternated the health behaviours it focused on each week. Thus it is possible that it made adolescent de-emphasized to track the other health behaviours. The other reason might be that MySteps® included separate tracking forms for self-monitoring all the behaviours. Perhaps integrating these forms into one and prompting to use the combined form every week can ensure a constant focus on all of three behaviours.

Future studies should attempt to improve the design of self-monitoring tool. It can be done either by integrating all targeted health behaviours in one single tracking form to make reporting convenient or by introducing web-based tracking forms to become more acceptable by adolescents. In addition, future studies should improve on how self-monitoring is assessed (number of times the tool is used / number of times self-monitoring is reported).

Effect on Change in BMI Z-Score: Our study found that self-monitoring of steps, sedentary time, and dietary intake had no significant effect on BMI z-score reduction at both 4 and

8months. Unlike our study, Saelens et al. reported that self-monitoring of diet intake on a daily basis was effective in reducing BMI z-score of overweight adolescents who participated in a 14-week web-based intervention.[78] In Saelens et al.'s study, participants self-monitored their consumption of five food and beverages on a daily basis.[78] In contrast, MySteps® participants alternated the behaviours they were prompted to self-monitor and on the weeks they focused on dietary intake, they were often asked to track one aspect of their diets (e.g., consumption of sugar-sweetened beverages). Saelens et al.'s findings suggest that having adolescents self-monitor their dietary intake more broadly and every week are perhaps needed to be more effective. Future studies should encourage participants to use the self-monitoring tool on a regular basis and perhaps ensure all health behaviours are continuously tracked.

5.2 Effect of Adherence on BMI z-score Reduction via Health Behaviours

The effect of adherence to the intervention components on reducing BMI z-score at 4 and 8months were not related to changes in health behaviours such as objectively measured MVPA, self-reported MVPA, objectively measured percent of sedentary time, self-reported screen time, and self-reported dietary quality. However, previous studies have reported different findings from our study. In a previous RCT among female adults (44-50 years), Hollis et al. reported that the number of steps taken and consumption of vegetables mediated their weight loss at both 12 months (only for vegetable intake) and 24 months and the other health behaviours including MVPA time, sitting time, and dietary consumption related to dairy, fruit, meat and alternatives, whole grain, sugary and high fat food, and meal frequency did not mediate the effect of the intervention on weight loss.[30] In one study, Lubans et al. reported that step counts taken by overweight and obese men mediated the relationship

between their weight loss and the effect of an in-person intervention with a primary aim to increase parent-child co-activity.[26]

Similar to our study, another Lubans et al.'s study did not find any of the health behaviours targeted by their weight management intervention (steps, portion size, dietary intake, fat intake, and alcohol intake) to mediate change in BMI in a behavioural modification intervention among overweight and obese men (18-60 years) at 6 months.[31] While the MySteps® intervention is quite different from the weight management intervention of Lubans et al. and it targets a different age group the results are same. In both studies, it appears difficult to isolate what changes in health behaviours explain the decrease in BMI z-score. In general, changes in health behaviours likely explain the decrease in BMI z-score. However, it may be that small changes across all these behaviours or combination of these behaviours can explain the decrease in BMI z-score. Alternatively, it may be that the measures used in this study were not precise enough to capture the change in these health behaviours that occurred as a result of participating in the MySteps® program. Measuring only one week may not be enough to get a true representation of their health behaviours and could lead to increase measurement errors. Future studies should determine whether these measurement errors explain our findings or whether it is small changes in a number of these health behaviours that explain the decrease in BMI z-score. More rigorous studies have to be done to address the underlying mechanism of these behavioural modification interventions so that we can isolate what changes adolescents make when they participate in these interventions.

5.3 Effect of Gender on Dietary Quality

This study found that gender had was significantly related dietary quality. Specifically, we found that boys had a lower dietary quality than girls. The small numbers of studies that have examined gender effect on adolescents' dietary quality (measured by HEI) are inconsistent – one U.S. study reported similar findings as this study;[117] whereas a study among Turkish adolescents observed no effect.[118] In Canada, dietary intake of adolescents varies by gender.[16] in comparison to girls, the CCHS data found that boys (14-18 years) consume more calories and refined sugar and a greater of proportion of their calories comes from fat. [16] Thus, it appears that Canadian boys have less adequate dietary pattern than girls a pattern that was also observed in this study.

5.4 Limitations

The findings should be interpreted in light of the following study limitations. Our study findings can only be generalized to a population of mostly obese people as most of the adolescents (81.01%) in the study were obese. In addition, the sample consisted of adolescents who took part in an intervention aimed at improving health behaviours and reducing weight. Therefore, the study findings can only be generalized to those willing to participate in a weight loss intervention. Similarly, the study findings are generalizable to adolescents from urban settings only, not from rural settings as our study population was from greater Vancouver area.

Another limitation of this study is the amount of adolescent's lost-to-follow up. Almost 34% of adolescents who took part in the baseline assessment did not complete the 4-month assessment and about 39% of them did not complete the 8-month assessment. Loss-to-follow

up is not uncommon in web-based behaviour modification obesity treatment interventions and it is likely higher than in-person interventions.[19] The missing data was corrected by using the full information maximum likelihood method (FIML) which provide unbiased estimates as long as the data is missing at random.[120]

There are possibilities that our study results are biased by measurement error. Self-reported dietary recall is subject to social desirability leading to the fact that the overweight and obese adolescents might not report all the food they consume. However, the private and anonymous feature of the web-based dietary recall tool used in MySteps® may have helped reduce such bias. MVPA and sedentary behaviour was assessed with both questionnaire and accelerometry and both methods have their strength and limitations. The questionnaires are known to overestimate MVPA and be subject to reporting biases[121] due to social desirability and cognitive challenge in estimating amount of time spent in physical activity.[122] In contrast to questionnaires which capture a limited set of behaviours, accelerometers are known to capture mainly walking-based activities including occupational activities.[103] However, accelerometers worn at the waist do not capture all activities as they minimize cycling and swimming activities for example.[123] Despite those limitations, the results were consistent when analyzed with the accelerometry data or the questionnaire providing some validity to the results.

Finally, given the design of this study it is difficult to fully assess causal relationships. For example, it is possible that those who noticed a greater change in their BMI z-score became more motivated to view the content of the intervention. However, to fully assess causal relationships would require more frequent measurement of these outcomes and behaviours.

5.5 Implications and Recommendations for Future Studies

The findings highlight the need to address the following issues in future studies: improving engagement of low income families, increase use of self-monitoring tools, testing whether inclusion of more balanced content impact the efficacy in a specific behaviours and BMI z-scores.

Firstly, future studies should focus on ensuring that low income families do not drop out from these interventions. Secondly, future studies should ensure that the self-monitoring tools are better utilized which can be accomplished by: 1) making self-monitoring a priority at the beginning of the program through training on how to use these tools; and 2) making self-monitoring of all the health behaviours constant throughout the program. Thirdly, future interventions have to balance the content of the intervention to ensure all the health behaviours associated with obesity improve. While it probably makes sense to incrementally change health behaviours, adolescents may need to learn to address all behaviours at once. It is unclear when MySteps® makes adolescents focus on a specific behaviour, whether they ignore the other behaviours they have learned. Future studies should examine whether taking an incremental and cumulative approach to behaviour change would improve the effectiveness of these interventions. Lastly, future mediation analyses should examine the synergistic effect of all these behaviour changes instead of looking at their independent effect. Most mediation analyses examine how each of the health behaviour targeted by the intervention mediate the effect of the intervention. However, it is possible that small changes in all the health behaviours can impact BMI z-score.

Chapter 6. Conclusion

With the rate of obesity in children and adolescents at alarming levels,[1] effective treatment strategies are needed to reverse the trend. Research on adherence to the components of behavioural modification intervention as a potential area to target for the treatment of childhood obesity is limited; specifically among adolescents. This dissertation supplements previous literature by providing support to the idea that more engagement in the intervention results in better outcomes. This study extends our knowledge about the importance of adherence to intervention components on behaviour change and reducing obesity in overweight and obese adolescents. Viewing more content of a web-based obesity treatment intervention can help reduce BMI z-score and improve dietary quality of adolescents. Behavioural modification interventions need sufficient time to observe the intervention effect in reducing obesity. Perhaps reducing obesity takes longer time compared to the time required for changing the health behaviours targeted by the intervention. Prompting participants to change the behaviours cumulatively might be helpful to speed up the reduction in BMI z-score.

The study could not establish the underlying mechanism of obesity reduction through behaviour change by looking at those behaviours individually. Future studies may explore the synergistic effect of changing the targeted behaviours as small changes on all these behaviours may be more important to look at. In conclusion, improving adherence to web-based behavioural modification intervention is one way to reduce levels of obesity among adolescents and improve some of their health behaviours. Future studies should find ways to maintain participate engaged with the intervention to promote greater effects.

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Appendix

Consort Diagram for MySteps® Study