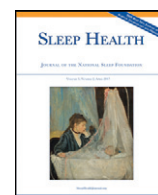




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## Earlier school start times are associated with higher rates of behavioral problems in elementary schools

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## ABSTRACT

**Background:** Early school start times may curtail children's sleep and inadvertently promote sleep restriction. The current study examines the potential implications for early school start times for behavioral problems in public elementary schools (student ages 5-12 years) in Kentucky.

**Method:** School start times were obtained from school Web sites or by calling school offices; behavioral and disciplinary problems, along with demographic information about schools, were obtained from the Kentucky Department of Education. Estimated associations controlled for teacher/student ratio, racial composition, school rank, enrollment, and Appalachian location.

**Results:** Associations between early school start time and greater behavioral problems (harassment, in-school removals, suspensions, and expulsions) were observed, although some of these associations were found only for schools serving the non-Appalachian region.

**Conclusions:** Findings support the growing body of research showing that early school start times may contribute to student problems, and extend this research through a large-scale examination of elementary schools, behavioral outcomes, and potential moderators of risk.

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Early school start times may contribute to *sleep restriction* in adolescents,<sup>1,2</sup> defined as receiving less than the adequate amount of sleep (ie, between 9 and 11 hours per night) that is recommended for children between the ages of 6 and 13 years by the National Sleep Foundation ([www.sleepfoundation.org](http://www.sleepfoundation.org)). Earlier school start times require earlier wake times.<sup>2</sup> This has recently been found for elementary school students (ages 5 through 11 years),<sup>3</sup> although overall reductions in sleep duration were not observed. Studies with adolescents consistently find that earlier start times are related to shorter sleep duration.<sup>1</sup> For example, early-adolescent students attending an early-starting middle school (at 7:15 AM) reported significantly more daytime sleepiness and 37 less minutes of total sleep than students attending a late-starting school (8:37 AM).<sup>4</sup> Conversely, postponing school start time by 30 minutes in a private high school resulted in an average of 45 additional minutes of sleep and a lower percentage of adolescent students suffering from sleep restriction and daytime sleepiness.<sup>5</sup> Thus, a substantial body of research documents associations between early school start times and student sleep restriction.

However, very few studies have examined the impact of school start times on the sleep and functioning of elementary school students, typically aged 5 through 11 years.<sup>6</sup> The National Sleep Foundation recommends that children between the ages of 6 and 13 sleep between 9 and 11 hours per night ([www.sleepfoundation.org](http://www.sleepfoundation.org)). Unfortunately, children aged 6-10 are only getting an average of 8.9 hours of sleep per night, whereas children aged 11-12 have an average of only 8.2 hours,<sup>7</sup> indicating that many American children have restricted sleep. Examination of elementary schools is an especially important direction for research because when school districts attempt to shift start times, they sometimes choose to have elementary schools start earlier so that adolescent students at middle and high schools can start later and bus schedules can be maintained.<sup>8,9</sup> Elementary students then must wake earlier.<sup>3</sup> In a recent study, however, elementary schools with earlier start times had lower average standardized test scores and were ranked lower on academic performance than other schools.<sup>6</sup> The implication is that the sleep restriction associated with early school start times would be shifted to younger children.

This sleep restriction may have important consequences for children's daytime functioning.<sup>10</sup> For example, short sleep duration is associated with increased risk for father-reported rule-breaking behavior and externalizing symptoms in an epidemiological study

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of 8-year-old children.<sup>11</sup> Restricted sleep is also associated with greater externalizing symptoms in children aged 7 through 12 years.<sup>12</sup> Consequently, early school start times may indirectly lead to increases in child behavior problems. Although one study did find that delayed high school start times improve mood and reduce depressive symptoms in adolescents,<sup>5</sup> no study to our knowledge has examined school start times in relation to behavioral adjustment of students. The current study examines rates of disciplinary actions (in-school removals, suspensions, and expulsions) as well as rates of behavioral incidents in relation to school start times. We hypothesize that earlier start times will be associated with greater behavioral problems.

The current study also advances research through examination of moderators of associations. School districts may be unable to delay all school start times, and therefore information about what schools may be most likely to benefit is important. Student socioeconomic status may serve as a moderator, as early school start times were related to poor academic performance only for those schools serving middle- or upper-class elementary students.<sup>6</sup> Based on these findings, we take the perspective of a cumulative risk model,<sup>13</sup> in which the accumulation of multiple risks that occurs in poverty prevents the amelioration of any one single risk factor from dramatically improving child outcomes such as behavior problems. Poverty is associated with lower parental warmth, less consistent discipline, greater harsh parenting practices, family violence and instability, poor housing, less cognitive stimulation and resources for education, poor quality childcare and schools, and dangerous and deteriorating neighborhoods.<sup>14,15</sup> It is likely that students who are struggling with poverty face such a wide range of obstacles to their achievement and to their sleep quality that school start times simply have little impact.<sup>16,17</sup>

We therefore hypothesize that the association between start times and school behavioral issues will be less strong for schools serving a greater number of impoverished students. We index student poverty in 2 ways: the percentage of students receiving free or reduced cost lunches and whether the county is designated as Appalachian. The Appalachian region occupies a majority of eastern Kentucky. It has a higher percentage of people who fail to complete high school diplomas and with lower family annual income compared with the non-Appalachian regions of Kentucky.<sup>18,19</sup> Therefore, schools in Appalachian counties are more likely to serve high rates of impoverished students.

## Method

Data were collected for all eligible public elementary schools in Kentucky. In Kentucky, an elementary school refers to a school having any combination of kindergarten (ages 5–6 years) through the sixth grade (ages 11–12 years). Schools were considered ineligible if they were vocational schools, alternative schools, schools that only included pre-kindergarten through the second grade, private schools, special education schools, and schools in juvenile justice centers. These exclusion criteria were designed to minimize variability in behavior problems due to school characteristics and the population being served. Two elementary schools were removed from analyses because their start time was 1:40 PM. We were unable to determine the start time for one elementary school. The resulting sample included 718 elementary schools serving a total of 310,470 children.

School start time data were collected via school Web sites or by calling the school office. Other variables were obtained via the Kentucky Department of Education Web site (<http://education.ky.gov>). Data are from the 2011/2012 school year. Means and standard

deviations are provided in Table 1. Independent variables included in the study are as follows:

- 1 School start times: Start times were computed as minutes since midnight.
- 2 School rank: percentile rank of a school based on overall school academic performance, ranging from 0 to 100. Higher percentile rank indicates better school performance. Schools are ranked against other schools of their level (ie, other elementary schools).
- 3 Appalachian county (APPALACHIAN): whether the school is located in a county that has been designated as Appalachian according to the Appalachian Regional Commission Web site (<http://www.arc.gov/about/index.asp>). There are 54 counties out of 120 in Kentucky that are designated as Appalachian.
- 4 Free and reduced cost lunches (FREELUNCH): percentage of students in the school receiving free or reduced cost lunches.
- 5 Teacher/student ratio (TSRATIO): the average number of students per teacher.
- 6 Percentage African American (AFRICAN AMERICAN): percentage of students who are African American in a given school. The average percentage across all elementary schools was 9.10% (SD = 14.52%) and ranged from 0% to 76.0%.
- 7 Percentage Hispanic (HISPANIC): percentage of students who are Hispanic in a given school. The average percentage across all elementary schools was 4.71% (SD = 6.70%) and ranged from 0% to 73%.
- 8 Enrollment: the number of children enrolled as students in each school.

Student behavioral problems were measured in several different ways. In most cases, measures of behavioral problems used in this study reflect the need for disciplinary action (eg, number of suspensions) rather than the specific forms of behavioral problems (eg, bringing a gun to school) because the disciplinary actions are the focus of school reports to the government. For each measure, 2 scores were available: the number of unique incidents reported for the year and the number of students involved for the year. Examining these 2 scores permits assessment of the frequency of behavioral problems and the number of students who are involved in these problems. Because the same student may be involved in multiple incidents across a school year, they provide different information. Information about each dependent variable is provided below. Common definitions of behavioral events are provided in the document *Common Definitions for Board Policy Violations in a School Situation* available at <http://education.ky.gov/school/sdfs/Documents/Board%20Policy%20Definitions%20final%202,013.pdf>. Kentucky guidelines for disciplinary actions are provided in the statute KRS 158.150 (available at <http://www.lrc.ky.gov/statutes/statute.aspx?id=3451>).

- 1 Total discipline: Discipline involving any of the following: in-school removal, out-of-school suspension, expulsion with or without services, corporal punishment, restraint, or seclusion. Few school districts in Kentucky use corporal punishment (eg, paddling), but it continues to be legal in the state and is more commonly used in rural or Appalachian districts. Restraint techniques may include physically escorting the student, carrying the student, cradling the student, or other forms of physical restraint. *Seclusion* refers to confinement of the student in a room or area but does not include time outs used to calm students.
- 2 In-school removals: Disciplinary action in which the student is removed from his/her regular educational setting during instructional time. Examples include alternative placement and in-school suspensions.
- 3 Out-of-school suspensions: Disciplinary action in which the student is placed on a temporary mandatory leave from school for a predetermined period of time, usually ranging from 1 day

**Table 1**  
Means, standard deviations, and other descriptive statistics for study variables

	Mean	SD
Start time	8:05 AM	35 min
Minimum start time	7:00 AM	
Maximum start time	9:10 AM	
Number of schools starting at:		
7:00-7:19	1 (0.1%)	
7:20-7:59	350 (48.7%)	
8:00-8:29	224 (31.2%)	
8:30-8:59	41 (5.7%)	
9:00-9:10	102 (14.2%)	
Enrollment	437.28	163.47
Student-teacher ratio	15.30	2.11
FREELUNCH	7.86	3.27
AFRICAN AMERICAN	9.10	14.52
HISPANIC	4.71	6.70

	Unique incidents		Total students	
	Mean	SD	Mean	SD
Total discipline	35.20	84.06	20.84	45.92
Corporal punishment	1.36	8.55	.83	4.67
In-school removal	23.25	81.79	11.09	32.31
Out-of-school suspension	14.09	35.31	8.99	19.19
Expelled with services	0	.07	0	.07
Expelled without services	10	.03	.02	.31
Total behavior problems	37.38	85.70	21.75	45.31
Harassment	5.94	15.26	4.32	9.78

to several weeks. During the suspension, the student is not allowed to attend classes or be on the school campus. Causes for suspensions include willful disobedience, use of profanity or vulgarity, assault or battery or abuse of other students or school personnel, threat of violence, possession of alcohol or drugs, damaging property, or other incorrigible bad conduct on school property or at school-sponsored events.

- 4 Expulsions with services: Disciplinary action in which the student is placed on an extended or permanent mandatory leave from school. Expulsions can occur with or without services. KRS 158.150 specifies that all expelled students must be provided with appropriate educational services in an alternative setting or program unless they pose a threat to those settings or programs. Infractions that may warrant an expulsion are the same as for suspensions. In addition, students who bring a weapon to school must be expelled for at least 1 year.
- 5 Expulsions without services: An expulsion in which the student is not provided alternative educational services because they are deemed to pose a threat to alternative settings. Reasons for which a student may be deemed a threat include, but are not limited to, physical assault, threat of violence, drug or alcohol use, sale of drugs or alcohol, or bringing a weapon to school.
- 6 Total behavior problems: The total number of behavioral incidents recorded for the school during the school year. Behavioral incidents include those involving policy violations (eg, truancy, dress code violations), harassment (see below), incidents involving drugs, alcohol, or weapons, and assaults (first degree or other).
- 7 Harassment: Behavioral events involving any of the following: bullying, harassment, threatening staff, verbal abuse, misdemeanor stalking, or harassing communications. Information about rates of specific forms of harassment was not available. The common definition of *bullying* is “physically or psychologically abusing another person by means of verbal or physical threats, intimidation, insults, or other aggressive behavior. This may include abuse based on race, ethnicity, gender, religion, or disability. These attacks, which substantially hinder another student’s health, safety, welfare, the right to attend school or participate in school activities, constitute harassment and bullying”

(p 4 of the *Common Definitions*). The common definition of *harassment* is “delivering disrespectful messages (verbal or gestural) to one or more people, which may include threats and intimidation, obscene gestures, pictures, or written notes. These messages may include negative comments based on race, religion, gender, age, and/or national origin; sustained or intense verbal attacks based on ethnic origin, disabilities, or other personal matters” (pp 4-5 of the *Common Definitions*). The common definition of *threatening staff* is “using verbal messages or physical actions toward a staff person or school representative that imply the threat of serious physical injury” (p 5). *Verbal abuse* is defined as “using abusive and demeaning language: words that attack or injure an individual, words that cause one to believe and untrue statement, or words that speak falsely of an individual. This can include talking back, name calling, and/or creating socially rude interactions” (p 5). Because harassment is of particular concern to children, parents, school systems, and communities, we chose to analyze this as a separate variable.

*Data analyses*

Because schools were nested within county (in Kentucky, there is 1 school district for each county), schools within the same county are not independent of each other, and multilevel modeling was required for data analysis (see Raudenbush and Bryk<sup>20</sup> for a detailed overview of this statistical procedure). At level 1, the within-county level, dependent variables (eg, behavioral outcomes) for schools (I) in counties (J) are modeled as a function of an intercept ( $B_{j0}$ ) and the effects of independent variables that vary from school to school within the same county (eg, school start times;  $B_{j1}$ - $B_{j8}$ ):

$$DISCIPLINE_{ij} = B_{j0} + B_{j1}(STARTTIME_{i1}) + B_{j2}(FREELUNCH_{i1}) + B_{j3}(TIMEXLUNCH_{i1}) + B_{j4}(AFRICAN AMERICAN_{i1}) + B_{j5}(HISPANIC_{i1}) + B_{j6}(TSRATIO_{i1}) + B_{j7}(ENROLLMENT_{i1}) + B_{j8}(RANK_{i1})$$

The above equation illustrates that we examined associations between start times and student behavior controlling for the percentage

of students receiving free or reduced cost lunches, teacher-student ratio, percentage of students identified as African American, percentage of students identified as Hispanic, number of students enrolled, and school rank. Interactions between level 1 variables can also be entered ( $B_{j3}$ ).

At level 2, the between-county level, each of the coefficients at level 1 is modeled as a linear function of an intercept (eg,  $\pi_{10}$ ; 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 (eg,  $\pi_{20}$ , designation as Appalachian county):

$$B_{j0} = \pi_{10} + \pi_{20}(\text{APPALACHIAN}_j)$$

$$B_{j1} = \pi_{11} + \pi_{21}(\text{APPALACHIAN}_j)$$

$$B_{j2} = \pi_{12}$$

$$B_{j3} = \pi_{13}$$

$$B_{j4} = \pi_{14}$$

$$B_{j5} = \pi_{15}$$

$$B_{j6} = \pi_{16}$$

$$B_{j7} = \pi_{17}$$

$$B_{j8} = \pi_{18}$$

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 ( $\pi_{20}$  represents the effect of Appalachian county designation on DISCIPLINE). Coefficients for the level 2 predictors of the other level 1 coefficients can be interpreted as interactions: they provide information concerning whether the level 1 coefficient varies based on between-county variables. Estimates of coefficients and their standard errors are only provided at level 2. Only unstandardized coefficients are presented in multilevel modeling.

Separate models were fit predicting each measure of behavioral problems (8 different behavior variables  $\times$  2 different scores each [unique events vs number of students involved] = 16 models for each moderator). 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  $P < .05$ .

**Results**

*Main effects of school start times*

Several unqualified main effects of school start times were observed (Tables 2 and 3). Earlier school start times were associated

with more overall disciplinary events,  $\pi_{11} = -.53, P < .01$ ; out-of-school suspensions,  $\pi_{11} = -.16, P < .01$ ; expulsions with services,  $\pi_{11} = -.0002, P < .05$ ; and behavioral problems,  $\pi_{11} = -.53, P < .01$ . Similarly, earlier school start times were related to a greater number of students receiving in-school removals,  $\pi_{11} = -.20, P < .01$ ; receiving out-of-school suspensions,  $\pi_{11} = -.09, P < .01$ ; being expelled with services,  $\pi_{11} = -.0002, P < .05$ ; engaging in behavioral problems,  $\pi_{11} = -.29, P < .001$ ; and engaging in harassment,  $\pi_{11} = -.06, P < .001$ . Findings can be interpreted as follows: a 1-hour-later school start time would be related to 32 fewer overall disciplinary actions, 12 fewer students receiving in-school removals, 10 fewer suspensions, and 5 fewer students receiving suspensions. Further, a 1-hour-later school start time would be related to 32 fewer behavioral incidents, 17 fewer students being involved in behavioral incidents, and 3-4 fewer students engaging in harassment. Although statistically significant, the effect sizes for expulsions with services are very small; to reduce expulsions by 1 or students expelled by 1, the start time would need to be 83 hours different. These small effects are likely due to the low number of students who were expelled; expulsions are discouraged for elementary school children in KRS 158.150.

*Interactions between school start times and FREELUNCH*

No significant interactions involving FREELUNCH were observed.

*Interactions between school start times and APPALACHIAN*

See Table 2 for coefficients of models predicting unique incidents of behavioral problems and Table 3 for coefficients of models predicting the number of students involved in behavioral problems. The school start times and APPALACHIAN interaction significantly predicted the number of students disciplined,  $\pi_{21} = .24, P < .05$ ; the total number of in-school removals,  $\pi_{21} = .45, P < .05$ ; and the total number harassment incidents,  $\pi_{21} = .08, P < .05$ . In all cases, the association between earlier school start times and greater disciplinary actions or behavioral problems was significant for non-Appalachian counties (with the association being  $\pi_{11} = -.30, P < .001$ , for total number of students disciplined;  $\pi_{11} = -.52, P < .001$ , for in-school removals; and  $\pi_{11} = -.10, P < .001$ , for number of harassment incidents) but not for Appalachian counties. In other words, for every additional minute later of school start time of non-Appalachian county schools, the number of students disciplined is .30 lower, the number of in-school removals is .52 lower, and the number of harassment incidents is .10 lower. A 1-hour-later start time for non-Appalachian schools would therefore be related to an estimated difference of 18 fewer students being disciplined, 31 fewer in-school removals, or 6

**Table 2**  
Estimated coefficients from models with interactions between elementary school start times and Appalachian county designation as predictors of total number of unique behavioral incidents.

	Total discipline	Corporal punishment	In-school removal	Out-of-school suspension	Expelled with services	Expelled without services	Total behavior problems	Harassment
Intercept ( $\pi_{10}$ )	21.94	-1.12	21.02	29.99**	-.01	.22	28.96	13.42**
APPAL ( $\pi_{20}$ )	15.24	4.15**	2.41	5.26	.01	.04	15.48	.11
Enrollment	.13***	.00	.09***	.03***	.00	.00	.14***	.02***
School rank	-.26*	.00	-.14	-.15**	.00	.00	-.26*	-.03
TSRATIO	-3.32*	.00	-2.75	-1.83**	.00	-.02*	-3.91*	-1.02***
FREELUNCH ( $\pi_{12}$ )	.01	.10	.55	-.82*	.00	.00	-.02	.09
AFRICAN AMERICAN	1.41***	.00	1.38***	.36**	.001*	.00	1.39***	.12*
HISPANIC	.85	.00	.74	.07	.00	.00	.89	.14
School start time ( $\pi_{11}$ )	-.53**	.00	-.52***	-.16**	-.0002*	.00	-.53**	-.10***
Start time $\times$ APPAL ( $\pi_{21}$ )	.38	-.03	.45*	.11	.00	.00	.38	.08*

Columns indicate the dependent variable being predicted. Statistical notation provided in parentheses corresponds to the equations provided in the analysis section. TSRATIO, teacher/student ratio; FREELUNCH, percentage students receiving free or reduced cost lunch; APPAL, Appalachian county designation. \* $P < .05$ , \*\* $P < .01$ , \*\*\* $P < .001$ .

**Table 3**

Estimated coefficients from models including interactions between elementary school start times and Appalachian county designation as predictors of the total number of students receiving discipline or engaged in behavioral problems

	Total discipline	Corporal punishment	In-school removal	Out-of-school suspension	Expelled with services	Expelled without services	Total behavior problems	Harassment
Intercept ( $\pi_{10}$ )	20.70	-.41	6.42	14.11*	-.01	.16	23.98	8.31**
APPAL ( $\pi_{20}$ )	6.70	2.26**	1.14	3.34	.01	.03	6.11	.03
Enrollment	.06***	.00	.04***	.02***	.00	.00	.07***	.01***
School rank	-.11	.00	-.03	-.08**	.00	.00	-.11	-.02
TSRATIO	-2.03*	.00	-1.16	-.79*	.00	-.01	-2.23*	-.62**
FREELUNCH ( $\pi_{12}$ )	.17	.04	.54	-.38	.00	.00	.17	.07
AFRICAN AMERICAN	.82***	.00	.55***	.25***	.001*	.00	.74***	.10**
HISPANIC	.38	.00	.30	.07	.00	.00	.32	.04
School start time ( $\pi_{11}$ )	-.30***	.00	-.20**	-.09**	-.0002*	.00	-.29***	-.06***
Start time $\times$ APPAL ( $\pi_{21}$ )	.24*	-.01	.16	.06	.00	.00	.21	.05

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

fewer harassment incidents. These associations control for school enrollment, rank, percentage of students receiving free or reduced cost lunches, the teacher-student ratio, the percentage of Hispanic students, and the percentage of African American students.

## Discussion

We had 2 main hypotheses: (1) earlier school start times will be associated with increased rates of behavioral incidents and disciplinary actions, and (2) earlier start times will be especially risky for discipline problems in schools serving fewer disadvantaged students. These hypotheses were largely confirmed. Earlier school start times were related to greater behavioral problems in schools, with some associations only found for non-Appalachian elementary schools. Unexpectedly, no significant interactions with the percentage of students receiving free lunch were observed.

In all cases where associations were found, earlier start times were related to more behavioral problems, including greater overall disciplinary actions, more overall behavioral incidents, more students being suspended, more total suspensions, more in-school removals, higher incidence of harassment, and more expulsions. Given that previous research has shown that the school start times are linked with sleep restriction in elementary school students<sup>3</sup> and that behavioral problems are often a consequence of poor sleep,<sup>10,12</sup> our current findings linking earlier school start times and behavioral problems support the hypothesis that sleep restriction might act as a mediator of the relation between earlier school start times and child behavioral problems. Indeed, early school start times may be linked to behavioral problems especially in preadolescent children, as they have relatively less executive control and self-regulation skills.<sup>21,22</sup>

Such behavioral difficulties may be an overlooked consequence of earlier school start times. The major focus of prior research on school start times has been to establish their effect on adolescent sleep and academic performance. However, school safety is a timely and highly important issue in American education. Increasingly, parents fear that their children will become the victims of bullying or violent crimes at school.<sup>23</sup> In dealing with student behavioral problems, teachers lose instruction time and become frustrated.<sup>24</sup> Disruptive students serve as a distraction and negatively impact the learning of other students.<sup>25</sup> They themselves suffer educational consequences when they are removed from the classroom.<sup>26</sup> Although it is premature to say that delaying school start times will have a causal effect on student behavior, findings from the current study highlight the need for additional research on this topic.

Findings also emphasize the need for research on elementary school start times. Research on school start times should not focus exclusively on adolescents, and communities should think carefully before they shift elementary school start times earlier so that middle

and high schools can start later. Adolescents have long been the focus of school start time research because they experience a delayed sleep phase.<sup>27</sup> However, sufficient sleep is of critical importance across development,<sup>28</sup> and many elementary school students are sleep restricted.<sup>29</sup> Fortunately, making school start times later for all grade levels may be a feasible solution for some school districts.<sup>9</sup>

Contrary to hypotheses, the percentage of students receiving free and reduced lunch did not significantly moderate any of the effects of school start times. However, some of the associations between school start times and disciplinary issues were significantly moderated by Appalachian school location. In these cases, significant relations between early school start times and greater behavior problems were found only for non-Appalachian schools. A possible explanation for these findings is the cumulative risk model.<sup>13</sup> The cumulative risk model posits that it is the number of risk factors to which a child is exposed, rather than any specific risk factor, that predicts development. Low-income fourth graders have 35% more negative life events in a year than middle-income fourth graders.<sup>16</sup> Examples of risk factors include exposure to violence,<sup>30</sup> marital conflict or divorce,<sup>31</sup> harsh and unresponsive parenting,<sup>32,33</sup> and exposure to toxins and parental smoking.<sup>34,35</sup> The implication is that school start times may in and of themselves have little impact when children are facing so many other challenges.

On the other hand, there were no observed interactions between school start times and percentage of students receiving free or reduced cost lunches. Although null findings should always be interpreted with caution, these findings do raise interesting questions. It is possible that Appalachian students are facing a larger number of risk factors than poor students in other counties while receiving fewer services to ameliorate their impact. It is also possible that students in Appalachian counties face a unique combination of risk factors. Specific constellations of risk factors may be more predictive of negative outcomes than a simple total of risk factors (eg, Copeland et al<sup>34</sup>). Latent class analysis indicates that the experience of poverty differs between contexts and that school functioning is differentially predicted by class membership.<sup>36</sup> Thus, the economic disadvantage associated with being in Appalachia may represent a separate constellation of risk factors for behavior problems than the more general free lunch measure. At the same time, it is important to emphasize that many associations between school start times and behavioral problems were consistent across Appalachian and non-Appalachian counties.

Findings should be interpreted in light of study limitations. The current study did not assess sleep directly and was unable to link individual student sleep problems to individual student behavior. Although there are several studies indicating that early start times are related to children's sleep (eg, Carskadon et al,<sup>1</sup> Dexter et al,<sup>2</sup> and Appleman et al<sup>3</sup>), additional research is needed to address this

issue. The current study is also limited by its cross-sectional design. Although we controlled for a number of potential confounding factors, including the racial composition of the schools, enrollment, school rank, and teacher-student ratio, we cannot infer that early school start times were the cause of school performance measures. An intriguing possibility is that early start times contribute to the sleep restriction of teachers and staff,<sup>37,38</sup> making them less patient with students, less able to handle minor student behavior problems which later turn into more serious ones, and perhaps more likely to assign severe punishments. It is also important to note that alternative schools were not included in the analyses, and therefore, additional research is needed to determine whether findings generalize to private schools, charter schools, or schools serving special populations. Finally, findings may not generalize to other states, especially to states that have varying levels of poverty or more racial diversity than Kentucky.

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 behavioral concerns, suggesting that an additional benefit of delayed school start times may be improved school safety. Second, we examine elementary schools. The majority of research on school start times has focused on middle and high schools, but findings from the current study suggest that younger children (aged 5–12 years) are also at risk. Third, we examined moderators of associations and found that some behavioral risks related to early start times were only for non-Appalachian students.

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