



INFLUENCES OF PHYSICAL ACTIVITY AND SLEEP ON BRAIN VOLUME IN EARLY CHILDHOOD

Christine W. St. Laurent^{1,2}, Melissa Horger², Lindsey Mooney², Tracy Riggins³ and Rebecca M.C. Spencer^{2,4}

¹Department of Kinesiology, University of Massachusetts Amherst; ²Department of Psychological and Brain Sciences, University of Massachusetts Amherst;

³Department of Psychology, University of Maryland College Park; ⁴Institute of Applied Life Sciences, University of Massachusetts Amherst



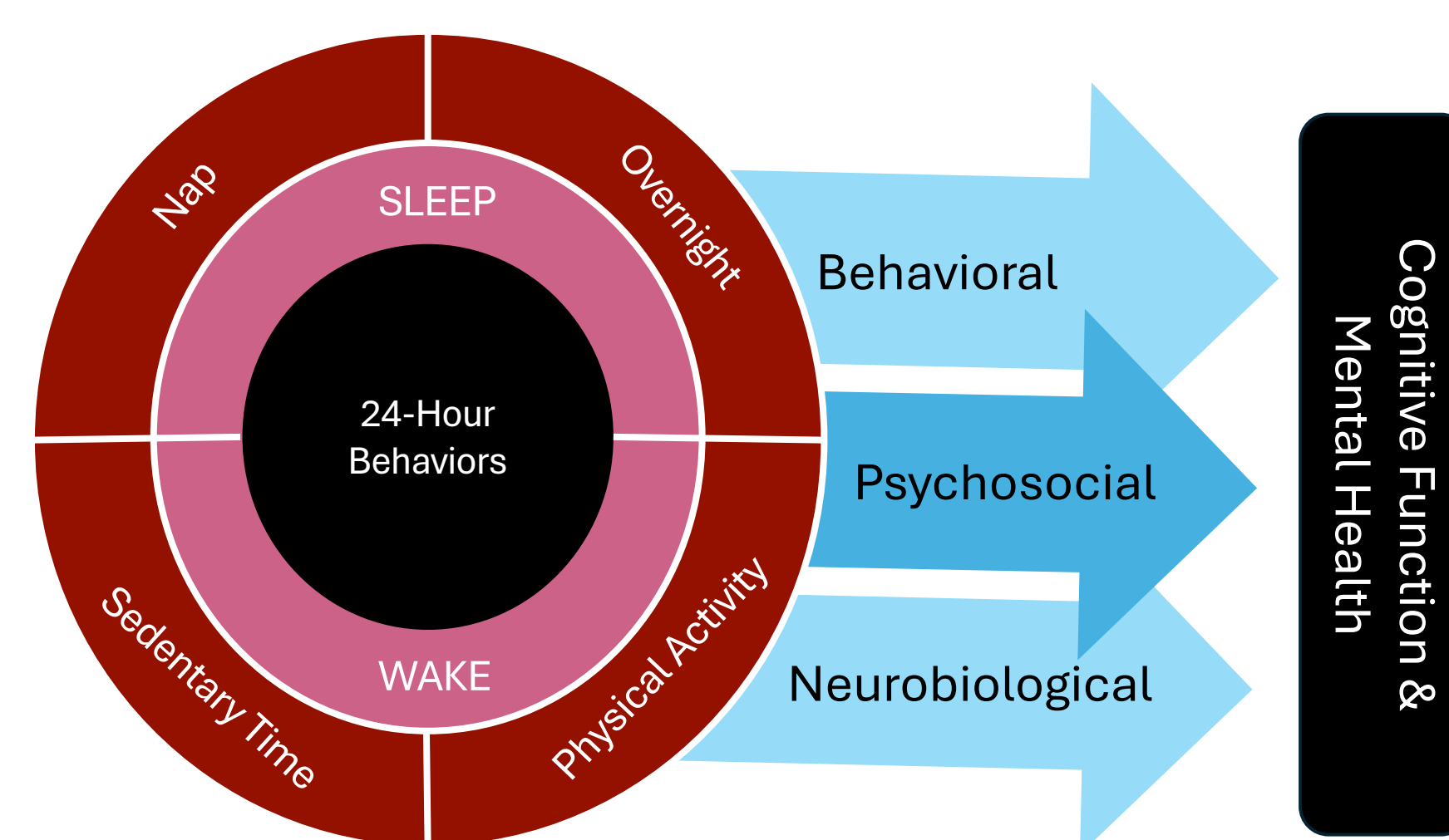
INTRODUCTION

Physical activity, sedentary behaviors, and sleep have been independently linked to cognitive function across development (1,2).

However, these ‘time-use’ behaviors are co-dependent and thus, may have interactive influences on cognitive performance (3).

Mechanistic pathways (e.g., neurobiological, psychosocial, and behavioral) that contribute to relations between physical activity, sleep, and cognitive abilities have been proposed, yet minimally studied in young children (4-6).

Studies in older children and adults have demonstrated that some brain regions may mediate the relations between independent behaviors (i.e., physical activity or sleep) and cognitive performance (4-6).



PURPOSE

To determine if physical activity and sleep, while accounting for their co-dependent nature, were associated with brain regions in preschool-aged children.

RESULTS

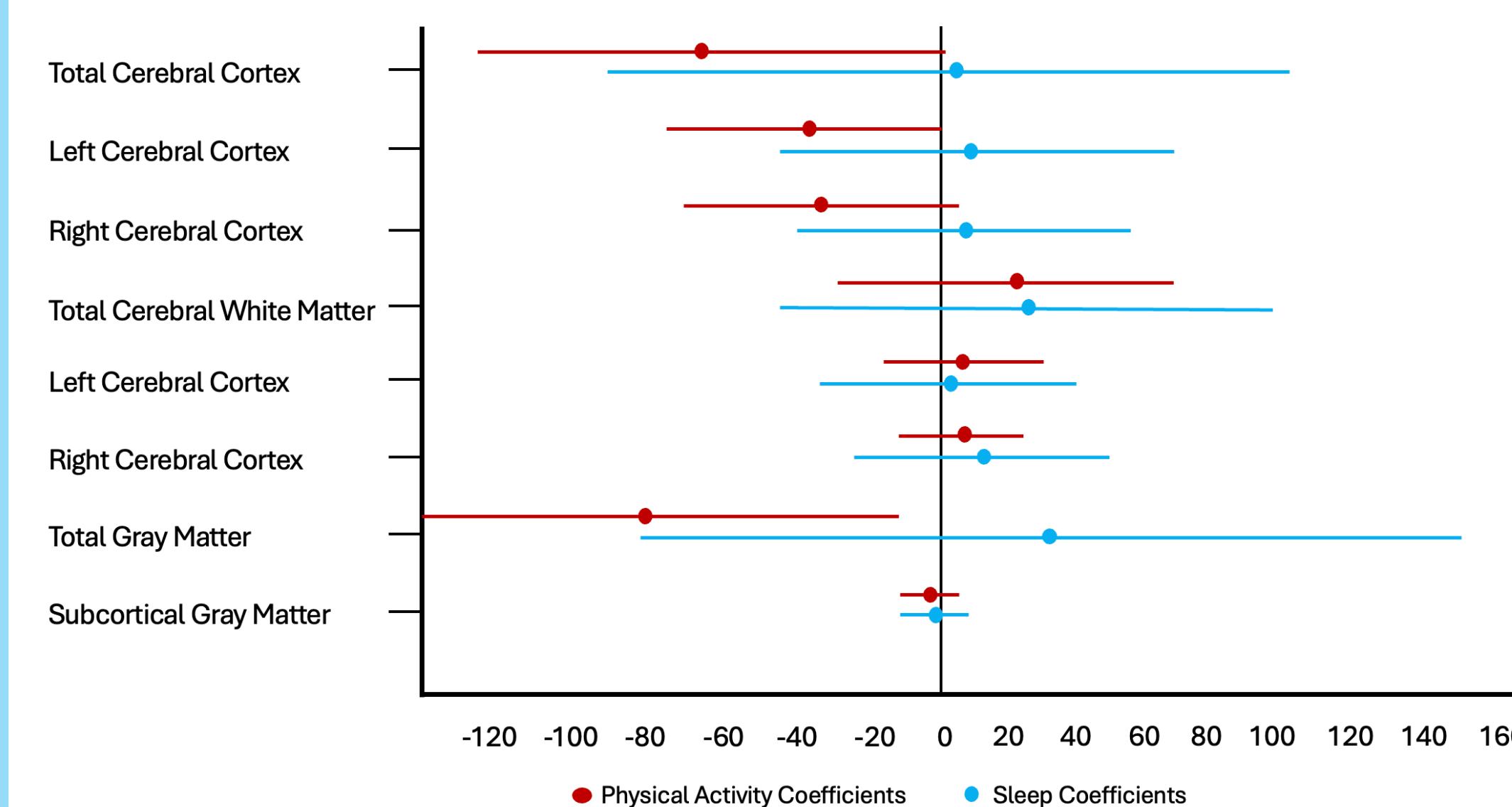
1. Multilevel Models Approach (with restricted maximum likelihood)

of Models: 8

Outcome: Volume of each brain region

Time-varying independent variables: total activity counts, 24-hour sleep duration, intracranial volume

Time invariant independent variables: Sex, age



- Higher activity levels in children were associated with less total gray matter ($B = -79.8, p = 0.03$)
- Other associations were not statistically significant

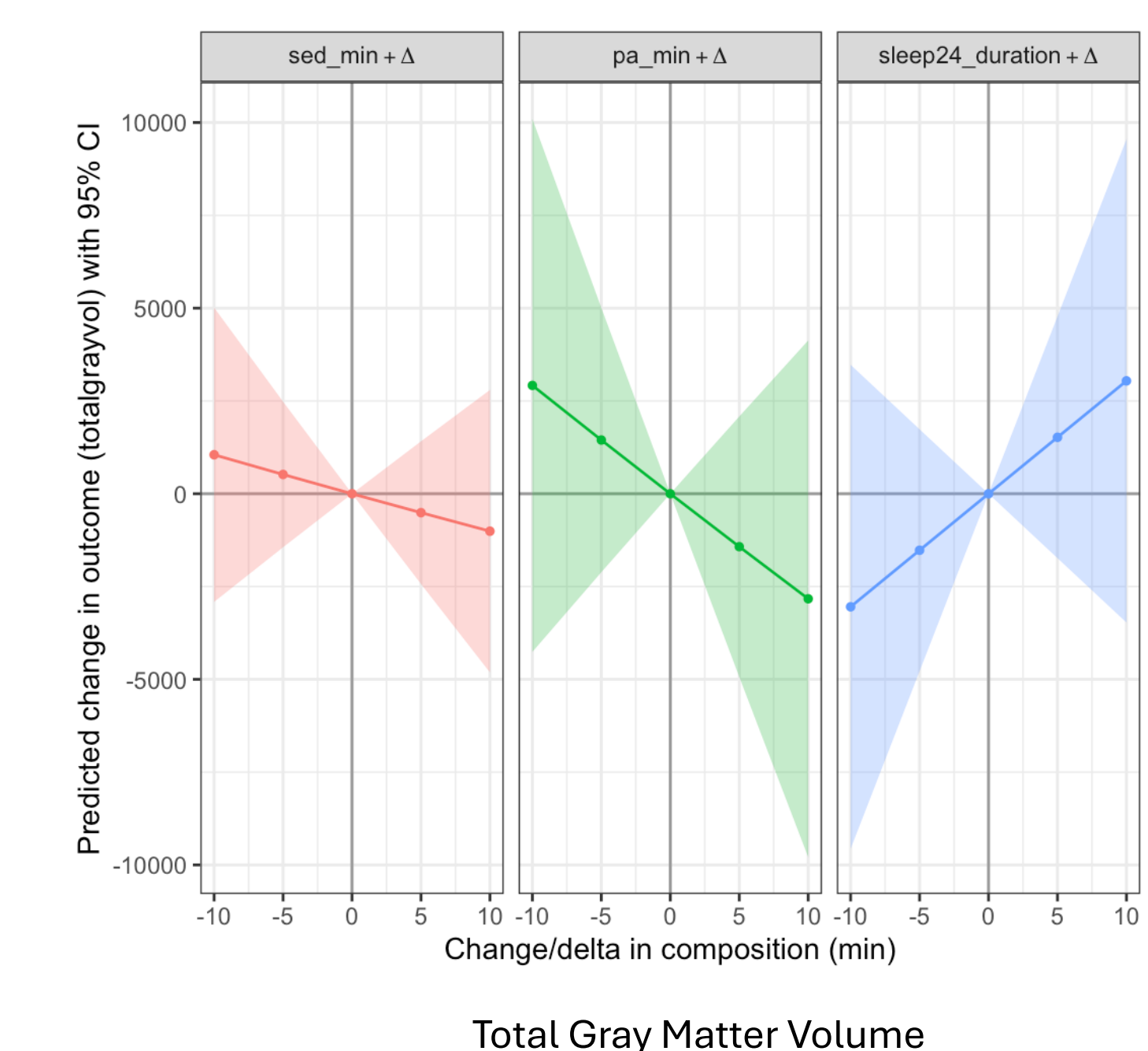
2. Compositional Data Analysis Approach (collapsed cross-sectional data with linear regression models)

of Models: 8

Outcome: Volume of each brain region

Compositional independent variables: Sedentary time, physical activity, and sleep, expressed as isometric-log ratios

Adjusted for: Intracranial volume



- The overall time-use composition was not associated with any brain measures
- Neither were physical activity and sleep

METHODS

Preschool-aged children repeated measurements at three time points approximately 6 months apart

Time 1
n = 22, 3.9 ± 0.4 years
73% Female, 27% Male

Time 2
n = 19, 4.5 ± 0.5 years
42% Female, 58% Male

Time 3
n = 13, 5.1 ± 0.4 years
54% Female, 46% Male

24-Hour Behaviors: Wrist Actigraphy



- Total Activity Counts
- 24-hour Sleep Duration
- Sedentary Time
- Total Physical Activity

Brain Volumes: Structural MRI



- Cerebral Cortex (total & hemispheric)
- Cerebral White Matter (total & hemispheric)
- Total Gray Matter
- Subcortical Gray Matter

CONCLUSIONS

We observed an inverse association between activity levels and total gray matter, but no associations with white matter.

This may suggest accelerated brain maturation, driven by improved neural efficiency or increased synaptic pruning rather than myelination.

To further explore these mechanisms in young children, longitudinal studies with greater variability in activity and sleep behaviors, and measures of brain function and cognitive performance are needed.

REFERENCES

- Erickson KI, Hillman C, Stillman CM, Ballard RM, Bloodgood B, Conroy DE, et al. Physical Activity, Cognition, and Brain Outcomes: A Review of the 2018 Physical Activity Guidelines. *Med Sci Sports Exerc.* 2019;51(16):1242-51.
- St. Laurent CW, Burkart S, Andre C, Spencer RMC. Physical Activity, Fitness, School Readiness, and Cognition in Early Childhood: A Systematic Review. *J Phys Act Health.* 2021;18(8):1004-13.
- Dumuid D, Olds T, Lange K, Edwards B, Lycett K, Burgner DP, et al. Goldilocks Days: optimising children's time use for health and well-being. *J Epidemiol Community Health.* 2021;75(1):e1-7.
- Gunnell KE, Poitras VJ, LeBlanc A, Schibili K, Barbeau K, Hedayati N, et al. Physical activity and brain structure, brain function, and cognition in children and youth: A systematic review of randomized controlled trials. *Ment Health Phys Act.* 2019;16(November 2018):105-27.
- Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics.* 2016;138(3).
- Valkenborghs SR, Noetel M, Hillman CH, Nilsson M, Smith JJ, Ortega FB, et al. The impact of physical activity on brain structure and function in youth: A systematic review. *Pediatrics.* 2019;144(4).