Restless Sleep is Associated with Weight Gain: A Within-Subject Analysis

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Background and Introduction

- The rising popularity of digital health trackers presents the opportunity to measure physiological quantities and health outcomes frequently, over time.
- **We focus on weight gain** as an outcome and examine its relationship to sleep patterns.
- We use longitudinal weight data combined with minute-level sleep data from over 6,000 users of digital health trackers across the United States.

Data

- **Inclusion/Exclusion criteria**: Included users had at least two months of data, with at least 5 nights of sleep and 5 weight measurements recorded in each month. 1,087 male and 5,207 female users met the inclusion criteria.
- **Data**: Minute-level sleep and daily weight measurements collected from fitness trackers for 11,552 users of a proprietary platform that incentivize healthier lifestyles (achievemint.com) between 1 April 2015 and 1 April 2016.
- We created a panel dataset consisting of weight change and sleep statistics aggregated monthly for each user.

Figure 2. On 3 tier scale of sleep depth, an awake episode is defined as a 1+ minute interval spent in a non-asleep state

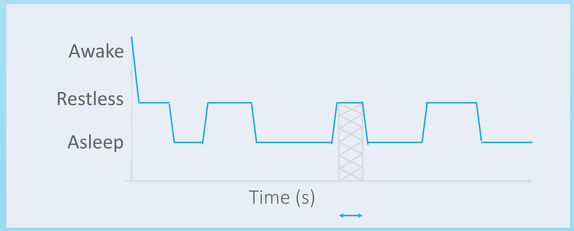

Figure 3. Correlation among explanatory variables

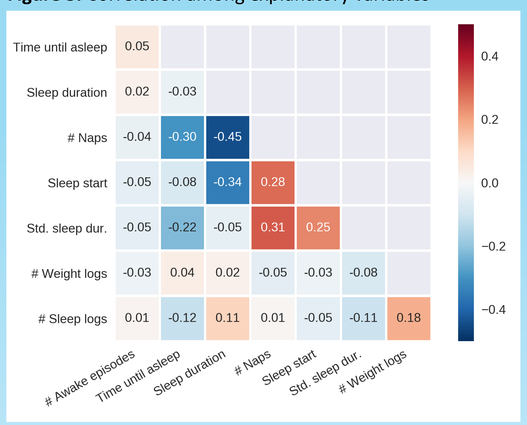

Figure 1. Descriptive statistics of the study population

Variable	Mean (std. dev.)
Population Size	6,294
Demographics	
Male %	17.27
Age	36.79 (9.82)
BMI	30.15 (7.34)
Weight Statistics	
Weight (kg)	85.05 (22.36)
Weight change (kg/mo)	-0.28 (8.98)
Weight logging duration (days)	201.88 (134.15)
# Weight recordings	33.46 (60.39)
# Weight recordings/mo	5.66 (8.61)
Sleep Statistics	
Sleep logging duration (days)	240.08 (132.53)
# Sleep recordings	120.19 (108.97)
# Sleep recordings / month	15.30 (9.99)
Sleep duration (hr/night)	7.03 (1.71)
Sleep start hr (24hr clock)	23.65 (1.99)
Hours in bed until sleeping	0.12 (0.12)
# Restless episodes during sleep	7.48 (3.28)
# Naps per day	0.20 (0.22)

Methods

- **Analysis**: We used fixed-effects panel regression **to control for heterogeneity between users**, with separate regressions for each gender.
- **Outcome variable:** User's monthly percent weight change.
- **Explanatory variables (aggregated monthly)**:
  - Mean nightly sleep start time,
  - Mean sleep duration,
  - Mean number of naps during the day,
  - Mean time in bed until sleeping,
  - Mean number of nightly restless episodes,
  - Standard deviation of sleep duration during the month
- **Control variables**:
  - Month of year (control for seasonal variation),
  - Tracking device used for weight and sleep tracking,
  - Frequency of weight and sleep measurements, since more frequent weight tracking has been shown to be associated with weight loss

Figure 4. Results of fixed-effects panel regression with monthly % weight change as outcome

	Female			Male		
Explanatory Variable	**Coefficient**	**P-value**	**95% CI**	**Coefficient**	**P-value**	**95% CI**
# Restless episodes during sleep	0.06	<.001***	[0.05, 0.07]	0.05	< .001***	[0.02, 0.08]
# Naps per day	-0.25	<.001***	[-0.39, -0.12]	-0.29	0.097	[-0.63, 0.05]
Log of # weight recordings/mo	-0.75	<.001***	[-0.78, -0.72]	-0.47	<.001***	[-0.52, -0.41]
Sleep start hr (24hr clock)	0.05	.001**	[0.02, 0.08]	-0.01	0.625	[-0.07, 0.04]
Std. dev. of sleep duration	0.07	.006**	[0.02, 0.11]	-0.05	0.38	[-0.16, 0.06]
Log of # sleep recordings/mo	0.08	.01*	[0.02, 0.13]	0.08	.199	[-0.04, 0.21]
Hours in bed until sleeping	-0.33	.089	[-0.71, 0.05]	-0.77	0.123	[-1.75, 0.21]
Sleep duration (hr/night)	-0.03	.077	[-0.07, 0.00]	-0.1	0.021*	[-0.19, -0.02]

Results

- The regression surfaced a **highly-significant association between restless episodes and weight gain in both genders**.
- Each additional restless episode per night was associated with a 0.058 and 0.052 percentage point monthly increase in weight for females and males respectively.
- For females, fewer naps, later bed times, and more variable sleep duration were also associated with weight gain.
- For males, shorter sleep duration was associated with weight gain.

Conclusions and Further Research

- We found significant association between frequency of restless episodes and weight gain in a population of digital health trackers, in free living conditions.
- Our results offer a scalable and accessible means of generating clinically actionable health data, given that many across the world increasingly own and use trackers and wearables today.
- By individually identifying those with these sleep difficulties, our results suggest it is feasible to offer personalized care that focuses on preventative risk factors such as weight gain.