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THE ASSOCIATION BETWEEN ELEMENTARY SCHOOL START TIME AND STUDENTS' ACADEMIC ACHIEVEMENT IN WAYZATA PUBLIC SCHOOLS

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The Association Between Elementary School Start Time and Students' Academic Achievement in Wayzata Public Schools

The following report details two analyses that were conducted with the purpose of examining the association between elementary school start time and students' academic achievement in mathematics and reading in Wayzata Public Schools. The first analysis examines the association between elementary school start time and students' academic achievement in elementary school. The second analysis examines the association between elementary school start time and students' academic achievement in middle school. Students' academic achievement was measured by the Minnesota Comprehensive Assessments (MCA) in mathematics and reading. Both analyses took part in two stages: (a) descriptive analyses that compared the means and standard deviations of MCA scores for students in/from early and late start time elementary schools, and (b) inferential analyses that examined the association between elementary school start time and students' academic achievement, controlling for students' demographic characteristics.

School Start Time and Academic Achievement in Elementary School

As noted above, the purpose of the first analysis was to examine the association between elementary school start time and elementary students' MCA scores in mathematics and reading. The analysis was restricted to students in grades 3-5 because MCA data are not available for students in grades K-2.

Descriptive Analyses

Means and standard deviations (unadjusted for student demographic characteristics) by school start time are presented in Table 1 for the MCA mathematics, and in Table 2 for the MCA reading. Effect sizes (Cohen's *d*) are also presented in Tables 1 and 2. The effect size quantifies the mean difference between students in early and late start time schools in terms of standard deviation units (i.e., standardized mean difference). For example, an effect size of 0.50 would indicate that the mean difference between the two groups is equal to half a standard deviation; so if the standard deviation equals 14 points, the mean difference between the two groups equals 7 points.

The results presented in Tables 1 and 2 show evidence of a small association between elementary school start time and academic achievement, with students in early start time schools performing better in 2010-2012, and students in late start time schools performing better in 2013-2015, for both mathematics and reading. There is a consistent trend in the data for both mathematics and reading; that is, in 2010 students in the early start time schools outperformed students in the late start time schools, with the difference between students in early and late start time schools decreasing to zero by 2012. Then, in 2013 the pattern reversed and students in the late start time schools outperformed students in the early start time schools with the difference increasing in magnitude through 2015 (particularly in reading). In all years for both subjects the effect of start time was small; the largest effect size ($d = 0.23$) in Tables 1 and 2 is for the MCA mathematics in 2014, where students in late start time schools scored 3.7 points higher (out of 98 points) on average than students in the early start time schools.

Table 1: Unadjusted Means and Standard Deviations for MCA Mathematics Scores by School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2010	568	67.07	13.04	1,694	65.34	12.85	-0.13
2011	557	63.62	15.40	1,760	63.61	15.20	-0.00
2012	575	64.88	14.57	1,745	65.18	14.54	0.02
2013	609	63.54	14.61	1,780	66.63	14.64	0.22
2014	695	63.81	16.40	1,813	67.49	16.03	0.23
2015	734	63.06	14.87	1,740	66.25	14.65	0.22

Note: n = sample size, M = mean, SD = standard deviation.

Table 2: Unadjusted Means and Standard Deviations for MCA Reading Scores by School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2010	573	69.83	15.22	1,718	68.27	15.90	-0.10
2011	557	70.72	15.50	1,745	69.35	15.36	-0.09
2012	574	70.32	15.36	1,740	69.68	15.58	-0.04
2013	606	60.67	15.90	1,773	62.42	15.72	0.11
2014	696	59.68	15.43	1,806	62.28	15.71	0.17
2015	734	59.84	15.62	1,733	62.79	15.47	0.19

Note: n = sample size, M = mean, SD = standard deviation.

Inferential Analyses

The next step was to fit an ANOVA model to the data for each year and subject separately. In addition to school start time, the following variables were included in the model as fixed effects: school (seven levels associated with each of the seven elementary schools), grade (3, 4, 5), free/reduced priced lunch status (yes, no), English language learner status (yes, no), special education status (yes, no), sex (male, female), and ethnicity (Asian, Black, Hispanic, Native American, White). Sensitivity analyses were also conducted where the ethnicity variable was recoded into two levels: not underrepresented students (Asian, White) and underrepresented students (Black, Hispanic, Native American). All results related to school start time (including the results of the interaction tests described in the next paragraph) were the same regardless of how ethnicity was coded. As such, the decision was made to use the ethnicity variable representing all five ethnic groups. Students MCA scores (1-99 scale scores) were the dependent variable.

Initially, ANOVA models were fitted that included six interaction terms representing the interactions between school start time and six of the other variables included in the model - grade and the five variables representing student demographic characteristics (the interaction between start time and school could not be tested because the two variables are not crossed). Using an adjusted alpha value of .004 (.05/14 tests), no evidence of statistically significant interactions were found in either subject in any year, which indicates that the association between school start time and academic achievement is the same for all student subgroups (included in the analysis). As such, all interaction terms were removed from the final models and are not represented in the results reported below. The results related to school start time are presented in Table 3 for the MCA mathematics, and in Table 4 for the MCA reading. Because the models represented in Tables 3 and 4 contain 8 fixed effects for each year and subject, the *p*-values should be compared to an adjusted alpha value of .006 (.05/8 tests).

The results presented in Table 3 for mathematics show evidence of statistically significant associations favoring students in early start time schools in 2010, 2013, and 2015; and evidence of a statistically significant association favoring students in late start time schools in 2014. No statistically significant associations between school start time and MCA mathematics scores were found in 2011 or 2012. The results presented in Table 4 for reading show evidence of a statistically significant association favoring students in late start time schools in 2014., and evidence of a statistically significant association favoring students in early start time schools in 2015. No statistically significant associations between school start time and MCA reading scores were found in 2010-2013.

The coefficients presented in Tables 3 and 4 can be interpreted as mean differences between students in the early and late start time schools adjusted for student demographic characteristics, grade, and school. The coefficients were obtained by dummy coding the fixed effects and fitting them to a regression model. The data are coded such that negative values favor students in early start time schools and positive values favor students in late start time schools. For example, the coefficient of 0.08 for mathematics in 2014 (see Table 3), indicates that on average students in the late start schools scored 0.08 points higher than students in the early start schools. Note that when not controlling for student demographic characteristics this difference equaled 3.7 points. Because the coefficients presented in Tables 3 and 4 are fairly small adjusted mean differences (never more than five out of 98 points), the statistically significant effects described in the previous paragraph can likely be attributed to the large sample sizes (all $N > 2,200$). Statistical significance is affected by sample size, such that small effects are more likely to be statistically significant in large samples than in small samples.

Table 3: Association Between Late School Start Time and the MCA Mathematics Scores

Year	Coefficient	*F*-value	*p*-value
2010	-1.18	9.49	.002
2011	0.37	0.00	.996
2012	-1.31	0.29	.591
2013	-0.13	30.51	<.001
2014	0.08	36.99	<.001
2015	-1.71	35.99	<.001

Table 4: Association Between Late School Start Time and the MCA Reading Scores

Year	Coefficient	*F*-value	*p*-value
2010	-4.54	5.17	.023
2011	-2.47	4.04	.036
2012	-1.23	0.96	.329
2013	0.79	7.27	.007
2014	0.41	17.74	<.001
2015	-0.23	24.01	<.001

Summary

The results suggest that the association between school start time and elementary students' academic achievement in Wayzata Public Schools is small to non-existent, particularly when controlling for student demographic characteristics, grade, and school. Whether controlling for student demographic characteristics, grade, and school or not, the mean difference between students in the early start time schools and students in the late start time schools is never more than five points (out of 98 points). The non-statistically significant interactions indicate that the small effect of school start time is the same for all student subgroups examined.

Limitations

There are several important limitations of the present analysis that should be kept in mind when interpreting the results. First, the data analyzed here were collected retrospectively and are observational in nature, which means that any observed differences between students in early and late start time schools cannot be said to be caused by school start time. Many other variables not accounted for in the present analysis (e.g., student-teacher ratio, instructional resources, building supports) could cause the differences observed between students in early and late start time schools. Statistical control of student demographic characteristics does not ensure the two groups of students are equal on all important variables, so the effect of school start time on students' academic achievement in elementary school is not isolated in the present analysis.

Second, as noted above, the present analysis was limited to MCA data, which means the effects of start time on the academic performance of students in grades K-2 was not considered. It is not known if the results of the present analysis for students in grades 3-5 would generalize to students in grades K-2. In addition, the MCAs are considered broad measures of mathematics and reading achievement, which means they assess students' academic achievement on a broad range of grade-appropriate content and skills. It is not known if the present results would generalize to measures of specific content and skills, or measures of off-grade content and skills.

Elementary School Start Time and Academic Achievement in Middle School

The purpose of the second analysis was to examine the association between elementary school start time and students' academic achievement in middle school. Students' elementary school start time was identified based on the start time associated with the school the student attended in fifth grade. The analysis was performed for students in sixth, seventh, and eighth grade separately, because any association between elementary school start time and middle school academic achievement was expected to decrease in magnitude over the middle school grades. Because the data set used for the present analysis is retrospective, the number of years of data available for each grade varied, such that five years of data were available for sixth-grade students, four years of data were available for seventh-grade students, and three years of data were available for eighth-grade students. Again, all data are coded such that negative values favor students from early start elementary schools, and positive values favor students from late start elementary schools.

Descriptive Analyses

Means and standard deviations for middle school MCA mathematics scores by elementary school start time are presented in Tables 5-7, for students in grades 6-8, respectively. Across middle school grades, the effect sizes associated with elementary school start time range from -0.16 to 0.09 (average effect size equals -0.02) for MCA mathematics scores, which indicates that there is almost no association between elementary school start time and middle school students' academic achievement in mathematics. The largest effect size (d = -0.16) is associated with sixth-grade students' mathematics performance in 2013 (see Table 5), where students who came from an elementary school with an early start time scored approximately 2 points higher (out of 98 points) on average than students who came from an elementary school with a late start time.

Table 5: Unadjusted Means and Standard Deviations for Sixth-Grade MCA Mathematics Scores by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2011	185	57.63	12.43	523	57.72	12.37	0.01
2012	196	59.92	11.15	554	59.33	11.88	-0.05
2013	174	60.40	10.30	576	58.62	12.27	-0.16
2014	191	58.35	14.00	519	58.94	13.43	0.04
2015	210	59.99	11.99	527	60.94	12.05	0.08

Note: n = sample size, M = mean, SD = standard deviation.

Table 6: Unadjusted Means and Standard Deviations for Seventh-Grade MCA Mathematics Scores by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2012	180	57.75	9.37	511	57.48	9.48	-0.03
2013	189	57.47	9.45	527	56.63	10.45	-0.08
2014	167	59.56	9.60	537	58.39	10.86	-0.11
2015	183	57.57	11.30	501	57.52	11.38	<-0.01

Note: n = sample size, M = mean, SD = standard deviation.

Table 7: Unadjusted Means and Standard Deviations for Eighth-Grade MCA Mathematics Scores by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2013	174	57.81	13.03	490	58.92	12.37	0.09
2014	180	59.98	11.29	502	59.12	12.49	-0.07
2015	160	61.56	11.01	527	60.61	12.14	-0.08

Note: n = sample size, M = mean, SD = standard deviation.

Means and standard deviations for middle school MCA reading scores by elementary school start time are presented in Tables 8-10, for students in grades 6-8, respectively. Across middle school grades, the effect sizes associated with start time range from -0.25 to 0.09 (average effect size equals -0.05) for MCA reading scores, which indicates that there is almost no association between elementary school start time and middle school students' academic achievement in reading. The largest effect size (d = -0.25) is associated with sixth-grade students' reading performance in 2011 (see Table 8), where students who came from an elementary school with an

early start time scored approximately 3.5 points higher on average than students who came from an elementary school with a late start time.

Table 8: Unadjusted Means and Standard Deviations for Sixth-Grade MCA Reading by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2011	184	68.46	13.52	529	65.09	13.09	-0.25
2012	195	65.82	13.23	546	66.78	14.35	0.07
2013	174	61.61	18.28	572	60.13	16.98	-0.08
2014	189	62.96	15.79	519	62.75	15.76	-0.01
2015	210	64.65	15.02	523	65.15	16.30	0.03

Note: n = sample size, M = mean, SD = standard deviation.

Table 9: Unadjusted Means and Standard Deviations for Seventh-Grade MCA Reading by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2012	181	65.16	13.04	519	64.30	12.66	-0.07
2013	190	60.89	15.00	521	59.32	16.26	-0.10
2014	167	63.38	14.57	539	62.73	16.16	-0.04
2015	183	61.49	15.41	500	61.28	14.79	-0.01

Note: n = sample size, M = mean, SD = standard deviation.

Table 10: Unadjusted Means and Standard Deviations for Eighth-Grade MCA Reading by Elementary School Start Time

	Early Start Time			Late Start Time			
Year	*n*	*M*	*SD*	*n*	*M*	*SD*	Cohen's *d*
2013	175	60.04	15.63	495	59.27	15.91	-0.05
2014	182	58.52	15.01	500	59.81	14.87	0.09
2015	159	63.69	15.03	524	62.26	15.13	-0.10

Note: n = sample size, M = mean, SD = standard deviation.

Inferential Analyses

The next step was to fit an ANOVA model to the data for each year, grade, and subject separately. In addition to start time, the following student demographic characteristics were included in the models as fixed effects: free/reduced priced lunch status (yes, no), English language learner status (yes, no), special education status (yes, no), sex (male, female), and ethnicity (Asian, Black, Hispanic, Native American, White). There is a single cohort of students in the mathematics data set that does not contain any students identified as an English language learner; as such, the mathematics models associated with sixth-grade students in 2011, seventh-grade students in 2012, and eighth-grade students in 2013 contain one fewer fixed effect than all the other mathematics models. In the reading data set, eight students in the same cohort were identified as English language learners; as such, the reading models for this cohort of students contain one more fixed effect than the mathematics models associated with this cohort of students. All the reading models contain the same number of fixed effects.

In addition, five interaction terms representing the interactions between elementary school start time and each of the student demographic characteristics were included in the initial models. Using an adjusted alpha value of .005 (.05/11 tests), there was evidence of two statistically significant interactions. For the mathematics data in 2014, the interaction between elementary school start time and seventh-grade students' special education status was statistically significant. An examination of the MCA mathematics means for special education students in seventh-grade in 2014 from early start elementary schools (M = 54.62, SD = 12.96) and late start elementary schools (M = 42.90, SD = 11.80) shows that special education students from early start elementary schools performed statistically significantly better than special education students from late start elementary schools. For the reading data in 2011, the interaction between elementary school start time and sixth-grade students' sex was statistically significant. An examination of the MCA reading means for male and female students in sixth-grade in 2011, show that for female students there is no difference between students from early start time elementary schools (M = 67.03, SD = 12.29) and students from late start time elementary schools (M = 67.43, SD = 13.12); whereas for male students the students from early start time elementary schools (M = 69.49, SD = 14.31) performed statistically significantly better than student from late start time elementary schools (M = 62.98, SD = 12.73). With the exception of the two interaction terms just described, no other interactions terms were statistically significant. All non-statistically significant interactions were removed from their respective final models.

The results related to the association between elementary school start time and middle school MCA scores are presented in Table 11 for the MCA mathematics, and in Table 12 for the MCA reading. The models represented in Tables 11 and 12 contained five, six, or seven fixed effects (five fixed effects for the models associated with the cohort containing no English language learners, and seven for the two models containing an interaction term), so the p-values should be compared to adjusted alpha values of .01, .008, and .007, respectively.

The results presented in Table 11 for mathematics show no evidence of a statistically significant association between elementary school start time and middle school students' academic achievement. The results presented in Table 12 for reading show evidence of a statistically

significant association between elementary school start time and sixth-grade students' reading achievement in 2011; however, the coefficient suggests the difference between students from early and late start time elementary schools is less than 1 point. The association between elementary school start time and middle school reading achievement was not statistically significant for any of the other grades or years.

Table 11: Association Between Late Start Time on the MCA Mathematics

Grade	Year	Coefficient	F-value	p-value
6th	2011	-0.001	0.01	.924
6th	2012	0.08	0.53	.466
6th	2013	-1.49	4.49	.034
6th	2014	-0.10	0.37	.544
6th	2015	1.19	1.31	.253
7th	2012	-0.20	0.14	.707
7th	2013	-0.11	1.30	.254
7th	2014	-0.08	2.24	.135
7th	2015	-0.48	0.004	.952
8th	2013	0.72	1.26	.261
8th	2014	-0.10	0.88	.348
8th	2015	-0.43	1.11	.291

Table 12: Association Between Late Start Time on the MCA Reading

Grade	Year	Coefficient	F-value	p-value
6th	2011	0.68	10.90	.001
6th	2012	1.50	0.83	.362
6th	2013	-1.03	1.28	.258
6th	2014	-0.65	0.03	.863
6th	2015	0.76	0.18	.673
7th	2012	-0.64	0.73	.394
7th	2013	-0.50	1.72	.190
7th	2014	0.15	0.27	.603
7th	2015	-0.47	0.03	.854
8th	2013	-1.07	0.37	.545
8th	2014	2.06	1.27	.260
8th	2015	-0.51	1.38	.240

Summary

The results detailed above suggest that there is essentially no association between elementary school start time and middle school students' academic achievement. The exceptions were for: (a) overall sixth-grade reading achievement in 2011, where students from late start time elementary schools scored on average less than one point (out of 98 points) higher than students from early start elementary schools; (b) the mathematics achievement of seventh-grade students receiving special education services in 2014, where special education students from late start time elementary schools scored on average 11.72 points lower than special education students from early start time elementary schools; and (c) the reading achievement of sixth-grade male students in 2011, where male students from late start time elementary schools scored on average 6.51 points lower than male students from early start time elementary schools.

Limitations

As with the analysis of elementary school data, the data analyzed here were collected retrospectively and are observational in nature, which means that any observed differences between students from early and late start time elementary schools cannot be said to be caused by school start time. Many other variables not accounted for in the present analysis could cause the few differences observed between students from early and late start time elementary schools. As noted previously, statistical control of student demographic characteristics does not ensure the two groups of students are equal on all important variables, so the effect of elementary school start time on students' academic achievement in middle school is not isolated is the present analysis.