Copyright

by

Jieyi Zhu

2018

The Report Committee for Jieyi Zhu

Certifies that this is the approved version of the following report:

# Identifying Patterns of Weight-Related Health Behaviors among US adolescents, and Associated Risk of Obesity

APPROVED BY

SUPERVISING COMMITTEE:

|  |
| --- |
| Timothy Keitt |
|  |

# Identifying Patterns of Weight-Related Health Behaviors among US adolescents, and Associated Risk of Obesity

by

Jieyi Zhu, B. AGRICULTURE; M. AGRICULTURE; M.A.

Report

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Science in Statistics

The University of Texas at Austin

December 2018

## Acknowledgements

Abstract

# Identifying Patterns of Weight-Related Health Behaviors among US adolescents, and Associated Risk of Obesity

Jieyi Zhu, M.S. Stat.

The University of Texas at Austin, 2018

Supervisor: Timothy Keitt

Little is known about the current complex pattern of weight-related health behaviors in US adolescents. The goal of this report was to develop and examine a comprehensive latent class analysis (LCA) model examining the prevalence of combined associations of physical activity (PA), sedentary behaviors (SB) and eating behaviors (EB) with obesity among female and male US adolescents (n= 12,031). Four classes and five classes were identified for female and male adolescents, respectively. Among which, 3 classes were similar and were characterized as “low PA/ low SB/ unhealthy EB”, “low PA/ moderately high SB/ unhealthy EB”, and “high PA/ low SB/ unhealthy EB”. In addition, “low PA/ low SB/ healthy EB” was unique to female adolescents, while “moderately high PA/ high SB/ Healthy EB” and “moderately high PA/ low SB/ healthy EB” were unique to males. Furthermore, selected sociodemographic characteristics of were examined based on each class across females and males. The proportion in each class who were classified as obese were different. The findings from this report provide insights of the current health needs for US adolescents, and imply that gender-specific intervention strategies were required to reduce the risk of obesity among adolescents.

Table of Contents

[List of Tables viii](#_Toc523389886)

[Chapter 1: Introduction 1](#_Toc523389887)

[1.1 Overview 1](#_Toc523389888)

[1.2 Physical activity and obesity 2](#_Toc523389889)

[1.3 Eating behaviors and obesity 2](#_Toc523389890)

[1.4 Sedentary behavior and obesity 3](#_Toc523389891)

[1.5 Latent class analysis 4](#_Toc523389892)

[Chapter 2 Data and Methodology 5](#_Toc523389893)

[2.1 Sample 5](#_Toc523389894)

[2.2 Measures 5](#_Toc523389895)

[2.2.1 Weight-related behaviors 5](#_Toc523389896)

[2.2.2 Body mass index 6](#_Toc523389897)

[2.3 Statistical analysis 8](#_Toc523389898)

[Charter 3 Results 9](#_Toc523389899)

[3.1 Descriptive Statistics 9](#_Toc523389900)

[3.2 Inter-correlations 9](#_Toc523389901)

[3.3 Latent Class analysis 10](#_Toc523389902)

[Chapter 4 Discussion 20](#_Toc523389903)

[References 23](#_Toc523389904)

## List of Tables

[Table 1: Weight-related health behavior categories and descriptions 7](#_Toc523390080)

[Table 2: Sample characteristics and descriptive statistics of weight-related behaviors 13](#_Toc523390088)

[Table 3: Inter-correlation of eight weight-related health behaviors 14](#_Toc523390089)

[Table 4: Determining the number of latent classes for male US adolescents using LCA 15](#_Toc523390090)

[Table 5: Determining the number of latent classes for female US adolescents using LCA 15](#_Toc523390091)

[Table 6: Four-class model of weight-related health behaviors among female US adolescents 16](#_Toc523390092)

[Table 7: Five-class model of weight-related health behaviors among male US adolescents 17](#_Toc523390093)

[Table 8: Weight status and sociodemographic differences among Latent Classes in female US adolescents 18](#_Toc523390094)

[Table 9: Weight status and sociodemographic differences among Latent Classes in male US adolescents 19](#_Toc523390095)

## Chapter 1: Introduction

### Overview

Obesity is one of the major public health concerns in recent years, since it may directly lead to developing chronic disease, such as diabetes, cardiovascular disease, and joint problems *etc*.([1](#_ENREF_1), [2](#_ENREF_2)). Research found that the rate of obesity in adolescents aged 12-19 years dramatically increased from 5% in 1980 to about 21% in 2012 ([3](#_ENREF_3)). Obesity is a puzzling disease which was caused by a complex combination of risk factors. Weight-related lifestyle choices, such as overeating and sedentary lifestyle, is one of the most important risk factors for obesity. The adolescent years are an ideal and crucial period to develop healthy behaviors. Many of the healthy lifestyle habits formed during this developmental stage usually last well into adulthood ([4](#_ENREF_4)). It has been reported that extremely obese adolescent may continue to suffer from obesity as adults without intervention ([5](#_ENREF_5)). Many previous studies have shown that between energy intake and energy expenditure ([6](#_ENREF_6), [7](#_ENREF_7)). This imbalance can be highly affected by a lot of weight related behaviors, such as physical activity, sedentary behavior, and eating behavior ([8](#_ENREF_8), [9](#_ENREF_9)). Poor eating habits such as, drinking sugar-rich beverages and eating calorie-dense food/snacks, are associated with the risk of obesity([10](#_ENREF_10), [11](#_ENREF_11)). Sedentary behaviors, such as television viewing, using computer for a long time, also increase risk of obesity. In contrast, a great deal of evidence has demonstrated that physical activity can reduce risk of obesity.

### Physical activity and obesity

Physical activity plays important role in reducing the risk of obesity. A recent research shows that poor physical fitness in adolescence strongly predicted the risk of obesity (OR 3.9, 95%CI 1.4-10.9) and abdominal obesity (4.8, 95%CI 1.9-12.0) ([12](#_ENREF_12)). Another report suggests that physical activity, such as resistance training, may promote a negative energy balance and may change body fat distribution ([13](#_ENREF_13)). However, physical activity levels are declining in all over the world contributing to the global obesity epidemic ([14](#_ENREF_14)). The U.S. Dept. of Health and Human Services, and other authorities established guideline to promote physical activity in youth. It recommends adolescent should get at least 60 minutes of moderate and vigorous-intensity per day with at least three days of muscle-strengthening physical activity each week ([15-17](#_ENREF_15)).

In this study, we examined the relationship of two physical activity variables: PA7DAY (physical activity at least 60 minutes per day on all 7 days) and DLYPE (attended physical education classes on all 5 days) with obesity.

### Eating behaviors and obesity

 Unhealthy eating behaviors are also important factors for increasing the risk of obesity. Eating habit can be developed during childhood and adolescence and will last into adulthood. Many researches have demonstrated that obesity is highly associated with the intake of calories-dense food such as fast-food, sugar-sweetened beverages ([10](#_ENREF_10), [11](#_ENREF_11)); while having breakfast and proper fruit and vegetable intake could prevent obesity ([18](#_ENREF_18)). A recent study developed by Yvonne C. Anderson et al.  reported that 54% of New Zealand students age 5-17 years had daily energy intake above the recommended guidelines, while fruit and vegetable intake was below the guidelines (mean 3.5 vs 5 servings per day), and the mean weekly breakfasts were less than the national average (5.9 vs 6.5) ([19](#_ENREF_19)).

### Sedentary behavior and obesity

In addition to physical activity and eating behavior, sedentary behavior (SB) is crucial in obesity. It has been reported that lack of physical activity and more time spend on sedentary behavior will increase the risk of obesity ([20](#_ENREF_20)). Because of the increased use of information and communication technology in modern society, the amount of time adolescents spend in sedentary activities has increased largely ([21](#_ENREF_21)). Sedentary behaviors such as watching TV, playing digital games and computers using are critical risk factors affecting obesity prevalence ([22](#_ENREF_22)). A computerized search developed by Laruen Arundell *et al.* showed that adolescents spent 57 % of the after-school period in sedentary time, and they spend 20 % of the period for TV viewing, 20% for non-screen based SB (including homework), 18% for screen-based SB (including TV viewing), 13% for homework/academics, 12% for motorised transport, 9% for social SB, and 6% for screen-based SB (excluding TV viewing) ([23](#_ENREF_23)). A guideline established by the association of pediatric and experts recommend that adolescents limit television and other screen time ( 2 hours per day)([8](#_ENREF_8), [24](#_ENREF_24)), [6](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3786734/#R6),[7](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3786734/#R7) but the sedentary time spend by adolescents usually more than the guideline. ( 2.5 to 3 hours of television per day and to spend an additional 1.5 to 2 hours using the computer ([25](#_ENREF_25)).Understanding correlates of specific sedentary behaviors can inform the development of interventions to reduce obesity ([26](#_ENREF_26)).

### Latent class analysis

Latent class analysis (LCA) is a statistical method for identifying underlying subgroup among subjects using categorical and cross-sectional observed indicators. It is a subset of structural equation modeling. LCA assumes that each indicator has its own probability distribution across the classes or subgroups, and that the overall population follows a finite mixture model ([27](#_ENREF_27)). Because of the complexity of weight-related behaviors, LCA is the best method to capture the meaningful key patterns of behaviors among the samples ([28](#_ENREF_28)). LCA has been successfully employed in a lot of studies. For example, it was used to study weight-related health behaviors among 2- and 4-year College Students([29](#_ENREF_29)), the association of obesity risk with eating and physical activity in children ([30](#_ENREF_30)), and physical activity and sedentary activity associated with overweight and obesity ([31](#_ENREF_31)). The results from those studies have demonstrated that LCA is an effective and valid approach in classifying individuals with similar characteristics.

In our project, LCA was used for two reasons. First, most of variables in our data are categorical variables. Second, the purpose of our study was to identify the latent subgroups with patterns of physical activity, eating behavior and sedentary behaviors and to examine the association of latent subgroups with obesity status.

## Chapter 2 Data and Methodology

### 2.1 Sample

The data used in this report were obtained from the Youth Risk Behavior Surveillance System (YRBSS), 2015. This is a three-stage cluster sample design survey monitoring priority health risk behaviors and the prevalence of obesity of students from 9th – 12th grade in USA. They were asked for six types of health risk behaviors questions including physical activity, dietary behaviors, weight control, sexual behaviors, alcohol and drug use, tobacco use, and violence, etc. These data are available through the Centers for Disease Control of Prevention (CDC).

This 2015 national YRBS data contains a total of 15,624 responses. Missing values in gender, race, grade, body mass index (BMI), and questions asking about physical activity, sedentary behavior and eating behavior diet were excluded. The final sample consisted of 12,031 adolescents were used in this study.

### 2.2 Measures

### 2.2.1 Weight-related behaviors

As shown in Table 1, eight weight-related behaviors were classified into three categories: physical activity, eating behavior, and sedentary behavior.

Physical activity includes two behaviors: PA7DAY (≥ 60min/day of physical activity on all 7 days) and DLYPE (attended all 5 days physical education class). PA7DAY was determined by the question asking the number of days student had physical activity for a total of at least 60 min per day during the past 7 days. The adolescents were dichotomized into either being physically active for at least 60 min per day on all 7 days or less than 7 days. For DLYPE, the number of days students go to physical education class per week was used for classifying adolescents into either they attended physical education classes on all 5 days or less than 5 days.

Eating behaviors includes four variables: FR3(ate fruit or drank 100% fruit juices three or more times per day), VEG3 (Ate vegetables three or more times per day), SODA1 (Drank a can, bottle, or glass of soda or pop one or more times per day), and BK7DAY (Ate breakfast on all 7 days). They were categorized by corresponding questions, respectively.

Two questions asking about sedentary behaviors. Students provided the number of hours they had spent on watching TV and using a computer for non-school work or playing video games on an average school day. These questions were used to classify TV3 (more than 3 hours TV viewing per day) and COMP3 (more than 3 hours using computer/playing video game per day), respectively.

### 2.2.2 Body mass index

Body mass index (BMI) is calculated using person’s weight in kilograms divided by the square of height in meter. It can be used as an indicator to classify persons who are underweight, normal weight, and overweight/obese. Adolescents with high BMI (at or above 95th percentile) were considered obese([32](#_ENREF_32)).

|  |  |
| --- | --- |
| **Category** | **Description** |
| **Physical activity** |  |
| PA7DAY | Whether the student was physically active doing any kind of physical activity that increased their heart rate and breath depth for at least 60 min per day on all 7 past days. |
| DLYPE | Whether the students attended physical education classes on all 5 school days. |
| **Eating behavior** |  |
| FR3 | Whether the student ate fruit or drank 100% fruit juices more than 3 times per day during the past 7 days. |
| VEG3 | Whether the student ate vegetables more than 3 times per day during the past 7 days. |
| SODA1 | Whether the student drank soda more than one times per day during past 7 days. |
| BK7DAY | Whether the student ate breakfast on all 7 days during the past 7 days. |
| **Sedentary behavior** |  |
| TV3 | Whether the students watched TV for more than 3 hours per day on an average school day. |
| COMP3 | Whether the students used a computer for something that was not school work or played video games for more than 3 hours per day on an average school day |

Table 1: Weight-related health behavior categories and descriptions

### 2.3 Statistical analysis

First, we fitted a set of LCA models with different number of latent class (1 to 7) to identify the model that best described distinct subgroups of weighted-related behaviors among female and male adolescents. The number of classes of the best model was determined by a combination of two aspects: 1) the relative fit indices, a lower value indicates a better model. It includes Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), adjusted BIC (ABIC), and consistent AIC (CAIC). BIC played a significant role in model selection. It was reported as the best indicator for determining the number of latent classes when compared models ([33](#_ENREF_33)); 2) Interpretability. Each latent class should not be near-zero in size, and should be meaningful and distinguishable from the others based on the item-response probability. Second, we examined the association of latent class with weight status, grade, age, and race for female and male adolescents. All LCA analyses were conducted using poLCA package in R software.

## Charter 3 Results

### 3.1 Descriptive Statistics

Table 2 showed the descriptive characteristics of all variables of the sample. A total of 12031 US adolescents was included in this study. The age ranged from 12 to 18 years old. Of all the participants, 6093 (50.6%) were female and 5938(49.4%) were male.

There were no obvious gender differences among grades, race, age, except weight status which showed more male adolescents (18.4%) than female (12%) adolescents were obese. In addition, two categories of weight-related behaviors, physical activity and eating behavior, showed significant gender differences. Higher percentage of male adolescents had PA7DAY (35.6%), DLYPE (35.6%), FR3 (22.7%) and VEG3(16.4%) than female adolescents who had 16.5%, 26.3%, 18.4% and 13.2% respectively. No obvious gender disparities in sedentary behaviors (TV3 and COMP3) was found.

### 3.2 Inter-correlations

Table 3 showed the inter-correlations of variables of our interest. The results showed that the relationship of most of variables were significantly correlated with each other, except for two pairs: TV3 and VEG3, DLYPE and COMP3. Fruit (FR3) and vegetable (VEG3) had strongest correlation among these variable, r = 0.394. Physical activity (PA7DAY) was positively correlated with FR3 (r = 0.137), VEG3 (r = 0.118), BK7DAY (r = 0.154), but negatively correlated with TV3 (r = -0.023) and COMP3 (r = -0.095). It suggested that active adolescents were more likely having healthy diet and having low sedentary time.

### 3.3 Latent Class analysis

#### 3.3.1 Latent class profiles

To determine the optimal number of latent classes, different number (1-7) of classes of weight-related behaviors for female and male adolescents were tested, and the results were showed in Table 4 and Table 5, respectively. The analysis yielded a 4-class model for female adolescents and 5-class model for male adolescents. These models had the lowest BIC (50598.62 for female and 55239.04 for male) practically interpreted the distinct classes of individuals with respect to their weight-related behaviors.

The probability of each weighted-related behavior of each latent class were shown in Table 6 (female adolescents) and Table 7 (male adolescents). Higher probabilities in the PA behaviors suggested that this subgroup had higher likelihood of being physically active; higher probabilities in SB items indicated that this subgroup were more likely spending more time on SB; higher probabilities in EB (fruit, vegetable) indicated higher likelihood of having healthy eating habits. The result showed that female adolescents had unique Class 1, while male adolescence had unique Class 1 and Class 5. The rest of classes (Class 2, 3 and 4) were very similar.

Class 1 (female: Low PA/ Low SB/ Healthy EB; male: Moderately high PA/ High SB/ Healthy EB) contained 12.5% and 19% of female and male adolescents, respectively. Both of female and male students in this subgroup had healthy eating habits. Female students were unlikely engaging in physical activity and sedentary behaviors, while male students were opposite.

Class 2 (labeled Low PA/ Low SB/ Unhealthy EB) was a largest subgroup for both female and male adolescents with 44.4% and 40.2% of female and male students, respectively. The individuals in this subgroup were unlikely to engage in physical activities and having healthy diet, but they spent less time on TV watching and computer using.

Class 3 (labeled Low PA/ Moderately high SB/ Unhealthy EB) was characterized by moderately high probabilities of engaging in sedentary time, but low probabilities of being engaged in physical activity and having healthy diet. Class 3 represented 4.8% and 23.1% of female and male students, respectively.

Class 4 (labeled High PA/ Low SB/ Unhealthy EB) included individuals who were physically active and unlikely to spend excess screen time, but they had bad eating habits. This class was comprised of 38.4% and 11% of female and male adolescents, respectively.

Class 5 (male: Moderately high PA/ Low SB/ Healthy EB) was unique for male students. The students in this subgroup had high probability of being engage in healthy life style. They were physically active, spending less screen time and having healthy diet. It contained only 6.7% of male adolescents.

#### 3.3.2 Composition differences across classes

Table 8 and Table 9 showed weight status and other sociodemographic characteristics across latent classes of female and male adolescents, respectively. The percentage of female students being obese was the highest in both class 2 and class 4 (14.1%), while male students had much more prevalent of obesity in classes 4 (19.5%) and 5 (20.9%). For both female and male students, the most prevalent of healthy weight was in class 3 (female: 75.4%, male: 68.7%).

For female students, Class 3 had the highest proportion of students in the 9th Grade (39%), while Class 4 of male students had the highest proportion in the 12th Grade (29.4%). Within female students, Class 1 and Class 3 had more than 27% of students were 17 years old and 15-16 years old, respectively, whereas there were more than 29% male students in Class 2 and Class 4 with age 16 and 17, respectively. Within female and male students, most of students were White and Hispanics in all classes.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Total**  **(n = 12031)** | **Female**  **(n = 6093)** | **Male**  **(n = 5938)** |
| **Characteristic** | % | % | % |
| **Grade** |  |  |  |
| 9th | 24.6 | 24.8 | 24.3 |
| 10th | 25.3 | 25.4 | 25.2 |
| 11th | 25.6 | 25.2 | 26.0 |
| 12th | 24.5 | 24.6 | 24.5 |
| **Race** |  |  |  |
| White | 42.1 | 42.7 | 41.5 |
| Hispanic | 35.9 | 35.6 | 36.1 |
| Black/African American | 10.9 | 11.1 | 10.6 |
| Asian | 4.5 | 4.3 | 4.8 |
| Others | 6.7 | 6.4 | 7 |
| **Age** |  |  |  |
| 12 or under | 0 | 0 | 0.1 |
| 13 | 0.1 | 0.1 | 0.1 |
| 14 | 9.2 | 10 | 8.4 |
| 15 | 24 | 24.6 | 23.5 |
| 16 | 26 | 26 | 26 |
| 17 | 25.8 | 25.8 | 25.7 |
| 18 or older | 14.8 | 13.4 | 16.3 |
| **Weight status** |  |  |  |
| Normal weight (5 to < 85th percentile) | 65.6 | 68.8 | 62.2 |
| Overweight (85 to < 95th percentile) | 16.6 | 17.2 | 16.1 |
| Obese (≥95th percentile) | 15.2 | 12.0 | 18.4 |
| **Weight-related Behaviors** |  |  |  |
| ≥ 3h/day of TV viewing | 26.4 | 26.2 | 26.5 |
| ≥ 3h/day of computer/video game | 43.8 | 44.8 | 42.8 |
| ≥ 3 times fruits/day | 20.5 | 18.4 | 22.7 |
| ≥ 3 times vegetables/day | 14.8 | 13.3 | 16.4 |
| ≥ 1 soda/day | 21.7 | 17.6 | 25.9 |
| All 7 days breakfast consumption | 34.9 | 30.4 | 39.6 |
| ≥ 60min/day of physical activity | 25.9 | 16.5 | 35.6 |
| All 5 days physical education class | 30.9 | 26.3 | 35.6 |

Table 2: Sample characteristics and descriptive statistics of weight-related behaviors

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TV3 | 1 |  |  |  |  |  |  |  |
| COMP3 | 0.132\*\* | 1 |  |  |  |  |  |  |
| FR3 | 0.02\* | -0.019\* | 1 |  |  |  |  |  |
| VEG3 | 0 | -0.041\*\* | 0.394\*\* | 1 |  |  |  |  |
| SODA1 | 0.124\*\* | 0.088\*\* | 0.1\*\* | 0.134\*\* | 1 |  |  |  |
| BK7DAY | -0.018\* | -0.045\*\* | 0.119\*\* | 0.11\*\* | -0.043\*\* | 1 |  |  |
| PA7DAY | -0.023\* | -0.095\*\* | 0.137\*\* | 0.118\*\* | 0.058\*\* | 0.154\*\* | 1 |  |
| DLYPE | 0.045\*\* | 0.009 | 0.063\*\* | 0.025\*\* | 0.035\*\* | 0.039\*\* | 0.192\*\* | 1 |
|  | TV3 | COMP3 | FR3 | VEG3 | SODA1 | BK7DAY | PA7DAY | DLYPE |

Table 3: Inter-correlation of eight weight-related health behaviors

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Female (n = 6093)** | | | | | | |
|  | df | AIC | BIC | ABIC | CAIC | G2 |
| **1-class** | 247 | 51621.45 | 51675.17 | 51649.75 | 51683.17 | 1667.6403 |
| **2-class** | 238 | 50731.65 | 50845.8 | 50791.78 | 50862.8 | 759.8416 |
| **3-class** | 229 | 50599.43 | 50774.01 | 50691.39 | 50800.01 | 609.6176 |
| **4-class** | **220** | **50363.6** | **50598.62** | **50487.4** | **50633.62** | **355.7878** |
| **5-class** | 211 | 50304.34 | 50599.8 | 50459.98 | 50643.8 | 278.5339 |
| **6-class** | 202 | 50286.26 | 50642.15 | 50473.73 | 50695.15 | 242.4487 |
| **7-class** | 193 | 50283.54 | 50699.86 | 50502.84 | 50761.86 | 221.7289 |

Table 4: Determining the number of latent classes for male US adolescents using LCA

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Male (n=5938)** | | | | | | |
|  | DF | AIC | BIC | ABIC | CAIC | G2 |
| **1-class** | 247 | 51621.45 | 56942.27 | 56916.85 | 56950.27 | 2386.5526 |
| **2-class** | 238 | 55548.91 | 55662.62 | 55608.6 | 55679.62 | 1028.698 |
| **3-class** | 229 | 55223.47 | 55397.38 | 55314.76 | 55423.38 | 685.2567 |
| **4-class** | 220 | 55040.71 | 55274.83 | 55163.61 | 55309.83 | 484.4979 |
| **5-class** | **211** | **54944.72** | **55239.04** | **55099.22** | **55283.04** | **370.5097** |
| **6-class** | 202 | 54898.26 | 55252.78 | 55084.36 | 55305.78 | 306.0474 |
| **7-class** | 193 | 54866.41 | 55281.13 | 55084.11 | 55343.13 | 256.1967 |

Table 5: Determining the number of latent classes for female US adolescents using LCA

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female (n =6093) 4 latent class** | | | |
|  | Class 1  Low PA/  Low SB/  Healthy EB | Class 2  Low PA/  Low SB/  unhealthy EB | Class 3  Low PA/  Moderately high SB/  Unhealthy EB | Class 4  High PA/  Low SB/  Unhealthy EB |
|  | (12.5%) | (44.4%) | (4.8%) | (38.3%) |
| ≥ 3h/day of TV viewing | 0.27 | 0.09 | 0.41 | 0.28 |
| ≥ 3h/day of computer/video game | 0.38 | 0.31 | **0.59\*** | 0.45 |
| ≥ 3 times fruits/day | **0.75\*** | 0.09 | 0.1 | 0.22 |
| ≥ 3 times vegetables/day | **0.73\*** | 0.06 | 0.04 | 0.09 |
| ≥ 1 soda/day | 0.31 | 0.01 | 0.27 | 0.23 |
| All 7 days breakfast consumption | 0.48 | 0.37 | 0.18 | 0.41 |
| ≥ 60min/day of physical activity | 0.27 | 0.15 | 0.05 | 1\* |
| All 5 days physical education class | 0.29 | 0.18 | 0.27 | 0.79\* |

Table 6: Four-class model of weight-related health behaviors among female US adolescents

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Male (n=5938) 5 latent classes** | | | | |
|  | Class 1  Moderately High PA/  High SB/  Healthy EB | Class 2  Low PA/  Low SB/  Unhealthy EB | Class 3  Low PA/  Moderately high SB/ Unhealthy EB | Class 4  High PA/  Low SB/  Unhealthy EB | Class 5  Moderately High PA/  Low SB/  Healthy EB |
|  | (19%) | (40.2%) | (23.1%) | (11%) | (6.7%) |
| ≥ 3h/day of TV viewing | **0.81\*** | 0.23 | 0.32 | 0.22 | 0.05 |
| ≥ 3h/day of computer/video game | **0.75\*** | 0.43 | **0.57\*** | 0.31 | 0.23 |
| ≥ 3 times fruits/day | **0.73\*** | 0.1 | 0.09 | 0.13 | **0.83\*** |
| ≥ 3 times vegetables/day | **0.54\*** | 0.04 | 0.1 | 0.06 | **0.74\*** |
| ≥ 1 soda/day | **0.61\*** | 0 | **0.73\*** | 0.19 | 0.34 |
| All 7 days breakfast consumption | **0.6\*** | 0.34 | 0.22 | 0.49 | **0.59\*** |
| ≥ 60min/day of physical activity | **0.56\*** | 0 | 0.13 | **1 \*** | **0.56\*** |
| All 5 days physical education class | **0.55\*** | 0.29 | 0.23 | **0.51\*** | 0.39 |

Table 7: Five-class model of weight-related health behaviors among male US adolescents

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Female (n =6093) 4 latent class** | | | |
|  | Class 1  Low PA/  Low SB/  Healthy EB | | Class 2  Low PA/  Low SB/  unhealthy EB | Class 3  Low PA/  Moderately high SB/  Unhealthy EB | Class 4  High PA/  Low SB/  Unhealthy EB |
|  | **%** | | **%** | **%** | **%** |
| **Weight status** |  | |  |  |  |
| Normal | 71.8 | | 65.4 | 75.4 | 67.8 |
| Overweight | 16.5 | | 18.3 | 15.2 | 16 |
| Obese | 9.8 | | 14.1 | 8 | 14.1 |
| **Grade** |  | |  |  |  |
| 9th | 23 | | 24.7 | 39 | 24.7 |
| 10th | 23.5 | | 27 | 26.8 | 25.7 |
| 11th | 26.8 | | 24.2 | 18.8 | 26.5 |
| 12th | 26.7 | | 24.2 | 15.5 | 23.2 |
| **Age** |  | |  |  |  |
| 12 | 0 | | 0 | 0 | 0.2 |
| 13 | 0.1 | | 0 | 0 | 0 |
| 14 | 9 | | 10.2 | 17.1 | 8.8 |
| 15 | 22.9 | | 25.4 | 27.9 | 25.5 |
| 16 | 26 | | 26 | 27.1 | 25.8 |
| 17 | 27.5 | | 25.3 | 18.8 | 26 |
| 18 | 14.4 | | 13 | 9.1 | 13.7 |
| **Race** |  | |  |  |  |
| White | 50 | | 37 | 40.3 | 39.1 |
| Hispanic | 30.9 | | 38.3 | 41.7 | 39.4 |
| Black or African American | 8.4 | | 13.8 | 9.7 | 11.3 |
| Asian | 4.7 | | 4.2 | 1.7 | 4.2 |
| Others | 6 | | 6.7 | 6.6 | 6 |

Table 8: Weight status and sociodemographic differences among Latent Classes in female US adolescents

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | | **Male (n=5938) 5 latent classes** | | | | |
|  | Class 1  Moderately High PA/  High SB/  Healthy EB | | Class 2  Low PA/  Low SB/  Unhealthy EB | Class 3  Low PA/  Moderately high SB/ Unhealthy EB | Class 4  High PA/  Low SB/  Unhealthy EB | Class 5  Moderately High PA/  Low SB/  Healthy EB |
|  | % | | % | % | % | % |
| **Weight status** |  | |  |  |  |  |
| Normal | 67.7 | | 63.1 | 68.7 | 61.6 | 58.4 |
| Overweight | 15.4 | | 17.4 | 13.7 | 14.6 | 16.9 |
| Obese | 14.6 | | 16.5 | 16.6 | 19.5 | 20.9 |
| **Grade** |  | |  |  |  |  |
| 9th | 26.9 | | 22.4 | 29 | 17.7 | 24.6 |
| 10th | 24.7 | | 28.6 | 24.8 | 25.1 | 24.8 |
| 11th | 26.1 | | 22.8 | 23.1 | 27.8 | 26.6 |
| 12th | 22.4 | | 26.2 | 23.1 | 29.4 | 24 |
| **Age** |  | |  |  |  |  |
| 12 | 0.1 | | 0 | 0 | 0 | 0.1 |
| 13 | 0.1 | | 0.2 | 0 | 0 | 0.1 |
| 14 | 8 | | 6.9 | 8.8 | 7.9 | 9 |
| 15 | 26.3 | | 21.3 | 24.4 | 17.8 | 23.9 |
| 16 | 25.6 | | 29.8 | 25.1 | 25.6 | 25.7 |
| 17 | 25 | | 23 | 24.1 | 29.5 | 25.7 |
| 18 | 14.8 | | 18.8 | 17.6 | 19.1 | 15.6 |
| **Race** |  | |  |  |  |  |
| White | 48 | | 37.4 | 25.7 | 45.7 | 39.3 |
| Hispanic | 31.7 | | 40.3 | 45.3 | 33 | 37.6 |
| Black or African American | 9.4 | | 8.7 | 16.6 | 10.3 | 11.1 |
| Asian | 3.2 | | 6.5 | 3.3 | 2.8 | 6.1 |
| Others | 7.7 | | 7.1 | 9.1 | 8.2 | 5.9 |

Table 9: Weight status and sociodemographic differences among Latent Classes in male US adolescents

## Chapter 4 Discussion

This study identified meaningful pattern of weight status related behaviors of a national representative sample of US adolescents, using LCA. Four and five latent classes were captured for female and male adolescents, respectively. In addition, we explored the demographic composition of subgroups for both female and male adolescents. The findings help us understanding the complex pattern of weigh related health behaviors and provide insights of the current health needs of US adolescents.

According to the correlation test of weigh-related variables, we found PA was significantly positively correlated with EB and negatively correlated to SB, suggesting that people who are physically active are more likely having healthy diet and lower level of SB. However, there was a literature reported that people who have excessive level of SB may not decrease PA or have bad EB ([34](#_ENREF_34)). The LCA results of female and male adolescents in this study confirmed the independent relationship of these three weight related behaviors. These behaviors were likely interrelated within each category but not across categories, since we found distinct and independent pattern of these behavior across latent subgroups.

Gender disparity among these weighted related behaviors were found in this study. According to Table 2, male adolescents had higher proportion of people being physically active and having healthy diet, but had lower proportion of people who had excessive level of SB, when compared to female adolescents. This finding was in line with literatures reported female adolescents had lower levels of PA, higher levels of SB, and less healthy diet than male adolescents ([31](#_ENREF_31), [35](#_ENREF_35), [36](#_ENREF_36)). Unlike these literatures, which reported the association of PA, SB, and EB separately with obesity, the finding in this study combined these behaviors together.

Although there were 3 classes were similar across female and male adolescents, the proportion of people in all classes were different across the sex groups. In addition, we found male adolescence had higher proportion of people being obese than female adolescence in each class. The Class 1 (Moderately High PA/ High SB/Healthy EB) in males, which had relatively high SB, physical activity and healthy diet compared to other classes, had the lowest proportion of obese in males. It is possible that SB is not such an important factor for the risk of obesity in this class for males. Class 2 (Low PA/ Low SB/ Unhealthy EB) were the largest for both females (44.4%) and males (40.2%). This class had the highest proportion of obese adolescents for females (14.1%), and had the second lowest percentage of adolescents being obese for males (16.5%). Class 3 (Low PA/ Moderately high SB/ Unhealthy EB), which was considered as the highest risk class for obesity, was significantly larger for males (23.1%) compared to females (4.8%). However, females had the lowest proportion (8%) of obese people, while males had 16.6%. Additionally, we found other classes which considered as the low risk group for obesity, had high percentage of adolescents being obese. For example, Class 4 (High PA/Low SB/ Unhealthy EB), had 14.1% obese female (the highest in females) and 19.5% obese male (second highest in males); Class 5, a unique class for males, had the highest proportion (20.9%) of obese adolescents. The possible explanation for this counterintuitive finding could be that the adolescents in these classes were obese to begin with but they were changing to a healthier life style before they filled out the survey. Therefore, a longitudinal study is required in the future.

The interpretation of the finding in this study have certain limitations. First, this was a cross-sectional survey that we cannot make an assessment of the causal relationships among the variables. Second, because of data limitation, we cannot rule out other confounding factors, such as previous weight-related behaviors and weight status. Third, all data were self-reported in the survey. Some data may be overestimated or underestimated. For example, adolescents may overestimate the time of physical activity, or underestimate the sedentary time which would cause bias. Finally, the obesity status may be not accurate since it was determined by the self-reported height and weight. To strengthen the validity of the finding in the future, these weight-related behaviors and other variables need to be objectively measured.

## References

1. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. J Pediatr. 2007;150(1):12-7 e2.

2. Li C, Ford ES, Zhao G, Mokdad AH. Prevalence of pre-diabetes and its association with clustering of cardiometabolic risk factors and hyperinsulinemia among U.S. adolescents: National Health and Nutrition Examination Survey 2005-2006. Diabetes Care. 2009;32(2):342-7. PMCID: 2628705.

3. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA. 2014;311(8):806-14. PMCID: 4770258.

4. Challenges in Adolescent Health Care: Workshop Report 2007.

5. Inge TH, Jenkins TM, Zeller M, Dolan L, Daniels SR, Garcia VF, et al. Baseline BMI is a strong predictor of nadir BMI after adolescent gastric bypass. J Pediatr. 2010;156(1):103-8 e1. PMCID: 2886665.

6. Hill JO, Wyatt HR, Peters JC. Energy balance and obesity. Circulation. 2012;126(1):126-32. PMCID: 3401553.

7. Butte NF, Christiansen E, Sorensen TI. Energy imbalance underlying the development of childhood obesity. Obesity (Silver Spring). 2007;15(12):3056-66.

8. American Academy of Pediatrics: Children, adolescents, and television. Pediatrics. 2001;107(2):423-6.

9. Gubbels JS, van Assema P, Kremers SP. Physical Activity, Sedentary Behavior, and Dietary Patterns among Children. Curr Nutr Rep. 2013;2(2):105-12. PMCID: 3637646.

10. Carlson JA, Crespo NC, Sallis JF, Patterson RE, Elder JP. Dietary-related and physical activity-related predictors of obesity in children: a 2-year prospective study. Child Obes. 2012;8(2):110-5. PMCID: 3647527.

11. Swinburn BA, Caterson I, Seidell JC, James WP. Diet, nutrition and the prevention of excess weight gain and obesity. Public Health Nutr. 2004;7(1A):123-46.

12. Pietilainen KH, Kaprio J, Borg P, Plasqui G, Yki-Jarvinen H, Kujala UM, et al. Physical inactivity and obesity: a vicious circle. Obesity (Silver Spring). 2008;16(2):409-14. PMCID: 2249563.

13. Strasser B. Physical activity in obesity and metabolic syndrome. Ann N Y Acad Sci. 2013;1281:141-59. PMCID: 3715111.

14. Physical Inactivity: A Global Public Health Problem. <http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/>.

15. Organization WH. Global recommendations on physical activity for health. 2011.

16. Services USDoHaH. 2008 Physical Activity Guidelines for Americans. 2008.

17. Haskell WL, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. Circulation. 2007;116(9):1081-93.

18. Spence C. Breakfast: The most important meal of the day? International Journal of Gastronomy and Food Science. 2017;vol 8:1-6.

19. Anderson YC, Wynter LE, Butler MS, Grant CC, Stewart JM, Cave TL, et al. Dietary Intake and Eating Behaviours of Obese New Zealand Children and Adolescents Enrolled in a Community-Based Intervention Programme. PLoS One. 2016;11(11):e0166996. PMCID: 5120841.

20. X.Garcia-Continente NA, Pérez-Giménez, C.Ariza, F.Sánchez-Martínez, M.J.López, M.Nebot. Eating habits, sedentary behaviours and overweight and obesity among adolescents in Barcelona. Anales de Pediatria. 2015;Vol 83(1):3-10.

21. Katzmarzyk PT. Physical activity, sedentary behavior, and health: paradigm paralysis or paradigm shift? Diabetes. 2010;59(11):2717-25. PMCID: 2963526.

22. Rey-Lopez JP, Vicente-Rodriguez G, Biosca M, Moreno LA. Sedentary behaviour and obesity development in children and adolescents. Nutr Metab Cardiovasc Dis. 2008;18(3):242-51.

23. Lauren Arundell EF, Jo Salmon, Jenny Veitch and Trina Hinkley. A systematic review of the prevalence of sedentary behavior during the after-school period among children aged 5-18 years. International Journal of Behavioral Nutrition and Physical Activity. 2016.

24. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. Pediatrics. 2007;120 Suppl 4:S164-92.

25. Nelson MC, Neumark-Stzainer D, Hannan PJ, Sirard JR, Story M. Longitudinal and secular trends in physical activity and sedentary behavior during adolescence. Pediatrics. 2006;118(6):e1627-34.

26. Babey SH, Hastert TA, Wolstein J. Adolescent sedentary behaviors: correlates differ for television viewing and computer use. J Adolesc Health. 2013;52(1):70-6. PMCID: 3786734.

27. Lanza ST, Rhoades BL. Latent class analysis: an alternative perspective on subgroup analysis in prevention and treatment. Prev Sci. 2013;14(2):157-68. PMCID: 3173585.

28. Stephanie T. Lanza LMC, editor. Latent Class and Latent Transition Analysis: With Applications in the Social, Behavioral, and Health Sciences2010.

29. Mathur C, Stigler M, Lust K, Laska M. A latent class analysis of weight-related health behaviors among 2- and 4-year college students and associated risk of obesity. Health Educ Behav. 2014;41(6):663-72. PMCID: 5051694.

30. Huh J, Riggs NR, Spruijt-Metz D, Chou CP, Huang Z, Pentz M. Identifying patterns of eating and physical activity in children: a latent class analysis of obesity risk. Obesity (Silver Spring). 2011;19(3):652-8. PMCID: 5310931.

31. Patnode CD, Lytle LA, Erickson DJ, Sirard JR, Barr-Anderson DJ, Story M. Physical activity and sedentary activity patterns among children and adolescents: a latent class analysis approach. J Phys Act Health. 2011;8(4):457-67. PMCID: 3100677.

32. Centers for Disease Control and Prevention. Available from: https://[www.cdc.gov/healthyweight/assessing/bmi/index.html](http://www.cdc.gov/healthyweight/assessing/bmi/index.html).

33. Karen L. Nylund TA, Bengt O. Muthén. Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. 2007.

34. Taveras EM, Field AE, Berkey CS, Rifas-Shiman SL, Frazier AL, Colditz GA, et al. Longitudinal relationship between television viewing and leisure-time physical activity during adolescence. Pediatrics. 2007;119(2):e314-9. PMCID: 1994915.

35. Azevedo MR, Araujo CL, Reichert FF, Siqueira FV, da Silva MC, Hallal PC. Gender differences in leisure-time physical activity. Int J Public Health. 2007;52(1):8-15. PMCID: 2778720.

36. Barreira TV, Schuna JM, Jr., Mire EF, Broyles ST, Katzmarzyk PT, Johnson WD, et al. Normative steps/day and peak cadence values for united states children and adolescents: National Health and Nutrition Examination Survey 2005-2006. J Pediatr. 2015;166(1):139-43.