Inadequate Sleep and Unhealthy Metabolism: Insights from the National Health and Nutrition Examination Survey

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Background I

- Well-defined relationship between **sleep health** vs. **BMI**
  - More sleep, lower BMI
- What is the relationship between sleep and other metabolic markers?
- Sleep health measured by the following characteristics:
  - Satisfaction/Quality
  - Alertness
  - Timing
  - Efficiency
  - Duration

Background II

- Data collected by National Health and Nutrition Examination Survey (NHANES) 2015-2016
  - Designed to assess the health and nutritional status of adults and children in the U.S.
    - Non-institutionalized civilian population
  - Includes demographics and health-related questions, along with a medical examination component and laboratory tests (i.e. blood work)
  - Sleep questionnaire data only collected from people 16 and older
    - 9971 survey participants total, 6327 with sleep data
- NHANES has always collected sleep duration data
  - First year collecting sleep timing
- Data published on CDC website for use in epidemiological studies and health sciences research

Objectives & Motivation

35% Americans lack the recommended nightly duration of sleep

Statistical Objectives

- Quantify relationship between **sleep health** and **metabolism**
- Adjust for confounding factors

Public Health Motivation

*"How does **sleep duration** & **bedtime** affect metabolic health?"*

Methods I

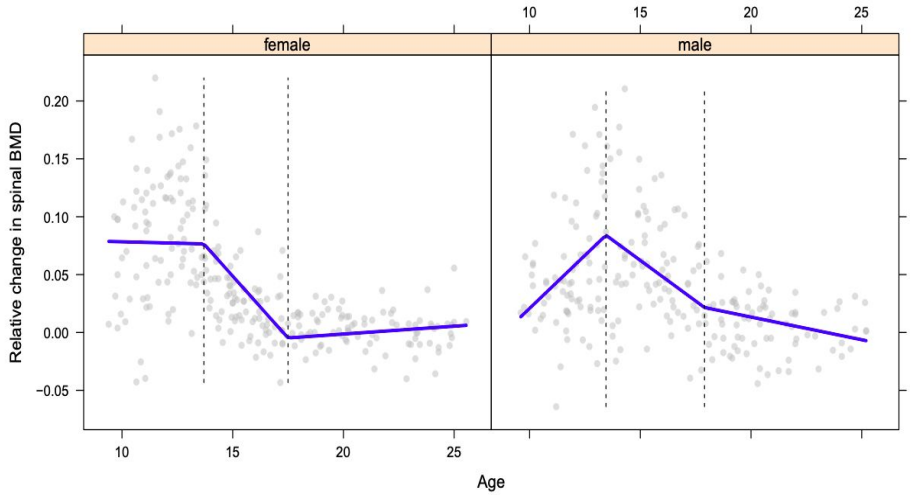
- NHANES Stratified Cluster Sample
  - *Why not simple random sample?*
    - Too expensive to travel everywhere to attain representative population
    - SRS will not reflect U.S. population, potential nonresponse bias
      - *Solution*: Primarily **cluster sampled** by geography (60 counties randomly selected out of 2,846), secondarily **stratified** by age and race (30 strata)
  - **Sample weight** is the estimated number of persons in the target population that he/she represents
    - E.g. A man with a sample weight of 12,000 represents 12,000 men in his race-Hispanic origin-income-age category
    - "Final" sample weight adjusts for base weights (unequal probabilties of selection), nonresponse, and the poststratification

Methods II

- ‘survey’ package in R— Analysis of Complex Survey Samples
  - ‘svydesign’— Survey Sample Analysis
    - Specifies the complex survey design by cluster ids, strata, sampling weights (and more)
  - ‘svyglm’— Survey-Weighted Generalised Linear Models
    - Fits a GLM to data from a complex survey design, taking into account sample weights and variance among clusters
    - Added splines to sleep health measurements to depict a realistic relationship with metabolic markers

Methods III

- **Splines** are piecewise polynomials that are connected to form smooth curves
  - Creates more flexibility in graphs
    - More degrees of freedom (df)
    - More knots
  - Trade-offs
    - Too few df leads to bias
    - Too many df leads to overfitting



What did we do?

Sleep Dimensions (Explanatory Variables)

- ~~Satisfaction/Quality~~
- ~~Alertness~~
- ~~Efficiency~~
- **Timing** - Midpoint of Bedtime and Wake Up Time
- **Duration**

Metabolic Markers (Response Variables)

- BMI
- Waist Circumference
- Glycohemoglobin
- High-density lipoprotein (HDL)
- Low-density lipoprotein (LDL)
- Systolic & Diastolic Blood Pressure
- Oral Glucose Tolerance

Confounding Variables

- Gender
- Age
- Race
- Income
- *Smoking (83% missing)*
- *Alcohol (47% missing)*

Results

Sleep Duration

Had Significant Effects on...

- ✓ BMI
- ✓ Waist Circumference
- ✓ HDL levels
- ✗ LDL levels
- ✓ Systolic & Diastolic Pressure
- ✓ Glycohemoglobin Levels
- ✓ Glucose Tolerance

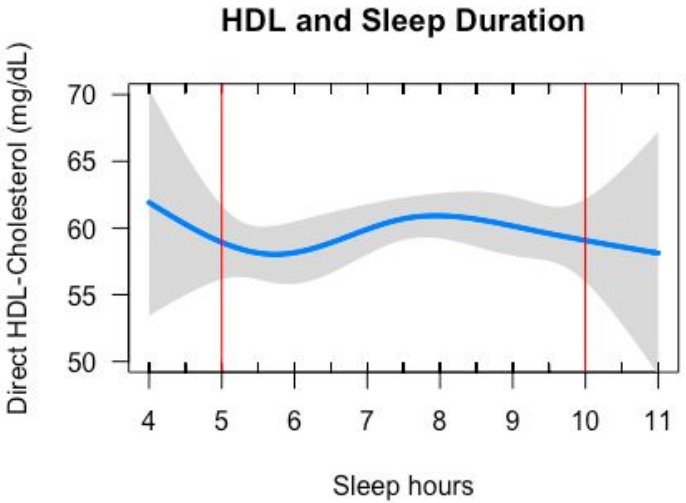
Sleep Timing

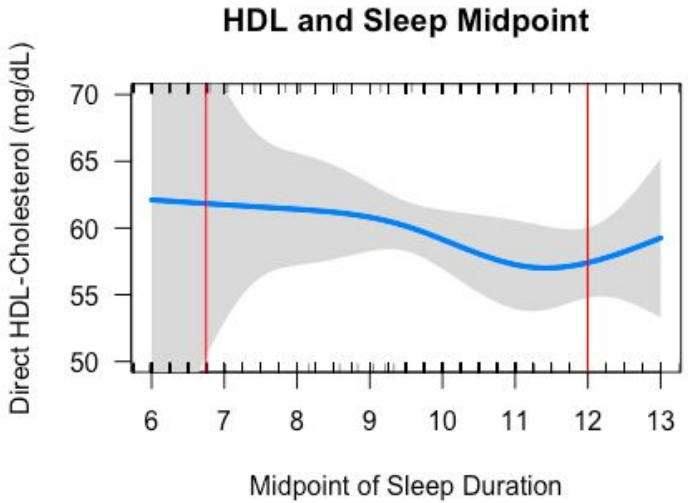
Had Significant Effects on...

- ✓ BMI
- ✓ Waist Circumference
- ✓ HDL levels
- ✗ LDL levels
- ✓ Systolic & Diastolic Pressure
- ✓ Glycohemoglobin Levels
- ✓ Glucose Tolerance

High Density Lipoprotein (HDL) Cholesterol

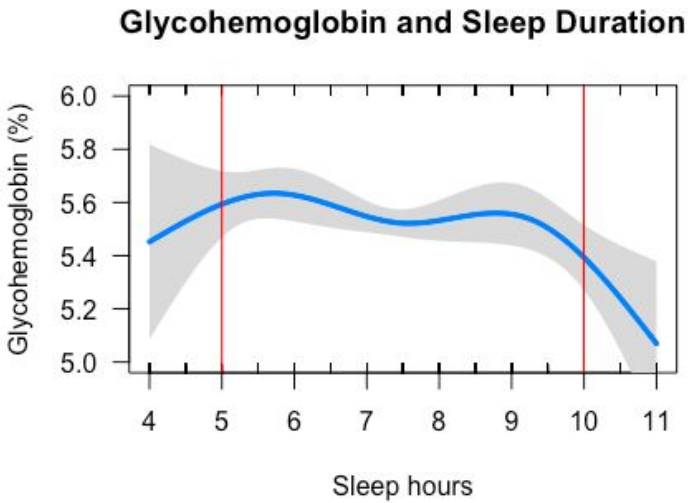
- Calculated p-values
  - $p < 0.0001$ for HDL and sleep duration
  - $p < 0.0001$ for HDL and sleep midpoint

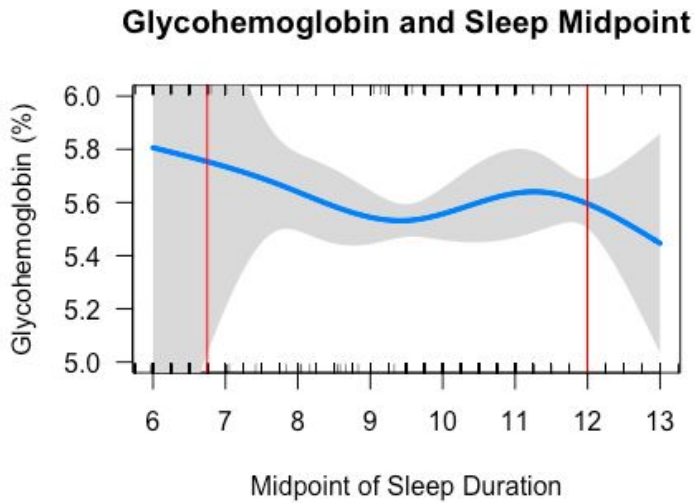




Glycohemoglobin

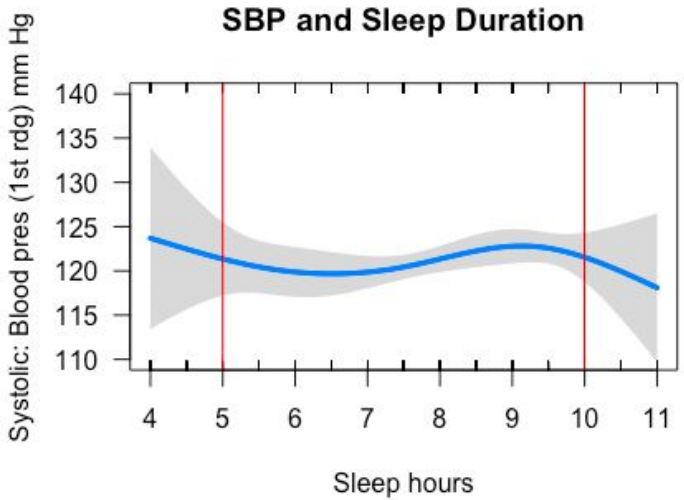
- Calculated p-values
  - $p < 0.001$ for glycohemoglobin and sleep duration
  - $p < 0.001$ for glycohemoglobin and sleep midpoint

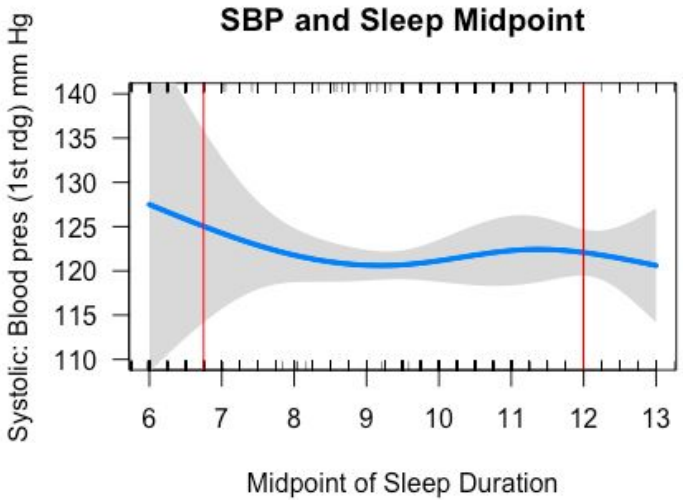




Systolic Blood Pressure

- Calculated p-values
  - P < 0.001 for systolic blood pressure and sleep duration
  - p < 0.001 for systolic blood pressure and sleep midpoint





Clinical Significance

Sleep Duration	ΔHDL (mg/dL)	ΔGlycohemoglobin (%)	ΔSystolic BP (mmHg)
8 vs. 5 hrs.	-3.16 (-4.91, -1.40)	0.11 (0.02, 0.19)	0.24 (-2.15, 2.64)
10 vs. 6 hrs.	-1.18 (-2.99,0.62)	0.02 (-0.10, 0.15)	-2.36 (-4.68, -0.04)
9 vs. 8 hrs.	0.94 (-0.43,2.30)	-0.07 (-0.13,-0.01)	-1.36 (-2.58, -0.14)

Sleep Midpoint	ΔHDL (mg/dL)	ΔBMI	ΔWaist Circum. (cm)
2AM vs. 5AM	-2.26 (-3.42, -1.09)	0.50 (-0.30, 1.30)	1.33 (-0.58, 3.25)
3AM vs. 4AM	-0.90 (-1.69, -0.12)	0.37 (-0.04, 0.77)	0.88 (-0.08, 1.84)

What did we learn?

Discussion I

- Sleep had a significant effect on most of the tested metabolic markers
- Consistent with other research?
  - ✓ BMI
  - ✓ Waist Circumference
  - ❓ HDL levels
  - ❓ Systolic Pressure
  - ❓ Diastolic Pressure
  - ❓ Glycohemoglobin Levels
  - ❓ Glucose Tolerance
- Existing recommendation of 7-8 hours sleep generally held up

Discussion II

- Sleep timing and duration
  - Significant when looked at separately, but together neither significant
  - Does one have a bigger effect on metabolism?
- Further exploring NHANES
  - Consider smoking and alcohol as confounders
  - Do moderate changes in sleep have an effect on metabolism? Or is significance being driven by extreme values of sleep?
    - Possibly look at middle 90% data
- Future questions to explore
  - Sleep time only collected only weekdays, not truly representative of natural circadian rhythm
  - Adding future NHANES data to the models

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