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Earlier School Start Times as a Risk Factor for Poor School Performance: An Examination of Public Elementary Schools in the Commonwealth of Kentucky

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Adequate sleep is essential for child learning. However, school systems may inadvertently be promoting sleep deprivation through early school start times. The current study examines the potential implications of early school start times for standardized test scores in public elementary schools in Kentucky. Associations between early school start time and poorer school performance were observed primarily for schools serving few students who qualify for free or reduced-cost lunches. Associations were controlled for teacher–student ratio, racial composition, and whether the school was in the Appalachian region. Findings support the growing body of research showing that early school start times may influence student learning but offer some of the first evidence that this influence may occur for elementary school children and depend on school characteristics.

Keywords: sleep, start time, school performance, free lunch

Adequate high-quality sleep is important for the daytime functioning of children (Paavonen et al., 2000). Consequences of inadequate sleep include irritability, emotional dysregulation, impulsivity, difficulties with attention, and poorer cognitive performance (Curcio, Ferrara, & De Gennaro, 2006). It is therefore important to understand factors that may hinder child sleep. For children, wake times are partially determined by school start times; to attend school, children must wake early enough to get ready and be transported to the school (Wolfson, Spaulding, Dandrow, & Baroni, 2007). By curtailing the sleep period, earlier school start times may reduce the amount of sleep children can obtain (Dexter, Bijwadia, Schilling, & Applebaugh, 2003) and lead to sleep deprivation. Thus, early school start times may indirectly lead to poor school performance by causing sleep deprivation (Dworak, Schierl, Bruns, & Struder, 2007). However, a large scale investigation of the potential impact of public school start times on academic achievement is lacking, and very little research has examined the impact of start times for elementary school students. The purpose of the current study is to address these gaps by examining associations between public elementary school start times and school performance measures in the public schools of Kentucky.

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Sleep problems have been linked to poor school performance and low attendance rates (Sadeh, Gruber, & Raviv, 2003). For example, sleep quality and quantity in school children are related to declarative and procedural learning (Curcio et al., 2006). Daytime sleepiness is associated with executive functioning problems such as poor concentration and difficulty focusing attention (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009; Buckhalt, El-Shiekh, Keller, & Kelly, 2009; El-Sheikh, Buckhalt, Keller, Cummings, & Acebo, 2007). Shorter sleep duration is also linked to working memory capacity and memory consolidation (Kopasz et al., 2010), cognitive abilities that are very important for academic performance. A recent meta-analysis of over a century of research demonstrated a small but reliable association between children's longer sleep duration and better performance on cognitive tasks and higher academic achievement (Astill, Van der Heijden, Van IJzendoorn, & Van Someren, 2012). Another recent meta-analysis suggests that sleepiness and sleep duration are related to child school performance (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010). Further, treatment of child sleep disorders is associated with improvements in attention (Chervin et al., 2006).

Early school start times are a potential cause of child and adolescent sleep deprivation because they curtail the sleep period (Knutson & Lauderdale, 2009). There are now a number of studies documenting the link between early school start times and lower sleep amount and daytime sleepiness in adolescents (e.g., Dexter et al., 2003; Epstein, Chillag, & Lavie, 1998; Li et al., 2013; Wahlstrom, 2002). For example, a change in high school start times from 8:25 a.m. to 7:20 a.m. was associated with student sleep deprivation and greater daytime sleepiness (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Wolfson et al. (2007) examined two middle schools, one starting classes at 7:15 a.m. (School E) and one starting at 8:37 a.m. (School L). Adolescents attending School E had significantly more daytime sleepiness and reported

37 fewer minutes of total sleep than adolescents attending School L. Further, adolescents attending School E had 4 times more tardies than those attending School L. Owens, Belon, and Moss (2010) examined a 30-min delay in start time at a private high school and observed a 45-min increase in average sleep duration, reduced percentage of sleep deprived students, and declines in daytime sleepiness.

Sleep deficits associated with early school start times may translate into poor school performance. A 1-hr delay in middle school start times (8:30) was associated with improved student performance on tests of attention and impulsivity compared to students attending school at the regular time (7:30); these improvements disappeared after the experimental group returned to the normal start time (Lufi, Tzischinsky, & Hadar, 2011). When schools in Wake County, North Carolina, delayed school start times, Edwards (2012) compared student performance on standardized tests of math and reading before (1999) and after (2006) the delay. A 1-hr delay in middle schools and high schools was related to improved test scores on math and reading (Edwards, 2012). Effects were especially strong for students with lower test scores. Notably, this study found no effects of school start times on elementary school students' performance.

Despite the strengths of these prior research studies, there are some notable gaps in research on school start times and academic performance. First, the majority of prior studies have been case studies or studies of schools in only one school district (although see Li et al., 2013, for an exception). This makes it difficult to judge the widespread impact of school start times on academic performance. It also leads to the second gap in research: There is currently little understanding of how school start times relate to student performance in schools with differing characteristics. Few studies have examined moderators of the association between school start times and child or adolescent functioning, and none have examined socioeconomic status variables as moderators. Finally, research has almost exclusively considered middle and high school students. School start times are proposed to be more influential for adolescents because of biological changes in sleep–wake regulation associated with puberty (Crowley, Acebo, & Carskadon, 2007). On the basis of evidence that early school start times are harmful for adolescents, some school districts have chosen to push middle and high school start times later and make elementary school start times earlier to retain staggered busing strategies (Kirby, Maggi, & D'Angiulli, 2011). It is therefore critical to investigate the impact of early school start times on elementary school students.

The current study addresses these research gaps. We examine associations between school start times and average standardized test scores for elementary schools in all public school districts in Kentucky. We chose not to include middle and high schools in our analysis because we found very little variability in middle and high school start times in Kentucky. We hypothesize that schools with earlier start times will have lower average student test scores and poorer school performance. We also examine two school differences as moderators of the association between school start time and student test scores: county designation as Appalachian and the percentage of students receiving free or reduced-cost lunches.

The Appalachian region includes the vast majority of eastern Kentucky. Appalachian counties are known for their low economic status, including high poverty levels and very few job opportunities (de Young, 1985). Although the Appalachian region has been improving in terms of academic performance and employment rates, it still lags behind non-Appalachian areas (Shaw, De Young & Rademacher, 2004; Wilson & Gore, 2009). For example, Appalachian counties have high school dropout rates that are double the national average (Laird, Cataldi, KewalRamani, & Chapman, 2008), making them the lowest completion rates in the United States (Ziliak, 2012). Because Appalachian schools experience greater problems, they may be especially susceptible to the possible effects of early school start times. We therefore hypothesize that associations between school start times and student test scores will be stronger for Appalachian school districts.

School start times may also have an important impact in schools serving economically disadvantaged populations. There is a well-documented achievement gap between poor and middle class students, and this gap has been steadily increasing over the last 70 years (H. F. Ladd, 2012). There are likely numerous reasons for this gap, including poorer student health, less access to high quality preschools, residential mobility or lack of mobility (e.g., it may be difficult for poor parents to move into areas with high quality schools), and the inability to afford expensive extracurricular activities that enhance cognitive development (Evans, 2004). Sleep may therefore be especially important for economically disadvantaged students (Buckhalt, 2011). A common indicator of poverty is eligibility for free or reduced-cost school lunch. We hypothesize that the association between school start times and test scores will be stronger for those schools with a higher percentage of students receiving free or reduced-cost lunches.

Method

Data were collected for all eligible public elementary schools in Kentucky. Schools were considered ineligible if they were vocational schools, alternative schools, schools that only included prekindergarten through the second grade (test data are not available for these grades), private schools, special education schools, and schools in juvenile justice centers. Two elementary schools were removed from analyses because their start time was 1:40 p.m. We were unable to determine the start time for one elementary school. The resulting sample included 718 elementary schools.

School start time data were collected via school websites or by calling the school office. Other variables were obtained via the Kentucky Department of Education website (http://education.ky.gov). Variables included in the study are listed below. Data are from the 2011–2012 school year (Kentucky Department of Education, 2011, 2012). Means and standard deviations are provided in Table 1.

School start times. Start times were computed as minutes since midnight.

Novice, Apprentice, Proficient, Distinguished (NAPD) scores. Each school had scores evaluating student performance on the Kentucky Performance Rating for Educational Progress (K-PREP) assessment in each of the following domains: reading, mathematics, science, social studies, and writing. These scores are referred to as NAPD scores because they were based on the percentages of children classified as novice, apprentice, proficient, and distinguished, based on cutoff scores (see http://www.education.ky.gov for details). K-PREP exams were administered in third and fourth grades. The possible range of the K-PREP scores was 0–30 for

Table 1
Means, Standard Deviations, and Other Descriptive Statistics of Study Variables

Variable	Elementary *M* (*SD*)	Middle *M* (*SD*)	High *M* (*SD*)
Start time	8:05 AM (35 min)	8:00 AM (20 min)	8:01 AM (18 min)
Minimum	7:00 AM	7:20 AM	7:20 AM
Maximum	9:10 AM	9:05 AM	9:05 AM
Schools starting at:			
7:00–7:19	1 (0.1%)	0	0
7:20–7:59	350 (48.7%)	151 (45.3%)	90 (39.0%)
8:00–8:29	224 (31.2%)	150 (45.1%)	121 (52.4%)
8:30–8:59	41 (5.7%)	22 (6.6%)	17 (7.4%)
9:00–9:10	102 (14.2%)	10 (3%)	3 (1.2%)
NAPD Language	66.24 (17.85)	30.77 (54.02)	66.06 (26.42)
NAPD Reading	62.01 (13.36)	58.94 (14.65)	55.46 (20.01)
NAPD Math	60.45 (13.40)	58.67 (15.41)	48.40 (35.19)
NAPD Writing	56.78 (12.46)	63.52 (16.90)	63.41 (18.54)
NAPD Science	88.58 (13.21)	74.69 (33.26)	46.99 (34.30)
NAPD Social Studies	78.47 (14.96)	72.85 (33.48)	44.73 (32.51)
Attendance rate	95.20 (1.23)	94.06 (10.68)	93.27 (1.83)
Retention rate	0.437 (.949)	0.231 (7.79)	3.33 (3.29)
Graduation rate			71.03 (37.45)
College transition rate			53.28 (25.56)
Student–teacher ratio	15.30 (2.11)	15.09 (9.18)	14.91 (10.90)

each subject at each grade, but cutoff scores differed by subject and grade. Table 2 presents details regarding cutoffs for classifications and grades in which the tests were administered. NAPD scores were computed as follows: Schools received 1 point for every percentage point of students scoring proficient or distinguished (for a maximum score of 100); half a point was awarded for each percentage point of students scoring apprentice. NAPD scores are therefore continuous, and higher scores represent better school performance.

School rank. This variable is the percentile rank of a school based on overall school performance, ranging from 0 to 100. Higher percentile rank indicates better school performance. Schools are ranked against other schools of their level (e.g., other elementary schools).

Attendance rate. Schools provided the percentage of enrolled students in attendance for every school day to the Kentucky Department of Education. The attendance rate is the average attendance percentage across the entire school year.

Retention rate. The retention rate is the percentage of a school's students who have been required to repeat a grade.

Appalachian county (APPALACHIAN). This variable identifies whether the school is located in a county that has been designated as Appalachian according to the Appalachian Regional Commission (http://www.arc.gov/about/index.asp). Fifty-four of the 120 counties in Kentucky are designated as Appalachian.

Free and reduced-cost lunches (FREELUNCH). This is the percentage of students in the school receiving free or reduced-cost lunches.

Teacher–student ratio (TSRATIO). The variable reflects the average number of students per teacher.

Percentage African American (AFRICAN AMERICAN). The percentage of students who are African American in a given school is reflected in this variable. The average percentage across all elementary schools was 9.14% (SD = 14.56%) and ranged from 0.0% to 76.0%. However, 65% of schools were 5% or less African American. Only 2.9% of schools served a population of students in which the majority was African American.

Percentage Hispanic (HISPANIC). The percentage of students who are Hispanic in a given school is reflected in this variable. The average percentage across all elementary schools was 4.70% (SD = 6.68%). However, 71.3% of schools were 5% or less Hispanic. Only two schools ($<$ 1%) served a population of students in which the majority was Hispanic.

Data Analyses

Because schools were nested within county (in Kentucky, there is one school district for each county), schools within the same county were not independent of each other and multilevel modeling was required for data analysis (see Raudenbush & Bryk, 2002 for a detailed overview of this statistical procedure). Multilevel modeling for nested data and similar procedures are common in educational research (e.g., Dettmers, Trautwein, Ludtke, Kunter, & Baumert, 2010; Goddard & Goddard, 2001; Shen, Leslie, Spybrook, & Ma, 2012; Wenglinsky, 2002), including research on school start times (Edwards, 2012). In multilevel modeling, within-county variability is partitioned from between-county variability. At Level 1, the within-county level, dependent variables (e.g., NAPD scores) for schools (I) in counties (J) are modeled as a function of an intercept (B_{j0}; the expected value of the dependent variable when there are scores of zero on the independent variables included in the Level 1 model) and the effects of independent variables that vary from school to school within the same county (e.g., school start times; B_{j1}):

$$\begin{aligned}\mathrm{NAPDMATH}_{IJ} = {} & \mathrm{B}_{J0} + \mathrm{B}_{J1}\,(\mathrm{STARTTIME}_{I}) \\ & + \mathrm{B}_{J2}\,(\mathrm{FREELUNCH}_{I}) + \mathrm{B}_{J3}\,(\mathrm{TIMEXLUNCH}_{I}) \\ & + \mathrm{B}_{J4}\,(\mathrm{AFRICAN\ AMERICAN}_{I}) \\ & + \mathrm{B}_{J5}\,(\mathrm{HISPANIC}_{I}) + \mathrm{B}_{J6}\,(\mathrm{TSRATIO}_{I}).\end{aligned}$$

Table 2
Per Grade Administration of Standardized Tests and Total Score Ranges Per Student Classification

Subject	Novice	Apprentice	Proficient	Distinguished
		Grade 3		
Reading	0–8	9–16	17–23	24–30
Mathematics	0–9	10–16	17–24	25–30
		Grade 4		
Reading	0–8	9–16	17–23	24–30
Mathematics	0–8	9–16	17–23	24–30
Science	0–9	10–17	18–24	25–30
Language Mechanics	0–9	10–17	18–25	26–30
		Grade 5		
Reading	0–9	10–17	18–24	25–30
Mathematics	0–8	9–16	17–25	26–30
Social Studies	0–10	11–18	19–25	26–30
Writing	0–9	10–17	18–24	25–30
		Grade 6		
Reading	0–9	10–17	18–24	25–30
Mathematics	0–8	9–15	16–25	26–30
Writing	0–9	10–17	18–24	25–30
Language Mechanics	0–9	10–17	18–24	25–30
		Grade 7		
Reading	0–9	10–14	15–20	21–30
Mathematics	0–8	9–14	15–22	23–30
Science	0–9	10–16	17–21	22–30
		Grade 8		
Reading	0–8	9–15	16–21	22–30
Mathematics	0–9	10–15	16–22	23–30
Social Studies	0–9	10–17	18–25	26–30
Writing	0–10	11–18	19–25	26–30
		Grade 9		
Reading	0–9	10–17	18–24	25–30
		Grade 10		
Mathematics	0–9	10–15	16–22	23–30
Writing	0–9	10–17	18–24	25–30
Language Mechanics	0–9	10–17	18–24	25–30
		Grade 11		
Writing	0–8	9–16	17–24	25–30
Science	0–9	10–15	16–22	23–30
		Grade 12		
Social Studies	0–9	10–18	19–25	26–30

The above equation illustrates that we examined associations between start times and school performance, controlling for teacher–student ratio, percentage of students identified as African American, and percentage of students identified as Hispanic. Coefficients for the independent variables are interpreted in essentially the same way as regression coefficients. Interactions between Level 1 variables can be entered (B_{j3}) and indicate whether level one coefficients vary based on the values of other Level 1 variables.

In essence, each county has its own regression equation. At Level 2, the between-county level, each of the coefficients at Level 1 is modeled as a linear function of an intercept (e.g., π_{10}; the expected value of the Level 1 coefficient for schools with values of zero on the other variables entered into the Level 2 equation) and the effects of independent variables that only vary from county to county and not within county (e.g., π_{20}, designation of Appalachian county):

$$B_{J0} = \pi_{10} + \pi_{20}\,(\text{APPALACHIAN}_J)$$

$$B_{J1} = \pi_{11} + \pi_{21}\,(\text{APPALACHIAN}_J)$$

$$B_{J2} = \pi_{12}$$

$$B_{J3} = \pi_{13}$$

$$B_{J4} = \pi_{14}$$

$$B_{J5} = \pi_{15}$$

$$B_{J6} = \pi_{16}.$$

Coefficients for the Level 2 predictors in the top equation can be interpreted as the first-order effects of the Level 2 variables on the dependent variable. That is, the coefficient π_{20} in the top equation above represents the effect of Appalachian county designation on NAPD math scores. Coefficients for the Level 2 predictors of the other Level 1 coefficients can be interpreted as moderation effects: They provide information concerning whether the Level 1 coefficient varies based on between-county variables. That is, the coefficient π_{21} indicates whether the effect of school start times on NAPD math scores depends on whether the school is located in an Appalachian county. Level 2 independent variables could be added to any of the Level 2 models, but such effects were not of interest in the current study. The coefficients π_{12} through π_{16} therefore indicate the average effects across all counties of the percentage of students receiving free or reduced-cost lunches, the interaction between this variable and school start times, AFRICAN AMERICAN, HISPANIC, and TSRATIO, respectively. Estimates of coefficients and their standard errors are only provided at Level 2. Only unstandardized coefficients are presented.

Separate models were fit predicting each NAPD subject score, school rank, attendance rate, and retention rate. School rank is an ordinal variable. However, alternative modeling techniques for estimating nested ordinal variables is beneficial primarily when there are seven or fewer categories (Bauer & Sterba, 2011). School rank had 99 different categories. We therefore use traditional multilevel modeling for these data. All continuous independent variables were mean centered before computing cross products. Designation of county as Appalachian (APPALACHIAN) was a dummy variable coded as 0 for non-Appalachian and 1 for Appalachian. Separate models were also fit for interactions between school start times and either FREELUNCH or APPALACHIAN. Effects were considered significant if $p < .05$. Significant interactions were plotted at ± 1 *SD* from the mean for school start times and FREELUNCH or for Appalachian/non-Appalachian counties. Significant interactions were probed using online utilities available at http://www.quantpsy.org (Preacher, Curran, & Bauer, 2006).

Results

Interactions Between School Start Times and FREELUNCH

Several significant interactions between elementary school start times and FREELUNCH were observed (see Table 3). The

Table 3
Model Results for Interactions Between Elementary School Start Times and Fraction of Students Receiving Free or Reduced-Cost Lunches

Variable	NAPD Language	NAPD Reading	NAPD Math	NAPD Science	NAPD Social Studies	NAPD Writing	School rank	Attendance rate	Retention rate
Intercept									
Intercept (π_{10})	68.145***	62.875***	62.481***	90.430***	80.10***	57.719***	52.937***	95.718***	0.365***
APPALACHIAN (π_{10})	−9.126***	−6.863***	−6.354***	−8.814***	−6.288**	−4.963**	−16.165***	−1.520***	0.313**
TSRATIO									
Intercept	1.520***	1.103***	.673**	.851***	1.226***	.798**	1.777***	.080***	−.041*
AFRICAN AMERICAN									
Intercept	−.523***	−.472***	−.417***	−.432***	−.413***	−.324***	−1.031***	−.005*	−.001
HISPANIC									
Intercept	−.487***	−.495***	−.402***	−.410***	−.347***	−.162*	−.692***	−.011**	−.009**
School Start Time									
Intercept (π_{11})	.059*	.038	.044*	.017	.058**	.055**	.137**	.002	.002*
FREE LUNCH									
Intercept (π_{12})	−.637*	−.705***	−.562**	.001	−.248	−.301	−.602	−.009	−.015
Start Time × LUNCH									
Intercept (π_{13})	−.017*	−.015***	−.012*	−.010*	−.010**	−.013**	−.029***	−.001*	.000

Note. Columns indicate the dependent variable being predicted. Statistical notation provided in parentheses corresponds to the equations provided in the analysis section.
* $p < .05$. ** $p < .01$. *** $p < .001$.

interaction predicted NAPD Language scores, $\pi_{13} = -.017$, $p < .05$; NAPD Reading scores, $\pi_{13} = -.015$, $p < .001$; NAPD Science scores, $\pi_{13} = -.010$, $p < .05$; NAPD Math scores, $\pi_{13} = -.012$, $p < .05$; NAPD Social Studies scores, $\pi_{13} = -.010$, $p < .01$; NAPD Writing scores, $\pi_{13} = -.013$, $p < .01$; school rank, $\pi_{13} = -.029$, $p < .001$; and school attendance rate, $\pi_{13} = -.001$, $p < .05$.

Interactions were plotted and were all nearly identical (see Figures 1 and 2 for examples). Results of probing the interactions are also shown in Table 4. The first two rows show the simple slopes for the effect of school start time on the dependent variable (see column heading) for lower and higher values of FREELUNCH. The bottom two rows illustrate the expected difference in the dependent variable for schools starting 1 hr later than another school. In all cases, there was a significant association between school start times and school performance only for schools with a lower percentage of students receiving free or reduced-cost lunches (e.g., school with more middle and upper class students). The difference in NAPD scores associated with a 1-hr difference in school start time ranged from 3 to almost 7 points. A 1-hr difference in school start time was associated with school rank improved by 14 percentile points, and an attendance rate that was .32 units higher.

Interactions Between School Start Times and APPALACHIAN

No significant interactions were observed.

Main Effects of School Start Times

Only one main effect of school start times that was not qualified by an interaction was observed. Later school start times were associated with higher retention rates, $\pi_{11} = .002$, $p < .01$. Every additional minute later in the school start time increased retention rates by 0.2%. A 1-hr difference in school start time would therefore be related to a 12% difference in retention rate.

Discussion

Prior research has indicated an association between early school start times and less total sleep time, more daytime fatigue and

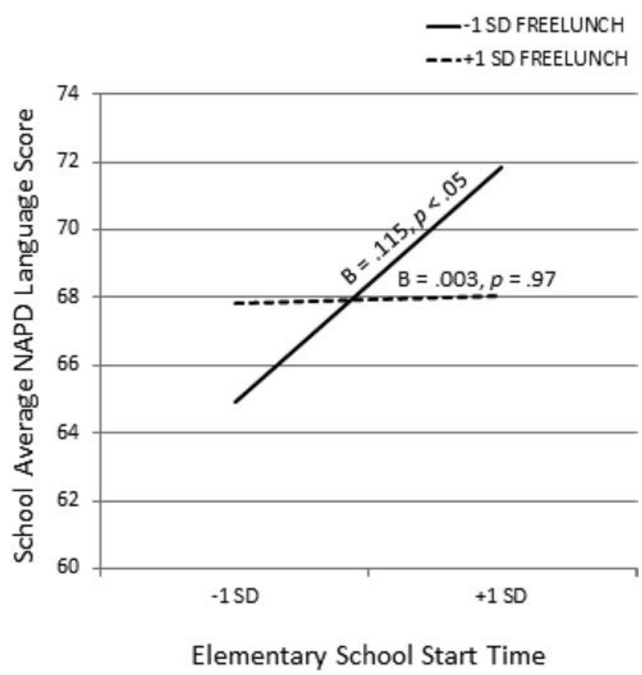

Figure 1. Interaction between Elementary School Start Time and FREELUNCH.

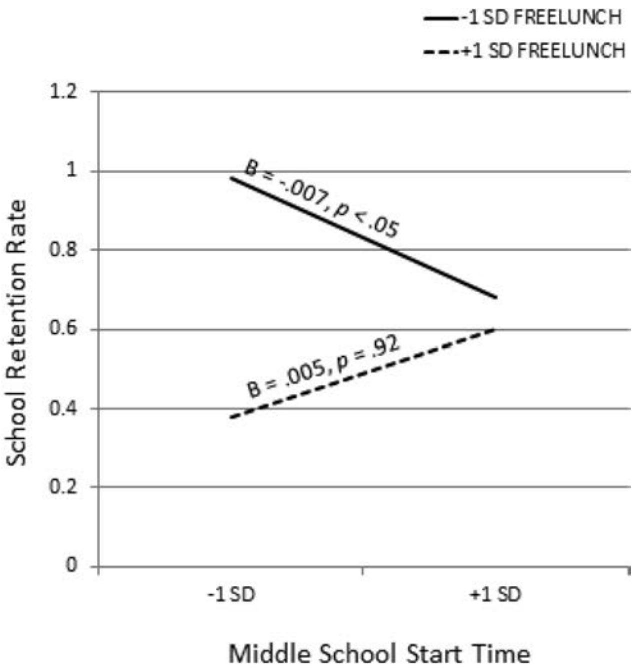

Figure 2. Interaction between Middle School Start Time and FREE LUNCH.

sleepiness, more school tardiness, and lower school academic performance (Epstein et al., 1998; Owens et al., 2010; Wahlstrom, 2002; Wolfson et al., 2007). However, no study to our knowledge has studied these associations between school start time, attendance rates, and academic performance on a statewide level. The present study investigated relations between school start times and a number of school performance standards in public elementary schools in Kentucky. We had two main hypotheses: (a) Earlier school start times will be associated with lower standardized test scores, poorer attendance, higher retention rates, lower school rank, and school underperformance; and (b) earlier start times will be especially risky for school performance standards in more disadvantaged schools, including Appalachian schools and schools with a higher percentage of students receiving free or reduced-cost lunches. Unexpectedly, findings indicated the earlier school start times were related to lower school performance predominantly for elementary schools with fewer students receiving free or reduced-cost lunches. No differences in associations between Appalachian and non-Appalachian counties were observed.

For those schools for which an association was found, earlier start times were related to poorer test scores, lower school rank, and more student absences. These findings are consistent with previous research (Epstein et al., 1998; Wahlstrom, 2002; Wolfson et al., 2007). The relationship between earlier start times and poorer academic performance may be explained by the physical, behavioral, and psychological ramifications of sleep deprivation. Earlier start times may lead to student sleep deprivation by placing constraints on the amount of sleep a child or adolescent is able to obtain (Dexter et al., 2003; Epstein et al., 1998; Wolfson & Carskadon, 1998; Wolfson et al., 2007). Students may therefore lose the ability to remain alert and focused in the classroom (Durmer & Dinges, 2005; Epstein et al., 1998). Sleep deprivation increases hyperactivity and behavioral dysregulation, impairing students' academic functioning (Dworak et al., 2007; Beebe, 2011; Wolfson & Carskadon, 1998). Sleep problems are also associated with asthma (Kakkar & Berry, 2009), compromised cardiovascular health (Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011), gastrointestinal problems (Chen, Liu, Yi, & Orr, 2011), and reduced effectiveness of the immune system (Bryant, Trinder, & Curtis, 2004; Irwin et al., 1996). Therefore, sleep deprivation resulting from early school start times may increase the frequency, severity, and duration of illness, resulting in increased rates of absenteeism.

Findings clearly show that—at least for middle and upper class students—earlier school start times can be associated with poorer school performance in elementary schools. The implication is that research on school start times should not focus exclusively on adolescents. Sufficient sleep is of critical importance across development (Fallone, Owens, & Deane, 2002). According to the National Sleep Foundation 2004 Sleep in America Poll, more than 25% of school-age children (first grade to fifth grade) obtain less than the recommended daily amount of sleep. Modern-day elementary school children may be taking on additional responsibilities, extracurricular activities, and/or entertainment opportunities that delay regular weeknight bedtimes. The use of media by children (e.g., television, video games) has been identified as especially problematic for delaying bedtimes, increasing sleep onset latency, and decreasing the amount of total sleep time

Table 4

Results of Probing Interactions Between School Start Times and Percentage of Students Receiving Free or Reduced-Cost Lunches

	NAPD							
Effects and differences of start times	Language	Reading	Math	Science	Social Studies	Writing	School rank	Attendance rate
Estimated effect of school start times								
Schools with lower FREELUNCH	.115*	.088*	.050*	.084*	.091*	.098**	.233***	.002*
Schools with higher FREELUNCH	.003	−.012	−.016	.004	.025	.012	.041	−.001
Difference in schools starting 1 hr apart								
Schools with lower FREELUNCH	6.90	6.23	3.01	5.03	5.48	5.90	14.01	0.32
Schools with higher FREELUNCH	0.18	−0.72	−0.96	0.24	1.50	0.72	2.46	−0.06

Note. The first two rows show the simple slopes for the effect of school start time on the dependent variable (see column heading) for lower and higher values of the moderator (FREELUNCH). The bottom two rows illustrate the expected difference in the dependent variable for schools starting 1 hr later than another school.

* $p < .05$. ** $p < .01$. *** $p < .001$.

obtained (National Sleep Foundation, 2011; Owens et al., 1999). As a result, early school start times may affect student performance even before the puberty-related delay in sleep phase.

Of particular concern is that the growing public support for delaying middle and high school start times is often at the expense of making elementary school start times earlier. Indeed, this has already occurred in two counties in Kentucky (Fayette and Jessamine; National Sleep Foundation, 2005a, 2005b). This is often done in order to preserve staggered bus scheduling (Kirby et al., 2011). Our findings suggest that these policy changes may simply be shifting the problem from adolescents to younger children, instead of eliminating it altogether. On the one hand, elementary school children are not experiencing the puberty-related phase shift in sleep–wake regulation. Therefore, earlier bedtimes and improved sleep hygiene may more readily prevent sleep deprivation in this student group. Nevertheless, if parents do not alter their children's sleep behavior in response to earlier start times, elementary school performance may suffer, and these reductions in early student learning may have implications for academic achievement over the long term (G. W. Ladd & Dinella, 2009). On the other hand, making school start times later for all grade levels may be a feasible solution for some school districts (Kirby et al., 2011).

The association between later start times and higher retention rates was unexpected and indicates that later school start times were associated with a greater number of children being held back a grade. To our knowledge, this is the first study to examine student retention in relation to school start times, and it is therefore difficult to draw firm conclusions about this finding. However, given that other indices of school performance were improved at later school start times, one possible explanation is that once the average students begin to improve, students with learning difficulties have an especially hard time keeping up. Lagging further behind the majority of students may lead to retention. This explanation is somewhat consistent with the findings that later school start times tend to benefit only those schools that have more middle or upper class students. On the other hand, this finding is inconsistent with other research suggesting that students with the lowest scores benefit from later school start times the most (Edwards, 2012).

Appalachian county designation did not moderate any associations, although it was consistently related to poorer school performance. On the other hand, the percentage of students qualifying for free and reduced-cost lunch (based on family income and therefore a measure of low socioeconomic status) consistently moderated associations between school start times and school academic success. Significant relations between early school start times and poor school performance were found only for schools with a lower percentage of students qualifying for free and reduced-cost lunches (e.g., for schools with a wealthier student population). In other words, schools with economically disadvantaged students were unlikely to show better school performance if their start times were later. This is inconsistent with recent policy proposals suggesting that later school start times are a promising mechanism for closing the achievement gap between poor and wealthy students (Jacob & Rockoff, 2011).

This lack of improvement in poorer school systems may be explained through a cumulative risk model (Evans, 2004; Sameroff, Seifer, Barocas, Zax, & Greenspan, 1987). According to Dubow and Ippolito (1994), poverty may be one of the single greatest risk factors for student academic performance. According to the cumulative risk model, poverty influences child development because of the accumulation of multiple stressors that accompany poverty (Sameroff et al., 1987). Indeed, poverty has been linked to a wide range of stressors in both the psychosocial and physical environments (Evans, 2004). For example, the psychosocial environment of poverty may be characterized by exposure to violence (Emery & Laumann-Billings, 1998), marital conflict or divorce (Liu & Chen, 2006), harsh and unresponsive parenting (Conger & Elder, 1994; Grant et al., 2003), low parental monitoring (Kilgore, Snyder, & Lentz, 2000), less cognitive stimulation (Hoff, Laursen, & Tardiff, 2002), less parental involvement in school systems (Benveniste, Carnoy, & Rothstein, 2003), schools with less highly trained teachers and greater violence (Clotfelter, Ladd, Vigdor, & Wheeler, 2006; Milam, Furr-Holden, & Leaf, 2010), and changes in schools and residences (Herbers et al., 2012). The physical environment of poverty may be characterized by exposure to toxins and parental smoking (Centers for Disease Control and Prevention, 2010; Legot, London, Rosofsky, & Shandra, 2012), noise (Evans & Kim, 2012), crowded housing conditions (Myers, Baer, & Choi, 1996), inadequate heat (Children's Defense Fund, 1995), lack of air conditioning (Federman et al., 1996), poor nutrition (Alaimo, Olson, Frongillo, & Briefel, 2001), and crumbling schools (National Center for Education Statistics, 2000).

The cumulative model of risk posits that no one specific risk factor is tied to child developmental outcomes. Rather, it the number of risk factors that predict developmental outcomes, including allostatic load, academic achievement, and mental health (Appleyard, Egeland, van Dulmen, & Sroufe, 2005). Several studies now indicate that the presence of four or more risk factors conveys special risk for compromised development (Sameroff, Bartko, Baldwin, Baldwin, & Seifer, 1998). Children growing up in poverty are likely to experience this number of risks. Low income fourth graders have 35% more negative life events in a year than middle income fourth graders (Attar, Guerra, & Tolan, 1994). Other studies report even larger discrepancies based on income; approximately 35% of children living in poverty—compared to only 5% in wealthier families—have six or more risk factors present in their lives (Liaw & Brooks-Gunn, 1994). The increased risk burden mediates the association between poverty and psychophysiological functioning and psychological stress (Evans & English, 2002).

The implication is that removing one risk factor may have little impact, unless it brings the child under the risk threshold. At the same time, there is an incremental influence over time: The longer one is exposed to the stresses and disadvantages associated with poverty, the greater the risk and the poorer the outcomes in psychological and cognitive domains (Lynch, Kaplan, & Shema, 1997). The impact of later school start times for impoverished school children may therefore be too little, too late, for academic performance. Indeed, later school start times may not even improve sleep in poor children. There is an increased incidence of sleep problems in the context of poverty, perhaps because of less comfortable sleep surfaces and room temperatures, room sharing, noise, and poor sleep hygiene (Buckhalt & Staton, 2011). As such, a delay in school start times may not be sufficient to overcome the numerous other obstacles that children in poverty face, including obstacles to obtaining adequate sleep.

Limitations

The current study did not assess sleep directly and did not differentiate different aspects of sleep. A meta-analysis about sleep and school performance has shown that different measures of sleep condition are related to school performance to differing extents: Sleepiness is most strongly related to school performance, followed by sleep quality and sleep duration (Dewald et al., 2010). Earlier school start time may jeopardize different facets of sleep, and further research is needed to differentiate these. The current study is also limited by its cross-sectional design and data from only one state. Although we controlled for a number of potential confounding factors, including the racial composition of the schools and teacher–student ratio, we cannot infer that early school start times were the cause of school performance measures. Findings may not generalize to other states, especially to states that have varying levels of poverty or more racial diversity than Kentucky. Finally, we used traditional estimation methods to predict school rank; this variable is a rank order variable, and the traditional estimation procedure may yield somewhat inaccurate estimates.

Despite these limitations, this study addresses some key gaps in the current literature on school start times. First, we demonstrate that there are associations between early school start times and school performance, particularly among elementary schools serving middle and upper class students. Identifying school characteristics that moderate associations between school start times and school performance has rarely been done for this topic. Finally, we provide one of the very few examinations of school start times and test scores in elementary schools. Our findings indicate that early school start times may be just as detrimental for young children as they are for adolescents.

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