Original Article

Change in weight status and academic performance among senior high school students in Taiwan

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Introduction: This study examines how the changes in weight status across the spectrum of a senior high school study are associated with academic performance measured by the university entrance exam scores. **Materials and Methods:** A unique dataset which compiles a national health examination profile and the General Scholastic Ability Test data bank in Taiwan was constructed. The final sample comprised 149,240 senior high school students of which 70,662 were males and 78,578 were female students. The school-level fixed effect models were estimated. **Results:** Students who were either (a) not overweight in the first year but overweight in the third year of senior high school, (b) overweight in both the first and third year, or (c) overweight in the first year but not overweight in the third year, were more likely to score lower on the university entrance exam, compared with their never-overweight counterparts. The findings differ by gender and test subjects. **Discussions:** The change in weight status during senior high school period is associated with subsequent university entrance exam outcome. Students who start senior high school being overweight should be paid attention. School-based programs and practices need to be implemented to reduce the prevalence of overweight among students.

Key Words: obesity, overweight, academic performance, senior high school students, Taiwan

INTRODUCTION

Adolescence is an important period for establishing lifetime patterns of diet and physical activity.[1-2] It is also a critical time for the development and persistence of overweight.[2-3] Adolescent overweight and obesity may increase the risk factors of health outcomes, such as cardiovascular diseases, dislipidemia, hypertension, type 2 diabetes, and obesity in adulthood.[4-6] More immediate consequences of overweight and obesity in adolescents are psychosocial influences, such as stigmatization from teachers and peers, low self-esteem, higher rates of anxiety disorders, depression and other psychopathologies.[7-10] These psychosocial influences are often related to the lower academic achievement of adolescents.[11-13]

Obtaining a good understanding of the relationship between weight status and academic performance among adolescents has important policy implications, particularly as the prevalence of adolescents with overweight and obesity has been on the rise in many countries of the world.[14-15] If overweight/obesity leads to lower academic performance during adolescence, then students' future university admissions, employment opportunities and earnings are likely to be affected.[16-17] However, understanding how weight status may affect academic performance is not an easy task due to a lack of suitable data. Several cross-sectional studies which examined the relationship between weight status and academic performance obtained mixed results as well.[18-23] For example, using a total of 572 6th and 7th grade students in Philadelphia, Shore et al found that overweight students showed 0.4 lower grade point average (GPA) scores and 11% lower national percentile reading scores than their non-overweight peers.[22] Mo-suwan et al found that overweight students in the third-to-sixth grades did not present lower GPA than their healthy-weight peers, while overweight students in the seventh-to-ninth grades showed lower GPA than their healthy-weight peers in Thailand.[18] Discrepancies in the results found in the previous studies may be driven by the differences in methodology and use of datasets from different grade cohorts and countries. In addition, these previous studies sampled students in a specific area and/or using self-reported data, such as school grades, height and weight.

The purpose of this study was to investigate whether the changes in weight status across the spectrum of a senior high school study were associated with academic performance measured by the university entrance exam scores in Taiwan. Our study contributes to the previous research mainly on three fronts: first of all, we merge two

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large-scale population-based datasets: the national administrative health examination profiles for senior high school students and the university entrance exam scores. In Taiwan, all university-bound seniors have to participate in the university entrance exam in the hope of university admission. This linkage, especially at the national level, is unique. To the best of our knowledge, this is the first attempt conducted on data from Taiwan to understand the relationship between weight status and academic performance among adolescents using administrative datasets. Secondly, the measurement of each senior high school student's weight status and the university entrance exam scores are administrative records, not self-reported. Therefore, the weight status and academic performance measures are objective and free from a self-reported bias. Lastly, we focus on Asian senior high school students who have not been extensively investigated before.

MATERIAL AND METHODS

Data

The first dataset used in this study is the national health examination profiles, administrated by the Department of Physical Education, Ministry of Education (MOE) in Taiwan. The information on height and weight of the senior high school students was documented in this dataset. In order to monitor and control for overweight and obesity among senior high school students, the MOE required each senior high school to submit height and weight records to the MOE periodically. Students' height and weight are measured during the first lecture of the physical education class in each academic year. In addition, gender and grade level of each student are documented in the dataset.

The second dataset is the scores of the General Scholastic Ability Test (GSAT) administered by the College Entrance Examination Center (CEEC), Taiwan. This is a nationwide dataset for all university-bound seniors who take the GSAT to pursue their studies at the tertiary level after their 3-year senior high school education. The GSAT, consisting of Chinese, English, Mathematics, Science and Social Studies, serves as the primary measurement for admission to universities. The higher the total score achieved on the GSAT, the better the chances to attend more prestigious universities. In addition, the CEEC dataset contains information on each examinee's age and family economic status, as students from low-income families with certification from the government are exempt from paying GSAT registration fees.

The most three recent available waves of university-bound seniors who took the university entrance exam in 2009, 2010 and 2011 were chosen. With the technical assistance provided by the MOE and CEEC, students' identification numbers and names provided links between the two datasets. This study attempts to go one more step beyond the commonly used cross-sectional analysis. Instead of using the body weight in each semester, we use the changes in weight status of each student from the first to third year of the senior high school study period. We matched each university-bound student's GSAT score and body weight status in the same year. The value of body weight represented each student's weight status in the third year. For each student, we then traced back his/her body weight status in the first year of high school. In so doing, we were able to construct the changes of weight status of each student from his/her first (freshman) to the third (senior) high school year. Using the students who took the 2009 university entrance exam as an example, we had their GSAT scores in 2009 and the body weight values for their third (2009) and first senior high school year (2007). The same procedure was conducted for the students who took the university entrance exam in 2010 and 2011. The final sample comprised 149,240 observations of which 70,662 were males and 78,578 were female students. We appreciate the technical assistance of the MOE and CEEC to merge the individual dataset and ethical approval of this study had been granted by the ethics review panels of the MOE and CEEC to use the data. All data were anonymized and were kept in strict confidence.

Measures of overweight and obesity status

The most practical tool to determine overweight and obesity status is the Body Mass Index (BMI).[24-25] BMI is a ratio of the body weight in kilograms divided by the square of the height in meters. The Health Promotion Administration, Ministry of Health and Welfare in Taiwan defines age-sex-specific BMI from the 85th up to the 95th percentile as "overweight" and to age-sex-specific BMI at or above the 95th percentile as "obesity". The cut-off points for overweight as BMI greater than 23.4 (22.7) for a 16-year-old boy (girl) and 23.7 (22.7) for an 18-year-old boy (girl). The cut-off points for obesity as BMI greater than 25.6 (25.3) for a 16-year-old boy (girl) and 25.6 (25.3) for an 18-year-old boy (girl).[26]

Senior high schools in Taiwan consist of three grades. Following the normal track of the education system in Taiwan, students enter senior high school at the age of 16 and graduate at the age of 18. Based on the cut-off points defined by the Health Promotion Administration, we determine male and female students' overweight (including obesity) status in the first and third year of senior high school, where the corresponding age-sex BMI below the 85th percentile was designated as 0 and above the 85th percentile was designated as 1. Hereafter, in this study we will define the term "overweight" as overweight including obesity.

To capture changes in weight status across the 3-year spectrum of senior high school study, we identified students' overweight and non-overweight trajectories and divided them into 4 different groups:

1. Not overweight in the first and third year of senior high school;
2. Not overweight in the first year but overweight in the third year;
3. Overweight in the first and third year of senior high school;
4. Overweight in the first year but not overweight in the third year.

We refer to these four groups of senior high school students as "*Never-Overweight*", "*Become Overweight*", "*Persistent Overweight*" and "*Become Non-overweight*", respectively.

Measure of academic performance

The GSAT consists of 5 subjects: Chinese, English, Mathematics, Science and Social Studies. Each subject test mainly contains computer-readable multiple-choice questions. Mathematics includes short-answer questions, and Chinese and English contain essay tests. The score of each subject ranges from 0 to 15 points; 75 points is the highest total score. We used the GSAT total scores and each subject test score to measure the academic performance of senior high school students.

Statistical analysis

How are the changes in weight status across the 3-year spectrum of senior high school study associated with academic performance measured by the university entrance exam scores? We sought to answer this question using the following school-level fixed effect model: (1)

$$Score_{ijt}=\alpha+\beta_1 BecomeOverweight_{ijt}+\beta_2 PresistentOverweight_{ijt}+\beta_3 BecomeNonoverweight_{ijt}+\beta_4 X_{ijt}+\mu_j+\upsilon_t+\varepsilon_{ijt}$$

where $Score_{ijt}$ is the overall/each subject test score of the university entrance exam of student i from senior high school j in graduation year t. *BecomeOverweight* is a dummy variable equal to 1 for the students who are not overweight in the first year but overweight in the third year. *PersistentOverweight* is a dummy variable equal to 1 for those who are overweight at the both points of time. *BecomeNonoverweight* is a dummy variable equal to 1 for the students who are overweight in the first year but become non-overweight in the third year. The students who are not overweight at the both periods of time are the reference group (*Never-Overweight*) in Eq. (1). X_{ijt} is a set of other explanatory variables, including age and family economic status of students. The family economic status is reflected by a dummy variable "low-income", which takes the value 1 if students are indicated as low-income status to exempt from paying GSAT registration fees in the CEEC dataset. Since school identification is available in our data, we include μ_j as the school fixed effect to control for unobserved confounders that may affect students' academic performance at the school level and remain constant over time within the same schools (e.g., quality of school teachers, school size and school location). υ_t is the year fixed effect which includes dummy variables for 2010 and 2011 (the reference group is 2009). ε_{ijt} is the random error term. In our preliminary analysis, the Hausman-Wu specification test was conducted to differentiate between fixed- and random-effect models,[27] and the use of a fixed-effect model was justified.

Given the specification in Eq. (1), the main variables of interest are the three dummy variables of weight status changes. The coefficients β_1, β_2 and β_3 respectively measure the differences in the university entrance exam scores among the students who become overweight, remain overweight, and become non-overweight, compared to their counterpart peers who are always non-overweight from the first to third year of senior high school. The ordinary least squares (OLS) method was used for model estimation with the standard errors clustered at the school level. To capture the potential gender differences,[19,28] we estimated Eq. (1) separately for male and female senior high school students.

RESULTS

Table 1 presents the means and standard deviations of the GSAT total scores and test scores for each subject by changes in weight status and gender. Regardless of gender, all kinds of scores measured by the university entrance exam (i.e., overall, Chinese, English, Mathematics, Science and Social Studies) are significantly lower among

Table 1. Descriptive statistics of the GSAT scores and students' basic characteristics stratified by changes in weight status and gender

	Never-Overweight		Become Overweight		Persistent Overweight		Become Non-overweight	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Male students (N=70,662)								
Overall score (0-75)	48.3	12.5	47.1***	12.1	46.4***	12.3	47.1***	12.6
Chinese score (0-15)	10.7	2.35	10.5***	2.32	10.5***	2.38	10.6***	2.43
English score (0-15)	8.91	3.57	8.47***	3.47	8.30***	3.52	8.61***	3.60
Mathematics score (0-15)	7.71	3.80	7.46***	3.66	7.24***	3.71	7.31***	3.76
Science score (0-15)	10.9	2.23	10.7***	2.19	10.6***	2.25	10.8**	2.26
Social Studies score (0-15)	10.2	2.80	9.95***	2.77	9.80***	2.80	9.85***	2.81
Age (years)	17.8	0.49	17.8	0.49	17.8	0.49	17.7	0.50
Low-income (if Yes=1)	0.01	0.10	0.01	0.11	0.01	0.10	0.01	0.11
Observations (%)	45,681 (64.7)		5,718 (8.09)		14,449 (20.5)		4,814 (6.81)	
Female students (*N*=78,578)								
Overall score (0-75)	47.9	11.8	47.1***	11.8	45.8***	11.6	46.1***	11.8
Chinese score (0-15)	11.4	2.26	11.2***	2.29	11.1***	2.32	11.1***	2.38
English score (0-15)	9.88	3.43	9.54***	3.42	9.13***	3.44	9.33***	3.47
Mathematics score (0-15)	6.56	3.42	6.41**	3.41	6.07***	3.27	6.10***	3.34
Science score (0-15)	11.0	2.29	10.8***	2.30	10.7***	2.32	10.7***	2.35
Social Studies score (0-15)	9.16	2.59	9.07*	2.59	8.85***	2.51	8.87***	2.53
Age (years)	17.7	0.47	17.7	0.46	17.7	0.47	17.8	0.47
Low-income (if Yes=1)	0.01	0.12	0.02	0.14	0.02	0.13	0.02	0.12
Observations (%)	58,031 (73.9)		5,231 (6.66)		11,706 (14.9)		3,610 (4.59)	

The t-tests were conducted to compare the mean scores of two groups (Become Overweight vs. Never-Overweight, Persistent Overweight vs. Never-Overweight and Become Non-overweight vs. Never-Overweight) among male and female students, respectively. *p<0.05, **p<0.01, ***p<0.001.

Become Overweight, *Persistent Overweight* and *Become Non-overweight* students, compared with the *Never-Overweight* students (the reference group). Interestingly, moving from overweight to non-overweight between the first and third year of senior high school is significantly associated with lower GSAT total scores and test scores for each subject in the third year.

Tables 2 and 3 present the estimation results of the fixed effect regression model for male and female senior high school students, respectively. Columns (1)-(6) in Table 2 show that the male students who became overweight between the first and third year of senior high school were significantly more likely to score lower on the overall GSAT, Chinese, English, Mathematics, Science and Social Studies tests by 0.837, 0.105, 0.323, 0.182, 0.101 and 0.126 points, respectively, compared with those who were never overweight (the reference group). The male students whose overweight persisted were significantly more likely to score lower on Chinese, English, Mathematics, Science and Social Studies subject tests by 0.085, 0.403, 0.262, 0.100 and 0.185 points, respectively, resulting in a reduction of 1.04 points in the overall GSAT score, compared with the never-overweight reference group. The male students who were overweight in the first year but became non-overweight in the third year were significantly more likely to score lower on the overall GSAT, Mathematics and Social Studies by 0.267, 0.147 and 0.117 points, respectively. In contrast, later onset non-overweight was not associated with the changes in the Chinese, English and Science test scores.

The estimation results for female students (Table 3) point to a pattern similar to that of the male students. In general, becoming overweight and persistent overweight was significantly negatively associated with the female student's academic performance as measured by the university entrance exam. However, in contrast to the findings of the insignificant effects among male students of later onset non-overweight on the Chinese, English and Science test scores, the female students who were overweight in the first year but became non-overweight in the third year were significantly more likely to score lower on the Chinese, English and Science subject tests by 0.084, 0.151 and 0.061 points, respectively, compared with the never-overweight female students (the reference group).

In addition, for both the male and female students, their age and family economic status matter for the academic performance. An additional year of age taking the university entrance exam would decrease the overall GSAT scores by 0.707 and 0.612 points among the male and female students, respectively. Our results also show that the male and female students from low-income households performed less well in the university entrance exam by 1.51 and 0.999 points, respectively.

DISCUSSION

Academic achievement during senior high school is an important determinant of future university admissions, job opportunities and earnings. Given that the evidence of the relationship between body weight and academic performance is inconclusive and the majority of the previous findings are from the western countries, we revisited this important topic by using the data available in Taiwan. In particular, we merged two unique Taiwan's national administrative datasets and investigated whether changes in weight status across the 3-year spectrum of senior high school study were associated with academic performance measured by the university entrance exam scores.

Our results showed that students who were either (a) not overweight in the first year but overweight in the third year of senior high school, (b) overweight in both the first and third year, or (c) overweight in the first year but not overweight in the third year, were significantly more likely to score lower on the university entrance exam, compared with their never-overweight counterparts. This find-

Table 2. Estimation results of the relationships between changes in weight status and the GSAT scores among 70,662 male students from 304 schools†

Variables	Overall score (1)	Chinese (2)	English (3)	Mathematics (4)	Science (5)	Social Studies (6)
BecomeOverweight‡	-0.837***	-0.105***	-0.323***	-0.182***	-0.101***	-0.126***
	(0.109)	(0.025)	(0.036)	(0.039)	(0.024)	(0.028)
PersistentOverweight‡	-1.035***	-0.085***	-0.403***	-0.262***	-0.100***	-0.185***
	(0.074)	(0.017)	(0.025)	(0.026)	(0.016)	(0.019)
BecomeNonoverweight‡	-0.267*	0.016	-0.047	-0.147***	0.027	-0.117***
	(0.118)	(0.027)	(0.039)	(0.042)	(0.026)	(0.030)
Age	-0.707***	-0.090***	-0.153***	-0.306***	-0.041**	-0.117***
	(0.064)	(0.014)	(0.021)	(0.023)	(0.014)	(0.016)
Low-income	-1.51***	-0.111	-0.485***	-0.428***	-0.217***	-0.266***
	(0.286)	(0.065)	(0.095)	(0.101)	(0.063)	(0.073)
Year 2011	2.13***	-0.117***	1.37***	1.27***	-0.847***	0.453***
	(0.077)	(0.017)	(0.026)	(0.027)	(0.017)	(0.020)
Year 2010	-1.31***	-0.618***	0.222***	-0.963***	0.071***	-0.025
	(0.078)	(0.018)	(0.026)	(0.028)	(0.017)	(0.020)
Constant	60.2***	12.5***	11.0***	12.9***	11.9***	12.0***
	(1.13)	(0.256)	(0.375)	(0.402)	(0.248)	(0.291)

Standard errors are in parentheses. *p<0.05, **p<0.01, ***p<0.001.
† School fixed effects are controlled in model estimation.
‡ The reference group is "*Never-Overweight*."

ing was robust across gender. The inverse association between body weight and academic performance found in this analysis is consistent with some of the previous studies.[18-22] More importantly, this study found that the change in weight status during the study period in senior high school was a significant factor associated with subsequent university entrance exam outcome.

We also found gender differences in the relationship between change in weight status and academic performance. For example, compared with the never-overweight peers, the female students, who were overweight in the first year but became non-overweight in the third year of senior high school, were significantly more likely to score lower on the Chinese, English and Science subject tests by 0.084, 0.151 and 0.061 points, respectively. In contrast, among the male students, moving from overweight to non-overweight between the first to third year of senior high school was not associated with the test scores for Chinese, English and Science.

Some body-image studies may be useful to provide possible explanations for the gender differences in the relationship between moving from overweight to non-overweight and academic performance. Body satisfaction/dissatisfaction becomes more pronounced during adolescence.[29-30] In particular, girls tend to be more dissatisfied with their bodies than boys do.[31-35] Body dissatisfaction is likely to increase the prevalence of trying to lose weight.[36] Here, we present a possible scenario. For example, if female students who are overweight in the first year of senior high school are dissatisfied with their body weight, then they may try hard to reach their ideal weight. Although they may successfully become non-overweight in the third year of senior high school, the time spent on losing weight and even using unhealthy weight reduction practices, such as dietary restriction and slimming tablets, may be likely to influence school learning, resulting in poor exam performance. Numerous studies have shown that unhealthy dietary behaviors lead to poor academic performance.[37-39] In addition, the nature of girls and how they learn Chinese, English and Science may be more sensitive to change in weight status than for boys or for other subjects. For example, girls tend to experience higher levels of weight stigmatization than boys, even at lower levels of overweight.[40-41] The female students who are overweight in the first year of senior high school may encounter more difficulties in interpersonal relationships with teachers and peers, resulting in poor exam performance later.[42-45] Teachers' and peers' responses to an individual's changing weight status may further explain the heterogeneity of our empirical findings between genders.

The implications of our findings are relatively straightforward. Schools should monitor students' body weight and track their weight trends over time. In particular, the students who start senior high school being overweight should be paid great attention to their weight trends and academic performance. If they are at risk of falling behind their peers, some strategies, such as tutoring and mentoring should be utilized. Meanwhile, school-based programs and practices, such as physical activity policies, school meal programs, or school health council, etc., need to be well-designed and effectively implemented. The school-based programs and practices can help reduce body weight among the students who start senior high school being overweight. Moreover, for those who are not overweight in the first year, the school-based programs and practices can prevent the escalation of body weight during the senior high school years.

Limitations

Although this study has reported some interesting findings, several research limitations should be mentioned. For instance, although using a fixed effect model allows control of all academic performance confounders that remain constant over time within the same school, we do not have extra information on family background to fur-

Table 3. Estimation results of the relationships between changes in weight status and the GSAT scores among 78,578 female students from 309 schools[†]

Variables	Overall score (1)	Chinese (2)	English (3)	Mathematics (4)	Science (5)	Social Studies (6)
BecomeOverweight[‡]	-0.585***	-0.098***	-0.247***	-0.123***	-0.084***	-0.034
	(0.096)	(0.023)	(0.033)	(0.034)	(0.023)	(0.026)
PersistentOverweight[‡]	-0.872***	-0.113***	-0.426***	-0.191***	-0.087***	-0.055**
	(0.068)	(0.016)	(0.023)	(0.024)	(0.016)	(0.018)
BecomeNonoverweight[‡]	-0.438***	-0.084**	-0.151***	-0.108**	-0.061*	-0.033
	(0.115)	(0.028)	(0.040)	(0.041)	(0.028)	(0.030)
Age	-0.612***	-0.082***	-0.150***	-0.216***	-0.062***	-0.102***
	(0.054)	(0.013)	(0.019)	(0.019)	(0.013)	(0.014)
Low-income	-0.999***	-0.065	-0.482***	-0.244***	-0.128**	-0.080
	(0.199)	(0.048)	(0.069)	(0.071)	(0.048)	(0.053)
Year 2011	1.14***	-0.418***	1.29***	1.23***	-1.09***	0.121***
	(0.063)	(0.015)	(0.022)	(0.022)	(0.015)	(0.017)
Year 2010	-1.72***	-0.689***	0.191***	-1.04***	-0.066***	-0.112***
	(0.063)	(0.015)	(0.022)	(0.023)	(0.015)	(0.017)
Constant	58.6***	13.2***	11.9***	10.2***	12.5***	10.9***
	(0.960)	(0.230)	(0.333)	(0.344)	(0.231)	(0.255)

Standard errors are in parentheses. *$p<0.05$, **$p<0.01$, ***$p<0.001$.
[†] School fixed effects are controlled in model estimation.
[‡] The reference group is "*Never-Overweight.*"

ther control for other factors that may be associated with the academic performance of students at the household level (such as the educational attainment and ethnicity of parents). Our findings would be more robust if this type of information could become available. Moreover, if data was available, some potential mediators (such as body image satisfaction and weight stigmatization) of the relationships between change in weight status and academic outcomes could be examined. Furthermore, a wider range of student achievements, such as in the classroom, extracurricular activities, community service, etc., might be useful in explaining the academic success of students.

AUTHOR DISCLOSURES

The authors appreciate the technical assistance provided by the College Entrance Examination Center and the Ministry of Education in Taiwan to preparing the statistical data. The findings of this study do not reflect their views and the authors accept any remaining errors. All authors have no conflict of interest.

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Original Article

Change in weight status and academic performance among senior high school students in Taiwan

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臺灣高中生體重變化與學業表現關係之探討

本文旨在探討臺灣高中生求學階段的體重變化狀況與其大學入學成績之關係。研究資料使用全國體檢數據與大學學科能力測驗成績的合併資料檔，有效樣本數為149,240位高中生，其中男、女學生分別為70,662與78,578人，並使用學校層級的固定效果模型進行估計。重要的分析結果，發現(a)高一時期體重正常，但至高三時變為超重、(b)高一與高三時期體重皆為超重者、(c)高一時超重，但至高三則變為正常体重者，與從未曾有過超重的對照組相比，這三類人群的大學入學考試成績偏低。體重變化與大學入學考試成績間的關聯，因性別與考試科目之不同而有所差異。本結果發現高中生在求學過程中的體重變化狀況會影響到其後的大學入學考試成績，故本研究建議有關單位未來應特別關注超重高中新生，為其應建立以學校為基礎的體重控制計畫，以降低超重的發生率。

关键词：肥胖、過重、學業表現、高中生、臺灣