TRACKING OBESITY RELATED BEHAVIORS FROM CHILDHOOD TO ADOLESCENCE: THE FUN 5 STUDY

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII AT MANOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
EPIDEMIOLOGY

MAY 2014

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Keywords: Obesity, childhood, adolescent, physical activity, fruit and vegetable consumption, sedentary behavior, theory of planned behavior, body mass index
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<td>Body Mass Index</td>
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<td>CDC</td>
<td>Centers for Disease Control and Prevention</td>
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<td>CFI</td>
<td>Comparative Fit Index</td>
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<td>CVD</td>
<td>Cardiovascular Disease</td>
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<td>FVC</td>
<td>Fruit and Vegetable Consumption</td>
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<td>MVPA</td>
<td>Moderate to Vigorous Physical Activity</td>
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<td>NHANES</td>
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<td>PA</td>
<td>Physical Activity</td>
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<td>PBC</td>
<td>Perceived Behavioral Control</td>
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<td>Root Mean Squared Error of Approximation</td>
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<td>SB</td>
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Abstract

Obesity in the United States has increased dramatically, and has become a public health crisis. Studies documented that healthy lifestyle, including healthy eating, increased physical activity (PA), and decreased sedentary behavior (SB), can lower the risk of becoming obese, as well as developing obesity related diseases. In order to explore the changing pattern of PA and fruit and vegetable consumption (FVC) from childhood to adolescence, as well as to investigate how childhood PA, FVC, and SB influence adolescence PA, FVC, and SB, this dissertation utilized the data of Fun 5 study, which is a longitudinal cohort study. Two cohorts of data were utilized for this dissertation, where students were followed up for five years. Using piecewise growth mixer modeling, and random coefficient model, paper one of this dissertation did not find any significant pattern of PA change from childhood to adolescent. Structural equation modeling revealed the applicability of theory of planned behavior (TPB) for childhood PA. Findings also documented that self confidence is the strongest variable to influence childhood PA followed by attitudes. Paper one did not find any impact of childhood and adolescent PA on adolescent obesity. Using piecewise growth mixer modeling, and random coefficient model, paper two revealed a declining pattern of FVC from childhood to adolescent. Structural equation modeling revealed the applicability of TPB for childhood FVC. Findings also documented that self confidence is the strongest variable to influence childhood FVC followed by subjective norms. Paper two did not find any impact of childhood and adolescent FVC on adolescent obesity. Using structural equation modeling, paper three of this dissertation revealed that all three childhood
behaviors (PA, FVC, SB) predicted the same adolescent behaviors, which implies that these behaviors develop at childhood and continue to adolescence. Findings suggest to target early childhood for intervention activities regarding increasing PA, FVC, and decreasing SB, as well as target children’s self confidence, subjective norms, and attitudes towards PA and FVC. Findings also recommend further studies to explore the change of obesity related behaviors from childhood to adolescent, as well as the predictive ability of these behaviors to adolescent obesity.
INTRODUCTION

Childhood obesity in the United States has increased dramatically over the last three decades. The percentage of obese (BMI ≥ 95th percentile) children aged 6-11 years has risen from 7% in 1980 to 18% in 2010, while the percentage of obese adolescents aged 12-19 years increased from 5% to 18% over the same period (1). Results from the 2009-2010 National Health and Nutritional Examination Survey (NHANES) estimate that about one third of children and adolescents aged 2-19 years are overweight or obese (BMI ≥ 85th percentile) (1). Excess weight puts children at greater risk for elevated cholesterol, plasma insulin, and systolic blood pressure (2, 3), which are risk factors for chronic conditions like cardiovascular disease (CVD) (4) and type 2 diabetes (5, 6). Childhood obesity also increases the risk for negative psycho-social consequences, such as discrimination and stigmatization, and may lead to low self-esteem, social alienation, lack of self-confidence, depression, and other mental health risks (7-10); moreover, it contributes to health care costs. Wang and colleagues (11) predict that the prevalence of overweight in children will nearly be double by 2030 contributing to approximately 16-18% of the total US healthcare costs.

This increasing prevalence of childhood obesity may be addressed by focusing on primary prevention to avoid the burden of disease, and economic consequences. Furthermore, as childhood obesity is a significant predictor of adult obesity (12-15), identifying the related risk behaviors for early intervention efforts is important to prevent adult obesity and its associated complications. Studies reveal that lack of physical activity (PA) (16-19), poor diet (16, 20), and sedentary behavior (SB) (16-19) are
key risk factors for obesity. The combination of unhealthy nutrition practices and decreased PA behaviors affect energy balance, which is the simplest explanation for weight gain. Several studies have found declining trends of PA from childhood to adolescence to adulthood (21-23). On the other hand, research has shown that SB, especially TV watching, increases with age and remains relatively consistent over time (24, 25), as well as obesity. Viner and Cole (25) report that each additional hour of watching TV on weekends at 5 years of age increases the risk of adult obesity by 7%. Studies further reveal that food behavior and food choices, especially fruit and vegetable consumption (FVC), are established in childhood or adolescence and may persist into adulthood (26-28). In addition, studies observe that many adolescents have developed multiple health risk behaviors related to PA, SB, and FVC, and the number of these health risks increases from childhood to adolescence (29-30).

Among the US populations, Native Hawaiians and other Pacific Islanders (NHOPI) are especially prone to obesity and its consequences (31-33). Novotny and colleagues (34) reveal that almost one in three NHOPI children of 5-8 years old is either obese or overweight. To decrease the prevalence of preventable diseases, it is essential to understand how childhood health behaviors influence adolescence. However, longitudinal research of obesity-related behaviors, with long term following up from childhood to adolescence, targeting the NHOPI populations, especially Hawaii, is very limited. Therefore, this study will track obesity-related behaviors in the Hawaii populations in the transition from childhood to adolescence.
Specific Aims

The specific aims of this study are:

1. To explore the changing pattern of PA from childhood to adolescence,
2. To explore the changing pattern of FVC from childhood to adolescence,
3. And to investigate how childhood PA, SB, and FVC behaviors influence adolescence PA, SB, and FVC behaviors.

FRAMEWORK OF THREE PAPERS

Recent literature documents that regular PA improves reductions in body adiposity, increases aerobic fitness, and contributes to a range of other health benefits from decreased blood pressure to increased bone mass in adulthood (16-19). PA also benefits children physically, mentally, emotionally, and socially (7, 8, 10, 17-19). Studies reveal that time spent in moderate to vigorous physical activity (MVPA) is positively associated with a lower childhood BMI (35, 36). Considering the health benefits of PA, the Centers for Disease Control and Prevention (CDC) recommends at least 60 minutes of MVPA for children every day (37). However, a significant number of US children do not follow this recommendation (38, 39). According to Beighle (40), less than half of the 6-11 year old children met the recommendation. Moreover, the percentage of children meeting recommended PA levels declines with age (21-23). In a pooled analysis of 26 studies, Dumith and colleagues (21) reveal a 7% PA decline per year among adolescents.
Conversely, several studies document that SB, especially TV watching, is associated with multiple risk factors for negative health outcomes, including obesity (24, 25, 41-43). Proctor and colleagues (44) reveal that eating meals in front of the TV, especially, salty snacks, pizza, and soft drinks may influence energy intake. Despite the negative health consequences, TV watching appears to increase with age (24, 25).

Healthy diets have health benefits and help reduce obesity (45). The Dietary Guidelines for Americans recommends a diet rich in FV, whole grains, and fat-free or low-fat dairy products for individuals of 2 years and older. The guidelines also recommend limiting the intake of solid fats for children, adolescents, and adults (46). However, most young people are not following these recommendations (46-48). Moreover, studies further reveal a decreasing pattern of FVC from childhood to adolescence to adulthood (26-28).

Several studies document that PA, SB, and FVC are associated with each other (29, 30, 49) and influence each other over time (49, 50). For example, Driskell and colleagues (30) document that healthy diet, intention to be active, and PA preferences cluster with PA. Lippke and colleagues (51) also reveal a strong correlation between nutrition and PA. These associations of obesity risk behaviors imply that a group of risk behaviors tend to occur together, and may be tied with common underlying factors; thus an intervention that addresses these behaviors together could potentially be more effective in the long run. Considering the interactions, researchers (52) suggest that multiple behavior change interventions may have a greater impact than single behavior change interventions.
Since PA, SB and FVC behaviors change from childhood to adolescents, it is also important to identify the age when these behaviors change. Findings of such studies may be helpful to develop age appropriate interventions. It is also important to find out how these behaviors in childhood influence adolescent behaviors, as during adolescence, individuals start to make their own choices and develop a personalized lifestyle. Therefore, this study provided evidence to answer two questions regarding the changing pattern of health behaviors from childhood to adolescence:

1. Do PA and FVC change from childhood to adolescence?
2. How do childhood PA, SB, and FVC behaviors influence adolescence PA, SB, and FVC behaviors?

This first paper answered whether PA changed from childhood to adolescents among Hawaii populations, and examined what accounts for behavior changes using the constructs of the theory of planned behavior (TPB). In addition, this paper also explored the influence of PA on obesity over time. The second paper answered the same question for FVC. Paper #3 explored how these behaviors (PA, SB, FVC) in childhood influenced adolescent behaviors over time. Figure 1 (next page) illustrates the model of the three papers framework.
Figure 1 Model of the three papers framework

**Childhood**

**Single behavior**

Paper 1: Tracking physical activity from childhood to adolescence

Predictors → PA → Obesity

Paper 2: Predictors of fruits and vegetables consumption from childhood to adolescence

Predictors → FVC → Obesity

**Adolescence**

**Multiple behaviors**

Paper 3: Predicting adolescents’ obesity related risk behaviors

PA, SB, FVC → PA, SB, FVC
PAPER ONE: TRACKING PHYSICAL ACTIVITY FROM CHILDHOOD TO ADOLESCENCE: THE FUN 5 STUDY

Introduction

Recent literature documents that regular physical activity (PA) helps to reduce body adiposity; increase aerobic fitness; decrease blood pressure; and increase bone mass in adulthood (16-19). PA also benefits children physically, mentally, emotionally, and socially (7, 8, 10, 17-19). Studies reveal that time spent in moderate to vigorous physical activity (MVPA) is positively associated with a lower childhood BMI (35, 36). The Centers for Disease Control and Prevention (CDC) also recommends that children should engage in MVPA for at least 60 minutes every day (37); however, a significant number of US children do not follow this recommendation (38, 39). According to Beighle (40), less than half of 6-11 year old children participate in MVPA for one hour per day. Moreover, the percentage of children meeting the recommended PA levels declines as they grow up (21-23). In a pooled analysis of 26 studies, Dumith and colleagues (21) reveal a 7% PA decline per year among adolescents; and the decline is more prevalent among females than males (53). Studies have also found that girls (54) and overweight children (55, 56) have lower overall MVPA levels than boys and normal weight children respectively.

Since lack of PA is one of the risk factors of childhood obesity (16-19), which increases the risk of remaining obese in adulthood as well as experiencing other long-term adverse health consequences (57, 58), children are the primary target for PA interventions. Interventions are based on the belief that PA changes over time (59). PA
tracking studies quantify whether a child will maintain his/her relative rank for activities within his/her cohort over time (60, 61). Tracking PA levels for periods of stability provides insights as to when the root determinants and early antecedents of PA behavior changes occur. The tracking studies can also be used to examine whether childhood PA values help to predict PA levels in later life (62). Such studies also suggest how to measure behavior risks, and identify targeted interventions for the “at-risk” children. Moreover, a high degree of association between childhood PA patterns and PA in later life might suggest that early measurement and intervention could promote healthy PA levels in later life. This strategy might have long-term implications for good health as the causal relationship between PA and cardiovascular disease (CVD) outcomes has been reported in adults (63, 64). Additionally, tracking studies help us to understand how PA develops naturally as related to health related phenomena. For example, knowing that PA remains stable from childhood to adolescence would provide evidence that the root determinants of PA occur in the early life.

There are several PA tracking studies (21,60-62, 65, 66), but very few have targeted children of ethnic minority groups (59, 67). In the US, the Native Hawaiian and other Pacific Islander (NHOPI) populations consist of diverse minority groups and are especially prone to obesity and its consequences (31-33). Novotny, Oshiro, and Wilkens reveal that almost one third of 5-8 year old NHOPI children are either obese or overweight (34). Studies also reveal a high prevalence of health risk behaviors and obesity/overweight among Hawaiian youth (68). According to the 2008 Hawai’i Physical Activity and Nutrition Surveillance Report, 71% of middle school children do not follow
the recommended 60 minutes of MVPA every day (68). Moreover, the longitudinal studies that track the PA level of the Hawai‘i population are very limited.

In order to develop effective PA interventions, a better understanding of PA behavior trends is necessary (69-71). Analyzing data under a strong theoretical framework might prove to be an efficient way to identify intervention targets and increase PA more effectively among children (71-74). However, most studies are not based on a strong theoretical framework (75), such as the theory of planned behavior (TPB) or the social cognitive theory (SCT). Consequently, the results from such studies have shown limited success in increasing PA levels (76). Baranowski, Anderson and Carmack (71) have reviewed 23 PA intervention studies, and reveal the importance of using behavioral theory for successful interventions. In addition, there are a few longitudinal studies considering the TPB, especially targeting the Hawai‘i population. Therefore, the specific objectives of this study were to:

1. track PA changes from childhood to adolescence among the Hawai‘i population.
2. apply the TPB constructs to explain childhood PA.

The secondary objective of this study was to examine whether childhood and adolescent PA can predict adolescent obesity.

**Conceptual model: TPB to explain childhood PA**

The TPB is frequently used to study a broad range of behaviors (77, 78) with a particular focus on health (78), including PA (79,80). The theory has been used
extensively to predict and influence PA in a variety of studies (81). Several meta-
analyses (80, 82, 83) have shown evidence of the applicability of the TPB in the
explanation of PA intentions and behavior. Plotnikoff and colleagues have found that
TPB explains 34% of variance in PA while SCT explains 24% (82). According to the TPB, a
person’s individual motivational factors predict his/her specific behavior (84). A
behavior is predicted by the intention and the perceived behavioral control (PBC) when
it is not completely volitional. The intention is hypothesized to be determined by
attitudes, subjective norms, and PBC. An attitude represents an individual’s assessment
of their own beliefs regarding the target behavior’s agency in producing effective
outcomes. The subjective norms represent a person’s evaluation of whether significant
others want them to engage in the target behavior and include his/her motivation to
comply with the desires of those significant others. The effects of attitude and
subjective norms on the behavior are mediated by the intention. The PBC represents an
individual’s assessment of their own capacity to affect behavioral engagement.

According to the TPB, children with strong intentions are more likely to engage in
PA than the ones with weaker intentions (84). Subjective norm, individual’s attitudes,
and PBC influence the intentions to engage in PA. Children who have positive attitudes
toward PA are more likely to have strong intentions than those with negative attitudes.
For instance, children who have fun (i.e., the experiential aspect of an attitude) being
physically active are more likely to make plans to be more active. Children who perceive
that significant adults (e.g., physical education teachers) expect them to engage in PA,
and are motivated to obtain their teacher’s approval, are likely to have strong intentions
to participate in PA. In other words, children who are aware of their teacher’s desire for them to be active, and want to please their teachers in that regard try to (i.e., develop an intention to) be more active. Finally, children who have control over their PA level under any circumstances are likely to have high intentions to perform PA compared to those with weaker control (85).

This paper explored the changing pattern of PA, and evaluated the TPB constructs to explain childhood PA among Hawai‘i populations. This paper also examined the ability of childhood and adolescent PA to predict adolescent obesity. We hypothesized that:

Hypothesis 1: Higher childhood PA precedes higher adolescent PA

Hypothesis 2: The TPB constructs explain childhood PA

a. children with favorable attitudes, strong perceptions about subjective norms, and strong PBC, all regarding PA, will express greater intentions to engage in PA compared to those reporting less positive cognitions

b. PBC in childhood will have a direct positive influence on childhood PA as well as be mediated by intention

c. children with greater intentions will do more PA compared to those with weaker intentions

d. Subjective norm or attitude in childhood will not directly predict childhood PA but be mediated by intention
Hypothesis 3: Childhood and adolescent PA can predict adolescent obesity

   a. children who have higher PA levels will have a lower BMI in adolescence compared to those who have lower PA levels
   b. adolescent who have higher PA levels will have a lower BMI in adolescence compared to those who have lower PA levels

**Methods**

*Design and sample*

For this study, we used the data of two cohorts from the Fun 5 study (86,87), which had adopted a longitudinal cohort design, and included three consecutive surveys - baseline (BL), one-year follow-up (T1), and five-year follow-up (T2). In cohort 1, 259 students from 4th-6th grades (9-12 years old) were randomly selected in 2006 for the BL survey. Out of 259 students, 172 participated in T1 (2007), and 116 in T2 (2011). In cohort 2 248 students participated in the BL survey in 2007, 176 in T1 (2008), and 88 in T2 (2012). We replicated the findings using two cohorts of students.

*Description of Fun 5 study*

The Fun 5 study is an evidence-based PA and nutrition promotion program, which has been implemented in over 160 Hawai‘i state-legislated elementary A+ after-school programs for ten years. The program has been implemented with the aim of promoting PA and fruit and vegetable consumption (FVC) among children. The program trained after-school staff on PA, nutrition, and sustainability. The nutrition component
included lessons on benefits of FV, managing portion sizes, and sugar intake. The staff was also encouraged to be good role models in terms of snacking during A+ time, and to acknowledge when the children brought healthy snacks. To promote FVC, the program developed and distributed an activity booklet for students, which included word searches, cross words, coloring pages, and word/picture matching activities addressing local culturally appropriate FV. In order to increase the children’s PA, the program offered after school students a variety of organized, non-competitive, non-gender-specific, and fun physical activities in which children of all skill levels could participate and experience success (86, 87).

**Data collection procedure**

After obtaining a written consent from parents, the BL surveys were administered in after-school classes by the Fun 5 staff at the beginning of the school year. It took about 15 minutes for the students to complete the survey. At the end of the school year, T1 was administered in after-school classes by the Fun 5 staff. For the T2 survey, the research staff mailed the BL participants at the addresses they provided on the consent form. The mail included a cover letter, a survey form, and a self-addressed and stamped envelope. The students who did not return the surveys were reminded twice through mail, once every two weeks. Data collection was stopped after three months. Each student received a $10 gift card for returning the follow-up survey. The study was approved by the University of Hawai‘i Human Studies Program.
Measures

Demographics Children reported their age, grade, and gender in the BL survey. At T2, they also reported their height in feet and inches, and weight in pounds. This information was converted into centimeters and kilograms; BMI percentile was calculated using the age- and sex-specific growth curves from the CDC (88). They also reported their ethnicity at T2.

PA The Fun 5 study adopted the Godin Leisure-Time Exercise Questionnaire to measure the PA of the children (89, 90). To fill in the questionnaire, children had to indicate the number of days per week, and the minutes per day in which they engaged in strenuous, moderate, and mild PA (not including physical education). The minutes per day were listed as 10-minute increments starting with zero minutes and ending with 60+ minutes. All PA levels were defined and examples were given. The number of days children engaged in each PA level was multiplied by the number of minutes spent in each PA level each day, resulting in a separate score of minutes per week for strenuous, moderate, and mild PA. Strenuous PA minutes per week and moderate PA minutes per week were added together and then divided by seven to calculate MVPA minutes per day. Only the children who reported both moderate and strenuous activities were included in the MVPA calculation. The Godin Leisure-Time Exercise Questionnaire has documented test-retest reliability (r = 0.81) and adequate validity (r = 0.39) when compared to kilocalories expended per day in a sample of 5th, 8th, and 11th graders (91). Children reported their PA at BL, T1, and T2.
**TPB Constructs** A five point Likert type scale (from “disagree a lot” to “agree a lot”) was used to measure the TPB constructs. The intention, attitude, subjective norms, and PBC were assessed by asking whether the children agree or disagree with these statements “I plan to be physically active at least five times a week”; “Physical activity is fun”; “Most people who are important to me think I should be physically active on a regular basis”; and “I believe I can be physically active every day” respectively. Children reported their intention, attitude, subjective norms, and PBC towards PA at BL, and T1.

**Statistical Analysis**

Descriptive statistics were produced for age, sex, ethnicity, BMI, and predictor and outcome variables. To examine hypothesis 1, we developed piecewise growth mixer modeling (92-95) of PA during BL to T1, and T1 to T2, with 2-level hierarchical linear modeling. We also used a random coefficient model to validate our results. These more complex analytic methods provide both the average trajectory across a group of individuals and capture heterogeneity in individual trajectories if it exists.

To examine hypothesis 2, structural equation modeling was used. We repeated the same model for BL data point of two cohorts. The overall fit of the models were assessed using a number of goodness of fit indices representing absolute, comparative and residual aspects of fit, specifically: chi-square index, comparative fit index (CFI), root mean squared error of approximation (RMSEA), and weighted root mean square residual (WRMR). The larger the probability associated with the chi-square, the better the fit of the model to the data (96). The CFI >.95 indicates excellent model fit (97). An
RMSEA of <.05 is excellent (96). The cut-off point for WRMR is <.90. Hypothesis 2a. was evaluated by the significance of standardized path coefficients of attitude, subjective norms, and PBC on intention; and $R^2$ on intention. Hypothesis 2b. was evaluated by the significance of standardized path coefficients of PBC on intention and childhood PA. Hypothesis 2c. was examined by the significance of standardized path coefficient of intention on childhood PA; and $R^2$ on childhood PA. Hypothesis 2d. was examined by the significance of standardized path coefficients of attitude, subjective norms on childhood PA.

A three-step multivariate linear regression was used to examine hypothesis 3. Covariates were entered into step one, childhood PA variable into step two, and adolescent PA variable into step three. Based on the available variables of the Fun 5 study data set, age, sex, ethnicity were assessed for statistical significance and were included in each PA level model as covariates if significant at $p < .05$. In cohort 1, 259 students participated in BL survey and only 116 students followed up till the end of the study and in cohort 2, out of 248 students, only 88 students followed up till the end of the study. Comparisons of BL predictor and outcome variables of students who continued the study and who lost to follow up were examined by t-test. Two cohorts of data were analyzed separately using the same analytical process.
Results

Descriptive statistics

A summary of individual characteristics is provided in Table 1. Average age of students of cohort 1 was 14.70 (SD=.87), and cohort 2 was 14.61 (SD=.92), almost half were girls for both cohorts, most of them were from fourth grade (45.2% for cohort 1, and 42.6% for cohort 2), the largest ethnic group represented was Asian (68.5% for cohort 1, and 60.5% for cohort 2), and the mean BMI percentile for age for cohort 1 was 58.42 (SD = 27.28), and cohort 2 was 67.35 (SD=25.08). Overall, students reported high-level attitude, mid level of subjective norms, intention, and PBC for both cohorts (Table 1).
Table 1 Descriptive statistics for respondents, predictors, and outcome variables

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline (BL)</th>
<th>One year follow-up (T1)</th>
<th>Five year follow-up (T2)</th>
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<td>248</td>
<td>172</td>
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<tr>
<td>Age (mean in years and SD)</td>
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<tr>
<td>Sex (in %)</td>
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</tr>
<tr>
<td>Boys</td>
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<tr>
<td>Girls</td>
<td>48.8</td>
<td>47.1</td>
<td></td>
</tr>
<tr>
<td>Education (in %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th Grade</td>
<td>45.2</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>5th Grade</td>
<td>39.0</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>6th Grade</td>
<td>15.8</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native Hawaiian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictor and outcome variables | Mean(SD)
--- | ---
Attitude | 4.23(1.13) 4.45(.97)
Subjective norms | 3.58(1.25) 3.70(1.26)
PBC | 3.95(1.18) 3.94(1.10)
Intention | 3.79(1.14) 3.81(1.20)
MVPA (in minutes/day) | 42.89(29.12) 38.40(29.13) 44.92(30.78) 40.20(30.95) 47.04(28.98) 45.06(28.68)
BMI percentile for age | 58.42(27.28) 67.35(25.08)

*SD = standard deviation, PBC= perceived behavioral control, MVPA=moderate and vigorous physical activity*

**Hypothesis one**

Figure 2a, and 2b present findings of observed PA for randomly selected samples of 10% of students over time from cohort 1 and cohort 2 respectively. Students’ reported PA showed no pattern for change over time. Table 2 presents findings from the piecewise growth mixer modeling. Mean MVPA for cohort 1 students was 42.66 minutes per day, which increased 2.59 minutes from time BL to T1, and further increased .08 minutes from time T1 to T2. Mean MVPA for cohort 2 students was 38.21 minutes per day, which increased 3.13 minutes from time BL to T1, and further increased 2.98
minutes from time T1 to T2. However, the increases were not statistically significant for both cohorts. Results from the random coefficient model revealed similar findings for PA change over time (table not shown).

**Figure 2a** Observed PA of 10% randomly selected students from Cohort 1 over time

![Graph showing PA change over time for Cohort 1](image)

**Figure 2b** Observed PA of 10% randomly selected students from Cohort 2 over time

![Graph showing PA change over time for Cohort 2](image)
Table 2: Piecewise growth mixer modeling for growth trajectories in PA over time for cohort 1 and cohort 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-ratio</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cohort 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>42.66</td>
<td>1.90</td>
<td>22.44</td>
<td>242</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BL to T1</td>
<td>2.59</td>
<td>2.69</td>
<td>0.96</td>
<td>242</td>
<td>0.336</td>
</tr>
<tr>
<td>T1 to T2</td>
<td>0.08</td>
<td>3.45</td>
<td>0.02</td>
<td>242</td>
<td>0.981</td>
</tr>
<tr>
<td><strong>Cohort 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>38.21</td>
<td>1.93</td>
<td>19.85</td>
<td>235</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BL to T1</td>
<td>3.13</td>
<td>2.67</td>
<td>1.17</td>
<td>235</td>
<td>0.243</td>
</tr>
<tr>
<td>T1 to T2</td>
<td>2.98</td>
<td>3.54</td>
<td>0.84</td>
<td>235</td>
<td>0.400</td>
</tr>
</tbody>
</table>

**Hypothesis two**

The TPB model was tested separately for both cohorts. The bivariate correlations among study variables are provided in Table 3. Significant intercorrelations were observed among TPB constructs, and all the constructs were associated with childhood PA. The hypothesized model revealed an excellent representation of the data in practical terms for both cohorts (Table 4). Figure 3a, 3b present the path coefficients of TPB constructs explaining children’s PA and intention at BL of cohort 1 and cohort 2 respectively. Attitude, subjective norms, and PBC explained 28-35% of the variance of intention to childhood PA, and intention explained 19-25% of the variance of childhood PA. Path coefficients revealed that attitude, subjective norms, and PBC were positively related with intention for childhood PA; and PBC, and intention were also positively
related to PA. Path coefficients also revealed that subjective norm or attitude did not directly predict PA, rather were mediated by intention.

Table 3 Bivariate correlation among TPB constructs to explain childhood PA

<table>
<thead>
<tr>
<th></th>
<th>Childhood PA</th>
<th>Intention</th>
<th>Attitude</th>
<th>SN</th>
<th>PBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Childhood PA</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>.37**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>.22**</td>
<td>.35**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>.14*</td>
<td>.34**</td>
<td>.24**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PBC</td>
<td>.28**</td>
<td>.43**</td>
<td>.40**</td>
<td>.35**</td>
<td>-</td>
</tr>
</tbody>
</table>

Cohort 2

<table>
<thead>
<tr>
<th></th>
<th>Childhood PA</th>
<th>Intention</th>
<th>Attitude</th>
<th>SN</th>
<th>PBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Childhood PA</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>.26**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>.12*</td>
<td>.36**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>.14*</td>
<td>.33**</td>
<td>.27**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PBC</td>
<td>.29**</td>
<td>.57**</td>
<td>.29**</td>
<td>.26**</td>
<td>-</td>
</tr>
</tbody>
</table>

** = significant at the 0.01 level; * = significant at the 0.05 level; SN = Subjective norms; PBC = Perceived behavior control
**Table 4** Goodness of fit indices for the models to explain childhood PA by TPB constructs

<table>
<thead>
<tr>
<th>Time</th>
<th>Chi²</th>
<th>RMSEA</th>
<th>CFI</th>
<th>WRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>df</td>
<td>p</td>
<td>Estimate</td>
</tr>
<tr>
<td>Cohort 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>1.58</td>
<td>2</td>
<td>.45</td>
<td>.00</td>
</tr>
<tr>
<td>Cohort 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>1.12</td>
<td>2</td>
<td>.57</td>
<td>.00</td>
</tr>
</tbody>
</table>

RMSEA= root mean squared error of approximation; CFI= comparative fit index; WRMR= weighted root mean square residual

**Figure 3a** Standardized path coefficients of TPB constructs with 95% confidence interval explaining PA of cohort 1-BL participants (n=251)

PBC=perceived behavioral control
Figure 3b Standardized path coefficients of TPB constructs with 95% confidence interval explaining PA of cohort 2-BL participants (n=247)

Hypothesis three

Results from three step linear regression revealed that controlling for gender and ethnicity, both childhood PA and adolescent PA were not statistically significant predictors of adolescent BMI (table 5).

Table 5 Predicting adolescent obesity by childhood PA, adolescent PA, and demographic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>Std. Er.</th>
<th>β</th>
<th>95%CI of B</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cohort 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.06</td>
</tr>
<tr>
<td>Sex</td>
<td>-108.31</td>
<td>45.57</td>
<td>-.23</td>
<td>-198.74, -17.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>8.95</td>
<td>26.16</td>
<td>.03</td>
<td>-42.97, 60.87</td>
<td></td>
<td></td>
</tr>
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(Table continued)

<table>
<thead>
<tr>
<th>Step 2</th>
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</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-109.47</td>
<td>47.11</td>
</tr>
<tr>
<td>Age</td>
<td>9.62</td>
<td>27.06</td>
</tr>
<tr>
<td>Childhood PA</td>
<td>-0.08</td>
<td>0.78</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3</th>
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</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-118.84</td>
<td>46.77</td>
</tr>
<tr>
<td>Age</td>
<td>10.75</td>
<td>26.72</td>
</tr>
<tr>
<td>Childhood PA</td>
<td>0.27</td>
<td>0.79</td>
</tr>
<tr>
<td>Adolescent PA</td>
<td>-1.54</td>
<td>0.82</td>
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</table>

<table>
<thead>
<tr>
<th>Cohort 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Age</td>
</tr>
</tbody>
</table>

| Step 2   |       |       |
| Sex      | -46.87 | 49.57 | -0.11 | -145.62, 51.89  |
| Age      | -36.31 | 29.75 | -0.14 | -95.57, 22.96   |
| Childhood PA | -0.06 | 0.87  | -0.01 | -1.80, 1.69     |

| Step 3   |       |       |
| Sex      | -50.66 | 49.45 | -0.12 | -149.19, 47.87  |
| Age      | -42.36 | 30.00 | -0.17 | -102.13, 17.41  |
| Childhood PA | 0.26  | 0.90  | 0.03  | -1.55, 2.06     |
| Adolescent PA | -1.13 | 0.88  | -0.15 | -2.88, 0.63     |
Discussion

The specific aims of this study were to investigate PA from childhood to adolescence, and to evaluate if the TPB constructs to explain childhood PA among children from Hawai’i. The secondary aim was to examine the ability of childhood and adolescent PA to predict adolescent obesity. While previous studies examined PA over time, as well as TPB constructs to explain childhood PA, very few studies have sought to understand these factors among NHOPI. NHOPI populations consist of diverse minority groups and are especially prone to obesity and its consequences (31-33). Studies also reveal a high prevalence of health risk behaviors and obesity/overweight among Hawaiian youth (68).

Piecewise growth mixer modeling and random coefficient modeling revealed no pattern for PA change from childhood to adolescence among Hawaiian populations. The FLAME study (98) supports our findings of no significant pattern for change among preschoolers. Two other longitudinal studies report no change of PA over time among young children (99, 100). However, several other studies (21, 101, 102) have revealed a significant PA change over time among children and adolescents. The results in these studies, on significant patterns of change are contradictory; furthermore, the direction of change is also contradictory. Several cross-sectional studies have documented that PA levels generally decline at rates ranging from 1% per year to over 20% per year (103, 104). In a longitudinal study, Kimm and colleagues (105) recruited 2379 females at 9-10 years of age and followed them for 10 years and found a 35% decline in PA levels. Dumith and colleagues (21) also noted a 7% PA decline per year among adolescents.
Conversely, some studies (62, 106) reported small increases (4–9%) in PA levels among children from 10 to 15 years of age.

Since the results are contradictory, it is important to compare the studies and conduct further research with proper methods. While almost all tracking studies have used Spearman rank correlation or Kappa coefficient for statistical analysis, we have used more advanced statistical methods, like piecewise growth mixer modeling, and random coefficient modeling. Random coefficient models with participant as a random effect were used to analyze the repeated measures at each assessment and data for all three time points simultaneously. These models take into account the underlying correlations between repeated observations. Both this study and the FLAME study (98) have used random coefficient modeling to evaluate PA change pattern, and noted similar results. Moreover, studies based on self-report measures have reported contradictory results, while, studies that collected objectively measured data on PA have reported somewhat more consistent results on PA tracking (99, 107, 108). In addition, a longitudinal study allows investigators to track individuals, to see how their PA changes over time. Therefore, a further longitudinal study with objectively measured PA assessment is recommended to confirm the findings.

This study also investigated the TPB constructs to explain childhood PA among NHOPC populations. Overall, the model was an excellent fit to the data for both cohorts, meaning that our results support the TPB as an appropriate theoretical model for explaining childhood PA behaviors. The model accounted for 28-35% of the variance in intention, and 19-25% of the variance in PA behavior, which is similar to most TPB-PA
studies in children and adolescent populations (109-115). Our findings indicate that when a child holds a positive attitude toward PA, perceives significant others believe he or she should participate in PA, and feels that he or she has the requisite ability to participate, that individual will form a strong intention. Similar findings have been reported by many studies (109, 111, 115). Strong intentions will then lead to more activity. For both cohorts, PBC was found to make the largest contribution to predicting PA intention followed by attitude. Results also showed that PBC is more strongly associated with intention than with PA, which is also reported in several studies (110-115).

The findings of this study provide us insights for tailoring future intervention designs for this population. To achieve higher activity levels among children, future interventions should implement strategies that reflect our findings on the importance of attitude and PBC. Findings of this study suggest that PA interventions aimed at children should attempt to provide information highlighting the benefits of participating in regular PA (109, 116); for example, making PA fun and enjoyable and developing strategies to show the importance of being physically active. More importantly, strategies in developing confidence in participating in PA when tired, busy with homework, and engaged with other friends in sedentary activities, are required to enhance the efficacy and control for PA behavior change. Indeed, Blanchard et al. (117) argue that improving self-efficacy along with access to PA facilities for children may enhance participation in PA in this target population.
Strengths and limitations of the study

The longitudinal design is a major strength of this study, which allowed us to evaluate changes over time and conclude regarding the predictors of change. In addition, two different cohorts allowed us to replicate our findings and validate our conclusions. However, there were limitations that should be acknowledged when interpreting the results. First, data were collected by self-report in a supervised group setting (BL and T1) and on mail-return questionnaires (T2), which might have introduced social desirability and recall bias. However, these methods are commonly used in childhood and adolescent PA studies. Moreover, PA measures have documented reliability and validity (91). Second, the ethnic composition of this population might limit the generalizability. Third, like all longitudinal studies, this study experienced lost to follow-up; however, the BL comparisons between participants who lost to follow up and who continued the study showed no statistically significant difference in predictor and outcome variables. These non significant differences however might not be enough to minimize the selection bias. Fourth, single indicators were used for the TPB constructs, which might have potentially limited the content validity of the constructs. However, at least one other study (109) has successfully used single items to measure subjective norms and intention. Moreover, our findings are similar to other TPB PA studies. Finally, this study did not collect data on some possible confounding variables, for example, socio-economic status, parents’ motivation towards PA, environmental factors, etc.
INTRODUCTION

Childhood obesity has dramatically increased and become a growing concern of the United States over the last three decades (1). Previous studies have documented that healthy eating behavior both in childhood and adolescence is not only important for proper physical growth and development, but also for preventing health problems such as obesity (43, 118-120). Furthermore, a poor diet can increase the risk for lung, esophageal, stomach, colorectal, and prostate cancers (121). Considering the benefits of a healthy diet, the Dietary Guidelines for Americans recommend a diet rich in fruit and vegetable, whole grains, and fat-free and low-fat dairy products for individuals 2 years and older. The guidelines also recommend limiting the intake of solid fats for children, adolescents, and adults (46). However, most young people are not following these recommendations (46-48). The state Indicator Report on Fruits and Vegetables, 2013 reveals that US adolescents consume fruit about 1.0 time and vegetables about 1.3 times per day (122). Moreover, studies further observed a decreasing pattern of the fruit and vegetable consumption (FVC) with age (27, 28, 123).

During adolescence, individuals start to make their own choices and develop a personalized lifestyle. Many of such choices are related to the risk factors for obesity such as unhealthy diet patterns, increased TV watching, and lack of physical activity (PA), which are generally modifiable. Modifying these behaviors at a young age is much easier
than at later ages. A longitudinal study on food choice behavior among adolescents (124) recommends the initiation of healthy diet interventions during childhood as it identifies that food habits develop during early life.

The Native Hawaiians and other Pacific Islanders (NHOPI) populations are prone to obesity and its impacts on their health (31-33). Novotny, Oshiro, and Wilkens find that almost one in three NHOPI children (5-8 years) is either obese or overweight (34). Evidence further reveals a high prevalence of health risk behaviors and obesity/overweight among youth in Hawai‘i (68). The state Indicator Report on Fruits and Vegetables in 2013 reveals that Hawai‘i adolescents consume less FV than the national average (122). According to the 2008 Hawai‘i Physical Activity and Nutrition Surveillance Report, 78% of middle school children do not consume the recommended amount (five daily servings) of FV (68). In order to design effective interventions, it is important to know the factors that influence FVC behavior. Moreover, information about the tracking of such behavior at different phases of life would be useful in planning for interventions. However, there are a lack of longitudinal studies addressing FVC tracking among the Hawaiian populations.

Moreover, most studies lack a strong theoretical framework (75) such as the theory of planned behavior (TPB) or the social cognitive theory (SCT). Although a number of interventions have been implemented, most of them have experienced limited success (76). Therefore, a better understanding of the theoretical constructs that explain FVC behavior would be helpful to develop effective FVC interventions (70, 72, 74). However, there are few studies that adopt the TPB using longitudinal data,
especially targeting the Hawaii populations. Therefore, the specific objectives of this study were to:

1. track FVC changes from childhood to adolescence among the Hawai‘i population.
2. apply the TPB constructs to explain childhood FVC.

The secondary objective of this study was to examine whether childhood and adolescent FVC can predict adolescent obesity.

**Conceptual model: TPB to explain childhood FVC**

The TPB is frequently used to study a broad range of behaviors (77, 78) with a particular focus on health (78), including FVC (125-127). Several studies reveal the applicability of the theory in predicting FVC among children and adolescent (125-127). According to the TPB, a person’s individual motivational factors predict the performance of his/her specific behavior (84). A behavior is predicted by the intention and the perceived behavioral control (PBC) when it is not completely volitional. The intention is hypothesized to be determined by attitudes, subjective norms, and PBCs. An attitude represents an individual’s assessment of their own beliefs regarding the target behavior’s agency in producing effective outcomes. The subjective norms represent a person’s evaluation of whether significant others want them to engage in the target behavior and include his/her motivation to comply with the desires of those significant others. The effects of attitude and subjective norms on the behavior are mediated by
the intention. The PBC represents an individual's assessment of their own capacity on behavioral engagement.

According to the TPB, children with strong intentions to consume more FV are more likely to do so than the ones with weaker intentions (84). Subjective norm, individual’s attitudes, and PBC influence intentions regarding FVC. Children who have favorable attitudes toward FVC are more likely to have strong intentions than those with negative attitudes. For instance, children who have fun (i.e., the experiential aspect of an attitude) eating FV are more likely to make plans to eat more. Children who perceive that significant adults (e.g., parents) expect them to eat FV, and are motivated to obtain the parents’ approval, are likely to have strong intentions to eat more FV. In other words, children who are aware of their parents’ desires for them to eat more FV, and want to please their parents in that regard, try to (i.e., develop an intention to) eat more FV. Finally, children who feel in control of their FVC are likely to report strong intentions to eat FV compared to children with weaker perceptions of control (125-127).

This paper explored the changing pattern of FVC, and evaluated the TPB constructs to explain childhood FVC among Hawai’i populations. This paper also examined the ability of childhood and adolescent FVC to predict adolescent obesity. We hypothesized that:

Hypothesis 1: Higher childhood FVC precedes higher adolescent FVC
Hypothesis 2: The TPB constructs explain childhood FVC

a. children with favorable attitudes, strong perceptions about subjective norms, and strong PBC, all regarding FVC, will express greater intentions to consume FVC compared to those reporting less positive cognitions

b. PBC in childhood will have a direct positive influence on childhood FVC as well as be mediated by intention

c. children with greater intentions will eat more FV compared to those with weaker intentions

d. Subjective norm or attitude in childhood will not directly predict childhood FVC but be mediated by intention

Hypothesis 3: Childhood and adolescent FVC can predict adolescent obesity

a. children who have higher FVC levels will have a lower BMI in adolescence compared to those who have lower FVC levels

b. adolescent who have higher FVC levels will have a lower BMI in adolescence compared to those who have lower FVC levels

Methods

Design and sample

For this study, we used the data of two cohorts from the Fun 5 study (86,87), which had adopted a longitudinal cohort design, and included three consecutive surveys - baseline (BL), one-year follow-up (T1), and five-year follow-up (T2). In cohort 1, 259 students from 4th-6th grades (9-12 years old) were randomly selected in 2006 for the BL

**Description of Fun 5 study**

The Fun 5 study is an evidence-based PA and nutrition promotion program, which has been implemented in over 160 Hawai‘i state-legislated elementary A+ after-school programs for ten years. The program has been implemented with the aim of promoting PA and FVC among children. The program trained after-school staff on PA, nutrition, and sustainability. The nutrition component included lessons on benefits of FV, managing portion sizes, and sugar intake. The staff was also encouraged to be good role models in terms of snacking during A+ time, and to acknowledge when the children brought healthy snacks. To promote FVC, the program developed and distributed an activity booklet for students, which included word searches, cross words, coloring pages, and word/picture matching activities addressing local culturally appropriate FV. In order to increase the children’s PA, the program offered after school students a variety of organized, non-competitive, non-gender-specific, and fun physical activities in which children of all skill levels could participate and experience success (86, 87).

**Data collection procedure**

After obtaining a written consent from parents, the BL surveys were administered in after-school classes by the Fun 5 staff at the beginning of the school year. It took about 15 minutes for the students to complete the survey. At the end of
the school year, T1 was administered in after-school classes by the Fun 5 staff. For the T2 survey, the research staff mailed the BL participants at the addresses they provided on the consent form. The mail included a cover letter, a survey form, and a self-addressed and stamped envelope. The students who did not return the surveys were reminded twice through mail, once every two weeks. Data collection was stopped after three months. Each student received a $10 gift card for returning the follow-up survey. The study was approved by the University of Hawai’i Human Studies Program.

**Measures**

*Demographics* Children reported their age, grade, and gender in the BL survey. At T2, they also reported their height in feet and inches, and weight in pounds. This information was converted into centimeters and kilograms; BMI percentile was calculated using the age- and sex-specific growth curves from the CDC (88). They also reported their ethnicity at T2.

*FVC* To measure FVC, children were asked to report the number of servings of fruits and the number of servings of vegetables they consumed daily. Responses were given using whole numbers from zero servings to 10+ servings. Examples of servings sizes were provided (e.g. one serving of fruit = size of one baseball). These items have documented validity and reliability in adolescents (128). Servings for fruits and servings for vegetables were summed for a combined daily fruit and vegetable consumption score. Only children who reported both fruit and vegetable servings were counted in the analyses using this variable. Children reported their FVC at BL, T1, and T2.
TPB Constructs A five point Likert type scale (from “disagree a lot” to “agree a lot”) was used to measure the TPB constructs. The intention, attitude, subjective norms, and PBC were assessed by asking whether the children agree or disagree with these statements “I plan to eat five or more servings of fruits and vegetables every day”; “Eating fruits and vegetables is fun”; “Most people who are important to me think I should eat five or more servings of fruits and vegetables every day; “I believe I can eat five or more servings of fruits and vegetables every day” respectively. Children reported their intention, attitude, subjective norms, and PBC towards FVC at BL, and T1.

Statistical Analysis

Descriptive statistics were produced for age, sex, ethnicity, BMI, and predictor and outcome variables. To examine hypothesis 1, we developed piecewise growth mixer modeling (92-95) of FVC during BL to T1, and T1 to T2, with 2-level hierarchical linear modeling. We also used a random coefficient model to validate our results. These more complex analytic methods provide both the average trajectory across a group of individuals and capture heterogeneity in individual trajectories if it exists.

To examine hypothesis 2, structural equation modeling was used. We repeated the same model for BL data point of two cohorts. The overall fit of the models were assessed using a number of goodness of fit indices representing absolute, comparative and residual aspects of fit, specifically: chi-square index, comparative fit index (CFI), root mean squared error of approximation (RMSEA), and weighted root mean square residual (WRMR). The larger the probability associated with the chi-square, the better
the fit of the model to the data (96). The CFI > .95 indicates excellent model fit (97). An RMSEA of < .05 is excellent (96). The cut-off point for WRMR is < .90. Hypothesis 2a. was evaluated by the significance of standardized path coefficients of attitude, subjective norms, and PBC on intention; and $R^2$ on intention. Hypothesis 2b. was evaluated by the significance of standardized path coefficients of PBC on intention and childhood FVC. Hypothesis 2c. was examined by the significance of standardized path coefficient of intention on childhood FVC; and $R^2$ on childhood FVC. Hypothesis 2d. was examined by the significance of standardized path coefficients of attitude, subjective norms on childhood FVC.

A three-step multivariate linear regression was used to examine hypothesis 3. Covariates were entered into step one, childhood FVC into step two, and adolescent FVC into step three. Based on the available variables of the Fun 5 study data set, age, sex, ethnicity were assessed for statistical significance and were included in each FVC level model as covariates if significant at $p < .05$. In cohort 1, 259 students participated in BL survey and only 116 students followed up till the end of the study and in cohort 2, out of 248 students, only 88 students followed up till the end of the study. Comparisons of BL predictor and outcome variables of students who continued the study and who lost to follow up were examined by t-test. Two cohorts of data were analyzed separately using the same analytical process.
Results

Descriptive statistics

A summary of individual characteristics is provided in Table 6. Average age of students of cohort 1 was 14.70 (SD=.87), and cohort 2 was 14.61 (SD=.92), almost half were girls for both cohorts, most of them were from fourth grade (45.2% for cohort 1, and 42.6% for cohort 2), the largest ethnic group represented was Asian (68.5% for cohort 1, and 60.5% for cohort 2), and the mean BMI percentile for age for cohort 1 was 58.42 (SD = 27.28), and cohort 2 was 67.35 (SD=25.08). Overall, students reported mid level attitude, subjective norms, intention, and PBC for both cohorts (Table 6).
Table 6 Descriptive statistics for respondents, predictors, and outcome variables

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline(BL)</th>
<th>One year follow-up(T1)</th>
<th>Five year follow-up(T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>259</td>
<td>248</td>
<td>172</td>
</tr>
<tr>
<td>Age (mean in years and SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (in %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>51.2</td>
<td>52.9</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>48.8</td>
<td>47.1</td>
<td></td>
</tr>
<tr>
<td>Education (in %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>45.2</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>39.0</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>6&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>15.8</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native Hawaiian</td>
<td></td>
<td></td>
<td>15.7</td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td></td>
<td>68.5</td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td>11.1</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td>4.7</td>
</tr>
</tbody>
</table>
### Predictor and outcome variables

<table>
<thead>
<tr>
<th>Predictor and outcome variables</th>
<th>Mean(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>3.33(1.43)</td>
</tr>
<tr>
<td>Subjective norms</td>
<td>3.68(1.27)</td>
</tr>
<tr>
<td>PBC</td>
<td>3.62(1.32)</td>
</tr>
<tr>
<td>Intention</td>
<td>3.50(1.29)</td>
</tr>
<tr>
<td>FVC (servings per day)</td>
<td>6.84(4.53)</td>
</tr>
<tr>
<td>BMI percentile for age</td>
<td>3.58(1.31)</td>
</tr>
</tbody>
</table>

*SD = standard deviation, PBC = perceived behavioral control, FVC = fruit and vegetable consumption*

**Hypothesis one**

Figure 4a, and 4b present findings of observed FVC for randomly selected samples of 10% of students over time from cohort 1 and cohort 2 respectively. Students’ reported FVC showed a decreasing pattern for change over time. Table 7 presents findings from the piecewise growth mixer modeling. Mean FVC for cohort 1 students was 6.84 servings per day, which slightly increased 0.26 servings per day from time BL to T1, and decreased 2.50 servings per day from time T1 to T2. Mean FVC for cohort 2 students was 7.41 servings per day, which decreased 0.78 servings per day from time BL to T1, and further decreased 2.30 servings from time T1 to T2. Decrease in all time
points were statistically significant. However, the increase in FVC of cohort 1 from BL to T1 was not statistically significant. Results from the random coefficient model revealed similar findings for FVC change over time (table not shown).

**Figure 4a** Observed FVC of 10% randomly selected students from Cohort 1 over time

![Figure 4a](image)

**Figure 4b** Observed FVC of 10% randomly selected students from Cohort 2 over time

![Figure 4b](image)
Table 7  Piecewise growth mixer modeling for growth trajectories in FVC over time for cohort 1 and cohort 2

<table>
<thead>
<tr>
<th>Time</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-ratio</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>6.84</td>
<td>0.29</td>
<td>23.60</td>
<td>246</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BL to T1</td>
<td>0.26</td>
<td>0.36</td>
<td>0.73</td>
<td>246</td>
<td>0.464</td>
</tr>
<tr>
<td>T1 to T2</td>
<td>-2.50</td>
<td>0.38</td>
<td>-6.56</td>
<td>246</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cohort 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>7.41</td>
<td>0.31</td>
<td>23.56</td>
<td>235</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BL to T1</td>
<td>-0.75</td>
<td>0.36</td>
<td>-2.05</td>
<td>235</td>
<td>0.042</td>
</tr>
<tr>
<td>T1 to T2</td>
<td>-2.30</td>
<td>0.41</td>
<td>-5.65</td>
<td>235</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Hypothesis two

The TPB model was tested separately for both cohorts. The bivariate correlations among study variables are provided in table 8. Significant intercorrelations were observed among TPB constructs, and all the constructs were associated with childhood FVC. The hypothesized model revealed an excellent representation of the data in practical terms for both cohorts (table 9). Figure 5a, 5b present the path coefficients of TPB constructs explaining children’s FVC and intention at BL of cohort 1 and cohort 2 respectively. Attitude, subjective norms, and PBC explained 50-51% of the variance of intention to childhood FVC, and intention explained 15-17% of the variance of childhood FVC. Path coefficients revealed that attitude, subjective norms, and PBC were positively related with intention for childhood FVC; and PBC, and intention were also positively
related to FVC. Path coefficients also revealed that subjective norm or attitude did not directly predict FVC, rather were mediated by intention.

Table 8 Bivariate correlation among TPB constructs to explain childhood FVC

<table>
<thead>
<tr>
<th></th>
<th>Childhood FVC</th>
<th>Intention</th>
<th>Attitude</th>
<th>SN</th>
<th>PBC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cohort 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childhood FVC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>.42**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>.25**</td>
<td>.36**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>.28**</td>
<td>.51**</td>
<td>.33**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PBC</td>
<td>.45**</td>
<td>.65**</td>
<td>.31**</td>
<td>.46**</td>
<td>-</td>
</tr>
<tr>
<td><strong>Cohort 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Childhood FVC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>.32**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude</td>
<td>.26**</td>
<td>.43**</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>.22**</td>
<td>.51**</td>
<td>.24**</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>PBC</td>
<td>.34**</td>
<td>.60**</td>
<td>.39**</td>
<td>.41**</td>
<td>-</td>
</tr>
</tbody>
</table>

** = significant at the 0.01 level; SN = Subjective norms; PBC = Perceived behavior control
Table 9 Goodness of fit indices for the models to explain childhood FVC by TPB constructs

<table>
<thead>
<tr>
<th>Time</th>
<th>Cohort 1</th>
<th></th>
<th>Cohort 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BL</td>
<td></td>
<td>BL</td>
<td></td>
</tr>
<tr>
<td>Chi²</td>
<td>0.82</td>
<td>1</td>
<td>0.25</td>
<td>1</td>
</tr>
<tr>
<td>RMSEA</td>
<td>0.00</td>
<td>.90%CI</td>
<td>0.00</td>
<td>.90%CI</td>
</tr>
<tr>
<td>CFI</td>
<td>1.0</td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>WRMR</td>
<td>.25</td>
<td></td>
<td>.14</td>
<td></td>
</tr>
</tbody>
</table>

RMSEA= root mean squared error of approximation; CFI= comparative fit index; WRMR= weighted root mean square residual

Figure 5a Standardized path coefficients of TPB constructs with 95% confidence interval explaining FVC of cohort 1-BL participants (n=248)

PBC=perceived behavioral control
Figure 5b  Standardized path coefficients of TPB constructs with 95% confidence interval explaining FVC of cohort 2-BL participants (n=243)

Hypothesis three

Results from three step linear regression revealed that controlling for gender, both childhood FVC and adolescent FVC were not statistically significant predictors of adolescent BMI (table 10).

Table 10  Predicting adolescent obesity by childhood FVC, adolescent FVC, and demographic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>Std. Er.</th>
<th>95% CI of B</th>
<th></th>
<th>R²</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>-120.86</td>
<td>45.82</td>
<td>-.25</td>
<td>-211.70, -30.01</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
(Table continued)

<table>
<thead>
<tr>
<th></th>
<th>Step 2</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-120.40</td>
<td>46.10</td>
<td>-.25</td>
<td>-211.82, -28.98</td>
</tr>
<tr>
<td>Childhood FVC</td>
<td>-.96</td>
<td>5.35</td>
<td>-.02</td>
<td>-11.57, 9.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Step 3</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-120.48</td>
<td>46.36</td>
<td>-.25</td>
<td>-212.43, -28.53</td>
</tr>
<tr>
<td>Childhood FVC</td>
<td>-1.04</td>
<td>5.67</td>
<td>-.02</td>
<td>-12.28, 10.21</td>
</tr>
<tr>
<td>Adolescent FVC</td>
<td>.37</td>
<td>8.66</td>
<td>.01</td>
<td>-16.81, 17.55</td>
</tr>
</tbody>
</table>

**Cohort 2**

<table>
<thead>
<tr>
<th></th>
<th>Step 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-72.71</td>
<td>49.29</td>
<td>-.16</td>
<td>-170.72, 25.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Step 2</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-68.81</td>
<td>49.62</td>
<td>-.15</td>
<td>-167.50, 29.88</td>
</tr>
<tr>
<td>Childhood FVC</td>
<td>-4.21</td>
<td>5.18</td>
<td>-.09</td>
<td>-14.51, 6.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Step 3</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-72.83</td>
<td>49.31</td>
<td>-.16</td>
<td>-170.93, 25.26</td>
</tr>
<tr>
<td>Childhood FVC</td>
<td>-6.42</td>
<td>5.34</td>
<td>-.13</td>
<td>-17.04, 4.21</td>
</tr>
<tr>
<td>Adolescent FVC</td>
<td>14.07</td>
<td>9.32</td>
<td>.17</td>
<td>-4.46, 32.61</td>
</tr>
</tbody>
</table>

**Discussion**

Several studies have revealed tracking FVC from childhood to adolescence (27, 123, 129-134), and some of them have observed decreasing FVC (27, 123, 129-131, 134) over time. However, none of these studies have examined whether the decrease is
statistically significant or not. They just focused on tracking FVC from childhood to adolescence. They defined tracking as the “stability overtime”. In other word, they either measured the tracking as the stability in the rank at a group label, or calculated the proportion of participants that stayed in the same group over time. Since FVC stability study cannot provide a direction of significant change, findings lack insight to develop age appropriated intervention, for example, findings do not suggest whether intervention is necessary to increase FVC and or what age to target. However, two studies (28, 133) have examined the significant change of FVC over time. But, they have only used two time points, which also lack the tracking pattern. This study, therefore, tried to study the FVC from childhood to adolescence with three time points’ data, which would help to determine the ideal age for intervention.

The specific aims of this study were to investigate FVC from childhood to adolescence, and to evaluate if the TPB constructs to explain childhood FVC among children from Hawai‘i. The secondary aim was to examine the ability of childhood and adolescent FVC to predict adolescent obesity. While previous studies examined FVC over time, as well as TPB constructs to explain childhood FVC, very few studies have sought to understand these factors among NHOPi. NHOPi populations consist of diverse minority groups and are especially prone to obesity and its consequences (31-33). Studies also reveal a high prevalence of health risk behaviors and obesity/overweight among Hawaiian youth (68).

Piecewise growth mixer modeling and random coefficient modeling revealed significant decline of FVC from childhood to adolescent for both cohorts. Several studies
observed the same results (27, 28, 123, 129-131, 133), although they did not test the significance. Wang and colleagues (132) noted that food intake and dietary habits normally change during this time due to individual factors like physiological development, changes in parental influence and social and environmental changes. Patterson and colleagues (27) also argued that children are restricted by what parents and schools provide them to eat, while, adolescents to a lesser degree as both autonomy and the influence of peers increases. At the same time, young adults are usually independent and may have more control over their food choice. For example, soft drinks consumption increases in young adulthood (135, 136). The findings of decreasing trend of FVC from childhood to adolescence imply that interventions need to target children to increase their FVC, as well as continue over time. In this regard, it is important to know the determinants of childhood FVC, which is another aim of this study.

This study applied TPB constructs to explain childhood FVC among NHOPi populations. Overall, the model was an excellent fit to the data for both cohorts, meaning that our results support the TPB as an appropriate theoretical model for explaining childhood FVC behaviors. The model accounted for 50-51% of the variance in intention, and 15-17% of the variance in FVC behavior, which is similar to most TPB-FVC studies in children and adolescent populations (125-127, 137, 138). Our findings indicate that when a child holds a positive attitude toward FVC, perceives significant others believe he or she should consume more, and feels that he or she has the requisite ability to consume, that individual will form a strong intention. Similar findings have been
reported by many studies (125-127, 137, 138). Strong intentions will then lead to more consumption. For both cohorts, PBC was found to make the largest contribution to predicting FVC intention followed by subjective norms. However, several studies found attitude is a stronger predictor of FVC intentions compared to subjective norms (125, 137), which contradicts with this study. This might be due to the age of the respondents. Those studies were conducted on youth, who have more control over their food choice (27), while this study was conducted on elementary school children. This study revealed that a subjective norm is a stronger predictor if FVC intention, which is reported in several studies (125, 139). The subjective norm finding is likely due to the parental influence of eating behaviors during childhood.

The findings of this study provide us insights for tailoring future intervention designs for this population. To achieve more FVC among children, future interventions should implement strategies that reflect our findings on the importance of subjective norms and PBC. Findings of this study suggest that subjective norms and PBC have important role on FVC intention, therefore, encouraging parents and schools to enable access to more FV, providing self regulation behavioral skills for FVC, as well as encouraging them by informing the benefits of FVC seem beneficial.

**Strengths and limitations of the study**

The longitudinal design is a major strength of this study, which allowed us to evaluate changes over time and conclude regarding the predictors of change. In addition, two different cohorts allowed us to replicate our findings and validate our conclusions.
However, there were limitations that should be acknowledged when interpreting the results. First, data were collected by self-report in a supervised group setting (BL and T1) and on mail-return questionnaires (T2), which might have introduced social desirability and recall bias. However, Baranoski and Domel have found that children are able to give accurate dietary information and are well aware of the foods they have eaten (140). Moreover, FVC measures have documented reliability and validity (128). Second, the ethnic composition of this population might limit the generalizability. Third, like all longitudinal studies, this study experienced lost to follow-up; however, the BL comparisons between participants who lost to follow up and who continued the study showed no statistically significant difference in predictor and outcome variables. These non significant differences however might not be enough to minimize the selection bias. Fourth, single indicators were used for the TPB constructs, which might have potentially limited the content validity of the constructs. However, at least one other study (109) has successfully used single items to measure subjective norms and intention; and another study (126) to measure PBC. Moreover, our findings are similar to other TPB FVC studies. Finally, this study did not collect data on some possible confounding variables, for example, socio-economic status, parents’ motivation towards FVC, availability of FV at home and school, environmental factors, etc.
PAPER THREE: PREDICTING ADOLESCENTS’ OBESITY RELATED BEHAVIORS: THE FUN 5 STUDY

Introduction

Childhood obesity has dramatically increased and become a growing concern of the United States over the last three decades (1). There is no single or simple solution to addressing the childhood obesity epidemic, but a healthy lifestyle, including healthy eating and physical activity (PA), can lower the risk of becoming obese (140). Recent literature document that regular PA improves reductions in body adiposity, increases aerobic fitness, and contributes to a range of other health benefits from decreased blood pressure to increased bone mass in adulthood (16-19). PA also benefits children physically, mentally, emotionally, and socially (7, 8, 10, 17-19). Studies reveal that time spent in moderate to vigorous physical activity (MVPA) is negatively associated with the change of childhood BMI (35, 36). Considering the health benefits of PA, the Centers for Disease Control and Prevention (CDC) recommends at least 60 minutes of MVPA for children every day (37). However, a significant number of US children do not follow this recommendation (38, 39). According to Beighle (40), less than half of 6-11 year old children met the recommendation. Moreover, the percentage of children meeting recommended PA levels declines with age (21-23). In a pooled analysis of 26 studies, Dumith and colleagues (21) reveal a 7% PA decline per year among adolescents.

Conversely, several studies document that sedentary behavior (SB), especially TV watching, is associated with multiple risk factors for negative health outcomes, including
obesity (24, 25, 41-43). In addition, Proctor and colleagues (44) reveal that eating meals in front of the TV, especially, salty snacks, pizza, and soft drinks may influence energy intake. Despite the negative health consequences, TV watching appears to increase with age (24, 25).

Healthy diets also have positive effects on health, including obesity (45). The Dietary Guidelines for Americans recommend a diet rich in fruit and vegetable, whole grains, and fat-free and low-fat dairy products for individuals 2 years and older. The guidelines also recommend limiting the intake of solid fats for children, adolescents, and adults (46). However, most young people are not following these recommendations (46-48). Moreover, studies further reveal a tracking pattern of fruit and vegetable consumption (FVC) from childhood to adolescence to adulthood (26-28).

Several studies document that PA, SB, and FVC are associated with each other (29, 30, 49) and influence each other over time (49, 50). For example, Driskell and colleagues (30) document that healthy diet, intention to be active, and PA preferences cluster with PA. Lippke and colleagues (51) also reveal a strong correlation between nutrition and PA. These associations of obesity risk behaviors imply that a group of risk behaviors tend to occur together, and may be tied with common underlying factors. An intervention that addresses these behaviors together could potentially be more effective in the long run. Considering the interactions, researchers (52) suggest that multiple behavior change interventions may have a greater impact than single behavior change interventions.
Since PA, SB and FVC change over time from childhood to adolescence, it is also important to identify the age when these behaviors change. Findings of such studies may be helpful to develop age appropriate interventions. It is also important to find out how these behaviors interact in changing from childhood to adolescence, as during adolescence, individuals start to make their own choices and develop a personalized lifestyle.

Among the US, the native Hawaiian and other Pacific Islander (NHOPI) populations consists of diverse minority groups and are especially prone to obesity and its consequences (31-33). Novotny, Oshiro, and Wilkens found that almost one third of 5-8 year old NHOPI children are either obese or overweight (34). Studies reveal a high prevalence of health risk behaviors and obesity/overweight among Hawaiian youth (68). According to the 2008 Hawai’i Physical Activity and Nutrition Surveillance Report, 71% of the middle school children do not follow the recommended 60 minutes of MVPA and most (78 %) do not consume the recommended amount (five daily servings) of FV. Moreover, this report shows that Pacific Islander and Asian middle school students are more inactive (those engaging in no MVPA in the past seven days) than all other ethnicities (68). Failure to meet recommended guidelines for PA, FVC, and SB places children at an increased risk for overweight/obesity and for chronic conditions such as cardiovascular disease and diabetes (1). Understanding how multiple health risk behaviors track overtime is essential to developing effective disease prevention strategies in populations with high percentages of NHOPI population. Thus, the primary
aim of this study was to find out how PA, FVC, and SB influence with each other in tracking from childhood to adolescence. We hypothesized that:

a. children with higher PA, FVC, and lower SB will have higher PA at adolescents compared to those with lower PA, FVC, and higher SB. We examined this from BL to T1, T1 to T2, and BL to T2.

b. children with higher PA, FVC, and lower SB will have higher FVC at adolescents compared to those with lower PA, FVC, and higher SB. We examined this from BL to T1, T1 to T2, and BL to T2.

c. children with higher PA, FVC, and lower SB will have lower SB at adolescents compared to those with lower PA, FVC, and higher SB. We examined this from BL to T1, T1 to T2, and BL to T2.

Table 11 presents the hypotheses in an abridged format.
### Methods

#### Design and sample

For this study, we used the data of two cohorts from the Fun 5 study (86,87), which had adopted a longitudinal cohort design, and included three consecutive surveys - baseline (BL), one-year follow-up (T1), and five-year follow-up (T2). In cohort 1, 259 students from 4th-6th grades (9-12 years old) were randomly selected in 2006 for the BL

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Table 11 Hypotheses to predict adolescents’ obesity related behaviors

<table>
<thead>
<tr>
<th>Hypotheses BL to T1</th>
<th>Hypotheses T1 to T2</th>
<th>Hypotheses BL to T2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td><strong>Hypothesis a</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA</td>
<td>+</td>
<td>PA</td>
</tr>
<tr>
<td>FVC</td>
<td>+</td>
<td>PA</td>
</tr>
<tr>
<td>SB</td>
<td>-</td>
<td>PA</td>
</tr>
<tr>
<td><strong>Hypothesis b</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA</td>
<td>+</td>
<td>FVC</td>
</tr>
<tr>
<td>FVC</td>
<td>+</td>
<td>FVC</td>
</tr>
<tr>
<td>SB</td>
<td>-</td>
<td>FVC</td>
</tr>
<tr>
<td><strong>Hypothesis c</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PA</td>
<td>-</td>
<td>SB</td>
</tr>
<tr>
<td>FVC</td>
<td>-</td>
<td>SB</td>
</tr>
<tr>
<td>SB</td>
<td>+</td>
<td>SB</td>
</tr>
</tbody>
</table>

BL = baseline, T1 = one-year follow-up, T2 = five-years follow-up, PA = physical activity, FVC = fruits and vegetable consumption, SB = sedentary behavior

**Description of Fun 5 study**

The Fun 5 study is an evidence-based PA and nutrition promotion program, which has been implemented in over 160 Hawai‘i state-legislated elementary A+ after-school programs for ten years. The program has been implemented with the aim of promoting PA and FVC among children. The program trained after-school staff on PA, nutrition, and sustainability. The nutrition component included lessons on benefits of FV, managing portion sizes, and sugar intake. The staff was also encouraged to be good role models in terms of snacking during A+ time, and to acknowledge when the children brought healthy snacks. To promote FVC, the program developed and distributed an activity booklet for students, which included word searches, cross words, coloring pages, and word/picture matching activities addressing local culturally appropriate FV. In order to increase the children’s PA, the program offered after school students a variety of organized, non-competitive, non-gender-specific, and fun physical activities in which children of all skill levels could participate and experience success (86, 87).

**Data collection procedure**

After obtaining a written consent from parents, the BL surveys were administered in after-school classes by the Fun 5 staff at the beginning of the school
year. It took about 15 minutes for the students to complete the survey. At the end of the school year, T1 was administered in after-school classes by the Fun 5 staff. For the T2 survey, the research staff mailed the BL participants at the addresses they provided on the consent form. The mail included a cover letter, a survey form, and a self-addressed and stamped envelope. The students who did not return the surveys were reminded twice through mail, once every two weeks. Data collection was stopped after three months. Each student received a $10 gift card for returning the follow-up survey. The study was approved by the University of Hawai‘i Human Studies Program.

**Measures**

**Demographics** Children reported their age, grade, and gender in the BL survey. At T2, they also reported their height in feet and inches, and weight in pounds. This information was converted into centimeters and kilograms; BMI percentile was calculated using the age- and sex-specific growth curves from the CDC (88). They also reported their ethnicity at T2.

**PA** The Fun 5 study adopted the Godin Leisure-Time Exercise Questionnaire to measure the PA of the children (89, 90). To fill in the questionnaire, children had to indicate the number of days per week, and the minutes per day in which they engaged in strenuous, moderate, and mild PA (not including physical education). The minutes per day were listed as 10-minute increments starting with zero minutes and ending with 60+ minutes. All PA levels were defined and examples were given. The number of days children engaged in each PA level was multiplied by the number of minutes spent in
each PA level each day, resulting in a separate score of minutes per week for strenuous, moderate, and mild PA. Strenuous PA minutes per week and moderate PA minutes per week were added together and then divided by seven to calculate MVPA minutes per day. Only the children who reported both moderate and strenuous activities were included in the MVPA calculation. The Godin Leisure-Time Exercise Questionnaire has documented test-retest reliability ($r = 0.81$) and adequate validity ($r = 0.39$) when compared to kilocalories expended per day in a sample of 5th, 8th, and 11th graders (91). Children reported their PA at BL, T1, and T2.

**FVC** To measure FVC, children were asked to report the number of servings of fruits and the number of servings of vegetables they consumed daily. Responses were given using whole numbers from zero servings to 10+ servings. Examples of servings sizes were provided (e.g. one serving of fruit = size of one baseball). These items have documented validity and reliability in adolescents (128). Servings for fruits and servings for vegetables were summed for a combined daily fruit and vegetable consumption score. Only children who reported both fruit and vegetable servings were counted in the analyses using this variable. Children reported their FVC at BL, T1, and T2.

**SB** To measure sedentary behavior, children were asked to report the number of hours per day that they watch TV, play videogames, and use the Internet (not for homework). Responses were given using whole hours from zero hours to 10+ hours. This measure has documented test-retest reliabilities in a sample of college students (141). Children reported their SB at BL, T1, and T2.
Statistical Analysis

Descriptive statistics were produced for age, sex, ethnicity, BMI, and predictor and outcome variables. Baseline demographic characteristics and outcome variables were compared between the students who completed three time points and the students lost to follow up. Assumptions of multivariate normality were assessed by comparing two estimating methods: maximum likelihood method, and maximum likelihood robust method. To examine the hypothesis structural equation modeling was used. We repeated the same model for both cohorts. The overall fit of the models were assessed using a number of goodness of fit indices representing absolute, comparative and residual aspects of fit, specifically: chi-square index, comparative fit index (CFI), root mean squared error of approximation (RMSEA), and standardized root mean square residual (SRMR). The larger the probability associated with the chi-square, the better the fit of the model to the data (96). The CFI >.95 indicates excellent model fit (97). An RMSEA of <.05 is excellent (96). The cut-off point for SRMR is <.90. Hypothesis a. was evaluated by the significance of standardized path coefficients of BL PA, FVC, and SB on T1 PA; standardized path coefficients of T1 PA, FVC, and SB on T2 PA; and standardized path coefficients of BL PA, FVC, and SB on T2 PA. Hypothesis b. was evaluated by the significance of standardized path coefficients of BL PA, FVC, and SB on T1 FVC; standardized path coefficients of T1 PA, FVC, and SB on T2 FVC; and standardized path coefficients of BL PA, FVC, and SB on T2 FVC. Hypothesis c. was examined by the significance of standardized path coefficient of BL PA, FVC, and SB on T1 SB;
standardized path coefficients of T1 PA, FVC, and SB on T2 SB; and standardized path coefficients of BL PA, FVC, and SB on T2 SB.

**Results**

**Descriptive statistics**

A summary of individual characteristics is provided in Table 1. Average age of students of cohort 1 was 14.70 (SD=.87), and cohort 2 was 14.61 (SD=.92), almost half were girls for both cohorts, most of them were from fourth grade (45.2% for cohort 1, and 42.6% for cohort 2), the largest ethnic group represented was Asian (68.5% for cohort 1, and 60.5% for cohort 2), and the mean BMI percentile for age for cohort 1 was 58.42 (SD = 27.28), and cohort 2 was 67.35 (SD=25.08). On average students of cohort 1 had 42.89 (SD = 29.12) minutes of MVPA per day at BL, 44.92 (SD = 30.78) at T1, and 47.04 (SD = 28.98) at T2. Students of cohort 2 had 38.40 (SD = 29.13), 40.20 (SD = 30.95), and 45.06 (SD = 28.68) minutes of MVPA at BL, T1, and T2 respectively. Students of cohort 1 consumed 6.84 (SD = 4.53), 7.04 (SD = 4.68), and 4.64 (SD =2.87) servings of FV per day at BL, T1 and T2 respectively. Whereas, cohort 2 students consumed 7.40 (SD = 4.78), 6.65 (SD = 4.23), and 4.07 (SD = 2.75) servings of FV at same time points respectively. On average students of cohort 1 watched TV 4.05 (SD = 2.82) hours per day at BL, 3.76 (SD = 2.99) at T1, and 3.16 (SD = 1.77) at T2. Students of cohort 2 watched 3.99 (SD = 3.27), 4.29 (SD = 3.22), and 3.61 (SD = 2.31) hours per day at BL, T1, and T2 respectively (Table 12). Comparison of maximum likelihood and maximum likelihood robust estimation revealed that the assumptions of multivariate normality were met.
Table 12 Descriptive statistics for respondents, predictors, and outcome variables

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Baseline (BL)</th>
<th>One year follow-up (T1)</th>
<th>Five year follow-up (T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>259</td>
<td>248</td>
<td>172</td>
</tr>
<tr>
<td>Age (mean in years and SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (in %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>51.2</td>
<td>52.9</td>
<td></td>
</tr>
<tr>
<td>Girls</td>
<td>48.8</td>
<td>47.1</td>
<td></td>
</tr>
<tr>
<td>Education (in %)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th Grade</td>
<td>45.2</td>
<td>42.6</td>
<td></td>
</tr>
<tr>
<td>5th Grade</td>
<td>39.0</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>6th Grade</td>
<td>15.8</td>
<td>17.4</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native Hawaiian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparative analysis on baseline demographic characteristics and outcome variables revealed no significant differences between the students who completed three time points and the students lost to follow up (table not shown).

**Hypothesis testing**

The hypothesized model revealed a poor fit of the data in practical terms for both cohorts (table 13). The model was revised with the non significant paths deleted and the revised model revealed a better fit of the data (table 14). Figure 6a, and 6b present the revised model’s path coefficients of childhood obesity related behaviors on adolescent obesity related behaviors for cohort 1 and cohort 2 respectively. In cohort 1,

<table>
<thead>
<tr>
<th>Predictor and outcome variables</th>
<th>Mean(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVPA (in minutes/day)</td>
<td></td>
</tr>
<tr>
<td>42.89(29.12)</td>
<td>38.40(29.13)</td>
</tr>
<tr>
<td>FVC (servings per day)</td>
<td></td>
</tr>
<tr>
<td>6.84(4.53)</td>
<td>7.40(4.78)</td>
</tr>
<tr>
<td>Hours of TV watching/day</td>
<td></td>
</tr>
<tr>
<td>4.05(2.82)</td>
<td>3.99(3.27)</td>
</tr>
<tr>
<td>BMI percentile for age</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SD = standard deviation, MVPA = moderate to vigorous physical activity, FVC = fruit and vegetable consumption.
T1 PA was significantly predicted by BL PA and FVC, but not BL SB. For T2 PA, T1 PA, FVC and SB did not significantly predict T2 PA. However, BL PA significantly predicted T2 PA (Figure 6a). For cohort 2, T1 PA was significantly predicted by BL PA and FVC like cohort 1, however, the direction of BL FVC to T1 PA was negative. T2 PA was significantly predicted by T1 PA, and BL FVC. T1 SB did not predict T2 PA (Figure 6b).

Only BL FVC significantly predicted T1 FVC, and T1 FVC predicted T2 FVC in cohort 1. In cohort 2, BL FVC significantly predicted T1 FVC, but T1 FVC did not predict T2 FVC. However, BL FVC significantly predicted T2 FVC. Only BL SB significantly predicted T1 SB, and T1 SB predicted T2 SB in cohort 1. In cohort 2 BL SB significantly predicted T1 SB, but T1 SB did not predict T2 SB.

**Table 13** Goodness of fit indices for the models to explain adolescent PA, FVC, and SB by childhood PA, FVC, and SB with all paths

<table>
<thead>
<tr>
<th>Time</th>
<th>Chi²</th>
<th>df</th>
<th>p</th>
<th>Estimate</th>
<th>90%CI</th>
<th>Pro&lt;=0.5</th>
<th>CFI</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1</td>
<td>9.47</td>
<td>3</td>
<td>.02</td>
<td>.11</td>
<td>.03-.19</td>
<td>.09</td>
<td>.93</td>
<td>.03</td>
</tr>
<tr>
<td>Cohort 2</td>
<td>8.16</td>
<td>3</td>
<td>.04</td>
<td>.10</td>
<td>.02-.18</td>
<td>.13</td>
<td>.96</td>
<td>.03</td>
</tr>
</tbody>
</table>

RMSEA= root mean squared error of approximation; CFI= comparative fit index; SRMR= standardized root mean square residual

To improve power and interpretability, the possibility of combining the cohorts was explored. Baseline demographics and all three behaviors were compared between cohorts at each time points using t-tests. None of the comparisons were significant.
(p>.05). Thus the two cohorts were merged. Similar to the individual cohort analysis, the overall model fit was not adequate. The model was revised with non-significant paths deleted and revealed a better fit of the data (table 15). Figure 6c presents the revised model’s path coefficients of childhood obesity related behaviors on adolescent obesity related behaviors for both cohorts combined. BL PA predicted T1 PA and T2 PA. T2 PA was also predicted by BL FVC. BL FVC predicted T1 FVC and T2 FVC. T2 FVC was also predicted by T1 FVC. BL SB predicted T1 SB, and T1 SB predicted T2 SB.

**Table 14** Goodness of fit indices for the revised models to explain adolescent PA, FVC, and SB by childhood PA, FVC, and SB with significant paths only

<table>
<thead>
<tr>
<th>Time</th>
<th>Chi² Value</th>
<th>df</th>
<th>p</th>
<th>Estimate</th>
<th>90% CI</th>
<th>Pro&lt;=0.5</th>
<th>CFI</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 1</td>
<td>24.70</td>
<td>19</td>
<td>.17</td>
<td>.04</td>
<td>.00-.08</td>
<td>.62</td>
<td>.94</td>
<td>.06</td>
</tr>
<tr>
<td>Cohort 2</td>
<td>19.81</td>
<td>20</td>
<td>.47</td>
<td>.00</td>
<td>.00-.06</td>
<td>.86</td>
<td>1.00</td>
<td>.06</td>
</tr>
</tbody>
</table>

RMSEA= root mean squared error of approximation; CFI= comparative fit index; SRMR= standardized root mean square residual

**Table 15** Goodness of fit indices for the model to explain adolescent PA, FVC, and SB by childhood PA, FVC, and SB combining both cohorts

<table>
<thead>
<tr>
<th>Time</th>
<th>Chi² Value</th>
<th>df</th>
<th>p</th>
<th>Estimate</th>
<th>90% CI</th>
<th>Pro&lt;=0.5</th>
<th>CFI</th>
<th>SRMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>With all paths</td>
<td>14.13</td>
<td>3</td>
<td>.01</td>
<td>.10</td>
<td>.05-.16</td>
<td>.05</td>
<td>.95</td>
<td>.03</td>
</tr>
<tr>
<td>Significant paths</td>
<td>23.79</td>
<td>21</td>
<td>.30</td>
<td>.02</td>
<td>.00-.05</td>
<td>.96</td>
<td>.99</td>
<td>.04</td>
</tr>
</tbody>
</table>

RMSEA= root mean squared error of approximation; CFI= comparative fit index; SRMR= standardized root mean square residual
**Figure 6a** Standardized path coefficients of childhood behaviors with 95% confidence interval explaining adolescent behaviors of cohort 1 participants in revised model (n=192), significant paths only

BL = baseline, T1 = one-year follow-up, T2 = five-years follow-up, PA=physical activity, FVC = fruit and vegetable consumption, SB = sedentary activity
Figure 6b Standardized path coefficients of childhood behaviors with 95% confidence interval explaining adolescent behaviors of cohort 2 participants in revised model (n=182), significant paths only

BL = baseline, T1 = one-year follow-up, T2 = five-years follow-up, PA=physical activity, FVC = fruit and vegetable consumption, SB = sedentary activity
**Figure 6c** Standardized path coefficients of childhood behaviors with 95% confidence interval explaining adolescent behaviors of participants for both cohorts in revised model (n=374), significant paths only.

BL = baseline, T1 = one-year follow-up, T2 = five-years follow-up, PA=physical activity, FVC = fruit and vegetable consumption, SB = sedentary activity.
Discussion

With an aim to evaluate the predictability of childhood obesity related behaviors (PA, FVC, and SB) to adolescent behaviors (PA, FVC, and SB), this study used the data of the Fun 5 study. While several cross-sectional and longitudinal studies examined the relationship between PA and FVC (51, 142-158), or SB and FVC (159-162), or PA and SB (149, 163-168), very few longitudinal study examined these three (PA, FVC, and SB) behaviors together. Moreover, longitudinal study on the relationship of these three behaviors targeting NHOpI populations is very limited. NHOpI populations consist of diverse minority groups and are especially prone to obesity and its consequences (31-33). Studies also document a high prevalence of health risk behaviors and obesity/overweight among Hawaiian youth (68).

This study hypothesized and found that high PA, high FVC, and low SB in childhood predict high PA, high FVC, and low SB in adolescence, which means that all behaviors themselves are stable from childhood to adolescents. This is consistent with other studies that have found that childhood PA and FVC are predictive of adolescent PA and FVC (65, 132, 169, 170), and childhood SB is predictive of adolescent SB (49, 66). Findings imply that obesity related behaviors are developed in early childhood and continue to adolescence.

Looking at the cross behavioral prediction, our hypotheses are not largely confirmed. Only 1 path was significant (BL FVC to T2 PA) out of 18 paths of cross behavioral prediction. Findings reveal that SB in childhood, especially TV watching is not related with PA. Other longitudinal studies (165, 166) documented same findings.
Robinson and colleagues (165) followed 279 adolescents for two years and observed that TV watching was not associated with the change of PA levels. Neumark-Sztainer and colleagues (166) followed 201 adolescents for 8 months and documented similar results. Anderson and colleagues (163), and Nigg and colleagues (164) also did not find any meaningful relationship between TV watching and PA. However, several cross-sectional studies revealed an inverse association between times spent watching TV and playing video games with PA (149, 167, 168).

Findings of this study also revealed that SB and FVC are not associated with each other. Olivares and colleagues (162) found similar results between nutritional status and television viewing. However, several longitudinal studies (159-161) found inverse relationship between SB and FVC.

This study provides some indication that childhood FVC predicts adolescents PA (one of two paths was significant). This is consistent with other studies examining the relationship between FVC and PA that documented significant positive relationship (142-150), whereas, several others found no relationship or moderate relationship (151-158). For example, Emmonos and colleagues (150) found that PA were associated with improved dietary behaviors, including FVC, while Dutton and colleagues (151), in their analysis of a PA intervention's impact on dietary quality found no effect on FVC or dietary fat intake. Wilcox and colleagues (152), however revealed significant decreases in calories, fat, and cholesterol in result of a PA intervention, but no changes for FVC or fiber intake.
This study documented inconclusive results regarding the cross behavioral prediction from childhood to adolescents. This might be due to small sample size, and a focus solely on these three behaviors. For example, while predicting adolescent PA, this study only used childhood PA, FVC, and SB, and did not consider behavioral, social, and environmental factors that might influence adolescents PA. Therefore, further longitudinal studies are recommended to examine the predictability of childhood obesity related behaviors to adolescent behaviors. Findings of which might be useful to develop age appropriate interventions to fight against obesity epidemic.

The major strength of this study was the longitudinal design, which allowed us to predict the adolescent behaviors by childhood behaviors. In addition, two different cohorts allowed us to replicate our findings and validate our conclusions. However, there were limitations that should be acknowledged when interpreting the results. First, data were collected by self-report in a supervised group setting (BL and T1) and on mail-return questionnaires (T2), which might have introduced social desirability and recall bias. However, Baranoski and Domel have found that children are able to give accurate dietary information and are well aware of the foods they have eaten (139). Moreover, PA (91), FVC (128), and SB (141) measures have documented high reliability and validity.

Second, the ethnic composition of this population might limit the generalizability. Third, like all longitudinal studies, this study experienced loss to follow-up. However, we compared the baseline characteristics of lost to follow-up students with all students and found no statistically significant difference in behaviors and demographics. These non significant differences might not be enough to minimize the selection bias due to lost to
follow up. Finally, this study solely focused on PA, FVC, and SB; did not collect data on some possible confounding variables, for example, socio-economic status, parents’ motivation towards specific behavior, environmental factors, etc.

The results of this study provide evidence that childhood obesity related behaviors predict same adolescent behaviors, which means that these behaviors develop in childhood, and continue to be stable through adolescence. Therefore, interventions in childhood to increase PA, and FVC, and decrease SB are recommended to fight against the obesity epidemic. This study, however, did not find cross behavioral prediction from childhood to adolescent, which implies that further study is necessary to study these relationships over time.

**CONCLUSION**

Obesity in the United States has increased over the past three decades, and has become a public health crisis. Studies showed that healthy lifestyle, including healthy eating, increased PA, and decreased SB, can lower the risk of becoming obese, as well as developing obesity related disease and negative psycho-social consequences. In order to explore the changing pattern of PA and FVC from childhood to adolescence, as well as investigate how childhood PA, FVC, and SB behaviors influence adolescence PA, FVC, and SB behaviors, this study utilized the data of Fun 5 study. The Fun 5 study is an evidence-based PA and nutrition promotion program, which has been implemented in over 160 Hawai’i state-legislated elementary A+ after-school programs for ten years in order to increase PA and FVC among elementary school children.
This dissertation is divided into three papers. In paper one, we tried to explore the changing pattern of PA from childhood to adolescence, as well as examine the TPB constructs to explain childhood PA. Paper one also examined the impact of childhood and adolescent PA on adolescent obesity. Using piecewise growth mixer modeling, and random coefficient model, paper one did not find any significant pattern of PA change from childhood to adolescent. Structural equation modeling revealed the applicability of TPB. Findings also documented that PBC is the strongest variable to influence childhood PA followed by attitudes. Paper one did not find any impact of childhood and adolescent PA on adolescent BMI.

In paper two, we tried to explore the changing pattern of FVC from childhood to adolescence, as well as examine the TPB constructs to explain childhood FVC. Paper two also examined the impact of childhood and adolescent FVC on adolescent obesity. Using piecewise growth mixer modeling, and random coefficient model, paper two revealed a declining pattern of FVC from childhood to adolescent. Structural equation modeling revealed the applicability of TPB. Findings also documented that PBC is the strongest variable to influence childhood FVC followed by subjective norms. Paper two did not find any impact of childhood and adolescent FVC on adolescent BMI.

In paper three, we tried to examine the predictability of childhood PA, FVC, and SB on adolescent PA, FVC, and SB. Structural equation modeling revealed that all three childhood behaviors predicted same adolescent behaviors, which implies that these behaviors develop at childhood and continue to be stable over time. Paper three,
however, did not find cross behavioral prediction, except BL FVC to T2 PA, in this population.

The overall findings of this dissertation point to the following intervention strategies to fight against childhood obesity:

• Target early childhood for intervention activities regarding increasing PA, FVC, and decreasing SB

• Address children’s self confidence, attitudes, and subjective norms towards PA

• Address children’s self confidence, subjective norms, and attitudes towards FVC

This study also recommends:

• Further study to explore the change of obesity related behaviors from childhood to adolescent, which should be a longitudinal study, with objectively measured indicators. Advanced statistical technique (piecewise growth mixer modeling, random coefficient model for example) is recommended for data analysis.

• Further study to examine the relationships of childhood and adolescent PA and FVC with adolescent obesity. Longitudinal study with objectively measured PA, FVC, and obesity should be adopted for such kind of study.

• Further study to explore the condition where cross behavioral relationships may exist.
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