Separating boys and girls and increasing weight? Assessing impacts of single-sex schools through random assignment in Seoul[1]

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Abstract

A growing body of research reports associations of school contexts, in which adolescents interact with their peers and react to adolescent culture, with adolescents' weight and weight-related behaviors. One interesting, but under-researched, dimension of school context that potentially matters for adolescents' weight is the gender composition. If boys and girls are separated into single-sex schools, they might become less concerned about physical appearance, which results in increased weight. Utilizing a unique setting in Seoul, Korea where students are randomly assigned into single-sex and coeducational schools within school districts, we estimate causal effects of single-sex schools on weight and weight-related behaviors. Our results show that students attending single-sex schools are more likely to be overweight, and the effects are more prominent among girls. We also find that girls in single-sex schools are less likely to engage in weight control behaviors.

JEL classification: I12, I21, J16

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1. Introduction

A growing body of literature in social science has explored the role of friends or peers in affecting health and health behaviors of individuals, particularly adolescents (e.g., Christakis and Fowler, 2007, 2012; Clark and Lohéac, 2007; Mueller et al., 2010). In a systematic review of studies addressing the influences of friends on body weight, Cunningham et al. (2012) found that the majority of studies confirm that mean weights of friends were significantly associated with the weight of an adolescent, even after controlling for various demographic and socioeconomic characteristics of individuals and families (e.g., Carrell et al., 2011; Halliday and Kwak, 2009; Renna et al., 2008; Toni and Gil, 2012; Trogdon et al., 2008). Recent studies also found that when their friends engaged in sports, exercise, and fast food consumption, adolescents were more likely to do so, and that adolescents exhibited similar patterns as their friends in healthy eating behaviors (Ali et al., 2011; Bruening et al., 2011). The significant associations of weight and weight-related behaviors of friends with those of an adolescent highlight the possible roles of contexts, in which adolescents interact with and are influenced by peers, in establishing social norms, expectations, and cultures regarding weight and weight-related behaviors.

Schools are an important context in which adolescents interact with peers and form adolescent cultures with specific values and preferences on weight and weight-related behaviors. A school is a venue not only for academic learning but also for "social" learning or socialization through which adolescents learn attitudes, values, and behaviors of their peers. Several studies have demonstrated the relevance of school contexts for influencing adolescents' risky behaviors such as smoking, drinking, and other substance use (Kumar et al., 2002; Lovato et al., 2010; West et al., 2004). However, the role of school contexts in influencing weight and weight-related behaviors has received relatively little attention. Previous research, which examined the effect of friends on adolescents' weights, mostly relied on school fixed-effect models (e.g., Renna et al., 2008; Trogdon et al., 2008). Although controlling for school fixed effects is a useful strategy for estimating effects of friends within schools, it does not allow the examination of the roles of any specific dimensions of school contexts, such as characteristics of school peers who are not friends, because the school fixed effects control for all school characteristics together without differentiating among them (Kumar et al., 2002; Muller et al., 2010).

On the other hand, studies that have explored the role of school contexts in influencing adolescents' health behaviors mostly have limited their focus on whether the proportion of students in a school with a certain behavior (e.g. smoking or drinking) or a certain characteristic (e.g. overweight) was associated with the behavior or characteristic of an adolescent (e.g., Carrell et al., 2011; Fletcher, 2010; Clark and Lohéac, 2007). An important aspect of the school context, which has received little attention regarding adolescents' weight and weight-related behaviors, is the gender composition of school. Physical attractiveness, popularity, appeal to the opposite sex, and dating, which likely influence adolescents' weight and weight-related behaviors, have been important components of adolescent culture in coeducational schools (Coleman, 1961) that are the dominant form of schooling in the United States and in a number of other countries. Unfortunately, the dominance of coeducational schooling in many countries makes it difficult to ask questions as: What would happen if boys and girls were separated into single-sex schools? Without opposite-sex peers, would boys and girls feel much less pressure and be less concerned about physical appearance and body size and shape, which may affect their weight-related behaviors and ultimately their weights? In contrast to the United States, there are several countries, including South Korea, New Zealand, and Israel, that have relatively balanced composition of single-sex and coeducational schools (Wiseman, 2008). These single-sex schools offer an interesting setting with which to examine how gender composition of a school might affect weight and weight-related behaviors of adolescents.

At the same time there is a growing attention to single-sex schooling as a way to improve overall achievement in many countries. For instance, the number of single-sex schools and single-sex classrooms within coeducational schools has dramatically increased in the United States after the amendment of Title IX of the US Education Act in 2006 that allows more flexibility to school districts to provide single-sex education (Doris et al., 2013). Reflecting the interest, numerous studies have recently examined the effects of single-sex schools on educational outcomes (e.g., Doris et al., 2013; Jackson, 2012; Mael et al., 2005; Park et al., 2012, 2013; Sullivan et al., 2010). However, with most studies exclusively focusing on educational outcomes, little research has explored impacts of single-sex schooling on health and health behaviors, particularly weight and weight-related behaviors, of adolescents.

A challenging issue in estimating the effect of friends and peers on any outcomes, including weight and weight-related behaviors, pertains to the selection of these groups. Adolescents generally are not randomly assigned friends and peers. This challenge also generally carries over for evaluating the impacts of single-sex schools on any outcomes, including weight and weight-related behaviors. In most countries students and families select into single-sex versus coeducational schools. The students who decide to attend single-sex schools rather than coeducational schools probably differ from those attending coeducational schools in both observed and unobserved characteristics, which makes it difficult to estimate unbiased effects of single-sex schools (Booth and Nolen, 2012a, 2012b; Jackson, 2012). Although the concern about selection bias for single-sex schools has been raised mainly in relation to educational outcomes, selection bias can be equally a concern in estimating the effect of single-sex schools on weights and weight-related behaviors. In this study, we assess causal effects of single-sex schools on weight and weight control behaviors by utilizing a unique setting in Seoul, South Korea (Korea, hereafter) where elementary- and middle-school graduates are randomly assigned into single-sex or coeducational schools by lottery.

Our study of causal effects of single-sex schools on student's overweight and obesity may have important policy implications. The prevalence of childhood overweight and obesity has risen rapidly in many countries. For example, over the last few decades overweight and obesity rates among American children have increased substantially (Cawley, 2010). Although the overweight and obesity rates in Korea are relatively low compared to other OECD countries, they have been increasing steadily. About 4% of the adult population is obese in Korea, and about 30% are overweight (including obese). OECD projections indicate that overweight rates will increase by a further 5% within ten years (OECD, 2013). In addition, child obesity rates are relatively high in Korea. According to the statistics released by Ministry of Education and Science Technology, obesity rates of Korean children have been steadily increasing from 11.2% in 2008 to 14.3% in 2011. At the same time, the share of severely obese children is on the rise from 0.8% in 2006 to 1.3% in 2011 (Ahn, 2013). Given the strong association between childhood obesity and adulthood obesity, increasing obesity among Korean adolescents raises a social and economic concern as an important risk factor contributing to chronic disease. In addition, there is evidence that obesity has a positive association with lower self-esteem, maladjustment, and hurts concentration in learning, which could result in lower academic achievement and behavioral problems in school (e.g., Cawley and Spiess, 2008; Levy et al., 2011). In this regard, identifying potential contributors to increased overweight and obesity among school-aged children is an important question of high policy relevance in Korea, which may be applicable to other countries as well.

2. RANDOM ASSIGNMENTS IN SEOUL

Before 1973, Korean high schools could select their students based on students' performance on entrance examinations administered by individual high schools. This selection process caused sorting of students into schools hierarchically ranked by family background and substantial gaps in academic performance across schools along with severe competition to get into prestigious high schools. Out of concerns about between-school inequality and academic pressure on students to do well on high school entrance examinations, the Korean government introduced a national educational reform known as the High School Equalization Policy. Under this policy middle school graduates have been randomly assigned to academic high schools within their school districts in most urban areas, beginning in 1974 in Seoul (the capital and the largest metropolitan area) and Busan (the second largest metropolitan area). Along with the earlier implementation of the No Middle School Entrance Examination Policy in 1968, these two major government policies have limited school choice in secondary education and created a de facto experiment, in which students after elementary school graduation are randomly distributed to middle and then high schools within school districts regardless of whether schools are single-sex or coeducational and private or public (Kim, 2003).

Although the equalization policies still are maintained, since the mid-1990s other metro areas except Seoul have loosened the equalization policy in order to respond to growing demand for school choice. In those districts with the modified version of the equalization policy, students are allowed to list the 2-3 high schools that they prefer. Then, 30 – 40% of enrollments in a school are ‘randomly’ selected among those students who show preference for that school, and the remaining enrollments are selected entirely by lottery without considering students’ preferences. Therefore in this study we focus on Seoul which maintained its original assignment rule for high school entrants until 2009 and still applies the original rule for middle school entrants.

As of 2012, there were 594 elementary schools (1st - 6th grades and all schools are coeducational schools), 379 middle schools (7th - 9th grades and 24.5 percent are single-sex schools) and 225 academic high schools (10th - 12th grades and 58.2 percent are single-sex schools) in Seoul.[2] There were 11 high school districts in Seoul, and each high school district was divided into 3 to 6 geographically smaller middle school districts. In total, there were 46 middle school districts in Seoul. According to the revised article 8 of the Enforcement Rule of the School Health Act in 2008, students should be assigned to middle schools and high schools within a half-hour distance from home by public transportation, which basically includes almost all schools within school districts, considering the size of Seoul.[3] The assignment formula either for middle or high schools is not known to the public, and the assignment process includes random draws using computer software developed for this specific task. However, educational stakeholders' perception, including students, parents, and educational administrators, is that distance from a student's home to school is likely to be considered to some extent for middle school assignment to reduce exposures to risk factors during commuting to school.[4] In contrast, as many studies in economics agree, student assignment into high schools, which occurs within much larger high school districts than middle school districts, is much closer to random (Choi et al., 2013; Hahn et al., 2013; Park et al., 2012).

Non-compliance with the initial school assignment is not a major concern for this study. In case of high schools, if students move their residences to a new school district for any reason including their dissatisfaction with their assignments, they are subject to another random assignment in the new district. Therefore, changing district of residence provides no guarantee that a student can attend a single-sex or coeducational high school as she or he wants in the new district. Park et al. (2012), moreover, showed that the actual percentage of households moving into different school districts during the ages for transition to high schools is very small.

In case of middle school, if students move their residences to a new school district, they are assigned to a school among a set of the closest schools that have vacancies at the time of move based on the matching table which links the residential block to which a student's new

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[2] The high school equalization policy is applied only to academic high schools (which are the major form of high schools) but not vocational and special purpose high schools. There were 73 vocational high schools and 19 special purpose high schools in Seoul.

[3] Note that before 2008, even the half hour distance rule did not exist in the Enforcement Rule of the School Health Act.

[4] The Seoul Educational Longitudinal Study (SELS) is based on a representative sample of elementary school students in Seoul and has followed 4th graders in 2010 until their 7th grade in 2013. Using SELS, we investigated how elementary school graduates were allocated to different middle schools when they finished their 6th grade in 2012. We found that 3,645 students in 107 elementary schools were distributed to 300 middle schools with 571 elementary-middle schools combinations. On average, there were 5.3 middle schools (standard deviation of 2.1) to which an elementary school sent their graduates. Note that there are about 8 middle schools (standard deviation of 3.3) in 46 middle school districts in Seoul.

address belongs and a list of candidate schools. However, there is variation in vacancies of schools, and the matching table is not open to the public and is consistently updated depending on changes of population composition and establishment of new schools. Hence, we believe that non-compliance is not likely to cause serious distortions in our estimates of the causal effect of single-sex schools. In short, although the assignment of students into Korean middle and high schools is not an experiment purposely designed to estimate the causal effect of an intervention, it provides an excellent opportunity for estimating the effect of single-sex schools on a variety of outcomes without the likely selection bias inherent in studies based on observational data.

3. DATA AND MEASURES

3.1. *Data*

In this study, we rely on two datasets for Korean adolescents. For the school-level analysis, we use a school-level database on health outcomes of middle and high school students compiled by the Korean government, as reported by each school in accordance with educational law. The compiled data are publicly available online (www.schoolinfo.go.kr). Starting with elementary school students, the Korean government mandated school-level physical examinations and release of information on a yearly basis. In 2009, the physical examinations were conducted for elementary school students. In the following year of 2010, middle schools started to conduct the same physical examinations and finally since 2011 the physical examinations for high school students were initiated and the results have been provided on the above website. The physical examinations are conducted for every student in the 5th to 12th grades, and the results are released in April of the following year. Hence, there are results for three years (2010, 2011, and 2012 examinations) at the middle school and for two years (2011 and 2012 examinations) at the high school level as of the writing of this paper. If a school is coeducational, each item is reported by gender. In regard to the weight-related measure, each school reported school mean body mass indices (BMI) for each grade level by gender.

An important advantage of these school-level data for this study is that we can track cohorts of 6th-grade students in 2009 until their 9th grade in 2012. Through this cohort we can investigate whether there was a prior BMI gap before entering middle school and how the BMI gap between coeducational and single-sex schools has evolved over time during three years in middle school. Importantly, this dataset includes every middle school in Seoul. In our estimation, we use 3,332 middle schools, which are grade-year specific observations of schools over 3 years. For high schools, we use 205 high schools[5], providing BMI information for 12th graders in 2011. This is the only cohort whose data are available and who entered high schools in 2009 before Seoul modified its high school assignment rule to expand school choice in 2010 (see Appendix). Distributions of middle schools and high schools by school type and their mean BMIs are presented in Panel A in Table 1.

In addition to the school-level analysis of students in Seoul, we also conduct individual-level analysis using data from a nationally representative sample of Korean middle and high school students (7th – 12th grades corresponding approximately to ages of 13-18), the Korea Youth Risk Behaviors Web-Based Survey (KYRBWS). KYRBWS is a cross-sectional survey of secondary school students conducted every year. It first started with 7th – 11th grades in 2005, and it has also included 12th grade since 2006. KYRBWS uses a two-stage cluster sampling, first randomly sampling schools and then randomly sampling one class per grade within selected schools. All students in the selected class are invited to participate in the survey (MEST, MHW, KCDCP, 2011). Students in the selected class are taken to a computer lab in the school where each student uses a computer connected with the internet. Using an individual identification number given by the survey team, each student logs into a website where he/she can respond to the questionnaire. We exclude 10th graders in 2010 and 10th and 11th graders in 2011 because they were assigned to high schools after the change of assignment rule in 2010 (see Appendix). As a result, our final sample includes 29,225 students in 308 middle schools and 16,544 students in 227 high schools in Seoul, covering 7 waves from 2005 to 2011. Panel B in Table 1 presents student and school distributions by gender and school type.

[TABLE 1 ABOUT HERE]

3.2. *Weight Status in KYRBWS*

In the survey, students were asked to report their heights and weights. Using their self-reported heights and weights, we calculated the respondents' BMI as weight in kilograms divided by height in meters squared (kg/m^2). To classify respondents into different categories of weight

[5] Out of 225 academic high schools in 2012, 10 high schools were founded since 2010. We further exclude two high schools to which the High School Equalization Policy is not applied and 8 high schools for which BMI information is not provided on the website.

status, we used the gender-age-specific growth chart specifically devised for Korean children and adolescents by the Korea Center for Diseases Control and Prevention. It provides BMI cut-off values corresponding to the 3rd, 5th, 10th, 25h, 50th, 75th, 85th, 90th, 95th, and 97th percentiles in the sex-age-specific distributions of BMI (Lim et al., 2009). Following the standard classification used by health researchers in Korea, we classified adolescents whose BMI was below the 5th percentile as underweight, those in the 5-84th percentile as normal, and those in the 85th percentile or above as overweight.[6]

3.3. *Weight-Control Behaviors in KYRBWS*

KYRBWS asked students since 2007 to indicate whether they have made efforts for weight control during the last 30 days by selecting one of the following responses: 1) they did not make any efforts; 2) they made efforts to lose weight; 3) they made efforts to gain weight; and 4) they made efforts to maintain the same weight. Following the work by Mueller et al. (2010) on a similar variable for US adolescents, we coded those who tried to lose weight as 1 and coded others as 0. Thus, this variable indicates the degree of engagement in weight control for losing weight. Note that this weight-control behavior measure is not available for 2005 and 2006 data. Therefore the sample for the analysis of the weight-control variable is smaller than the total sample used for the analysis of BMI and weight status.

4. RESULTS

4.1. *Results from Analyses Using School-Level Data*

4.1.1. *OLS Regression of School Mean BMI by School Type*

[TABLE 2 ABOUT HERE]

Columns 1 – 3 in Table 2 present the results of ordinary least squares regressions predicting school mean BMI by school type using school-level data for middle school students in Seoul from 2010 to 2012. Firstly we estimate school-district fixed-effects models by including 45

[6] Although adolescents in the 95th percentile or above are often classified as obese separately from those overweight (85th-94th percentiles), we combine those in the 85-94 percentiles and in the 95 percentile or above into overweight.

dummies for school districts separately for girls and boys. The first three columns in Table 2 show estimation results using a cohort that started middle schools in the 7th grade in 2010. For this cohort, school level mean BMIs by gender are available for three years: 2010 (7th grade), 2011 (8th grade) and in 2012 (9th grade). We can see that all-girls schools show school mean BMI higher by 0.464 than girls in coeducational schools in the 7th grade and the gap increases to 0.549 in the 9th grade. Although it is not statistically significant in the 7th grade among boys of the same cohort, the BMI gap between boys in single-sex schools and boys in coeducational schools is growing over time and significantly differs by 0.439 in the 9th grade.

Column 4 in Table 2 presents estimation results when we combine all nine available groups, three grades (7th-9th) across three years (2010-2012), with additional dummy variables for 8th and 9th grades as compared to the reference category of 7th grade, and two dummy variables to capture year fixed effects. The result confirms that all-girls schools have higher school mean BMI by 0.42 than coeducational schools for girls and all-boys schools have higher school mean BMI by 0.34 than coeducational schools for boys. Considering that the average height of Korean girls in secondary schools is about 160cm, an increase of BMI by 0.42 amounts to an increase in school mean weight by 1.08 kg.

The last column in Table 2 shows the estimation result for the 12th grade in 2011. We find boys in single-sex schools compared to boys in coeducational schools show a higher mean BMI by 0.291. Although it is not statistically significant at 10%, girls attending single-sex schools also tend to have higher BMI.[7]

4.1.2. *Is BMI Gap among Middle School Students due to a Prior Gap in 6th Grade?*

[TABLE 3 ABOUT HERE]

As discussed earlier, although it is not known for sure, distance from home to school has been perceived as a factor considered in middle school assignment process. This raises a possibility that the BMI gaps we find in Table 2 might come from prior differences before entering middle

[7] We have school mean BMI information at the high school level for 6 groups (three grades over two years; all groups except for the 12th grade in 2011 entered high schools after the modification of assignment in 2010). In Korea students are highly dedicated to preparation for college entrance in the 12th grade. When we investigate weight control behavior using KYRBWS, we find a dramatic decrease in students' effort to control weight when they progress from 11th grade to 12th grade. We think this could be one of the reasons for the narrowing BMI gap by school type among girls in 12th grade. When we use all 6 groups from high school data, we also find a significant difference in BMI among girls. However, because of recent modification of the assignment rule for high school entrants for other five groups, we only report our findings using the 12th grade in 2011.

schools. To address this concern, in Table 3, we investigate a prior body mass index at the 6th grade by gender.[8] After calculating mean BMI separately for boys and girls attending neighboring elementary schools within a 1km radius from each middle school, we regress the corresponding mean BMI of each gender on the variable to indicate whether the middle schools are single-sex or not.[9] Columns 1 and 3 in Table 3 show regression results using a cohort that was in the 6th grade in 2009. This cohort is the same cohort as the one for which we examine BMI changes over three years during middle school in Table 2. There is no significant difference in prior BMI in 6th grade before entering middle school for both boys and girls. Columns 2 and 4 in Table 3 provide results when we combine all available information from four cohorts who were in the 6th grade in elementary school between 2009 and 2012. This result consistently confirms that there is no prior BMI difference between girls (boys) in coeducational middle schools and girls (boys) in single-sex middle schools. Hence, these results provide more confidence that the BMI gap observed at the middle school level reflects differences appearing after entering middle schools.

4.2. *Results from Analyses Using the Individual-Level Data, KYRBWS*

4.2.1. *Weight Status by School Type*

[FIGURE 1 ABOUT HERE]

Figure 1 presents the distribution of weight status by school type for boys and girls, separately with the pooled data across 7th – 9th grades and 10th – 12th grades. Most evident is that the percentage of middle and high school students who are classified as overweight is higher among students attending single-sex schools than their counterparts in coeducational schools for both girls and boys. For instance, 11.6 percent of girls attending all-girls high schools have overweight status, while only 9.9 percent of girls attending coeducational high schools have the same status. The percentage of boys with overweight status is 16 percent and 14.8 percent for coeducational and all-boys schools, respectively. The opposite pattern is observed for

[8] We use 554 public elementary schools after excluding 40 private elementary schools. Public elementary schools in Korea are free of tuition and students are assigned to public schools based on their home addresses. In contrast, private elementary schools select their students among applicants without any restriction on residence. Students attending private elementary schools are more likely to have better family backgrounds to cover tuition and other expenses.

[9] The average number of elementary schools matched to a middle school within a 1km radius is 4.1. Results are robust when we use alternative radii between 0.8 and 1.6 km.

underweight status. The percentage of students with underweight status is slightly higher among students attending coeducational schools than students attending single-sex schools, although the difference in underweight between the two school types seems smaller than the difference in overweight.[10] In short, by suggesting some substantial differences in weight status between students attending single-sex and coeducational schools, Figure 1 invites further investigation to systematically estimate the causal effect of single-sex schools on weight.

4.2.2. *Checking Randomness: Balance on Family Background*

Before moving to further results, it is important to check balance on some major family background measures as a way to verify the extent to which student assignments into single-sex and coeducational schools are random. If the assignment is indeed random, we should see no significant difference in observed family background measures between students attending single-sex schools and their counterparts attending coeducational schools. Our individual-level data from KYRBWS do not have many family background measures but they do contain father's schooling attainment, mother's schooling attainment, family structure, and subjective perception of economic status from 1 (lowest) to 5 (highest). The schooling levels of fathers and mothers are divided into four categories: 1) middle school or less; 2) high school; 3) college or above and 4) (respondents) do not know or missing. We distinguish students living with two-biological parents from all others (including missing cases).

[TABLE 4 ABOUT HERE]

Table 4 presents the results of logit analysis predicting attendance at a single-sex school (vs. a coeducational school) by father's schooling, mother's schooling, family structure, and perceived economic status for girls and boys, separately. We conduct the logit analysis for middle schools and high schools, separately. As shown in columns 2 and 4, the family background measures are not significantly associated with the likelihood of attending a single-sex school for both girls and boys in high schools. Although we could include only these four measures of family background, the result is consistent with the claim that student assignment in Seoul high schools is random. In addition, in earlier studies of educational outcomes, using different datasets Park et al. (2012, 2013) have found evidence of balanced prior achievement

[10] According to the chi-square test, the null hypothesis of no association between school type and weight status should be rejected for both girls (p = .002) and boys (p = .013) in middle schools, and also for both girls (p = .026) and boys (p = .085) in high schools.

and family background measures such as household income, home ownership, and the number of books at home between students attending single-sex high schools and those attending coeducational high schools.

For middle school students, however, girls attending all-girls middle schools are more likely to live with both parents and have fathers with less education compared to girls in coeducational middle schools. On the other hand, boys attending all-boys middle schools have mothers with lower education and the distribution of perceived economic status slightly differs between boys in each type of schools. As noted earlier, there are 46 middle school districts in Seoul. Although KYRBWS is nationally representative, in each wave, sampling 40-50 middle schools from 46 middle school districts might result in some unbalanced measures among middle school cohorts. However, our finding in Table 3, showing prior BMI balance in the 6th grade before entering middle school, partially assuages this concern. In addition, we control for family background measures in the following analyses and find that including family background measures does not make a meaningful change in the estimated effects of single-sex schooling on the outcomes of interest.

4.2.3. ***OLS Regression of BMI***

[TABLE 5 ABOUT HERE]

In Table 5, we present the result of ordinary least squares regressions predicting adolescents' BMI by school type using data for middle and high school students in Seoul from 2005 to 2011. As mentioned earlier, we exclude data for 10th graders in 2010 and 10th and 11th graders in 2011 who entered high schools after the modification of school assignment in Seoul. We estimate two sequential models. Model 1 in columns 1 and 4 includes only a dummy variable for single-sex schools, student's grade (two dummy variables for 8th (11th) and 9th (12th) grades as compared to the reference category of 7th (10th) grade for middle (high) school students) and five dummy variables to capture year fixed effects.[11] Model 2 adds family background measures to Model 1 to see how the coefficient of single-sex schools changes after controlling for family background. In Model 1 of Panel B, attending a single-sex high school is significantly associated with the increased BMI by 0.2 for girls and by 0.18 for boys. Given that one standard deviation

[11] Please note that because we do not have information to identify school locations, we cannot control for school district fixed effects in the analyses using KYRBWS.

of BMI is 2.51 for high school girls and 3.18 for high school boys, the effect of single-sex high schools on BMI is equivalent to 0.08 standard deviations for girls and 0.06 standard deviations for boys. The corresponding figures for middle school students are 0.11 (= 0.3/2.61) standard deviations for girls and 0.06 (= 0.197/3.23) standard deviations for boys (Panel A). In Model 2, as expected given random assignment, the coefficients of single-sex schools hardly change after controlling for family background measures.

4.2.4. *Is the BMI Gap Spurious?*

As a falsification test, using KYRBWS, we examine whether there is any significant difference in height by school type, which is supposedly insensitive to school contexts and peer interactions. In Table 5, column 3 for girls and column 6 for boys investigate whether we can find an effect of single-sex schools on student's height in centimeters (Panel A for middle school students and Panel B for high school students). For both middle and high school students, we do not find any significant relationship between attending single-sex schools and a student's height. This result provides more confidence that the BMI gap by school type results from the gap in weight, which would be more sensitively affected by school contexts and peer interactions.

4.2.5. *Analysis of Weight Status and Weight Control Behavior*

[TABLE 6 ABOUT HERE]

We now turn to the multinomial logit analysis of weight status (overweight, underweight, and normal weight). In Table 6, columns 2 and 5 pertain to the likelihood of overweight as compared to normal weight as the reference, while columns 1 and 4 indicate comparisons of underweight and normal weight. Similar to the result for BMI, students attending single-sex schools are more likely to be overweight and less likely to be underweight than their counterparts attending coeducational schools. Specifically, we find that the relative-risk ratio for being overweight versus being normal is 19% (18%) higher for girls (boys) in single-sex middle schools than their counterparts (boys) in coeducational schools (Panel A). The relative-risk ratio for overweight is 20% higher for girls attending all-girls high schools compared to girls in coeducational high schools. Although it is not significant at 10%, the relative-risk ratio for being overweight versus being normal is 8% higher for boys attending all-boys high schools than boys in coeducational high schools (Panel B).

To identify potential channels that generate BMI gaps between students in single-sex schools and coeducational schools, we investigate whether there is a difference in health-related behaviors by comparing engagement in weight control behaviors for students in single-sex schools compared to students in coeducational schools. As shown in columns 3 and 6 in Table 6, we conduct logit analysis controlling for individual BMI, grade and year fixed effects, and family background characteristics. We find that girls in all-girls middle schools compared to girls in coeducational middle schools show about 8.7% lower odds of engaging in weight control to lose weight (Panel A). Although it is not significant at 10%, girls attending all-girls high schools have 8.1% lower odds of engaging in weight control to lose weight (Panel B). This behavioral difference would work as one of the mechanisms to cause relatively higher BMI among girls in all-girls schools compared to their counterparts in coeducational schools.

5. Discussion

A growing body of research reports associations of school contexts, in which adolescents interact with their peers and react to adolescent culture, with weight and weight-related behaviors of adolescents, independent of effects of individual and familial characteristics. In this study, we examine one specific school context, single-sex schools vs. coeducational schools, which potentially matters for adolescents' weight. We conjecture that when boys and girls are separated into single-sex schools without opposite-sex peers, boys and girls feel much less pressure and are less concerned about physical appearance and body size and shape, which could increase their weights. Utilizing a unique setting in Seoul, Korea where students are randomly assigned into single-sex and coeducational schools within school districts, we estimate causal effects of single-sex schools on BMI and weight-related behaviors. Consistent with our hypothesis, our results show that students attending single-sex schools are more likely to have higher BMI, and the effects are more prominent among girls. We also find that girls in single-sex schools are less likely to engage in weight control behaviors compared to girls in coeducational schools.

There are some limitations in our study. Firstly, this study uses self-reported measures of height and weight when we conduct individual level analysis using KYRBWS. Using the 2008 wave of KYRBWS, Bae et al. (2010) showed that self-reported weight tended to be understated and self-reported height tended to be overstated, and obese adolescents tended to underreport their weight and overstate their height more than non-obese adolescents. This tendency is also confirmed in our study when we compare mean BMI for both boys and girls from KYRBWS and School Information data, which was obtained through physical examinations at school. The relatively smaller effects of single-sex schooling on BMI we find from KYRBWS may be partially due to this bias in self-reported measures. Additionally, due to privacy concerns and data confidentiality, KYRBWS does not provide school district information, which does not allow us to control for school district fixed effects in the individual level analysis. For a sensitivity check, however, we conduct an analysis by not controlling for school district fixed effect using school-level data. This analysis reveals that failure to control for school district fixed effects results in small underestimates of the effects of single-sex schools on BMI without changing our findings of significant effects of single-sex schools on BMI when we control for school district fixed effects.

Although we show that single-sex schools have a causal effect on students' BMI and find evidence that there is a difference in weight control behavior among girls in single-sex schools and coeducational schools, further research is needed to verify mechanisms of generating this effect of single-sex schools and to explain gender differences. Finally, it would be desirable to extend this research to examine risk-taking behaviors (Booth et al., 2014; Bougheas et al., 2013) and other behavioral outcomes such as smoking, drinking, and romantic relationships beyond our focus on weight and weight-related behaviors.

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Figure 1: Distribution of Weight Status by School Type and Gender.

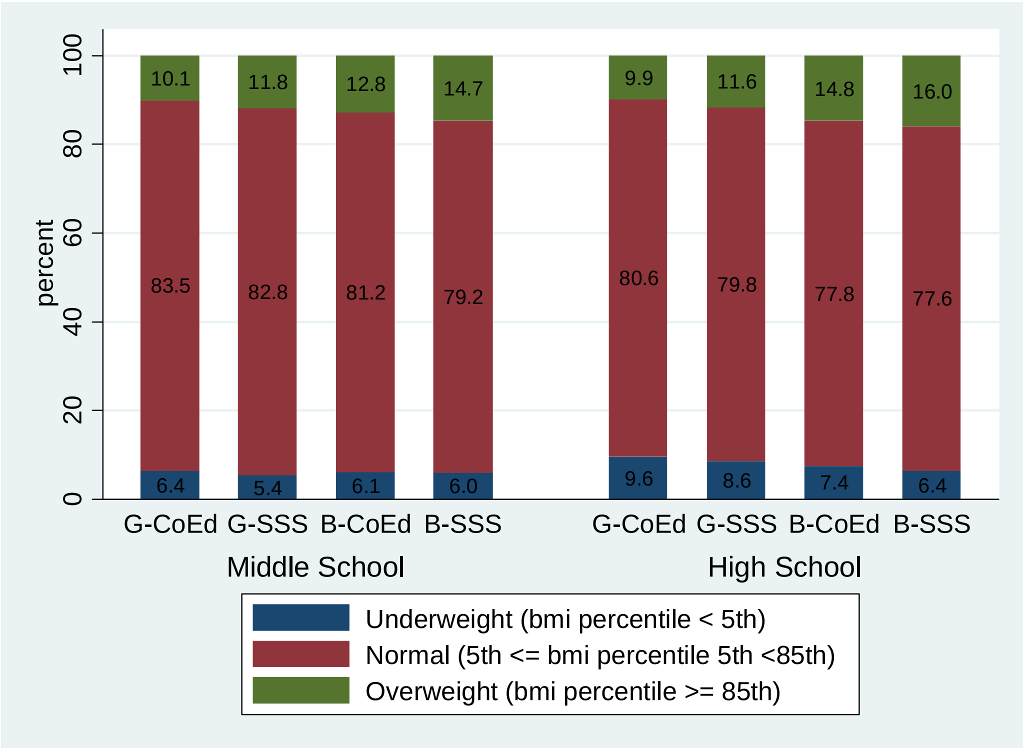

Table 1. Descriptive Statistics (School Information Data and KYRBWS).

	Middle School		High School	
Panel A. School Information Data	N = 3,332		N = 205	
	(3 Years*3 Grades)		(1 Year*1 Grade)	
School Type (%)				
All-boys schools	12.8		32.2	
All-girls schools	11.7		27.8	
Coed schools	75.5		40.0	
School Level Mean BMI				
Girls in Coed schools	20.6	(0.71)	21.5	(0.64)
Girls in all-girls schools	21.0	(0.66)	21.7	(0.61)
Boys in Coed schools	21.2	(0.68)	22.7	(0.49)
Boys in all-boys schools	21.6	(0.68)	23.1	(0.46)
Panel B. KYRBWS (2005 - 2011)				
Students	N = 29,225		N = 16,544	
School Type (%)				
Girls in Coed schools	37.8		16.5	
Girls in all-girls schools	11.5		30.8	
Boys in Coed schools	39.8		19.6	
Boys in all-boys schools	10.9		33.1	
BMI				
Girls in Coed schools	19.6	(2.61)	20.5	(2.46)
Girls in all-girls schools	19.9	(2.63)	20.7	(2.53)
Boys in Coed schools	20.3	(3.2)	21.6	(3.13)
Boys in all-boys schools	20.5	(3.32)	21.8	(3.2)
Height				
Girls	159.4	(5.45)	161.7	(4.98)
Boys	166.5	(8.28)	174.4	(5.46)
Family Background				
Household income	3.3	(0.94)	3.1	(0.92)
Father's education	14.3	(2.19)	14.0	(2.3)
Mother's education	13.8	(2.23)	13.3	(2.26)
Schools	N = 308		N =227	
School Type (%)				
All-boys schools	11.4		33.0	
All-girls schools	11.4		29.1	
Coed schools	77.2		37.9	

Note: Values in parentheses are standard deviations.

Table 2: OLS Regression of School Mean BMI by School Type.

	Girls				
	2010: 7th	2011: 8th	2012: 9th	All (7th-9th)	2011: 12th
Single-Sex School	0.464***	0.451***	0.549***	0.420***	0.163
	(0.099)	(0.119)	(0.117)	(0.062)	(0.114)
Constant	20.086***	20.214***	20.771***	19.921***	21.479***
	(0.199)	(0.237)	(0.233)	(0.037)	(0.207)
N	319	323	323	2,898	139
R-sq	0.249	0.233	0.210	0.376	0.229

	Boys				
	2010: 7th	2011: 8th	2012: 9th	All (7th-9th)	2011: 12th
Single-Sex School	0.137	0.349***	0.439***	0.342***	0.312***
	(0.096)	(0.107)	(0.100)	(0.050)	(0.088)
Constant	21.571***	21.886***	22.257***	21.307***	22.819***
	(0.193)	(0.225)	(0.213)	(0.109)	(0.145)
N	322	328	329	2,926	148
R-sq	0.199	0.229	0.224	0.364	0.245

Note: We control for dummy variables for 46 middle school districts and 11 high school districts.
*** p<0.01, ** p<0.05, * p<0.1.

Table 3: Comparison of BMI of 6th Grade Students Attending Nearby Elementary Schools.

	Girls		Boy	
	2009	2009-2013	2009	2009-2013
Single-Sex MS	-0.001	0.012	-0.025	0.001
	(0.069)	(0.024)	(0.066)	(0.024)
Constant	19.419***	19.451***	20.972***	20.717***
	(0.000)	(0.090)	(0.000)	(0.084)
N	323	1,493	328	1,493
R-sq	0.447	0.322	0.348	0.255

Note: Nearby elementary schools are selected within a 1km radius from each middle school.
*** p<0.01, ** p<0.05, * p<0.1.

Table 4: Logit Models of Attending Single-Sex Schools by Family Background.

	Girls		Boys	
	Attending all-girls schools (vs. coeducational)		Attending all-boys schools (vs. coeducational)	
	Middle School	High School	Middle School	High School
Father's education (ref: middle school or less)				
High school	-0.222*	0.193	-0.015	-0.101
	(0.121)	(0.133)	(0.099)	(0.106)
College	-0.085	0.208	-0.079	0.077
	(0.153)	(0.159)	(0.123)	(0.126)
Do not know/Missing	-0.247**	0.199	-0.051	0.127
	(0.126)	(0.196)	(0.109)	(0.137)
Mother's education (ref: middle school or less)				
High school	0.060	-0.029	-0.229**	0.139
	(0.131)	(0.134)	(0.116)	(0.110)
College	0.016	-0.112	-0.198	0.008
	(0.188)	(0.162)	(0.149)	(0.148)
Do not know/Missing	0.100	-0.296*	-0.237**	-0.095
	(0.144)	(0.160)	(0.102)	(0.128)
Both parents at home	0.383***	-0.176	-0.141	0.040
	(0.102)	(0.119)	(0.098)	(0.100)
Economic status (ref: lowest)				
Lower middle	0.033	0.129	-0.083	0.046
	(0.117)	(0.122)	(0.106)	(0.120)
Middle	-0.054	0.119	-0.206**	-0.042
	(0.126)	(0.123)	(0.103)	(0.121)
Upper middle	-0.072	-0.048	-0.166*	-0.051
	(0.132)	(0.134)	(0.101)	(0.132)
Highest	-0.082	-0.198	-0.153	-0.132
	(0.150)	(0.184)	(0.129)	(0.145)
Constant	-1.302**	0.717	-0.933	0.620
	(0.524)	(0.577)	(0.573)	(0.534)
N	14,414	7,822	14,811	8,722

Note: Dummy variables for students' grade and survey years are included in each model. Values in parentheses are robust standard errors adjusted for schools.
*** p<0.01, ** p<0.05, * p<0.1.

Table 5: OLS Regression of Student's BMI and Height by School Type.

	Girls			Boys		
	Model 1	Model 2	Height	Model 1	Model 2	Height
Panel A. Middle School						
Single-Sex school (vs. coed)	**0.300*****	**0.305*****	**0.089**	**0.197****	**0.210*****	**0.188**
	(0.061)	(0.057)	(0.113)	(0.082)	(0.079)	(0.162)
Student's grade (ref: 7th grade)						
8th grade	0.541***	0.522***	2.177***	0.274***	0.270***	6.437***
	(0.056)	(0.056)	(0.111)	(0.063)	(0.064)	(0.162)
9th grade	0.877***	0.846***	3.327***	0.772***	0.770***	10.401***
	(0.057)	(0.056)	(0.111)	(0.065)	(0.066)	(0.145)
Constant	19.110***	20.199***	156.460***	19.943***	20.139***	159.373***
	(0.046)	(0.201)	(0.429)	(0.047)	(0.234)	(0.540)
N	14,414	14,414	14,414	14,811	14,811	14,811
R-sq	0.021	0.028	0.072	0.010	0.014	0.277
Controls	No	Yes	Yes	No	Yes	Yes
Panel B. High School						
Single-Sex school (vs. coed)	**0.200****	**0.197****	**0.087**	**0.184****	**0.167****	**0.001**
	(0.089)	(0.082)	(0.118)	(0.073)	(0.069)	(0.116)
Student's grade (ref: 10th grade)						
11th grade	0.166**	0.214***	0.683***	0.474***	0.497***	1.193***
	(0.080)	(0.079)	(0.148)	(0.087)	(0.090)	(0.172)
12th grade	0.431***	0.488***	0.534***	0.732***	0.856***	1.785***
	(0.077)	(0.088)	(0.172)	(0.078)	(0.089)	(0.182)
Constant	20.305***	20.938***	160.570***	21.198***	21.305***	172.937***
	(0.087)	(0.280)	(0.492)	(0.070)	(0.283)	(0.534)
N	7,822	7,822	7,822	8,722	8,722	8,722
R-sq	0.006	0.013	0.008	0.010	0.014	0.026
Controls	No	Yes	Yes	No	Yes	Yes

Note: We control for dummy variables for survey years, educational attainment of father and mother, subjective economic status, whether there are both parents at home. Values in parentheses are robust standard errors adjusted for schools.

*** p<0.01, ** p<0.05, * p<0.1.

Table 6: Analyses of Overweight and Underweight Compared to Normal Weight and Weight Control Behavior.

(Multinomial) Logit specification	Girls			Boys		
	Underweight vs. Normal	Overweight vs. Normal	Weight Control	Underweight vs. Normal	Overweight vs. Normal	Weight Control
Panel A. Middle School						
Single-Sex school (vs. coed)	**-0.169***	**0.173****	**-0.091***	**-0.004**	**0.168*****	**-0.021**
	(0.095)	(0.075)	(0.050)	(0.117)	(0.062)	(0.064)
BMI			0.317***			0.323***
			(0.010)			(0.009)
Student's grade (ref: 7th grade)						
8th grade	-0.204**	-0.029	0.126**	0.117	-0.153***	-0.211***
	(0.084)	(0.066)	(0.049)	(0.082)	(0.059)	(0.063)
9th grade	-0.131	-0.172**	0.059	0.140	-0.033	-0.364***
	(0.088)	(0.076)	(0.053)	(0.089)	(0.060)	(0.063)
N	14,414	14,414	10,469	14,811	14,811	10,730
Panel B. High School						
Single-Sex school (vs. coed)	**-0.096**	**0.180****	**-0.085**	**-0.137**	**0.078**	**0.059**
	(0.101)	(0.084)	(0.062)	(0.100)	(0.060)	(0.069)
BMI			0.183***			0.293***
			(0.010)			(0.012)
Student's grade (ref: 10th grade)						
11th grade	0.316***	0.135	-0.064	0.309**	0.272***	-0.048
	(0.110)	(0.111)	(0.082)	(0.132)	(0.076)	(0.086)
12th grade	0.465***	0.245**	-0.999***	0.414***	0.399***	-0.592***
	(0.119)	(0.101)	(0.096)	(0.133)	(0.078)	(0.087)
N	7,822	7,822	5,812	8,722	8,722	6,484

Note: We control for dummy variables for survey years, educational attainment of father and mother, subjective economic status, whether there are both parents at home. Values in parentheses are robust standard errors adjusted for schools.
*** p<0.01, ** p<0.05, * p<0.1.

Appendix A. Datasets Used by Year and Grade Level

Year \ Grade	Elem. School	Middle School			High School		
	6th	7th	8th	9th	10th	11th	12th
2005	N/A	IND	IND	IND	IND	IND	N/A
2006 - 2008	N/A	IND	IND	IND	IND	IND	IND
2009	SCH	IND	IND	IND	IND	IND	IND
2010	SCH	SCH, IND	SCH, IND	SCH, IND	X	IND	IND
2011	SCH	SCH, IND	SCH, IND	SCH, IND	X	X	SCH, IND
2012	SCH	SCH	SCH	SCH	X	X	X

Note: SCH: School Information, IND: KYRBWS, X: Both datasets are available; however, we exclude students who were assigned to high schools after the change of assignment rule in 2010.