Healthy Sleep and Obesity Prevention in Young Children

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Inadequate Sleep and Obesity Risk in Young Children

- Examine the literature on the association between inadequate sleep and obesity in children age 0 - 5 years
- Review possible mechanisms for the relationship between sleep and obesity
- Outline additional consequences of insufficient sleep on children's health and development
- Understand risk factors for and unhealthy sleep, including the role of stress
- Discuss potential intervention strategies
  - Healthy Sleep education
The Epidemic of Inadequate Sleep

• Decline in children’s average reported sleep duration over time
  - Cohort data from the 1970s to the 1990s show*:
    • 10 year olds getting 15 minutes less sleep per night
    • 5 year olds getting almost 30 min less sleep per night

• Inadequate sleep amounts compared to “ideal” at all ages (parent and self-report data)
  - NSF poll survey data (2004) average sleep amounts
    • 5 year olds average 9.7h, 10 year olds 9.1 h
    • 7.5-10.9 year old boys average 9.9h

* Iglowstein et al, Pediatrics (2003); 111 (2)
Sleep Duration and Weight: Children

- All cross-sectional studies in children show negative relationship between SD and obesity \(^8\), \(^13\), \(^29\), \(^37\), \(^39\), \(^48\), \(^67\), \(^76\), \(^95\), \(^102\)
  - Across age, racial/ethnic, SES groups
    - US, CA, UK, EU, Tunisia, Brazil, China, Japan, Taiwan
    - Strongest association young children
  - Overall increased risk of obesity by almost two-fold\(^11\)
    - Less consistent in adults\(^69\); OR \(\sim 1.5\) adults\(^11\)
    - No evidence “U shaped curve” relationship in children
  - Also correlated with abdominal adiposity (waist circumference)\(^12\) high body fat mass\(^102\)
  - Relationship seems “dose dependent” (ie, the less sleep, the greater the weight)
    - Linear dose-response for children <10 years old only\(^15\)
Sleep Duration and Weight: Children

- Even modest SD differences may be important
  - Obese children average 31 minutes less sleep\textsuperscript{29}
- 60-80\% increase in odds of being a short sleeper in obese children\textsuperscript{11}
- Increased SD reduces risk OW/Ob
  - For additional hr sleep, odds of obesity decrease by 80\%\textsuperscript{31}
SD and Weight: Children

• Relationship SD/weight persists after controlling for confounders:
  - Extrinsic: TV viewing, breast-feeding, mat smoking, single parent status, physical activity, season of the year
  - Intrinsic: Birth weight, parental obesity
  - Intake patterns: diet, snacking, breakfast

• Risk of obesity associated with inadequate sleep equal to or higher than most other identified risk factors
  - Of 21 potential risk factors, only mat smoking, parental BMI, TV viewing, intake junk food higher risk than SD\textsuperscript{72}
  - Five-fold increased risk for short SD/Ob vs snacking (1.3x), TV viewing (2.1x)\textsuperscript{13,75,102}
Longitudinal Prospective Studies

- 8170 children (Japan) Toyama cohort study
  BMI ages 3 (T1) and 6 (T2) years old (2002)\textsuperscript{75}
  - SD$\leq$9h age 6 (boys): 37% Ob/Ob, 34% NW/Ob, 22% NW/NW
  - SD$\leq$9h age 6 (girls): no significant group differences

- 150 children (US) followed 0-9.5yrs (2004)\textsuperscript{1}:
  - Negative correlation SD at 3-5yo and BMI at 9.5yo
  - Aver 30 min less sleep predicted overweight

- 8234 children (UK) (2005)\textsuperscript{72}:
  - SD at age 38 months independently associated obesity at age 7 year olds in dose-dependent fashion
Longitudinal Prospective Studies

• 5493 2 year olds (UK) followed for 5 years (2005)72:
  - SD <10.5hrs independent association obesity age 7 years (OR 1.4)
• 785 children (US) age 9-11 years (2007)50
  - SD 3rd grade independently associated greater overweight risk in 6th grade independent of weight status in 3rd grade
  - For each additional hour of sleep 3rd grade, 40% less likely to be overweight grade 6
  - Increased risk OW in children with greatest decline SD 3rd to 6th grade
Longitudinal Prospective Studies

• 2281 3-12 year olds (US) (2007)\textsuperscript{78}:  
  - Less sleep, later BT, early am waking predicted higher BMI 5 yrs later

• 1441 3-12 year olds (US) followed 5 years (2007)\textsuperscript{77}  
  - Each additional hour sleep associated with 5.3% decline in overweight risk and BMI% decrease 11%  
  - Sleep effect negatively correlated with age

• 1138 children (Canada) followed from birth for 6 years (2008)\textsuperscript{96}:  
  - Risk of obesity 4x higher in persistent short sleepers (<10hrs vs >11hrs)
Longitudinal Prospective Studies

• 915 children (US) multi-site group practice followed for 3 years (2008)\textsuperscript{92}
  - Average daily sleep duration 6mths-2yrs (< 12hrs/d) inversely associated obesity at age 3 years old (OR 2)

• 1579 children (US) followed for 3 years (2008)
  - Infant sleep duration (<12hrs/d) associated overweight age 3 years (OR 1.8)

• 1037 children (NZ) SD assessed ages 5, 7, 9, and 11 years (2008)\textsuperscript{44}
  - Shorter sleep times associated with higher BMI at age 32 years
Mechanisms: Metabolic

• Effects of sleep deprivation on neurohormones\textsuperscript{81,89}
  - Increased leptin \rightarrow increased appetite
  - Decreased gherlin \rightarrow increased calorie intake (amount, calorie dense foods, carbs)

• Increase insulin resistance/metabolic alterations:
  - Sleep loss associated with increased levels of cortisol\textsuperscript{46}
    - Activation HPA axis by sleep-related stress\textsuperscript{54,5,6}
  - Sleep loss results in activation of the sympathetic nervous system\textsuperscript{80}
  - Sleep loss associated with up-regulation pro-inflammatory mediators (CRP, IL-6)\textsuperscript{101}
  - Inadequate sleep linked to insulin resistance in obese children\textsuperscript{25}

• Altered thermoregulation (\downarrow core body $T^\circ$)
Mechanisms: Energy Consumption

- Fatigue $\rightarrow$ reduced physical activity
  - NSF adolescent poll 2006: 32% report too tired to exercise
  - Decreased SD associated increased TV viewing, decreased sports participation$^{102}$
  - Obese children experience fatigue comparable with pediatric patients receiving cancer treatment$^{99}$

- Decreased SD $\rightarrow$ more time awake and increased opportunity to eat
Mechanisms: Behavior

- Behavioral/mood/cognitive effects
  - EDS → changes in eating patterns
  - Caregivers may use food to pacify
  - Children may use food to self-soothe
  - Caregivers may have difficulties with limit setting food intake and sleep habits
  - Reinforcement value of food may differ
Mechanisms: Behavior

• Behavioral/mood/cognitive effects

EDS  →  changes in eating patterns

- Decreased SD associated with increased emotional lability\textsuperscript{61}
- Food-related tantrums, increased anger/frustration, decreased soothability
  strong predictor BMI\textsuperscript{1}
- Children with both internalizing and externalizing behavioral problems increased concurrent and future risk overweight\textsuperscript{49}
SLEEP RESTRICTION
• Amount (no. of hours)
• Duration (no. of days)
• Relationship to individual sleep needs

ALTERATIONS METABOLIC PROFILE
(leptin, ghrelin, insulin, glucose, orexin, serotonin)

SLEEPINESS/FATIGUE

SLEEPINESS-RELATED IMPAIRMENTS
• Mood
• Attention
• Impulse control
• Int/Ext behavior
• Motivation
• Judgment

CHANGES IN EATING BEHAVIOR (PARENTAL/CHILD)
• Food amounts
• Food types/preferences
• Timing

APPETITE DYSREGULATION
Alterations in hunger/satiety

Increased opportunity to eat

INCREASED ENERGY INTAKE

INCREASED BMI

REDUCED ENERGY EXPENDITURE

REDUCED PHYSICAL ACTIVITY/INCREASE SEDENTARY BEHAVIOR

ALTERATIONS METABOLIC PROFILE

INCREASED ENERGY INTAKE

REDUCED PHYSICAL ACTIVITY/INCREASE SEDENTARY BEHAVIOR

INCREASED BMI

REDUCED PHYSICAL ACTIVITY/INCREASE SEDENTARY BEHAVIOR

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REDUCED PHYSICAL ACTIVITY/INCREASE SEDENTARY BEHAVIOR

INCREASED BMI
Sleep Across Childhood

- Newborns spend 16-17/24h asleep; 50% SWS/50% REM
  - By age 60 years, SWS is 3-5% of sleep
- By age 2y, average child has spent 9500h (~13mths) asleep vs 8000h awake
- Between 2-5y, time asleep = time awake
- In school-age children, sleep occupies 40% of the 24h day
- Sleep is the primary activity of the brain during early development
Inadequate Sleep in Children: Impact

• Mood regulation and emotional changes:
  - Irritability, mood instability, less positive mood

• Behavioral problems:
  - Internalizing
  - Externalizing (aggressiveness, hyperactivity, impulsivity)

• Performance deficits
  - Poor academic functioning
  - Social impairments
  - Decreased QOL

• Neurocognitive deficits
  - Attention
  - Executive functions (organization, self-monitoring, planning)
  - Memory
  - Verbal creativity

Family disruption*
  - Increased parent stress
  - Maternal depression

Impact of Inadequate Sleep in Children: Mechanisms

- Sleep deprivation/prolonged wakefulness directly affects brain:
  - Neuronal functions
  - Neuronal “plasticity”: ability of the brain to change structure/function in response to the environment
  - Gene activation/expression
  - Neurogenesis
  - Brain cell protection/repair from stress
  - Neurotransmitters (serotonin, dopamine)
  - Melatonin production/circadian biology
    - Cellular metabolism, neurogenesis, brain/eye development
  - Highest susceptibility during critical developmental periods
Impact of Inadequate Sleep: Physical

- **Growth**: disruption of normal growth hormone release during sleep
- **Immune function**: sleep deprivation impairs host defenses
- **Metabolic regulation**: shorter sleep duration (<8hrs) in 3-6 year olds associated with hyperglycemia and obesity (OR 2.1)\(^92\)
- **Injuries** more common in sleepy children*

Stress and Sleep

• Biobehavioral response to stress\textsuperscript{S1}:
  - “Turn on” (acute stress): hypervigilance, anxiety, agitation, increased sympathetic tone (delayed, disrupted sleep)
  - “Shut down” (chronic stress): withdrawal, increased threshold for adverse stimuli (extended sleep)

• Bi-directional relationship
  - Sleep deprivation/prolonged wakefulness, sleep disruption increases the stress response and stress hormones\textsuperscript{S4,5}
    - Short SD associated with increased am cortisol levels; low sleep efficiency (TST/TIB) associated with higher cortisol levels across the day and in response to stress\textsuperscript{S6}
    - Activation HPAA associated insulin resistance, fat accumulation
  - Altered HPAA function leads to disrupted sleep

• Sleep-wake most vulnerable system in response to trauma (e.g., child abuse)
  - Difficulty separating bedtime, bedtime refusal, longer sleep onset, nighttime fears, night wakings, decreased SD; PTSD
Risk Factors for Inadequate Sleep

• Sleep duration lower in high risk children (low SES, black/Hispanic)\textsuperscript{50,82,92}
  
  - 43\% 10-11yo minority (black, Hispanic) boys average < 9h (vs 18\% non-minority girls)
  
  - At age 2 years, black, Hispanic, and Asian infants slept 0.40, 0.82, and 0.95 fewer hours per day respectively compared to white infants\textsuperscript{60}
  
  - Low SES, lower maternal education, black/Hispanic/minority children age 6 months to 2 years old more likely to sleep < 12hrs\textsuperscript{92}
Risk Factors: Unhealthy Sleep Habits

• Late bedtimes
  - Protective effect longer SD on weight mediated by earlier bedtimes\(^{49}\)
  - Age effect: later BT may have greater effect on weight in younger (3-7.9 vs 8-12.9 years old) \(^{78}\)
  - Shift to later BT start as early as 8-9 years old\(^ {78}\)
  - Weekday/Weekend BT differences seen at 3-5 years old
  - ~ Five-fold increased risk for minority children having a bedtime >11p\(^ {82}\)

• Electronics
  - Infant TV/video viewing associated with shorter sleep duration at age 1 and 2 years\(^ {58}\)
  - Increased TV viewing, TV in bedtime routine, TV in bedroom associated shorter sleep duration 4-11 year olds\(^ {60}\)
  - Hours of TV viewing/\(d\) age 2 years associated shorter sleep duration\(^ {92}\)

• Irregular sleep – wake schedule
  - Children with “irregular sleeping habits” at 2-4 years predicted increased BMI, % obesity at 21 years (2007)\(^ {52}\)
  - Disrupted sleep schedules associated with negative adjustment to pre-school\(^ {52}\)

• Premature curtailment daytime naps
  - Decreased daytime sleep associated with obesity risk\(^ {77}\)
Risk Factors: Unhealthy Sleep Habits

• 1343 white, 355 black, 128 Hispanic mother-child pairs assessed for obesity risk factors (2010)$^2$
  - Average early SD < 12hrs: OR black~3.7, Hispanic 2.5-3
  - TV in bedroom: OR black and Hispanic~8
    • Adjusted for parental BMI, SES

• Cross-sectional study 8550 4 year olds (2010)$^3$
  - 18% obese
  - Association obesity and household routines
    • Eating family meals >5x/wk (57%)
    • Adequate nighttime sleep (>10.5hrs) (58%)
    • Limited screens (<2hrs/d) (40%)
  - Independent association each routine with obesity
    • Prevalence obesity 3 routines 13% vs 24% none (40% lower prevalence)
  - Presence routines vary across racial/ethnic groups, maternal education, income, single parent (p<.001)
Additional Risk Factors: Sleep Apnea

• Increased prevalence of OSA in obese children
• Increased prevalence of obesity in children with OSA
  – Children with OSA more fast food, less healthy food consumption, less participation organized sports; increased gherlin
• Overlapping high risk groups obesity/inadequate sleep/OSA: Black (OR 3.5), Hispanic; low SES
• Overlapping adverse neurocognitive and metabolic outcomes obesity/inadequate sleep/OSA
  – Impairments attention, executive functions, decrements academic performance
  – Increased insulin resistance
  – Increased systemic inflammation (cytokines)
  – Increased risk potential for adult cardiovascular disease
• Conclusion: “a perfect storm”
Obesity Prevention: Where Does Sleep Fit In?

Diet

Exercise
Interventions

• Healthy Sleep Education
  - Sleep as integral component of all childhood obesity prevention programs ("3 legged stool")
    • Start in pre-school
    • Parent/child-focused
    • Venues:
      - Health care providers’ office
      - Head Start
      - Children’s museums
      - Daycare facilities
      - Community centers

• Sleep health screening in primary care settings, especially in high risk groups
  - Obstructive sleep apnea
  - Inadequate sleep/unhealthy sleep habits

• Policy
  - Nap guidelines school settings
  - Caffeine labeling/restrictions sales/marketing to children
Healthy Sleep Education

- Potentially improves success rates of standard obesity prevention measures (diet, exercise)
- Has significant additional benefits for children’s health, learning and development
- Promotes establishment of life-long healthy sleep habits
- Positively impacts sleep in the entire family
- Incurs little cost to families
- Has a low risk of adverse consequences
- May reduce long-term neurodevelopmental/cardiovascular consequences associated with obesity
Components of Healthy Sleep Education

- Practices Promoting Sleep Regulation (Circadian and Homeostatic)
  - Maintain an organized and consistent sleep-wake cycle
  - Set and enforce a consistent bedtime weekdays and weekends
  - Set and enforce a consistent wake time weekdays and weekends
  - Keep a regular daily schedule of activities, including meals
  - Avoid bright light in the bedroom during the night or in the early morning hours
  - Increase light exposure in the morning
  - Establish an appropriate napping schedule

- Practices Promoting Sleep Conditioning
  - Establish a regular and consistent bedtime routine
  - Avoid spending time in bed awake (watching TV, cell phone use)
  - Don’t use bed for punishment
Components of Healthy Sleep Education

• Practices Reducing Arousal and Promoting Relaxation
  - Keep electronics out of the bedroom and limit use of electronics before bedtime
  - Reduce stimulating play at bedtime
  - Avoid heavy meals and vigorous exercise close to bedtime
  - Reduce cognitive and emotional stimulation before bedtime
  - Eliminate caffeine

• Practices Promoting Adequate Sleep Quantity and Quality
  - Set an age-appropriate bedtime and wake time to ensure adequate sleep
  - Maintain a safe and comfortable sleeping environment (low noise and light levels, cooler temperatures, age-appropriate bedding and sleeping surface)
Assessment Healthy Sleep Habits

- CMOM survey 2010 (N=248)
  - Demographics: 61% white/16% Hispanic/7% black; 96% HS grad
  - 91% 1-5yo
  - ~23% do not have set BT/WT 7d/wk
  - 23% ≥ 1 electronic in BR
  - 4% no regular bedtime routine

- HCH survey 2010 (N=150)
  - Demographics: 22% white/45% Hispanic/25% black; 48% HS grad
  - 57% 1-5yo
  - ~40/50% do not have set BT/WT 7d/wk
  - 73% TV in BR
  - 27% no regular bedtime routine

Owens et al, unpublished data
Parental Healthy Sleep Knowledge/Attitudes

- **CMOM:**
  - 52% of parents underestimate their child’s sleep needs
  - 80% believe child gets enough sleep
  - 75% believe child has healthy sleep habits

- **Sleep knowledge**
  - 35% <50% correct
  - Association sleep duration/obesity: 56% incorrect/DK
  - Weight and increased risk sleep problems: 25% incorrect/DK

- **27% average too little sleep for age**
  - Associated with lack regular bedtime, parental knowledge sleep needs

- **HCH:**
  - 83% of parents underestimate their child’s sleep needs
  - 80% believe child gets enough sleep
  - 78% believe child has healthy sleep habits

- **31% plan to change sleep habits**

- **Sleep knowledge**
  - 71% <50% correct
  - Association sleep duration/obesity: 77% incorrect/DK
  - Weight and increased risk sleep problems: 25% incorrect/DK

- **25% average too little sleep for age**
  - Associated with lack regular bedtime, parental knowledge sleep needs
Summary

• Inadequate/poor sleep is a major risk factor for obesity, especially in young children

• Both the risk factors for and consequences of inadequate sleep and obesity are magnified in racial/ethnic minority and poor children

• Obesity, insufficient sleep, and sleep apnea are inter-related and have similar and potentially additive long-term adverse neurocognitive and cardiovascular effects

• Targeted interventions to improve sleep health have the potential to reduce obesity rates and significantly improve quality of life, especially in vulnerable populations
Questions and Comments????