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UNT | HEALTH SCIENCE CENTER

Beyond Short Sleep: What Role Does Sleep Play in Obesity?

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Institute of Cardiovascular and Metabolic Diseases

Relevant Disclosure

Under Accreditation Council for Continuing Medical Education guidelines disclosure must be made regarding relevant financial relationships with commercial interests within the last 12 months.

Brandy M. Roane, PhD, CBSM

I have no relevant financial relationships or affiliations with commercial interests to disclose.

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Learning Objectives

At the end of the presentation the audience should be able to:

1. Differentiate key sleep parameters that influence obesity
2. Summarize how these sleep parameters contribute to obesity
3. Identify sleep parameters to target and external factors that need further consideration to reduce obesity rates

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"…Sufficient sleep is not a luxury—it is a necessity—and should be thought of as a vital sign of good health."

Wayne H. Gills, MD, MS, Director, Division of Population Health, National Center for Chronic Disease Prevention and Health Promotion

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So, what do we mean by 'sufficient sleep'?

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Sleep Terms

- **Sleep Duration**
  - How much you slept

Different than time you spend in bed

- **Sleep Quality**
  - How well you slept

Not dependent on how much sleep you get

- **Sleep Restriction**
  - Shortening of the sleep duration

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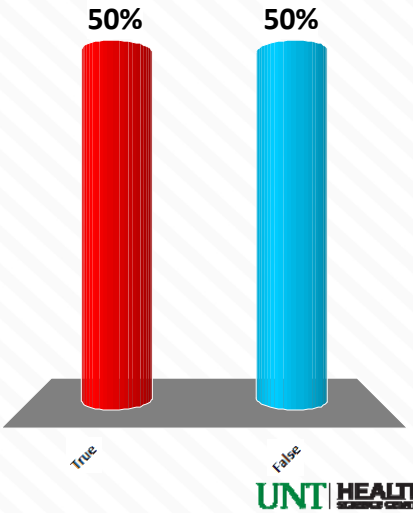
7-9 hours of sleep is good for everyone, regardless of age.

A. **True**

B. **False**



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True or False?

7-9 hours of sleep is good for everyone, regardless of age.

FALSE

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So, how much sleep is enough sleep?

The answer: It depends.

Newborns	16-18 hours
Toddlers	13-15 hours
Preschool schoolers	11-13 hours
Elementary schoolers	11-12 hours
Middle schoolers	10-11 hours
Teens	9-10 hours
Adults (including Older Adults)	7-9 hours

Data from National Institutes of Health.

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Sleep Durations in Children and Teens

From: **2014 Sleep in America Poll: Sleep in the Modern Family**

National Sleep Foundation. 2014. Retrieved from http://www.sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2014-sleep-in-the-modern-family

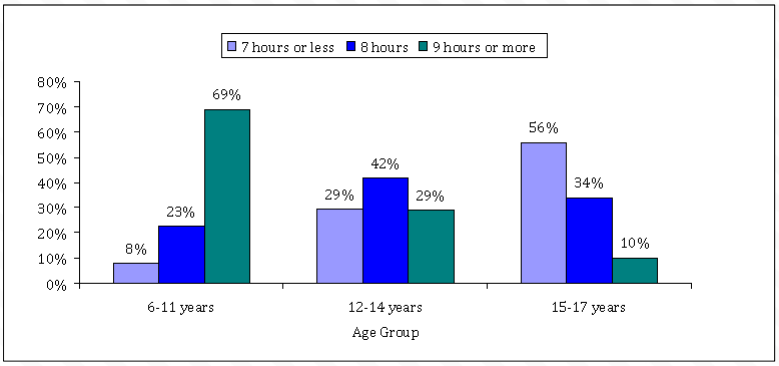

Figure Legend:

Amount of sleep the child needs as estimated by the parent.

Date of download: 4/5/2017

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How does sleep relate to obesity?

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Obesity Trends in Children and Teens

From: **Trends in Obesity Prevalence Among Children and Adolescents in the United States, 1988-1994 Through 2013-2014**

JAMA. 2016;315(21):2292-2299. doi:10.1001/jama.2016.6361

Increased BMI

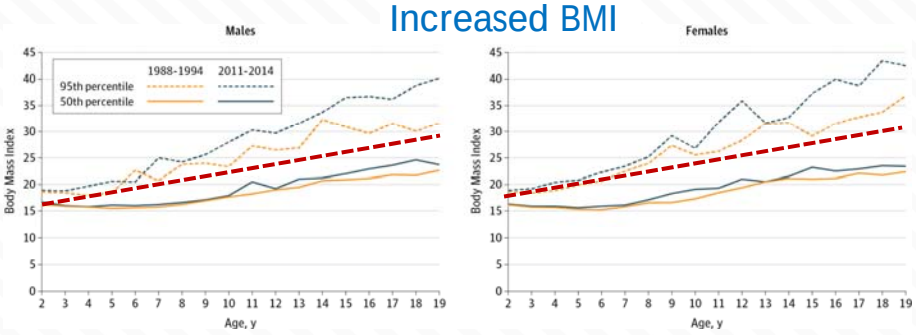

Figure Legend:

Weighted Estimates for US Children and Adolescents Aged 2 to 19 Years in the 50th and 95th Percentiles of Body Mass Index From 1988-1994 and 2011-2014Data are from the National Health and Nutrition Examination Surveys.

Sleep Trends in Children and Teens

From: **Never Enough Sleep: A Brief History of Sleep Recommendations for Children**

Lisa Anne Matricciani et al. Pediatrics 2012;129:548-556

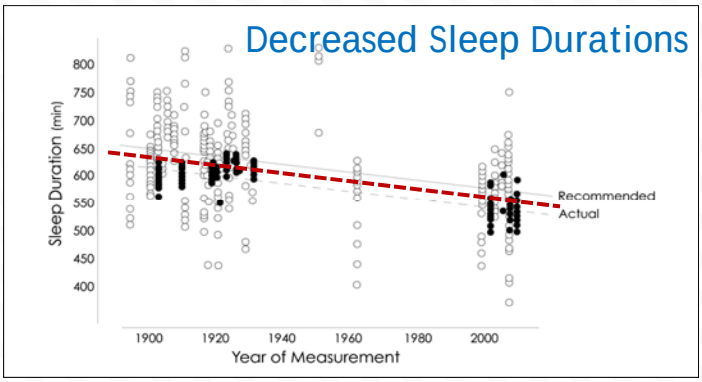

Figure Legend:

Historical trends in recommended sleep (minutes per day, adjusted for age). Open circle and solid line indicate trends in recommended sleep duration. Filled circles and dotted line indicate actual sleep duration.

From: **Meta-Analysis of Short Sleep Duration and Obesity in Children and Adults**

Cappuccio et al. Sleep 2008; 31(5):619-626. doi:10.1093/sleep/31.5.619

Meta-analysis of cross-sectional studies shows that shorter sleep durations increased risk of obesity

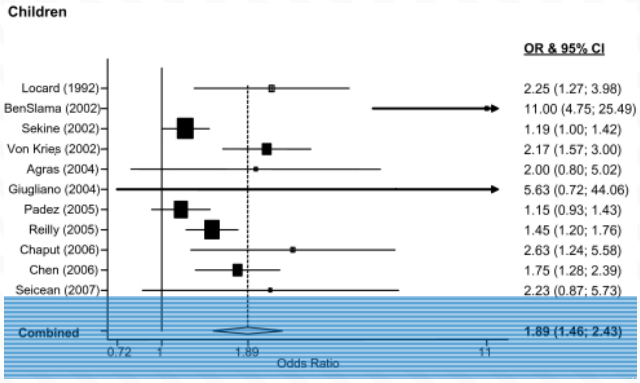

Figure Legend:

Forest plot of the associations between short duration of sleep and obesity in studies carried out in children. OR and 95 CI indicate odds ratio and 95% confidence intervals.

Short Sleep and Obesity

- Short sleep is associated with several obesity markers including…
  - BMI,
  - hyperglycemia, and
  - adverse metabolic changes to insulin, leptin, adiponectin, and lipid levels

Koren et al., 2011, Hasler et al., 2004; Kong et al., 2011; Leproult et al., 2010, Spruyt et al., 2011; Bell et al., 2010; Cappuccio et al., 2008; Chaput et al., 2010; Garaluet et al., 2011; Ievers-Landis et al., 2008; Sung et al., 2011; Olds et al., 2011

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From: **Short sleep duration is associated with increased obesity markers in European adolescents: effect of physical activity and dietary habits. The HELENA study**
Garaulet et al. Sleep 2011; 35(10):1308-1317. doi:10.1038/ijo.2011.149

	Male					Female					All				
	Sleep				P-value	Sleep				P-value	Sleep				P-value
	<8 h n = 488		≥8 h n = 1075			<8 h n = 598		≥8 h n = 1150			<8 h N = 1086		≥8 h N = 2225		
	Mean	s.e.	Mean	s.e.		Mean	s.e.	Mean	s.e.		Mean	s.e.	Mean	s.e.	
BMI	21.73	0.18	21.07	0.23	0.03	21.43	0.14	21.02	0.10	0.0320	21.71	3.52	21.17	3.70	<0.0001
Skinfolds (suma) (mm)	44.00	1.20	43.94	0.77	0.964	57.82	0.96	57.57	0.67	0.836	51.15	0.766	51.24	0.518	0.922
Body fat (%)	14.89	0.43	14.51	0.28	0.455	25.98	7.03	24.10	7.83	<0.0001	20.96	8.80	19.74	8.87	<0.0001
Fat mass index	3.45	0.11	3.33	0.07	0.371	5.60	0.11	5.25	0.07	0.010	4.58	0.07	4.35	0.054	0.020
Waist circumference (cm)	75.50	9.13	73.83	9.58	0.001	70.57	7.55	69.96	7.95	0.121	72.78	8.65	71.83	8.98	0.004
Hip circumference (cm)	92.03	8.48	89.97	9.07	<0.0001	93.62	7.30	92.44	8.24	0.004	92.90	7.89	91.24	8.74	<0.0001

Sex-differences emerge for the association between short sleep and obesity markers

Body fat (%)
Fat mass index
Waist circumference (cm)

Figure Legend:

Abbreviation: BMI, body mass index. Fat mass index ¼ body fat (BIA)/height^2. Statistical Analysis ANCOVA. P-values after adjusting for Tanner stages and country. Bold face indicates statistical significance (P=0.05)

From: **Short Sleep Duration is Associated with Increased Obesity Markers in European Adolescents: Effect of Physical Activity and Dietary Habits. The HELENA Study**

Garaulet et al. Sleep 2011; 35(10):1308-1317. doi:10.1038/ijo.2011.149

	Number of sleep hours											
	Males				Females				Total population			
	r	P	P*	P**	r	P	P*	P**	R	P	P*	P**
BMI	−0.055	0.041	0.256	0.041	−0.089	0.0001	0.042	0.0001	−0.070	0.0001	0.314	0.0001
Sum of skinfolds	0.039	0.155	0.430	0.799	−0.031	0.227	0.807	0.043	0.005	0.801	0.616	0.098
BIA body fat (%)	0.029	0.285	0.436	0.285	−0.121	0.0001	0.001	0.0001	−0.045	0.0150	0.401	0.0150
BIA fat mass index	0.020	0.456	0.905	0.493	−0.095	0.0001	0.018	0.004	−0.38	0.038	0.252	0.008
Waist circumference	−0.052	0.042	0.245	0.042	−0.071	0.0001	0.107	0.0001	−0.061	0.0010	0.461	0.0010
Hip circumference	−0.097	0.0001	0.007	0.001	−0.132	0.0001	0.0001	0.001	−0.114	0.0001	0.0001	0.0001

Sex-differences emerge for the association between short sleep and obesity markers

Sum of skinfolds
BIA body fat (%)
BIA fat mass index

Figure Legend:

Abbreviation: BMI, Body mass index. *P* after adjusting for Tanner stages, center and gender (in the total population). **P* after adjusting for Tanner stages, center and gender (in the total population) and for inactivity (accelerometer). ***P* after adjusting for Tanner stages, center and gender (in the total population) and for food intake variables (all variables significantly related to sleep duration, Table 3). Fat mass index=body fat (BIA)/height^2. Statistical analysis: partial correlation. Bold face indicates statistical significance ($P<0.05$).

From: **Dietary Intake Following Experimentally Restricted Sleep in Adolescents**

Beebe et al. Sleep. 2013: 36(6): 827-234. doi:10.5665/sleep.2704

41 teens, cross-over experimental design

- Short sleep condition = 6.5 hours, Healthy sleep = 10 hours
- 59% females
- 54% Caucasian, 37% African American
- Mean age = 15.3 y (SD = 0.7)
- Mean BMI = 23.4 (SD = 4.0)

	Sleep restriction	Healthy sleep	*t* (df = 40)	P	Effect size (d)
Sweetened beverages	2.06 ± 2.22	1.56 ± 2.22	1.40	0.170	0.22
Unsweetened beverages	2.32 ± 2.12	3.16 ± 3.16	-1.60	0.118	-0.25
Fruits and vegetables	0.53 ± 1.13	0.45 ± 1.09	0.63	0.758	0.05
Meat and eggs	1.07 ± 1.13	1.02 ± 1.20	0.49	0.773	0.05
Processed snacks	1.36 ± 1.54	1.47 ± 1.65	-0.36	0.724	-0.06
Fast-food entrees	1.15 ±1.32	1.21 ± 1.48	-0.20	0.841	-0.03
Grains and starches	1.98 ± 1.66	1.69 ± 1.40	1.20	0.237	0.19
Sweets and desserts	1.89 ± 2.35	0.82 ± 0.99	2.52	0.016	0.39

Data are presented as mean ± standard deviation. Significance P values reflect nondirectional/exploratory two-tailed tests.

Figure Legend:

Data are presented as mean + standard deviation. Significance P values reflect nondirectional/exploratory two-tailed tests.

Association between short sleep and obesity not always significant.

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From: **Does Sleep Duration Predict Metabolic Risk in Obese Adolescents Attending Tertiary Services? A Cross-Sectional Study**
Sung et al. Sleep. 2011: 34(7): 891-898. doi:10.5665/sleep.1122

133 obese teens, cross-sectional design

- Tertiary care weight-management clinic
- 66% females
- 32% Caucasian
- Mean age = 13.2 y (SD = 1.8)
- Mean BMI = 37 (SD = 7.2)

Outcome Variable	Sleep duration (hours/night)								
	Parent-report			Self-report			Actigraphy		
	Beta Coeff	95% CI	P	Beta Coeff	95% CI	P	Beta Coeff	95% CI	P
BMI z-score[a]	-0.02	-0.07, 0.02	0.4	-0.01	-0.05, 0.04	0.8	-0.03	-0.09, 0.02	0.2
Metabolic markers[b]									
Waist circumference (cm)	-1.6	-3.6, 0.5	0.1	0.6	-1.2, 2.3	0.5	0.3	-1.8, 2.4	0.8
Triglycerides (mg/dL)	2.3	-9.6, 14.1	0.7	12.3*	2.5, 22.1	0.01	13.6*	1.1, 26.1	0.03
HDL-cholesterol (mg/dL)	-2.7*	-4.4, -1.0	0.002	-0.9	-2.6, 0.7	0.3	-0.8	-2.8, 1.2	0.4
Systolic blood pressure (mmHg)	0.05	-0.2, 0.3	0.6	-0.04	-0.2, 0.1	0.7	0.05	-0.2, 0.3	0.7
Diastolic blood pressure(mmHg)	0.01	-0.2, 0.2	1.0	-0.03	-0.2, 0.1	0.7	-0.2	-0.2, 0.02	0.1
Fasting glucose (mg/dL)	-0.5	-2.1, 1.1	0.5	-1.3	-2.6, 0.1	0.07	-0.8	-2.6, 0.9	0.4
HOMA-IR	0.2	-0.8, 1.2	0.7	-0.02	-0.8, 0.8	1.0	0.8	-0.2, 1.8	0.1

Figure Legend:

*Significant association in opposite direction to hypothesized relationship. [a]Adjusted for age, gender, race, socio-economic status, and obstructive apnea. [b]Adjusted for age, gender, race, socio-economic status, BMI z-score, and obstructive apnea

Beyond Short Sleep

- **Sleep timing** (i.e., later bedtimes) associated with
  - consuming more calories,
  - later eating times, and
  - consuming unhealthy food
- **Sleep variability** associated with
  - higher BMIs
  - negative metabolic consequences

Baron et al., 2011; Sato-Mito et al., 2011a; Sato-Mito et al., 2011b; Olds et al., 2011; Spruyt et al., 2011; Moore et al., 2011

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From: **Sleep Duration, Sleep Regularity, Body Weight, and Metabolic Homeostasis in School-aged Children**

Spruyt et al. Pediatrics 2011; 127(2):e345-e352. doi:10.1038/oby.2011.100/full#f2

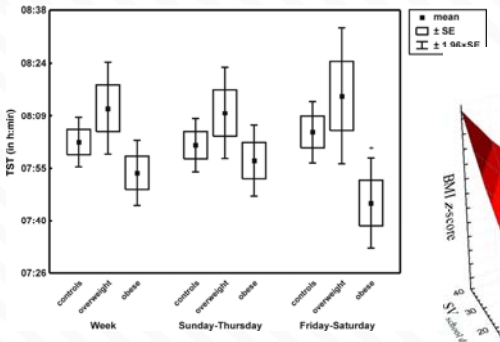

Figure Legend:

Mean TSTs for normal-weight, overweight, and obese children. *P < .05.

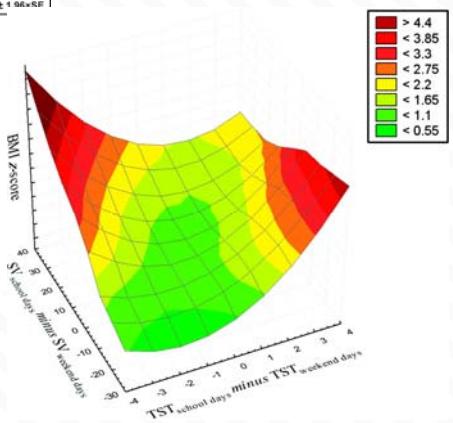

Figure Legend:

Surface plot depicting interrelationships between BMI z scores, SV values, and TST values for 308 community children.

PEDIATRICS

Why the inconsistencies?

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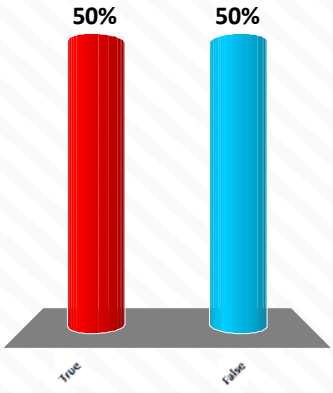
A consistent wake time is more important than a consistent bedtime for maintaining a stabile circadian rhythm.

A. True
B. False



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True or False?

A consistent wake time is more important than a consistent bedtime for maintaining a stabile circadian rhythm.

TRUE

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From: **Dietary Intake Following Experimentally Restricted Sleep in Adolescents**

Beebe et al. Sleep. 2013: 36(6): 827-234. doi:10.5665/sleep.2704

Teens were asked to maintain a consistent wake time across all 3 weeks

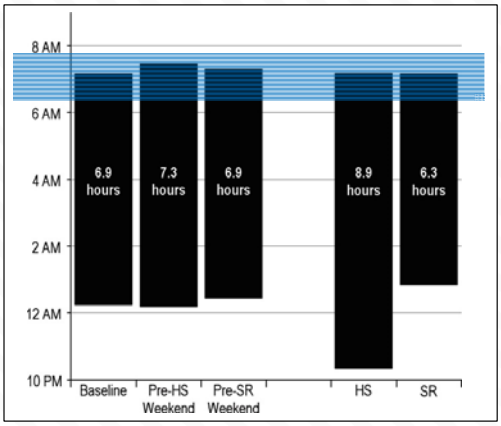


Figure Legend:
Average sleep patterns, as estimated by actigraphy, for the baseline condition, the weekends that preceded each experimental condition, and each experimental condition (SR, sleep restriction; HS, healthy sleep condition). Mean sleep onset time is marked by the bottom of each bar, and sleep offset by the top of each bar. Mean sleep duration is printed within each bar. The baseline and weekend sleep durations did not significantly differ ($P > 0.05$) but collectively were significantly shorter than the HS condition ($P < 0.001$) and longer than the SR condition ($P = 0.001$). The adolescents averaged 2.53 h (SD = 0.68) more sleep during the HS condition than the SR condition ($P < 0.001$) due to changes in sleep onset ($P < 0.001$) without differences in wake times ($P = 0.561$).

From: **Changes in Children's Sleep Duration on Food Intake, Weight, and Leptin**

Hart et al. Pediatrics. 2013:132:e1473-e1480

Children were asked to maintain a consistent wake time across both weeks

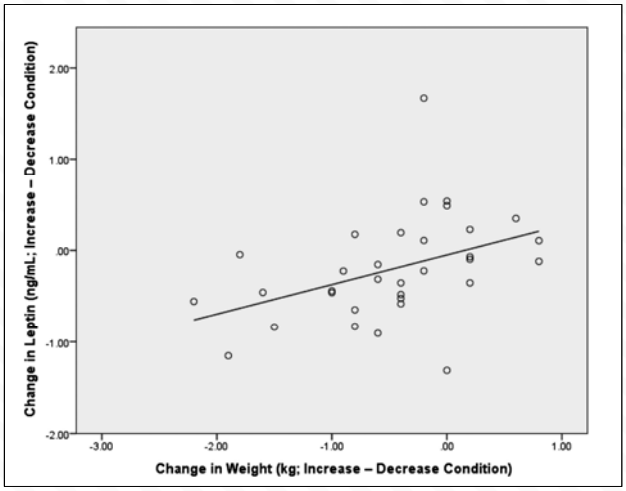
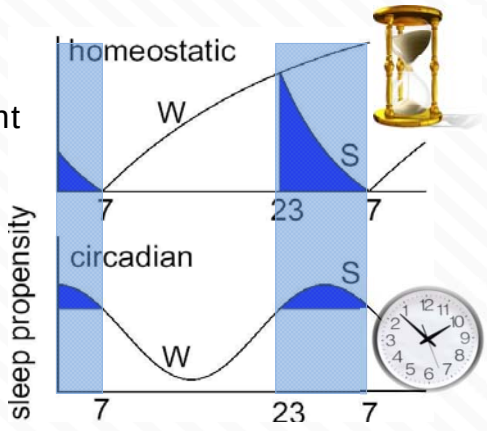


Figure Legend:

Scatterplot and associated regression line for the association between difference in child weight and difference in fasting leptin between the increase and decrease sleep conditions. The *x*-axis represents difference in weight as: Increase Condition weight – Decrease Condition weight. The *y*-axis represents the difference in leptin as Increase condition Leptin – Decrease Condition Leptin.

Two Factor Model of Sleep

- **Homeostatic Sleep Drive**
  - Sleep-wake dependent
- **Circadian Rhythm**
  - Sleep-wake independent
  - Typically entrained to light-dark cycle



Adapted from Jenni & Carskadon, 2007

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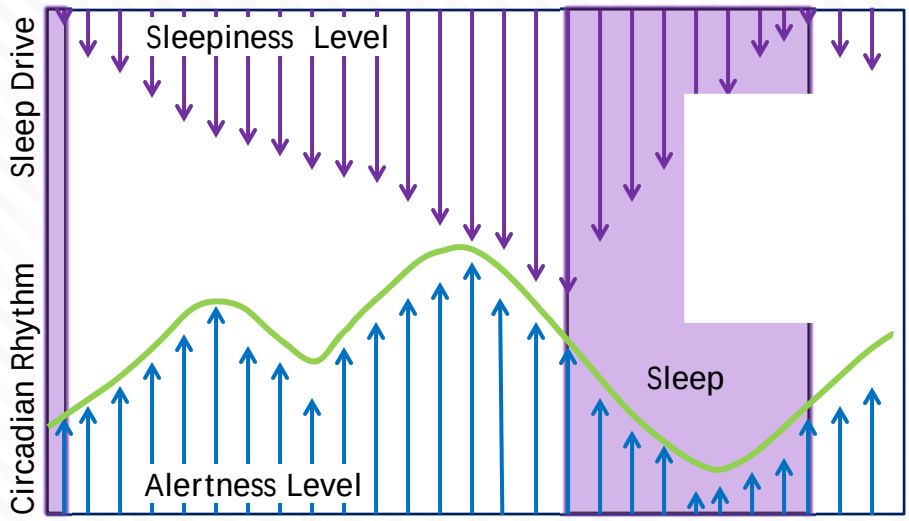
Two Factor Model of Sleep



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Sleep and the *Circadian Clock* are connected, but distinct.

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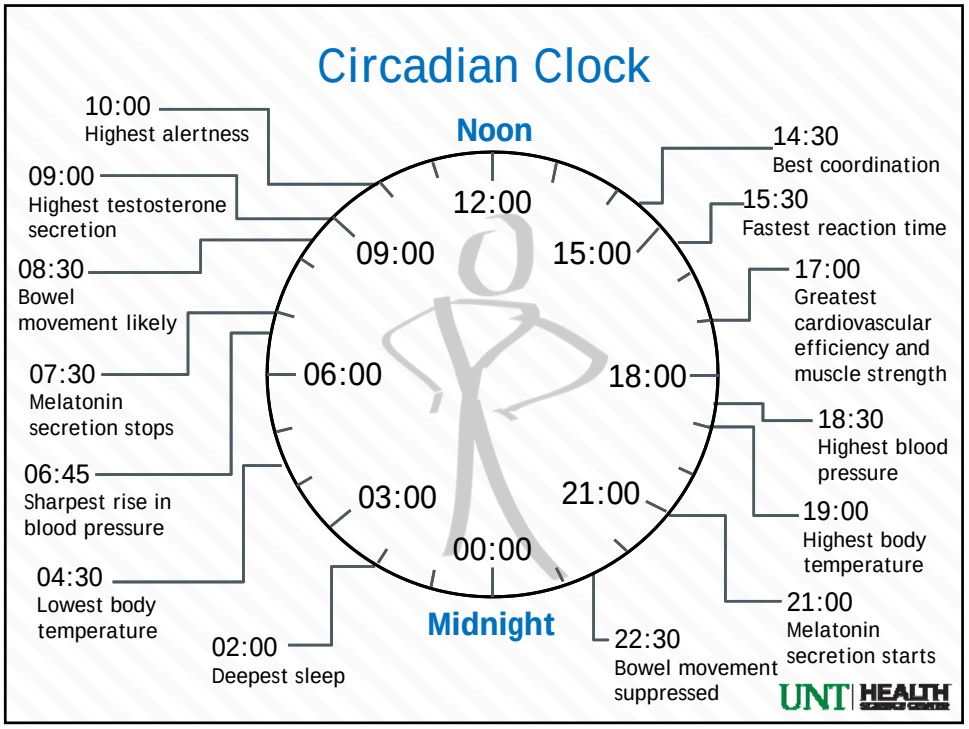

From: **Nature Review Rheumatology**

Buttgereit, F. *et al.* (2015) Clocking in: chronobiology in rheumatoid arthritis *Nat. Rev. Rheumatol.* doi:10.1038/nrrheum.2015.31

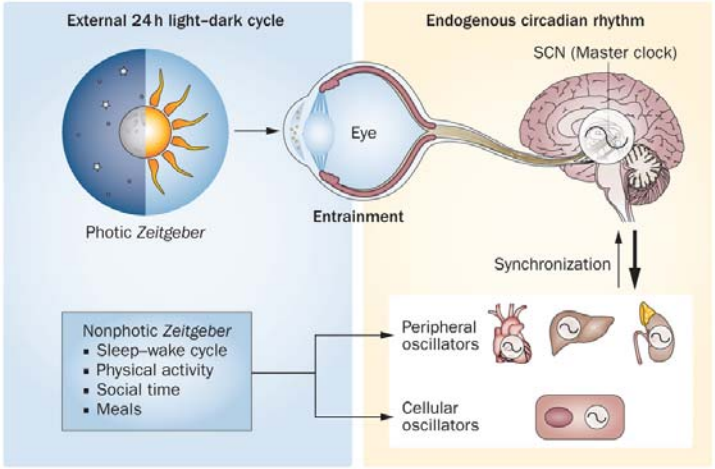

Figure Legend:

Internal circadian clocks and external Zeitgebers

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From: **Consequences of Circadian Misalignment on Metabolic, Autonomic, and Endocrine Function**
Frank A. J. L. Scheer et al. PNAS 2009;106:4453-4458

Circadian misalignment

- sleep and wakefulness occurring at times incongruent with biological time

Social jetlag is another term used to describe circadian misalignment

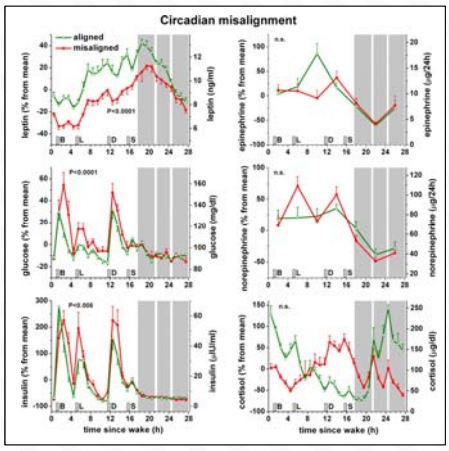

Figure Legend:

Consequences of circadian misalignment on metabolic, autonomic, and endocrine function. Data are plotted according to time-since-wake, during normal circadian alignment (open green symbols; scheduled awakening at habitual wake time) and during circadian misalignment (filled red symbols; scheduled awakening 12 h out of phase from habitual wake time). P-values, statistical significance for effect of misalignment [based on 24-h cycle for variable mainly driven by circadian cycle (cortisol) and 28-h cycle for variables mainly driven by behavioral cycle (others)]; gray area, scheduled sleep episode; short vertical gray bars, meal times as in Fig. 1.

Quick Recap…

- Shorter sleep duration is associated with…
  - higher BMIs
  - adverse weight-related changes
- Later bedtimes associated with…
  - consuming more calories,
  - later eating times, and
  - less accessible healthy food options
- Sleep variability associated with…
  - higher BMIs
  - circadian misalignment

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From: **What Role Does Sleep Play in Weight Gain in the First Semester of University?**
Roane et al. Beh Sleep Med 2014;106:4453-4458

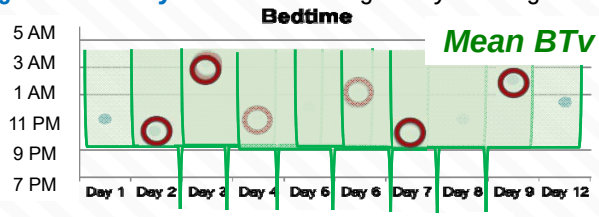
Sleep Pattern Predictors
- Total Sleep Time (TST)
- Bedtime (BT)
- Waketime (WT)
- Total sleep time variability (TSTv)
- Bedtime variability (BTv)
- Waketime variability (WTv)

Additional Predictors
- Sex
- Ethnicity/Race
- Mood (CES-D)
- Chronotype (MEQ)

Outcome
- Weight change

- **Night-to-Night Variability** calculated using 4-day moving windows

Example



Mean BTv = 3.4

Variability = 5 5 3.8 3.1 3.1 4 4

From: **What Role Does Sleep Play in Weight Gain in the First Semester of University?**
Roane et al. Beh Sleep Med 2014;106:4453-4458

Sex difference in weight change

- Males with greater sleep duration variability were **30%** more likely to gain weight
- Females - no significant difference

Mean Calculated Weight change = **+1.9 lbs**

	R^2	p			
Model fit	0.19*	0.005			
	R^2 *Change*	*B*	*t*	*Tolerance*	p
Block 1	0.02				0.305
Sex		−0.12	−1.36	0.836	0.154
Ethnicity/race		0.07	0.80	0.942	0.372
Block 2	0.003				0.803
MEQ scores		0.06	0.54	0.549	0.603
CES-D scores		−0.01	−0.12	0.902	0.841
Block 3	0.032**				0.043
TST		−0.45	−1.49	0.074	0.117
Block 4	0.037				0.082
BT		−0.51	−1.32	0.046	0.158
WT		0.22	0.69	0.065	0.451
Block 5	0.092*				0.005
TSTv		0.25**	2.06	0.443	0.036
BTv		−0.13	−1.25	0.657	0.215
WTv		0.19	1.42	0.375	0.157

Figure Legend:

*p < 0.01. **p < 0.05. MEQ = mean phase preference score. CES-D = mean depression score. TST = calculated mean sleep duration. BT = calculated mean bedtime. WT = calculated mean wake time. TSTv = calculated mean variability in sleep duration. BTv = calculated mean variability in bedtime. WTv = calculated mean variability in wake time.

Still unsure which sleep parameters need to be targeted to improve obesity markers

From: **Teen Sleep and Health Project**
Roane (manuscript in preparation)

34 teens, experimental randomized design

- Mean age = 15.2 years (SD = 1; range = 14-17 years)
- 73.5% females
- 20.6% Caucasian, 41.2% Black American, 23.5% Hispanic

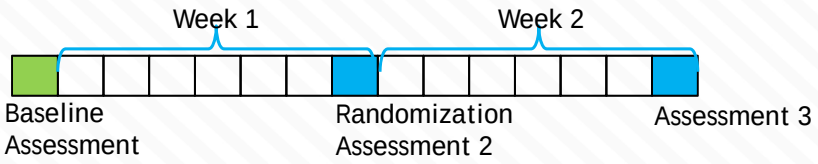
Primary Study Aim

- Examine the differential and cumulative effects of altering sleep duration and sleep variability on dietary intake and physical activity

Roane et al. (in preparation).

From: **Teen Sleep and Health Project**

Roane (manuscript in preparation)



Measures (in-lab)
- Sex
- BMI status
- Pubertal status
- Mood symptoms
- Chronotype

Daily records (at-home)
- Sleep diaries
- Social rhythms
- Menstrual status
- Dietary recall (3x/week)

Objective measures (in-lab)
- Height and weight
- DLMO

Objective measures (at-home)
- Actigraphy
- Accelerometery

Outcomes
- Meal times
- Caloric intake
- Physical activity
- Social rhythms
- Daytime sleepiness
- Mood
- DLMO

Roane et al. (in preparation).

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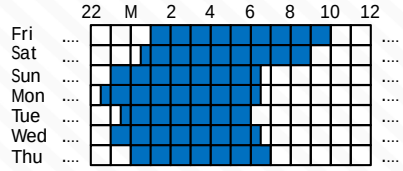
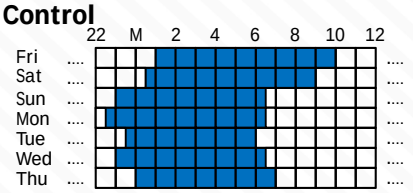
From: **Teen Sleep and Health Project**

Roane (manuscript in preparation)

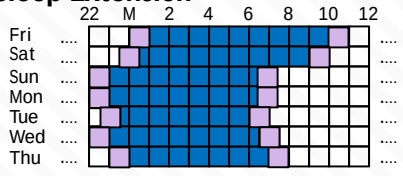
Baseline



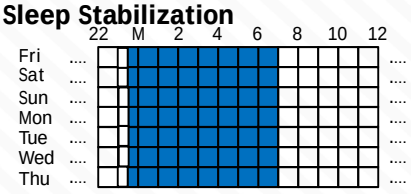
Control



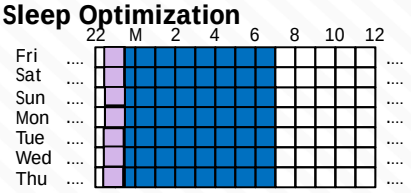
Sleep Extension



Sleep Stabilization



Sleep Optimization



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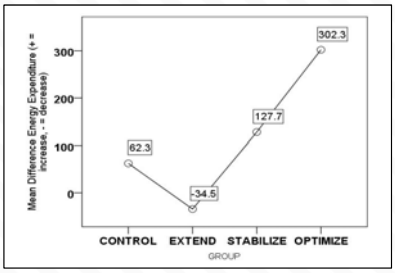
From: **Teen Sleep and Health Project**

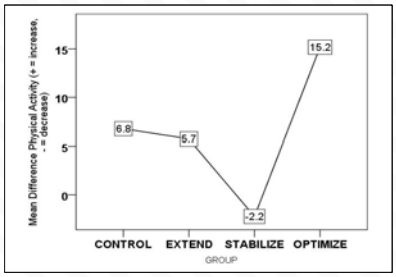
Roane (manuscript in preparation)

Final analyses will consider sex

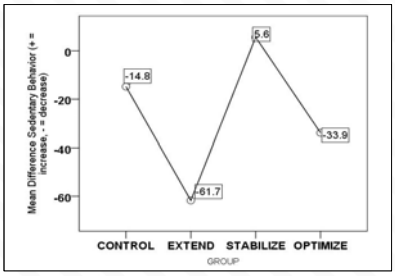
Energy Expenditure



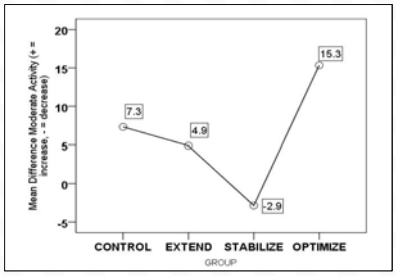
Physical Activity



Sedentary Behavior



Moderate Activity



Roane (in preparation).

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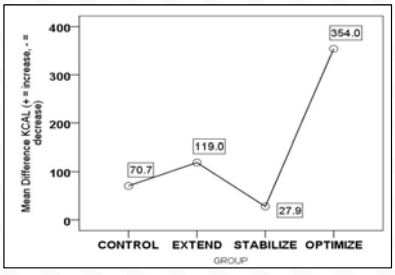
From: **Teen Sleep and Health Project**

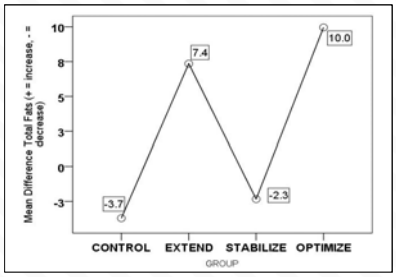
Roane (manuscript in preparation)

Final analyses will consider sex

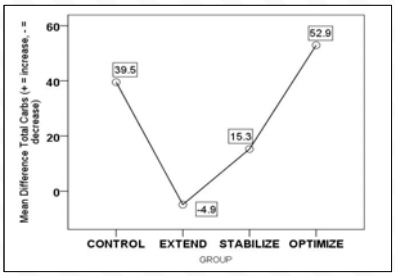
Total KCal



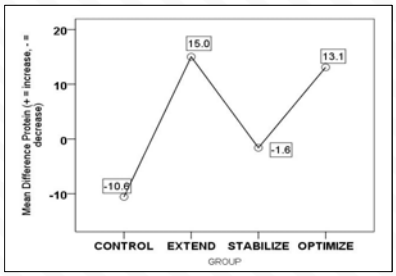
Total Fats



Carbohydrates



Protein



Roane (in preparation).

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Quick Recap…

- Differentiating Sleep Parameters…
  - Sleep duration, sleep quality, insufficient sleep, sleep timing, and circadian misalignment
- Contributors to obesity…
  - Insufficient sleep, sleep timing, and sleep variability

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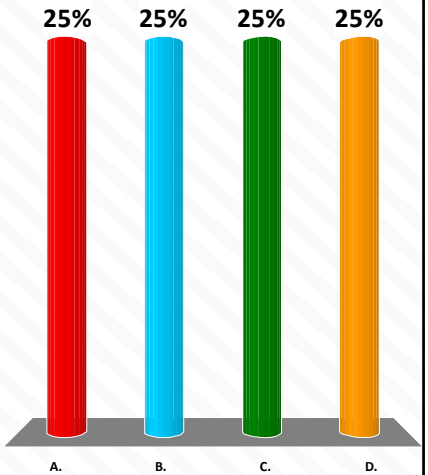
What is the likely underlying mechanism by which sleep impacts obesity markers?

A. Early school start times
B. Insufficient sleep
C. Circadian misalignment
D. Late bedtimes



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Multiple Choice

What is the likely underlying mechanism by which sleep impacts obesity markers?

A. Early school start times
B. Insufficient sleep
C. Circadian misalignment
D. Late bedtimes

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Additional Considerations when Intervening

- Age
- Sex differences
- Race / ethnic differences
- Chronotype
- Duration of intervention

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Questions Still Needing Answers

- Do specific sleep parameters when improved show differential affects when examined for longer than a week?
- What is the role of sex differences when altering specific sleep parameters to improve obesity markers?
- What is the role of race / ethnic differences when altering specific sleep parameters to improve obesity markers?
- How long does sleep need to be altered for sustained improvement in obesity markers?

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Sleep Trends in Teens

From: **2006 Sleep in America Poll: Sleep in Teens**

National Sleep Foundation. 2006. Retrieved from http://www.sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2006-sleep-in-teens

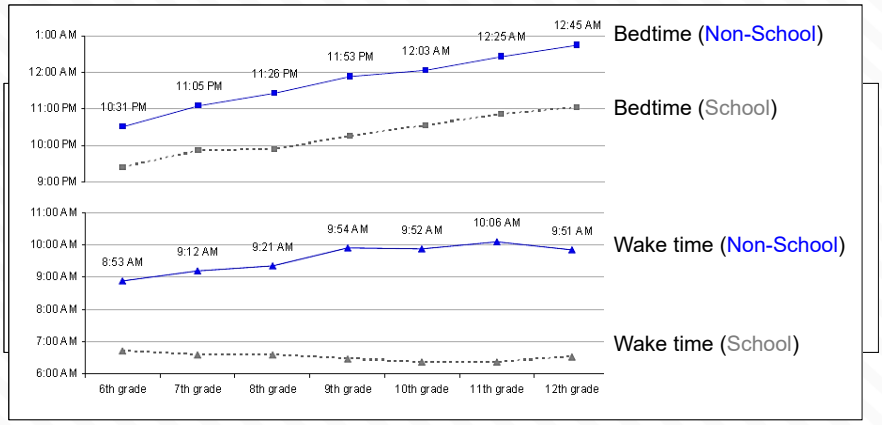

Figure Legend:
Adolescents' typical non-school day

Sleep Trends in Children

From: **2004 Sleep in America Poll: Sleep in Children**

National Sleep Foundation. 2004. Retrieved from http://www.sleepfoundation.org/sleep-polls-data/sleep-in-america-poll/2004-sleep-in-children

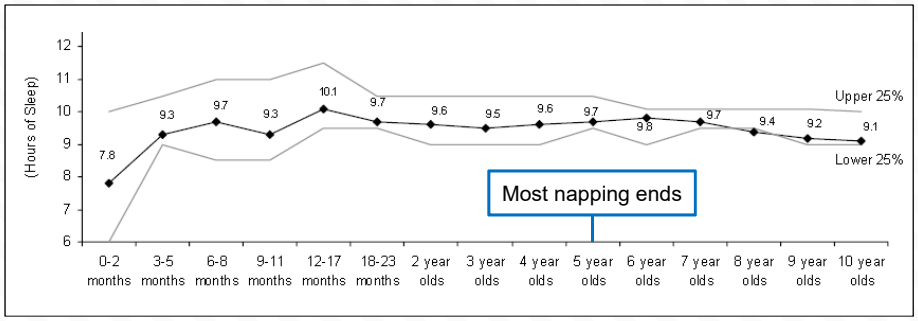

Figure Legend:

Average number of hours children slept at night by age (past two weeks). Approximately 50% of the population in each age group falls between the two solid gray lines.

From: **National Sleep Foundation's sleep time duration recommendations: methodology and results summary**
Hirshkowitz et al. 2015: Sleep Health: 1(1): 40-43. doi: 10.1016/j.sleh.2014.12.010

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