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미국 청소년의 비만에 관한 종단적 분석

Longitudinal Data Analysis for School-aged Adolescents' Obesity Rates across the States

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요약

이 연구의 목적은 미국 취학 아동-청소년의 BMI 변화율이 어떻게 달라지고 있는지, 그리고 청소년 발달 상태에 따른 비만을 유발하는 해로운 행동들이 청소년들의 비만 현상에 어떻게 영향을 미치는지 종단적으로 밝히는데 있다. 1999-2011 미국 청소년 위험 행동 조사 데이터를 사용하였으며, 총 연구 대상은 260,293명이다(9-12학년). 미국 취학 청소년들의 비만율에 미치는 종단적 시간의 효과를 검증하기 위해 인구통계학적 특성, 영양 및 신체활동 관련 행위들을 공변량으로 통제한 최소자승법 회귀분석과 위계적 선형 모델링이 활용되었다. 취학 청소년들의 BMI 퍼센티지는 시간과 유의미한 관련이 있는 것으로 나타났으며 특히 종단적 시간은 아이들의 BMI 퍼센티지에 상당히 긍정적인 효과가 있는 것으로 나타났다. 따라서 지난 10년 동안의 미국 아동 비만을 줄이기 위한 신체 활동 및 영양 정책은 미국 아동들의 비만 유지 및 감소를 위한 매우 효과적인 정책이었으며, 향후 청소년의 비만 요인 감소와 장애요소를 극복을 위한 정책을 강화하는데 더욱 많은 관심을 기울여야 할 것이다.

■ 중심어 : | 청소년 비만 | 종단적 분석 | 미국 | 신체 활동 | 영양 |

Abstract

The objectives of this research is to examine: 1) how the rates of adolescents' BMI change over time in terms of the state level; and 2) development difference in the state level of BMI in terms of children's obesogenic behaviors from 1999 to 2011. Data were drawn from the 1999-2011 Youth Risk Behavior Survey in the United States (N=260, 293, grades 9-12, and 27 states). Ordinary least squares regression and hierarchical linear modeling were utilized to capture a longitudinal time effect of school-aged adolescents' obesity rates across the states, controlling for demographics and nutrition- and physical activity-related behaviors. The state's level of children's BMI percentile was significantly associated with longitudinal time. Longitudinal time effect across the states appears to play an important factor associated with children's decrease of BMI percentile. Therefore the states' implementation of physical activity and nutritional policies seems to be effective for preventing and reducing childhood obesity during last decade. More attention should focus on enforcing the policy and overcoming current barriers in order to minimize children's obesogenic factor.

■ keyword : | Childhood Obesity | Longitudinal Data Analysis | States | Physical Activity | Nutrition |

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I. Introduction

Current health risks and future health outcomes are highly associated with high rates of being overweight and/or obese during childhood[12], especially since the developmental stage of childhood is an important period when fundamental health behaviors are developed for the future (e.g., maintaining healthy and normal weight, eating fruit and vegetable, less-fat food, and avoiding junk food)[40]. Once an individual has negative and poor health behaviors or practices, those lifestyles are not easily modified, and instead, continue to deteriorate[40]. The Centers for Disease Control and Prevention [CDC] [7] defines childhood obesity as having 95% or higher percentile of body mass index (BMI) based on age and gender. During the last two decades the prevalence of childhood obesity has doubled in 6 to 11 years old children and tripled in 12 to 19 years old adolescents[6].

Childhood obesity is detrimental to an individual's physical health[20] such as glucose tolerance[13], cardiovascular diseases in adulthood[25], eating disorders[10], insulin resistance and abnormal lipid accumulation[25]. It also affects negative mental[35] and develops low self-esteem and depression[28]. Moreover, childhood obesity decreases overall health and physical functioning in later adult health outcomes[43], which causes cancers of the esophagus, colon and rectum, liver, gallbladder, pancreas, and kidney[15], and leads to increased mortality[19][22].

A lack of physical activity is one of the unhealthiest behaviors of adolescents' obesity[27][30]. According to USDHHS[40], children need to engage in vigorous physical activity for at least 60 minutes per day for appropriate development, both mentally and physically. However, about 61.1% of adolescents do not participate in more than 60 minutes of physical activity per day and even 17% of them do not engage in any types of activity[37]. It is remarkably important for children to maintain normal weight during these years because of the critical stage of developing fundamental health behavior for their future.

Many researchers also reported multiple causes for childhood obesity such as being less active and an increase in caloric consumption[30], engaging in a more sedentary lifestyle[29], gene, family, community and socio-economic factors (e.g., level of income and education, gender, and living condition)[23]. As being line with[30], recommended levels of physical activity (e.g., at least 30 minutes a day more than three times a week) and healthy eating habits (e.g., more fruits and vegetable, less trans-fatted snacks, and less sugar-sweetened beverages) can remarkably contribute to either prevent or minimize adolescents' overweight and/or obesity and related diseases as well (e.g., diabetes, cardiovascular disease, stroke, cancers)[39].

For school-aged adolescents, schools provide many chances to learn and practice diverse healthy behaviors and eating habits. Students are not only learning something new and studying, but they are also involved in social and emotional relationships between peers and teachers, and in an organization that may affect their health behavior. School-age adolescents spend nearly half of their daily hours at school. In addition, school provides about 50 percent of children's total amount of daily caloric intake[26] According to the USDHH[38], physical activity policies and nutrition policies are the most prominent environmental factors affecting adolescent's obesity. School can be one of the most modifiable environmental settings for minimizing and preventing childhood obesity by utilizing physical activity and nutritional policies. School polices related to children's eating and physical activity behavior could have a

huge influence on reducing of childhood obesity. Interestingly, transition from adolescents to young adults is the critical developmental stage that affects substantially later healthy behaviors over the lifetime. Once an individual had negative and poor health behaviors or practices, those life styles are not easily modified, and instead, continues to deteriorate[40].

Therefore, an implementation of intervention programs or policies for childhood obesity is essential to improve better quality of life for children and adolescents. One of the biggest reasons of health-related policies and implementation of childhood obesity prevention is because the highest cost-benefit ratio of medical or social interventions is in childhood[18]. Therefore, if policy makers or stakeholders demand better results for intervention polices, the developmental stage (e.g., children and adolescents) should be focused.

Since the 1990s, a number of adolescents' obesity prevention programs have implemented in either the individual; physical activity[3][16], nutrition[16], and sedentary life style (e.g., watching TV) [29] or community level[17]; parents[34] and school[14][24]. Few studies have conducted to analyze longitudinal time effects on adolescents' obesity rate over time across the states. The purpose of this research is to explore a longitudinal time effect of school-aged adolescents' obesity rates across the states. Followings are the research questions;

1) From 1999 to 2011, how the rates of adolescents' BMI change over time in terms of the state level?
2) Does the aggregated of consumptions of fruits and vegetables, amounts of physical activity, and the level of sedentary life style predict the state level of BMI percentile?
3) What are the relationships between mean BMI percentile and the effect of physical activity, sedentary life style, and consumptions of fruits and vegetables?
4) Are there development difference in the state level of BMI percentile that depends on the level of physical activity, consumption of fruits and vegetables and amounts of sedentary life style?

2. Methods

2.1 Study Sample

This study collected data form the 2012 Youth Risk Behavior Surveillance System (YRBSS)[8], a school-based survey, representing a sample of public and private high school students in the U.S from 1999 to 2011. The CDC conducts this nation-wide survey in both public and private high school students form 9^{th} grade to 12^{th} including 50 states every other year for to monitor youth's health-risk behaviors and the prevalence of obesity, level of physical activity and drugs abuse etc.. This study was exempted by the Institutional Review Board at the authors' institution.

In advance of data collection this study was submitted to and exempted by the Institutional Review Board(IRB) at Indiana University due to the nature of the sedentary data sets, including no human participants. YRBSS, school-based survey, is a one of the most representative sampling of schools needed to be contacted to secure individual level data across 50 states of CDC local agents. Table1 shows total 32 (64%) states CDC responded and 5 states (e.g., Pennsylvania and Virginia state) were excluded the data analysis due to either the lack of time points (e.g., less than 3 periods of time) or missing data such as level of physical activity, consumptions of fruits and vegetables, and a sedentary life style.

2.2 Study Design and Measures

This study was a multi-year retrospective longitudinal data analyzing study by utilizing a multi-year retrospective cross-sectional data. The proposed study has a large number of participants with multiple time point of data.

BMI percentile. Based on self-reported height and weight from the participation, BMI was calculated as weight in kilograms divided by square of height in meters and the BMI percentile calculations were converted based on BMI forage and gender growth chart for children (U.S. Department of Health and Human Services [USDHH])[39]. Because individual children have different the size and growth patterns in the United States in which indicate the relative proportion of the child's BMI number among children.

Consumption fruits and vegetables. Consumptions of fruits, vegetables, and nutrition were measured on a 7-point Likert scale using 6 items; for example a) "During the past 7 days, how many times did you drink 100% fruit juices such as orange juice, apple juice, or grape juice?" (1 = I did not drink 100% fruit juice during the past 7 days, 7 = 4 or more times per day), b) "During the past 7 days, how many times did you eat fruit?" (1 = I did not eat fruit during the past 7 days, 7 = 4 or more times per day).

Physical activity. Physical activity was assessed on an 8-point Likert scale using 2items; for example, "In an average week when you are in school, on how many days do you go to physical education (PE) classes?" (1 = 0 days, 8 = 7 days).

Sedentary behavior. Students' sedentary behavior was assessed by 1 item: a) a 7-point Likert scale "On an average school day, how many hours do you watch TV?" (1 = I do not watch TV on an average school day, 7 = 5 or more hours per day).

2.3 Statistical Analysis

All data analyses were conducted using SAS (version 9.3). Descriptive statistics were reported to describe study participants' characteristics such as age, gender, consumptions of fruits and vegetables, a level of physical activity and BMI percentile using mean, standard deviations and percentage. Descriptive statistics and pairwise correlations were used to report participants' characteristics and variable correlations, respectively.

In advance of main data analysis, data of level of physical activity, consumptions of fruits and vegetables, and a level of sedentary life style were aggregated to capture and examine the effect of means of each state based on year. Ordinary least squares regression and hierarchical linear modeling were utilized. Outcome variable (Y) was the scale variable of mean of BMI percentile and covariates (X's) are following: the mean of the level of consumption fruits and vegetables, the means of amounts of physical activity, and the mean of the level of sedentary life style controlling, age, male, grade and race/ethnicity. To avoid multicollinearity effect, the variance inflation factors (VIF) were computed for each predictor. If VIF $>$ 10 then, there was a problem with multicollinearity[31].

3. Results

[Table 1] shows the descriptive statistics of the study sample. 27 states and 260,293 students were participated (Mage = 16.00 ± 1.22 years, range = 12-18, female N=132,311, 51.09%). The minimum number of students nested in state was 1071 and the maximum one was 9708. There were three independent variables (i.e., consumptions of fruits and vegetables (Mean = 14.08 ±5.30) and amounts of

physical activity (Mean = 4.99 ±2.66) and the level of sedentary life style (Mean = 3.80 ± 1.78). The race of the participants was diverse with most of them being Whites (65.64%), followed by Blacks (14.23.7%), mixed race (13.97%), and Hispanic (6.17%). Their grade of year was evenly distributed; 29.51% of them were 9th grade followed by 10th grade(27.11%), 11th grade(24.32%) and 12th grade(19.06%).

Table 1. Descriptive of the Participants

	Demographic variables	N	%
Sex	Male	126,671	48.91
	Female	132,311	51.09
	Missing	1,311	
AGE	12years old or younger	658	0.25
	13 years old	723	0.28
	14 years old	26,891	10.36
	15 years old	68,100	26.23
	16 years old	70,451	27.13
	17 years old	59,449	22.89
	18 years old	33,391	12.86
	Missing	630	
Education	9th Grade	75,932	29.51
	10th Grade	69,771	27.11
	11th grade	62,584	24.32
	12th Grade	49,058	19.06
	Missing	2948	
Race/Ethnicity	Black	36,501	14.23
	White	168,412	65.64
	Hispanic	15,830	6.17
	Mixed Race	35,833	13.97
	Missing	3717	

3.1 Exploratory analyses

The main purpose of this study is to investigate whether state's BMI percentile is predicted by level of physical activity, the level of consumption of fruits and vegetables and level of amount of sedentary life style (e.g., watching TV) controlled the effect of age, gender (male), race/ethnicity, and grade over time across states. Before the model specification, exploratory analyses were performed on effects of the state level of variables on states' BMI percentile to exam if the effects of variables (e.g., level of physical activity, the amounts of consumption of fruits and vegetables, and level of amount of sedentary life style controlled the effect of gender, race/ethnicity, and grade) differ states' BMI percentile over time. Due to the small number of states (27), those effects are assumed fixed slope on states' BMI percentile but need to be tested whether fixed one or not.

According to Nonparametric Smoothing, as seen [Figure 1], the mean of BMI percentile of each state tend to slightly increase or level off with time. In addition, based on Smoothed Trajectories combined (Spline & OLS) [Figure 2], both Spline and OLS Smoothed Trajectories combined shows that the state BMI percentile score tends to increase over time. The variability of states' score has less variation at the beginning comparing to the latter one. Finally, An unconditional growth model shows that the state levels of BMI percentile differ in the way they change over time; state differ in their intercepts (initial value) and their slopes (rate of change) are different over time.

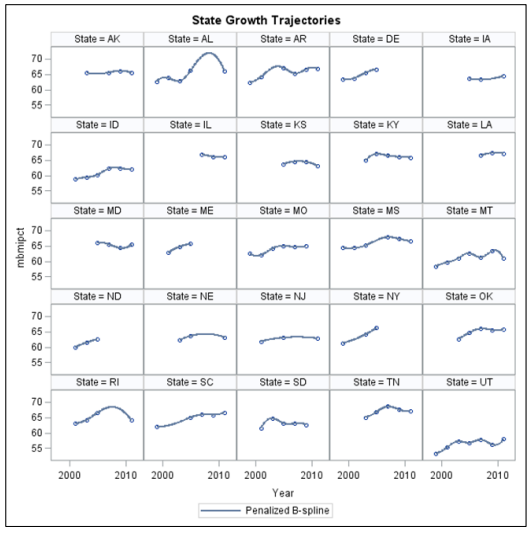

Figure 1. Nonparametric Smoothing of States Growth Trajectories

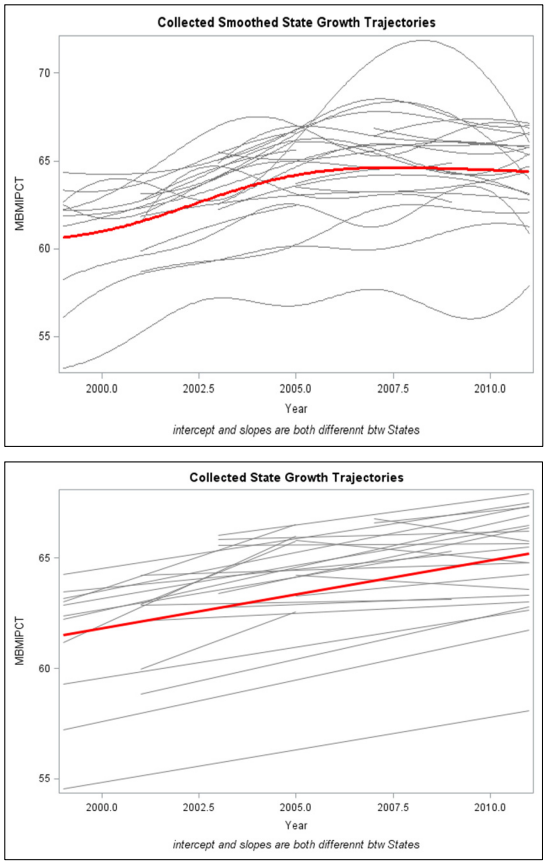

Figure 2. Smoothed Trajectories combined (Spline & OLS)

Before testing initial model parameters of this study, each covariate need to be explored if any random effects of slope can be applied. As seen [Figure 3], plots of each state showed the effects of time, level of physical activity, consumptions of fruits and vegetables, age, race/ethnicity, gender and grade on state's BMI percentile within each state (black lines) looked varying in terms of intercept. However, time, age, gender and ethnicity across the schools seem to be fixed (red line).

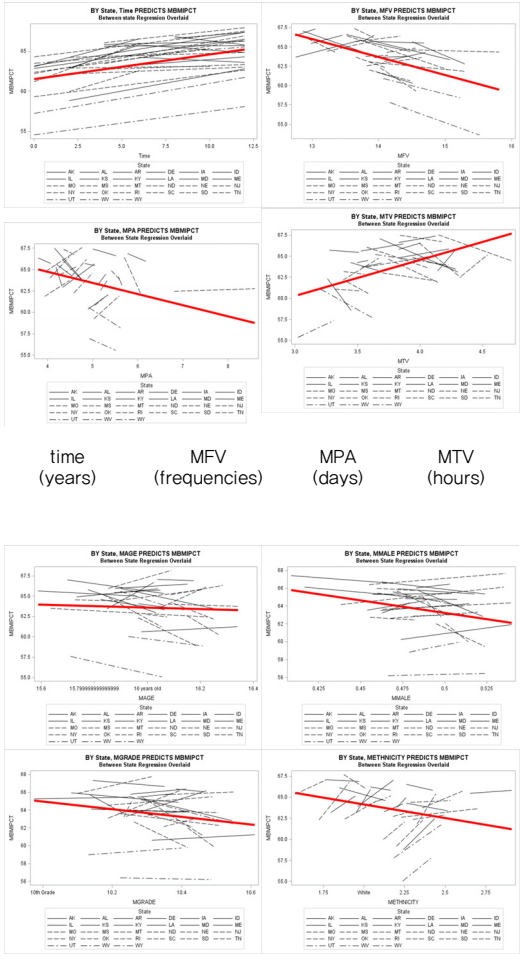

Figure 3. Plots of within- and between-state effects of physical activity, consumption of fruits and vegetable, sedentary life style, age, gender (male), race/ethnicity and grade on state's BMI percentile by each state

※ time(years), MFV(frequencies), MPA(days), MTV(hours), MAGE(year-old)

3.2 Model specification

For the initial model, a full model based on research interest with all possible main effects was built. As mentioned earlier, the plots of multilevel regression in terms of effects of each variable (i.e., level of physical activity, consumptions of fruits and vegetables and level of sedentary life style) seemed be varied across

the schools. Therefore, all the effects of those variables seem to be random slope model testing with likelihood ratio test.

According to the t-value (<.05) of testing fixed effects of initial model with predictors, 5 exploratory variables (i.e., time, grade physical activity, consumption of fruits and vegetables, and level of sedentary life style) were statistically significant, whereas age, gender, race/ethnicity terms were not statistically significant and dropped from the model.

1) Final model with checking random effect of slope.

Based on random slope model testing with likelihood ratio test, only the level of sedentary life style is statistically significant with (= 5.99). So MTV random slope was included for final model of this study.

2) Final model with random slope effect

$$\overline{BMIPC}_{.j} = \pi_{0i} + \pi_{1i}(Time_{ij}) + \pi_{2i}(\overline{FV}_{.j}) + \pi_{3i}(\overline{PA}_{.j}) + \pi_{4i}(\overline{TV}_{.j}) + \pi_{8i}(\overline{Grade}_{.j}) + \epsilon_{ij}$$

$$\pi_{0i} = \gamma_{00} + \zeta_{0i}$$
$$\pi_{1i} = \gamma_{10}$$
$$\pi_{2i} = \gamma_{20}$$
$$\pi_{3i} = \gamma_{30}$$
$$\pi_{4i} = \gamma_{40} + \zeta_{0i}$$
$$\pi_{8i} = \gamma_{80}$$

where $\epsilon_{ij} \sim N(o, \sigma_{\epsilon}^2)$ and $\begin{bmatrix}\zeta_{0i}\\ \zeta_{4i}\end{bmatrix} \sim N\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}\sigma_0^2 & \sigma_{04}^2\\ \sigma_{40}^2 & \sigma_4^2\end{bmatrix}\right)$

Final growth model showed time significantly affect the state's level of BMI percentile if the effects of all the other predictors are controlled, which as increasing one unit of time, 0.35 of state level of BMI percentile will be increased (p<.0001). As increasing one unit of grade, in addition, -2.1952 of state level of BMI percentile will be decreased (p=0.0175).

Table 2. Final growth model statistics

Covariance Parameter Estimates					
Cov Parm	Subject	Estemate	Standard Error	Z Value	Pr Z
τ_0^2	State	98.9746	49.2699	2.01	0.0223
τ_{10}^2	State	-25.5190	13.1647	-1.94	0.0526
τ_{11}^2	State	6.6169	3.5201	1.88	0.0301
Residual		0.7463	0.1240	6.02	<.0001
Solution for Fixed Effects					
Effect	Estimate	Standard Error	DF	t Value	Pr>|t|
Intercept	84.2153	10.6150	26	7.93	<.0001
time	0.3526	0.02896	67	12.18	<.0001
mgrade	-2.1952	0.9011	67	-2.44	0.0175
mfv	-0.7323	0.2204	67	-3.32	0.0014
mpa	-0.6134	0.2265	67	-2.71	0.0086
mtv	3.5736	0.6989	26	5.11	<.0001

One unit of consumptions of fruits and vegetables make decrease -0.7323 of state level of BMI percentile (p=0.0014). Increase of one unit of level of physical activity contribute to decrease -0.6134 of state level of BMI percentile (p=0.0086). Finally, as increasing one unit of the level of sedentary life style, 3.5736 of state level of BMI percentile will be increased (p<.0001).

According to covariance parameter estimates, covariance between intercept and the level of sedentary life style shows negative value. In other words, if higher intercept of state level of BMI percentile, lower rates of change state level on BMI percentile over time.

4. Discussion

This study is multi-year cross-section longitudinal study from 1999 to 2011 to explore a longitudinal time effect of school-aged adolescents' obesity rates across the states. Based on our study results, the

obesity rate of states level has increased over time. In other words, from 1999 to 2011, the state BMI percentiles have been changed over time in terms of the stage level. In addition, consumptions of fruits and vegetables and, amounts of physical activity can be negative predictors on the state level of the BMI percentile. Whereas the level of sedentary life style can be a significant positive predictor on the state level of BMI percentile.

More specifically, the final growth model showed time significantly increased the state's level of BMI percentile if the effects of all the other predictors are controlled. According to [2], in Pennsylvania child and adolescent BMI trends are declined at both the middle school and high school from 2005 to 2009. This finding is in line with this particular longitudinal study of adolescents' BMI percentile across stats although study population is much larger. Since the 1990s, a number of adolescents' obesity prevention programs have implemented through increasing physical activity[3][16], taking more balanced and diverse nutrition[16], and reducing sedentary life style (e.g., watching TV) [29] in either the individual or community level[17], parents[34], school[14][24].

Our study results further supported that increasing the level of sedentary life style affected an increase of state level of BMI percentile. However, consumptions of fruits and vegetables and the level of physical activity were negatively associated with state level of BMI percentile as expected, respectively. One of the most unhealthy behaviors of adolescents' obesity is a lack of physical activity[27][30] and engaging in a more sedentary lifestyle[29], Being less active and an increase in caloric consumption [30] also have a negatively influence on childhood obesity. [30] recommended levels of physical activity (e.g., at least 30 minutes a day more than three times a week) and healthy eating habits (e.g., more fruits and vegetable) can remarkably contribute to either prevent or minimize adolescents' overweight and/or obesity and related diseases as well (e.g., diabetes, cardiovascular disease, stroke, cancers)[39].

Given the fact that childhood obesity has been shown to be influenced by inadequate dietary habits such as unbalance between energy intake and expenditure[31], insufficient fruit and vegetable consumption[42], only one out of five high school students eat 5 or more servings of fruits and vegetables per day [11] and less than one fourth of younger children consume the nutrients recommended by the guidance by federal [1]. [41] indicates that sedentary life style of childhood (e.g., watching TV, video game, and computer use) should not be allowed no more than two hours per day unless developing obesity. Many other researchers also stress the importance of physical inactivity and prevention of sedentary lifestyles (e.g., TV/video watching, video game playing, reading, and computer using) [9][29][33].

4.1 Implications

School can be one of the modifiable environmental settings for minimizing and preventing childhood obesity by utilizing physical activity and nutritional policies. Determining factors that contribute to decreased childhood obesity will help educators and medical professionals facilitate engagement in school-based preventive obesity programs. This study reveals that children's eating and physical activity behavior could have a huge influence on reducing of childhood obesity.

Several interesting associations were shown. First, behavioral factors (i.e., sedentary lifestyle and physical activity) prove to be significantly associated with adolescents' obesity. The second association of great interest, the amounts of consumption of fruits and vegetables has significantly connection with

adolescents' obesity. So, policy makers and/or stake holders should not rule out those nutrition practices despite of that of the low cost-benefit ratio of medical or social interventions.

According to the [38], physical activity and nutrition policies are the most prominent environmental factors affecting adolescent's obesity. However, there are few schools implementing well-structured physical activity programs and nutrition policies for students due to pressure of academic achievement, lack of financing, and poor quality of exercise program[36]. Our study results shows childhood obesity were positively associated with the students' healthier behaviors (e.g., increased physical activity and nutrition) to potentially decrease adolescent's obesity.

Multiple factors and reasons cause adolescent obesity including excessive intake nutrition, less activity, and more sedentary lifestyles. Therefore, the only individuals' efforts may be not able to conquer the epidemic and complex of childhood obesity without cooperating with social structures and policies. Schools are one of the most desirable infrastructures to ensure the next generation wellness because, for school-aged adolescents, schools provide many opportunities for students to learn and practice diverse healthy behavior and eating habits. Students do not only learn from lessons, but also get involved in social and emotional relationships among themselves, peers, and teachers, which may, in turn, affect their health behaviors, as school-age adolescents spend nearly more than half of their daily hours at school and school provides about 50 percent of children's total amount of daily caloric intake[26].

Despite the huge benefits of prevention of childhood obesity, preventable obesity intervention and service programs are not fully provided for adolescents[21]. A commitment to and implementation of intervention programs or policies for childhood obesity is vital for health educators and professionals, policy makers, and stakeholders to improve better quality of life for children and adolescents. One of the biggest reasons why policy makers or stakeholders should implement health-related policies or interventions is because the cost-benefit ratio of medical or social interventions demonstrates the highest developmental stage/approximate is in childhood[18]. Therefore, if policy makers desire better results for intervention polices, then the developmental stage (e.g., children and adolescents) should be targeted in terms of the ratio of cost and benefits. In other words, smaller rewards are expected with respect to medical or social interventions in adulthood.

4.2 Study Limitations

This study should be interpreted in light of the following limitations. Firstly, this study utilized self-reported measurements to assess all study variables from students' one-day recollection which may be inaccurate due to recall bias, respondent bias, or interview bias. Secondly, this study was conducted in certain region of the U.S.; therefore, the results of this research cannot be generalized to all adolescents in other states. Lastly, the YRBSS dataset excludes households without telephones, which may result in a biased survey population due to under representation of certain segments of the population. Therefore, the future evaluation and research studies regarding children's obesity prevention should take these limitations into consideration. However, we believe that these limitations do not overweigh the contribution of this study.

5. Conclusion

In the past decade, many states have implemented

state school polices of childhood obesity such as nutrition standards, nutrition education, and physical activity. The evidence of this study supports the school policies of childhood obesity for how school-based interventional policies affect student's practice and implementation of obesity prevention behaviors. As illustrated in this study, children's eating and physical activity behaviors will have a huge influence on reducing of childhood obesity. A commitment to and implementation of intervention programs or policies for childhood obesity is vital for health educators and professionals, policy makers, and stakeholders to improve better quality of life for children and adolescents.

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