Published in final edited form as:
*J Sleep Res*. 2014 June ; 23(3): 335–338. doi:10.1111/jsr.12117.

# Relations between Daytime Pre-ejection Period Reactivity and Sleep in Late Childhood

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## Summary

The sympathetic nervous system and children's sleep serve critical arousal regulation functions. Shortened pre-ejection period, a reliable indirect index of greater sympathetic nervous system activity, has been associated with reduced sleep duration and quality in adults, but limited evidence exists in children regarding associations between pre-ejection period and sleep. We examined relations between pre-ejection period reactivity in response to a lab-based stressor and multiple parameters of actigraphy-based sleep duration and quality in children. The sample included 123 boys and 112 girls (*M* age = 11.31 years, *SD* = .63 years). Controlling for body mass index, sex, and pre-ejection period baseline, increased sympathetic nervous system reactivity, indexed by a lower level of pre-ejection period during the challenge than the baseline, was associated with worse sleep quality indicated by lower sleep efficiency, greater sleep activity, and greater long wake episodes. Findings add to a small literature on relations between sympathetic nervous system functioning and children's sleep, suggesting that poor sleep quality is related to dysregulation of the stress response system.

### Keywords

pre-ejection period; sleep; children; actigraphy

## Introduction

Physiological regulation serves critical arousal functions and individual differences in regulation are hypothesized to have important influences on sleep (Dahl, 1996). Sleep and arousal are on different ends of the arousal regulation continuum (Dahl, 1996) and linking sleep with cardiac measures, such as pre-ejection period (PEP), could illuminate important facets of this continuum (Bonnet, 2012). Although sympathetic nervous system (SNS) activity including PEP is altered by sleep insufficiency (Mullington, Haack, Toth, Serrador, & Meier-Ewert, 2009), few studies have examined relations between PEP during non-nocturnal conditions and sleep in children. PEP reactivity to stressors is a reliable, indirect index of cardiac SNS reactivity. Martikainen et al. (2011) investigated relations between

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Conflicts of interest: There are no known conflicts of interest.

PEP reactivity and sleep in children, reporting null effects for sleep quality and inconsistent effects for sleep duration.

Building on this scant literature, we examined relations between PEP reactivity to a psychosocial stressor and actigraphy-derived sleep minutes and quality (efficiency, activity, long wake episodes) in 11-year-old children. We hypothesized shortened PEP (greater SNS activity) in response to a social-stressor would be related to shorter and worse quality sleep.

## Methods

### Participants

The sample was drawn from the third wave of a larger study (Auburn University Sleep Study; AUSS) examining biopsychosocial influences on health; data collection occurred in 2011–2012. Fifth and sixth graders (n = 277) from public schools in the Southeastern United States were between the ages of 8 and 10 at recruitment with no diagnosed learning or sleep disorder. Those with actigraphy and PEP data available were included, resulting in an analytic sample of 235 children (123 boys, 112 girls; *M* age = 11.31 years, *SD* = .63); 63% of children were European- and 37% were African-American. Participants in the analytic sample did not differ from the full sample on main study variables.

### Procedures

At home, children wore actigraphs on their non-dominant wrists for seven consecutive nights and completed sleep diaries to cross-validate actigraphic assessments. Sleep data were collected during the regular school year excluding holidays. Following actigraphy, children came to the lab (*M* = 1.74 days interval, *SD* = 5.85) to measure their PEP, height in inches, and weight in pounds. Body mass index (BMI) was calculated using the standard formula (703 x (weight/height$^2$); http://www.cdc.gov) and was covaried.

Following electrode placement and an adaptation period, PEP was measured while the child was seated quietly (baseline; 3 min) and during a modified Trier Social Stress Task for Children (TSST-C; Buske-Kirschbaum et al., 1997) that is a well-established procedure for evoking mild social-evaluative stress (Kudielka, Hellhammer, & Kirschbaum, 2008). Children were given three minutes to prepare a speech about something interesting that happened to them in the past year, and then asked to deliver the three-minute speech while seated, during which PEP was derived. Children were told their speech would be recorded and scored by a panel of judges. The study was approved by the University Institutional Review Board and parental consent and child assent were obtained.

### Measures

**PEP—**PEP is defined as the period between the electrical invasion of the ventricular myocardium (Q wave of the ECG) and the opening of the aortic valve and was derived from an electrocardiogram and impedance cardiogram. Cardiac data was collected with the Mindware BioNex 8-slot chassis acquisition system (Mindware Technologies Ltd., Gahanna, OH, USA). Thoracic impedance ($Z_o$) data was collected using the four spot impedance electrode configuration (Berntson & Cacioppo, 2004). Voltage electrodes were placed at the apex and base of the thorax and dual electrodes were placed on the back 1.5 inches above and below the voltage electrodes. Data were sampled at 1000 Hz and amplified with a gain of 5000, and acquired data were filtered, rectified, and smoothed using MindWare BioLab 3.2 software. Respiration used in the calculation of PEP was derived from $Z_o$. PEP during the baseline (PEP-B) was averaged over the three minutes of assessment; similarly, PEP during the task was averaged over three minutes; units are in ms. PEP reactivity (PEP-R) was calculated by subtracting PEP-B from PEP during the task; a negative number denotes shortened PEP and increases SNS activity in response to challenge.

**Sleep—**Actigraphy was used to record and estimate sleep between bedtime and wake time. Octagonal Basic MotionLogger (Ambulatory Monitoring Inc., Ardsley, NJ, USA) actigraphs measured activity in 1-min epochs using zero-crossing mode. The analysis software package (AW2, 2002; Ambulatory Monitoring, Inc.) utilized the Sadeh algorithm (Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995). Nights with medication use for an acute illness were excluded from analyses, as were participants with < 3 nights of data. Most children had valid actigraphy data for 7 nights (40.3%), and the rest between 3 and 6 nights. When using actigraphy, the assessment of multiple sleep parameters is recommended (Sadeh, Raviv, & Gruber, 2000). Averages across the week for the following sleep variables were derived: (a) Sleep Minutes – total between sleep onset and wake time; (b) Sleep Efficiency – percentage of epochs scored as sleep between sleep onset and wake time; (c) Sleep Activity – percentage of epochs with activity > zero; and (d) Long Wake Episodes – number of waking episodes ≥ 5 minutes. Good night-to-night stability over the week for the actigraphy variables was observed ($\alpha$ =.81 to .94).

### Analysis plan

To reduce outlier effects, values > 3 *SDs* among primary study variables were recoded as the highest observed value < 3 *SDs* (Osborne, 2010); nine values were recoded among sleep variables and three among PEP variables. Sex, BMI, and PEP-B were all correlated with at least one sleep variable and/or PEP-R (see Table 1) and were controlled in analyses. Using hierarchical multiple regressions, associations between PEP-R and each sleep parameter were examined. Control variables were entered in the first step, followed by PEP-R in a second step. Analyses were performed using SPSS version 19.

## Results

Most children (69.6%) exhibited an increase in PEP from baseline to task; 28.9% showed a decrease and the rest (1.5%) showed no change; recall shortening or a decline in PEP levels from resting to challenge conditions denote increased SNS activity. A *t*-test indicated that on average, children had higher PEP during the task ($M$ = 110.75; $SD$ = 10.85) compared with baseline ($M$ = 108.53; $SD$ = 11.40; $t(223) = 4.43$, $p$ <.01). Means, standard deviations, and correlations among primary study variables are presented in Table 1. Note the large SD associated with PEP-R indicative of individual differences in responding to the task.

After taking into account the effect of control variables in step 1, PEP-R indicated by shortening of PEP (a lower level during task than baseline reflecting increased SNS reactivity) was associated with reduced sleep minutes at the trend level and worse sleep quality indexed by lower sleep efficiency, higher sleep activity, and more frequent long wake episodes (Table 2). Across models, PEP-R explained 1% to 7% of unique variance in the various sleep parameters; the total models including the controls accounted for 9% to 15% of variance in the sleep parameters.

## Discussion

Findings extend the literature on relations between daytime physiological regulation and sleep in children and demonstrate that higher cardiovascular SNS reactivity indexed by shortened PEP in response to a lab challenge is related to worse sleep quality (and approached conventional levels of statistical significance for sleep minutes). We found associations between PEP reactivity and sleep quality, but null effects were reported in Martikainen et al.'s (2011) study. The source of the discrepancy is not evident; both studies utilized actigraphy and examined PEP reactivity to the Trier task (albeit theirs included a math task). Their sample was slightly younger and more homogeneous than our sample. Further, children averaged ~ 8.4 hrs of sleep in their study; ours had ~7.3 hrs. Future investigations may clarify how relations between PEP activity and sleep may unfold across development and the influence of other individual differences.

It is not possible to determine causal relations between PEP reactivity and sleep from this correlational study. Children with higher SNS reactivity to the lab stressor may have worse quality sleep due to reduced ability to regulate emotions during mid-night awakenings interfering with their ability to return to sleep more quickly. By contrast, low quality sleep may lead to dysregulation of the stress response systems, including the SNS. These findings highlight the importance of further explication of relations between SNS activity and sleep in children.

## Acknowledgments

Support: The project described was supported by Grant Number R01HL093246 from the National Heart, Lung, and Blood Institute awarded to Mona El-Sheikh. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

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**Table 1**

Means, SDs, and Correlations Among Study Variables.

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. PEP-R | - | | | | | | | |
| 2. Sleep minutes | −.05 | - | | | | | | |
| 3. Sleep efficiency % | .02 | .76** | - | | | | | |
| 4. Sleep activity | −.01 | −.54** | −.77** | - | | | | |
| 5. Long wake episodes | −.08 | −.62** | −.91** | .70** | - | | | |
| 6. Sex | .05 | −.12~ | −.13* | .14* | .15* | - | | |
| 7. BMI | −.00 | −.26** | −.18** | .09 | .17** | −.00 | - | |
| 8. PEP-B (ms) | .13~ | .14* | .11 | −.05 | −.10 | −.15* | −.12~ | - |
| *M* | 2.36 | 436.30 | 88.65 | 39.27 | 3.25 | -- | 21.60 | |
| *SD* | 7.44 | 56.34 | 7.88 | 13.93 | 2.21 | -- | 5.84 | |

Note. PEP-R = pre-ejection period reactivity; BMI = body mass index; PEP-B = pre-ejection period at baseline; females were coded as 0 and males were coded as 1.

~ <.10,

* *p* <.05;

** *p* <.01

## Table 2

Regression Analyses Predicting PEP Reactivity

| | **Sleep Minutes** ***b*(*SE*)** | ***F*** | **Sleep Efficiency** ***b*(*SE*)** | ***F*** | **Sleep Activity** ***b*(*SE*)** | **F** | **Long Wake Episodes** ***b*(*SE*)** | ***F*** |
|---|---|---|---|---|---|---|---|---|
| *Step 1 Controls* | | 9.85** | | 4.59* | | 1.85 | | 4.22** |
| BMI | −3.22 (.69)** | | −.27 (.10)** | | .26 (.18) | | .07 (.03)* | |
| Sex | −17.05(7.72)* | | −2.02(1.11)~ | | 3.45 (2.01)~ | | .63 (.32)~ | |
| Baseline PEP | .69 (.37)~ | | .05 (.05) | | −.02 (.09) | | −.01 (.01) | |
| *Step 2* | | 8.25** | | 5.80*** | | 5.04** | | 4.69** |
| PEP reactivity | 1.00 (.56)~ | | .24 (.08)** | | −.54 (.14)*** | | −.06 (.02)* | |
| *Fit Statistics* | | | | | | | | |
| Step 1 $R^2$ | .14 | | .07 | | .03 | | .06 | |
| Total Model $R^2$ | .15 | | .11 | | .10 | | .09 | |

Note. PEP reactivity = calculated by subtracting PEP during baseline from PEP during the lab task; BMI = body mass index; PEP-B = pre-ejection period baseline; European Americans were coded as 0 and African Americans were coded as 1; Females were coded as 0 and males were coded as 1.

~ <.10;

* *p* <.05;

** *p* <.01;

*** *p* <.001.