The Science Behind Changing School Start Times

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National Jewish Health

Overview

- Adolescents and sleep
- Consequences of insufficient sleep
- Outcomes from districts that have made changes
- Elementary school start times research

Adolescents need 8.5 to 9.25 hours of sleep per night

7 out of 10 adolescents in the US

get 7 hours or less per night

Carskadon et al. (1980, 2002), McKnight-Eily et al. (2011), NSF (2006, 2014), Owens et al. (2014)

So?

Sleep doesn't matter

I sleep less than that and do just fine

Sleep is for slackers

WRONG!!

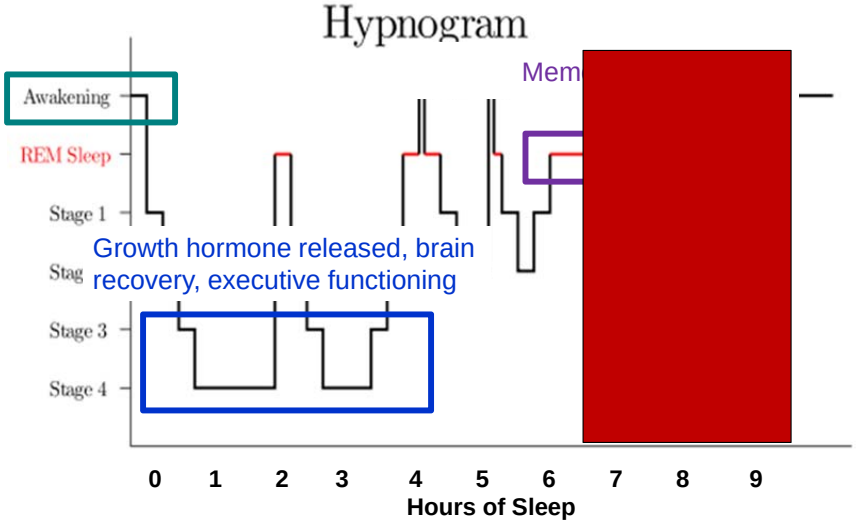
You have to breathe

You have to eat

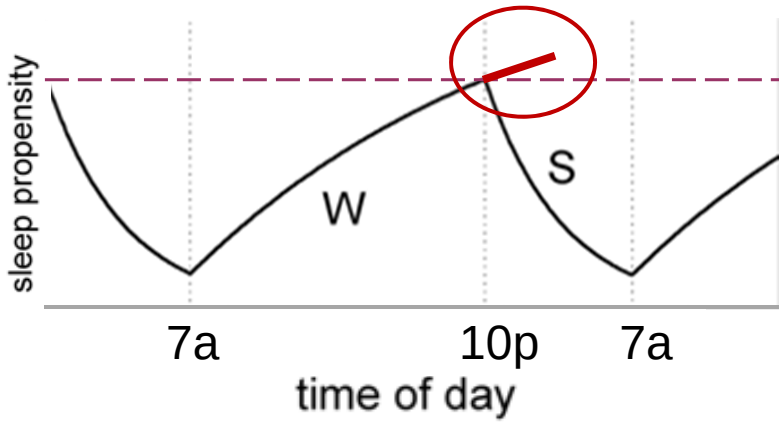
You have to sleep!

Sleep is not a passive state and is essential for health, daytime functioning, and well-being

Stages of Sleep



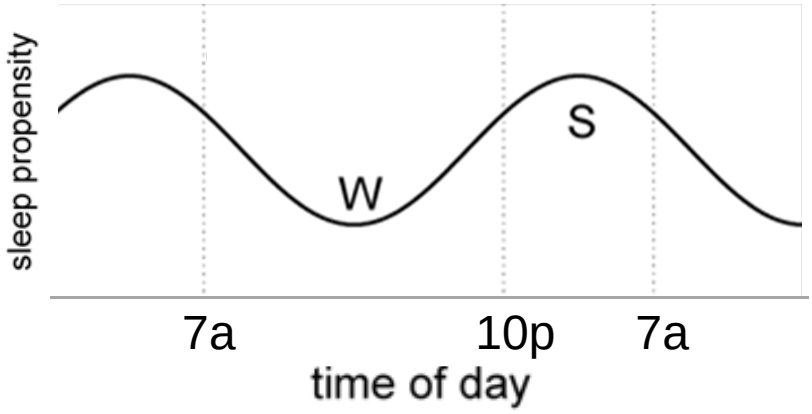
Process S – Sleep Homeostasis



Borbely (1982); Van Dongen et al. (2003)

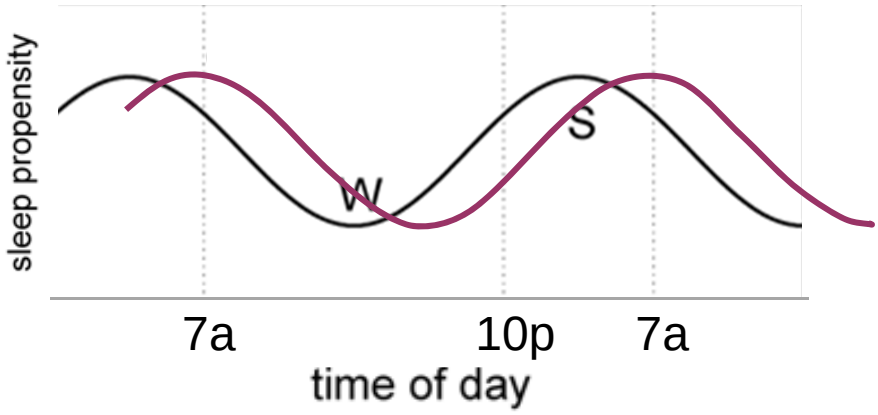
Well if teens just turned off their phones and went to bed earlier, then they wouldn't have any problems waking up

Process C - Circadian Rhythm



Borbely (1982); Carskadon et al. (1980, 2002)

Circadian Misalignment



Borbely (1982); Carskadon et al. (1980, 2002)

Faces of Deficient Sleep

Deficient Sleep in Children/Adolescents

- Mood and affect changes
- Behavior problems
  - Non-compliance
  - Aggression
  - Hyperactivity
  - Poor impulse control

- Risk taking behaviors and increased accidents

Beebe (2011); Gruber et al. (2012); Owens et al. (2014)

Deficient Sleep in Children/Adolescents

- Neurocognitive deficits
  - Attention
  - Memory
  - Executive functioning

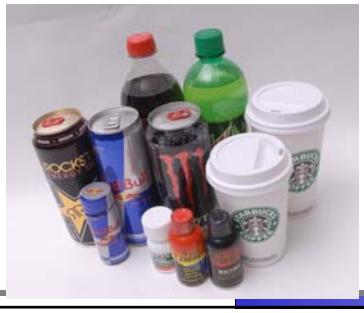
- Weight gain
  - Increased caloric intake
  - Increased consumption fats and carbs

Beebe et al. (2010); Beebe et al. (2013); Gruber, Wiebe et al. (2012); Gruber, Michaelsen et al. (2012); Hart et al. (2013); Sadeh et al. (2003)

Signs of Deficient Sleep

- Needs to be awakened in morning
- Sleeps 2+ hours on weekends or vacations than weekdays
- Falls asleep in school or other inappropriate times
- Behavior/mood differ following nights of increased sleep

Extrinsic Sleep Disruptors



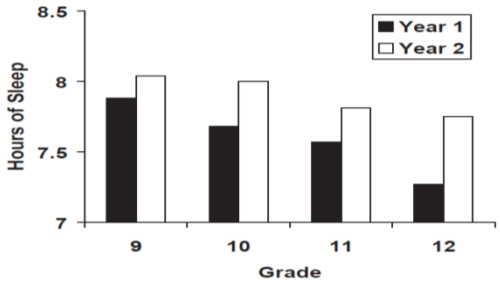
Later School Start Time Outcomes

- Multiple studies have demonstrated the benefit of changing to a later school start time…
- Students getting > 8 hours sleep/night
- Better academic outcomes
- Better attendance rates
- Higher graduation rates
- Reduced tardiness
- Less depression
- Less caffeine use
- Fewer car crashes

Boergers et al. (2014); Danner & Phillips (2008); McKeever et al. (2017); Owens et al. (2010); Wahlstrom (2002); Wahlstrom et al. (2014); Wolfson et al. (2007)

Fayette County, KY

- Started school 1 hour later
  - 7:30am to 8:30 am
  - 8:00am to 9:00am
- Increased total sleep time
  - 8+ hours: 36% to 50%



- 16.5% decrease in number of motor vehicle crashes

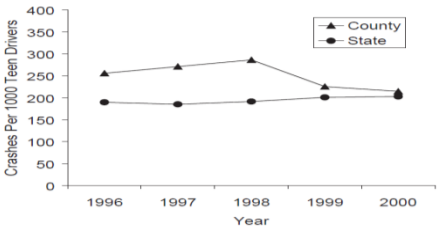


Figure 3—Number of motor vehicle crashes per 1000 drivers aged 17 or 18 years in the study county and state.

- **No changes in # hours spent on homework, jobs, sports/activities**

Danner & Phillips (2008)

What about here in Colorado?

- Fairview High School
  - 7:35 am to 8:05 am
  - Went from 33.6% to 42.5% of students getting > 8 hours of sleep
  - Tardies down from 2.44 to 2.15
  - Overall GPA increased
    - 1st period class most notable change, increasing between 0.2 and 0.3 for 11th and 12th graders
  - Current start time 8:00 am

Wahlstrom et al. (2014)

What about here in Colorado?

- Boulder High School
  - 7:30 am to 8:00 am (9:00 on Wed)
  - After change 42.5% of students getting > 8 hours of sleep
  - Tardies down from 3.7 to 3.16
  - GPA increased

Wahlstrom et al. (2014)

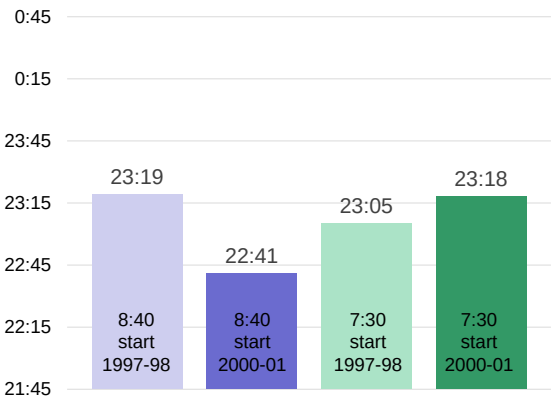
What about here in Colorado?

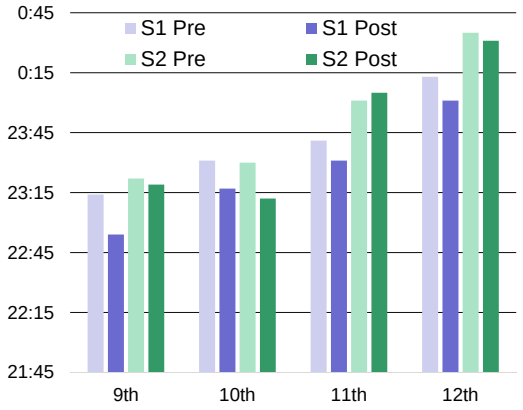
- Academy School District 20
  - 7:05 to 7:45 a.m.
  - Combined middle and high school students on same buses
  - Eliminated bus routes with few students
  - Fewer tardies and “happier students”
  - Did not affect athletics or after-school activities

If teens have later start times, they will simply go to bed later

Bedtimes don't significantly change

- Students do not stay up later, but wake later

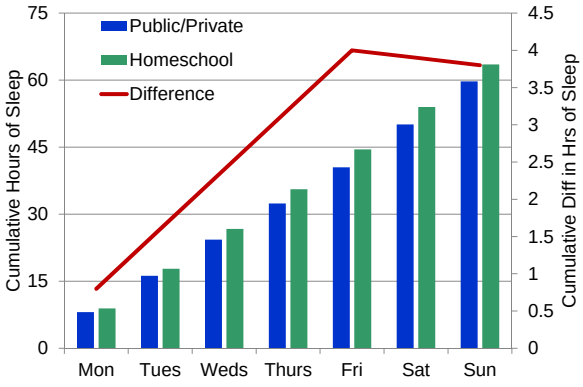


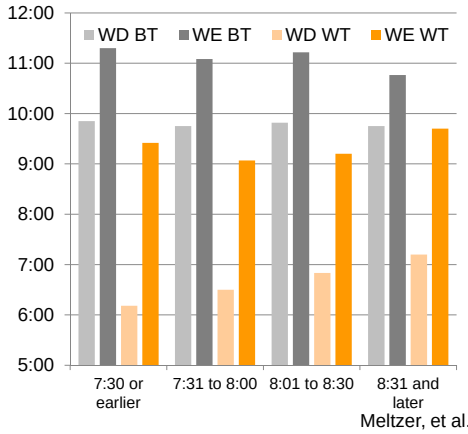


Boergers et al. (2014); Danner & Phillips (2008); Owens et al. (2010); Wahlstrom (2002); Wahlstrom et al. (2014); Wolfson et al. (2007)

Increased sleep due to wake times

- Homeschool students wake same time as public schools start
- Cumulative sleep debt (49 m/day = 4 h/wk = 144h/yr)





Meltzer, et al. (2015)

And what about sports?

- Wilton, CT changed start times with strong opposition from coaches
  - Next year high school had the best season, winning several state championships
  - Increased extra-curricular participation across grades

<u>Stanford athletes increased time in bed to 10 hrs/night</u>

- Basketball
  - Faster sprint (0.7 seconds)
  - Free throws 9% more accurate
  - Improved mood, decreased fatigue

Mah et al. (2011)

And what about sports?

- Football
  - 20 yard shuttle went from 4.71 to 4.61 seconds
  - 40 dash improved from 4.99 to 4.89 seconds
- Swimming
  - 15 meter sprint 0.51 seconds faster
  - Reacted 0.15 seconds quicker of the blocks
  - Improved turn time by 0.10 seconds

Michael Phelps won a gold medal by ***0.01 seconds***

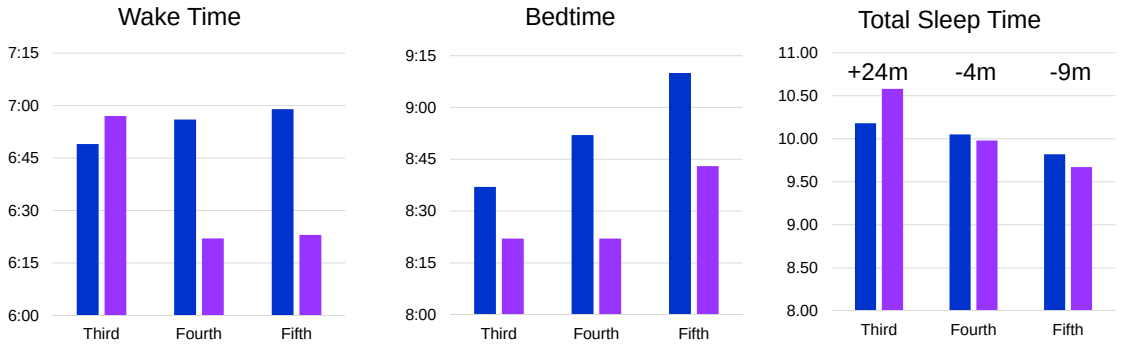
Mah et al. (2008); Mah et al. (2010)

That's nice, but what about elementary school students? Won't starting earlier cause them to get less sleep?

Change to Start Time in Northeast Elementary School

3rd grade: **9:10 a.m.** → **7:45 a.m.**

4th/5th grade: **8:20 a.m.** → **7:45 a.m.**



Appleman et al. (2015)

Minneapolis School District

- School start times changed from 8:40 → 7:40 a.m.
- Students were more alert at start of day and remained energized throughout day
- Students had fewer morning transitions and were more ready to learn
- Teachers and students were more patient and productive in the afternoon
- Fewer behavior problems
- Increased participation in school activities
- Buses were on time at start and end of day

Wahlstrom (1998)

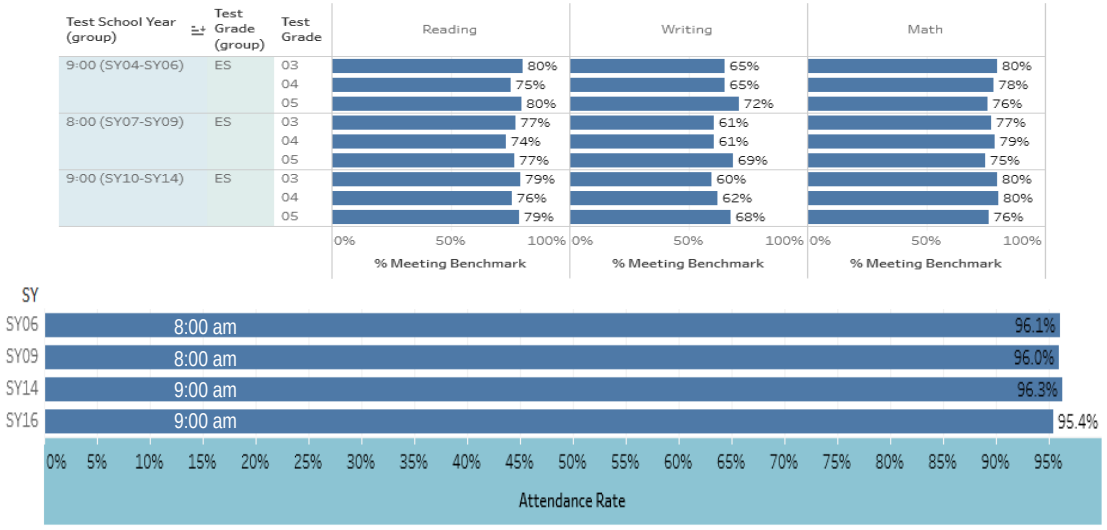
CCSD Historical Trends by Start Time

School Year Grouping	School Year (copy)	Grade Level (group)	Reading Standards					Math Standards						
			1	2	3	4	G	1	2	3	4	5	6	G
8:00 (SY07-SY09)	2007	ES	2.8	2.8	2.8	2.8		2.9	2.8	2.8	2.8	2.8	2.8	
	2008	ES	2.8	2.8	2.8	2.9		2.9	2.8	2.9	2.9	2.8	2.8	
	2009	ES	2.8	2.8	2.8	2.8		2.9	2.8	2.9	2.9	2.8	2.8	
9:00 (SY10+)	2010	ES	2.8	2.8	2.8	2.8		2.9	2.9	2.9	2.9	2.9	2.9	
	2011	ES	2.8	2.8	2.8	2.8		2.9	2.9	2.9	2.9	2.9	2.9	
	2012	ES	2.8	2.8	2.8	2.8		2.9	2.9	2.9	2.9	2.9	2.9	
	2013	ES	2.8	2.8	2.8	2.9		2.9	2.9	2.9	3.0	2.9	2.9	
	2014	ES	2.8	2.8	2.8			2.8	2.8	2.8	2.8	2.8		
	2015	ES	2.8	2.7	2.8			2.8	2.8	2.8	2.8	2.9		
	2016	ES	2.8	2.7	2.8			2.8	2.8	2.8	2.8	2.8		
	2017	ES	2.7	2.7	2.7			2.7	2.8	2.8	2.8	2.8		

CCSD Historical Trends by Start Time

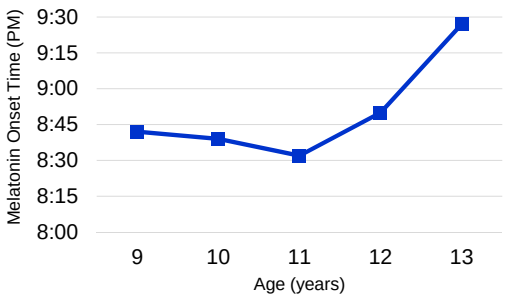
School Year Grouping	Grade Level (group)	Grade Level	Reading Standards					Math Standards						
			1	2	3	4	G	1	2	3	4	5	6	G
8:00 (SY07-SY09)	ES	0	2.8	2.8	2.8	2.9		2.8	2.9	2.9	2.9	2.9	2.9	
		1	2.8	2.8	2.8	2.8		2.9	2.8	2.8	2.9	2.8	2.8	
		2	2.8	2.7	2.8	2.8		2.9	2.8	2.9	2.9	2.8	2.8	
		3	2.8	2.8	2.8	2.8		2.9	2.8	2.8	2.8	2.8	2.8	
		4	2.9	2.8	2.8	2.9		2.9	2.8	2.8	2.9	2.8	2.8	
		5	2.9	2.8	2.9	2.9		2.9	2.9	2.9	2.9	2.9	2.9	
9:00 (SY10+)	ES	0	2.8	2.9	2.8	2.9		2.8	2.9	2.9	2.9	2.9	2.9	
		1	2.7	2.8	2.8	2.8		2.9	2.8	2.8	2.9	2.8	2.9	
		2	2.7	2.7	2.7	2.8		2.9	2.8	2.8	2.9	2.9	2.9	
		3	2.8	2.7	2.8	2.8		2.8	2.8	2.8	2.8	2.8	2.8	
		4	2.8	2.7	2.8	2.9		2.8	2.8	2.8	2.9	2.8	2.8	
		5	2.9	2.8	2.9	2.9		2.9	2.9	2.9	2.9	2.9	2.9	

CCSD Historical Trends by Start Time

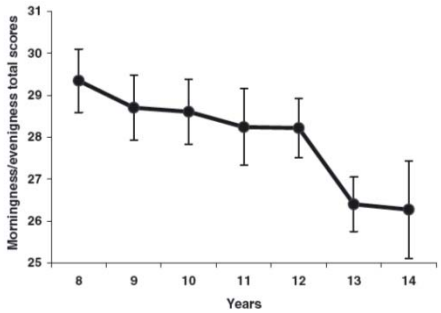


Circadian Rhythms and Elementary School Aged Children

- Change in melatonin onset doesn't begin until between ages 11 and 13



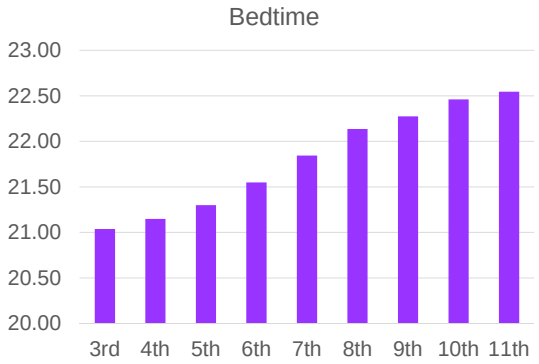
- Self-reported circadian preference changes between ages 12 and 13

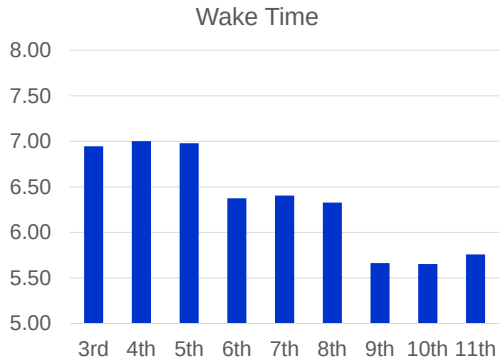


Crowley et al. (2014); Russo et al. (2007)

Weekday Sleep Driven by Wake Time (which is driven by school start times)

- Bedtimes increase steadily with increasing grade
  - ES → MS: 40 m, MS → HS: 34 m
- Wake times consistent across school level
  - ES: 6:58, MS: 6:33, HS: 5:41





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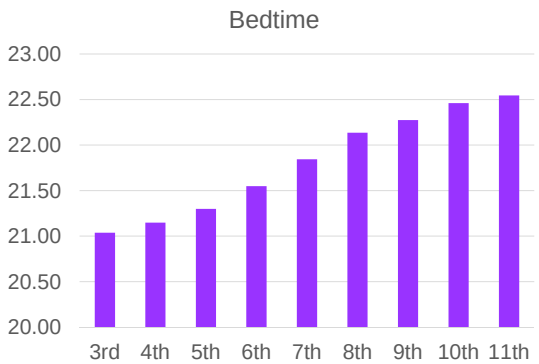

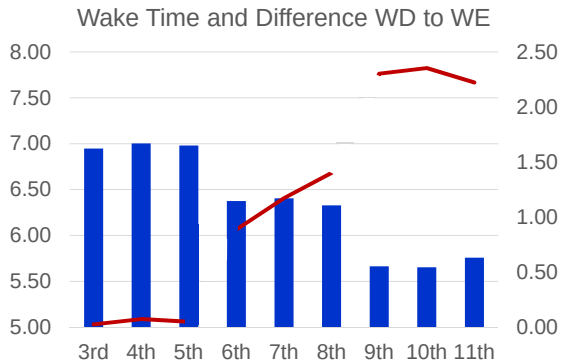

But what about all those studies showing how earlier start times are bad for elementary school students?

References:

[1] "University of Kentucky study: Early school start times may be detrimental to young children." Lexington Herald-Leader. August 19, 2014. http://www.kentucky.com/news/local/education/article44504058.html

[2] "How Much Sleep Do We Really Need?" National Sleep Foundation. http://www.sleepfoundation.org/article/how-sleep-works/how-much-sleep-do-we-really-need

[3] "More Sleep Linked to Improved Child Alertness, Behavior." American Academy of Pediatrics. October 15, 2012. https://www.aap.org/en-us/about-the-aap/aap-press-room/pages/More-Sleep-Linked-to-Improved-Child-Alertness-Behavior.aspx

[4] Lexington Herald-Leader. "University of Kentucky study … detrimental to young children." Op cit.

[5] "Less Sleep, More Struggles for Elementary and Middle School Students". Brown Medical School and Bradley Hospital. SLEEP December 2005. https://www.brown.edu/Administration/News_Bureau/2005-06/05-046.html

Kentucky Study

9-11 hours

Avg 9.3 hr
+27m vs -54m

Kentucky Study

8 hrs 1st/2nd
6.5 hrs ≥3rd

References:

[1] "University of Kentucky study: Early school start times may be detrimental to young children." Lexington Herald-Leader. August 19, 2014. http://www.kentucky.com/news/local/education/article44504058.html

[2] "How Much Sleep Do We Really Need?" National Sleep Foundation. http://www.sleepfoundation.org/article/how-sleep-works/how-much-sleep-do-we-really-need

Impact of Sleep Extension and Restriction on Children's Emotional Lability and Impulsivity
Reut Gruber, Jamie Cassoff, Sonia Frenette, Sabrina Wiebe and Julie Carrier
Pediatrics 2012;130;e1155; originally published online October 15, 2012; DOI: 10.1542/peds.2012-0564

[4] Lexington Herald-Leader. "University of Kentucky study … detrimental to young children." Op cit.

Experimental Restriction of Sleep Opportunity in Children: Effects on Teacher Ratings
Gahan Fallone, PhD; Christine Acebo, PhD; Ronald Seifer, PhD; Mary A. Carskadon, PhD
E. P. Bradley Hospital, East Providence, RI; Department of Psychiatry and Human Behavior, Brown Medical School, Providence, RI

Kentucky Study

9h: 9:30p-6:30a
10h: 8:30p-6:30a
11h: 7:30p-6:30a

Avg 9.3 hr
+27m vs -54m

Kentucky Study

8 hrs 1st/2nd
6.5 hrs ≥3rd

Kentucky Study

Journal of Educational Psychology
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0022-0663/15/$12.00 http://dx.doi.org/10.1037/a0037195

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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Sleep Health 3 (2017) 113–118

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journal homepage: sleephealthjournal.org

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

Peggy S. Keller, PhD*, Lauren R. Gilbert, PhD, Eric A. Haak, MS, Shuang Bi, MS, Olivia A. Smith, BS
University of Kentucky

Sleep and Academic Performance

- Statistical models to predict how school start times impact academics and behavior
- Start time calculated as minutes since midnight (so no comparison of early vs. late starting schools)

Start time 8:05 AM (35 min)

$$NAPDMATH_{IJ} = B_{J0} + B_{J1}(STARTTIME_I) + B_{J2}(FREELUNCH_I) + B_{J3}(TIMEXLUNCH_I) + B_{J4}(AFRICAN\ AMERICAN_I) + B_{J5}(HISPANIC_I) + B_{J6}(TSRATIO_I).$$

9:00–9:10 102 (14.2%)

Keller et al. (2014)

Sleep and Academic Performance

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

Variable	NAPD						School rank	Attendance rate	Retention rate
	Language	Reading	Math	Science	Social Studies	Writing			
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.
*$p < .05$. **$p < .01$. ***$p < .001$.

Keller et al. (2014)

Sleep and Academic Performance

Table 4

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

Effects and differences of start times	NAPD						School rank	Attendance rate
	Language	Reading	Math	Science	Social Studies	Writing		
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.

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

Keller et al. (2014)

Sleep and Academic Performance

Conclusion: Earlier school start times can be associated with poorer school performance in elementary schools

Keller et al. (2014)

Sleep and Behavior

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 (π_{10})	20.70	−.41	6.42	14.11*	−.01	.16	23.98	8.31**
APPAL (π_{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 (π_{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 (π_{11})	−.30***	.00	−.20**	−.09**	−.0002*	.00	−.29***	−.06***
Start time × APPALL (π_{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. *$P < .05$, **$P < .01$, ***$P < .001$.

Keller et al. (2017)

Sleep and Behavior

- Low base rate of 3% of students K-6
  - 1.6% of incidents were in 6th graders
  - Outcomes driven by 6th graders? If yes, more reason to change middle school start times…
- One study, has not been replicated
  - MANY studies showing negative impact of early start times on adolescents
  - MANY studies showing benefits for adolescents of later start times

Take Home Message

- Sleep essential for learning, growth, development
- Adolescents significantly sleep deprived, with school start times as one of the strongest contributing factors
- Changing start times is not coddling students, but setting them up for success in life
- Evidence base limited for benefits or consequences of elementary schools starting earlier

Recommendation to start middle/high schools no earlier than 8:30 a.m.

- American Academy of Pediatrics
- Centers for Disease Control and Prevention
- American Medical Association
- American Academy of Sleep Medicine
- American Academy of Child and Adolescents Psychiatrists
- American Psychological Association
- National Association of School Nurses
- American Thoracic Society
- National Sleep Foundation

"If sleep doesn't serve an absolutely vital function, then it is the greatest mistake the evolutionary process ever made"

Dr. Allan Rechtschaffen

Questions?

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