Longitudinal Changes in Activity and Sleep Behaviors from Activity Trackers Are Associated with Change in Depression Severity

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Background
- Consumer digital health tools have created new opportunities to explore relationships between everyday behavior and mental health status.
- Intense longitudinal objective data related to physical activity and sleep may provide insights related to changes in behavior and changes in mental health status over time.

Objectives
- We sought to examine the relationship between change in activity and sleep behaviors and change in self-reported depression status over a 9-month period.

Methods

STUDY POPULATION
- In 2017, members of the Achievement online health community (a product of Evidation Health) were invited to participate in a 1-year observational cohort study on mental health.
- Participants were 18 years or older, lived in the U.S., and had a self-reported diagnosis of anxiety or depression.

BEHAVIORAL AND HEALTH OUTCOMES DATA
- Participants tracked their activity and sleep levels using consumer wearable activity trackers, and recorded weight and food logs using health and fitness apps.
- Surveys were completed at baseline, and quarterly thereafter, to assess depression as measured by the Patient Health Questionnaire 9-item Scale (PHQ-9).
- PHQ-9 scores range from 0 to 27. An Increase in score indicates worsening depression.

STATISTICAL ANALYSIS
- Steps and sleep behavior data were examined for intraday data availability and completeness for each 90-day window prior to the first four survey timepoints (baseline, months 3, 6, and 9).
- Behavioral features were constructed for each 90-day panel window.
  - Minute-level tracker data were used to construct over 300 data features capturing behavioral aspects of daily living.
  - Daily features were aggregated using the mean, 5th/95th percentile, standard deviation, and other distribution characteristics.
- Using a random effects framework, we conducted univariate regressions to identify associations between behavioral data features and change in PHQ-9.

Results

STUDY POPULATION

<table>
<thead>
<tr>
<th>Demographics</th>
<th>N = 639</th>
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<tbody>
<tr>
<td>Age, mean years (SD)</td>
<td>33.1 (8.8)</td>
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<tr>
<td>Female, n (%)</td>
<td>537 (84.0)</td>
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<td>Baseline PHQ-9 score, mean (SD)</td>
<td>9.0 (5.7)</td>
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Tracker Data Coverage, median
- Panel 0 (-90 days to baseline) | 89 days
- Panel 1 (baseline to month 3) | 90 days
- Panel 2 (month 3 to month 6) | 89 days
- Panel 3 (month 6 to month 9) | 86 days

UNIVARIATE REGRESSION ANALYSIS
- Multiple features were found to be significantly associated with increased PHQ-9 scores over time:
  - More time spent in bed on days with the longest sleep periods.
  - More time spent awake in bed on the most restless nights.
  - Greater variability in the time spent being active.
  - A greater number of minutes per day with nonzero step counts was associated with decreased PHQ-9 scores.

Limitations
- Limiting analysis to participants with dense interday data reduced the sample size from the ~1,300 enrolled to 639.
- The study population was largely female and young, limiting generalizability of the results.

Conclusions
- For a given participant, spending more time in bed (awake or asleep) over time, becoming more active later in the day, and having more fluctuations in activity over time were all significantly associated with worsening depression.
- Becoming more active throughout the day over time was significantly associated with improvement in depressive symptoms.
- Longitudinal activity and sleep data from consumer wearables may serve as a potential indicator of worsening depression in individuals with depression or anxiety.
- Future research is needed to validate these findings and to explore the utility of wearable tracker data as potential digital biomarkers for mental health status.