Validation of Basis Science Advanced Sleep Analysis

Estimation of Sleep Stages and Sleep Duration

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Abstract

Basis Science launched Advanced Sleep Analysis in January 2014 and became the first wrist-based tracker to detect REM, deep (slow wave), and light Non-REM sleep stages. Advanced Sleep Analysis combines sleep stage, toss-and-turn, sleep duration metrics, and more to provide users with a comprehensive view of their sleep.

To further develop and validate the sleep staging and sleep duration components of Advanced Sleep Analysis, Basis is partnering with sleep researchers at the Stress and Health Research Program, a joint venture between the University of California, San Francisco (UCSF), the San Francisco Veterans Affairs Medical Center (SFVAMC), and the Northern California Institute of Research and Education (NCIRE). None of the institutions were compensated in any form for these studies.

These researchers conducted sleep studies known as polysomnography, the gold standard for examining sleep, in order to evaluate the Basis sleep algorithm’s estimation of sleep duration and sleep staging. Preliminary results from these ongoing studies are described in this report. Sleep duration and sleep staging detected via the Basis Band were compared to polysomnography (PSG) data scored by sleep technologists. The Advanced Sleep Analysis algorithm demonstrated excellent agreement with polysomnography data for sleep duration (4.3% mean difference) and sleep staging (r = 0.92).

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Introduction

During sleep, the body cycles between different sleep states in order to recover mentally and physically. Rapid eye movement (REM) sleep is theorized to be essential for strengthening memories, boosting mood, and consolidating information learned during the day\cite{2,21}. During deep sleep, your body repairs muscles and tissues, stimulates growth and development, and boosts your immune system\cite{3,4,5}. Light sleep allows the body to transition to either deep or REM sleep\cite{6}.

Polysomnography (PSG), a comprehensive sleep study measuring several physiological signals, is the gold standard for measuring these sleep states. PSG studies are typically used by clinicians to evaluate sleep quality in those with suspected sleep disorders or by researchers in both normal subjects, or patients with sleep disorders. During PSG studies, an array of sensors is attached to the patient, measuring activity in the brain, eye, muscles, and heart. These signals are then analyzed and interpreted by a sleep technologist, who creates an in-depth report of the patient’s night sleep, including time spent in each sleep state.

The Basis Band’s sensors measure heart rate, motion, temperature, and perspiration. Through combinations of multiple sensors, the Basis sleep algorithm is able to measure physiological correlates of sleep stages, and thereby estimate times each user was in light, REM or deep sleep. These measurements are not possible with sensors that only detect motion (actigraphs). To ensure the accuracy of the sleep algorithm, Basis partnered with clinical sleep researchers who performed studies comparing the Basis sleep algorithm with PSG data. Excellent agreement was observed between Basis and PSG estimation of sleep duration and sleep states. Results from the initial phase of this study are described in this report, with additional studies ongoing.

Methodology

To further develop and validate the sleep duration estimation and sleep staging of our Advanced Sleep Analysis, Basis partnered with The Stress and Health Research Program, a joint venture between the University of California, San Francisco (UCSF), the San Francisco Veterans Affairs Medical Center (SFVAMC), and the Northern California Institute of Research and Education (NCIRE). Prior to work with SFVAMC, Basis developed, trained and validated the Advanced Sleep Analysis algorithm on data from over 600 sleep events from studies at Basis. For initial external validation of the algorithm, sleep studies, known as polysomnography (PSG), were performed at SFVAMC on 12 subjects for one or two nights per subject for a total of 19 subject-nights. Basis B1 Bands were worn concurrently during these studies. PSG data were scored by registered sleep technologists at SFVAMC. Analysis of sleep duration and sleep stage percentages comparing the Basis sleep algorithm to PSG were performed at Basis.
Results & Discussion

Detection of Sleep Stages

Excellent correlation ($r = 0.92$) was observed for duration and percentage of night sleep spent in each state between the Basis sleep algorithm estimation and the PSG (see Figures 1 and 2). The results were highly statistically significant ($p < 0.01$).

The agreement observed between Basis and the scored PSG data is especially encouraging considering even trained sleep scorers routinely disagree in their assessments of sleep stages. In a study of over 2,500 trained sleep scorers recently published in the Journal of Clinical Sleep Medicine, inter-scorder agreement was observed to be approximately 83%\(^7\). Given this inherent variability in scoring, complete agreement between the PSG and Basis is unlikely, and the Basis sleep algorithm performance should be considered very good.

See Figure 3 for example hypnograms overlaying sleep stages estimated by the Basis sleep algorithm and PSG. As shown in the hypnograms, the algorithm shows good agreement with PSG for timing of sleep stages.

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Footnote:

\(^{7}\) Inter-scorer agreement was observed to be approximately 83%.
Example Hypnogram #1

Example Hypnogram #2

Figure 3  | Example hypnograms overlaying PSG and Basis estimated sleep stage during sleep event.
Estimation Of Sleep Duration

The Basis sleep algorithm estimation of sleep duration matched closely with PSG-measured sleep duration (see Figure 4). On average, the Basis estimation of duration was 4.3% different from the PSG*. A difference in duration of 10% or less was observed in 89% of nights.

* Percentage difference calculated as the absolute value of the difference between PSG and Basis, divided by PSG

![Figure 4](image)

**Figure 4** Comparison of PSG and Basis estimation of total sleep duration.

Summary

The Basis sleep algorithm demonstrated excellent agreement with polysomnography (PSG) data for both sleep duration and sleep state estimation. Preliminary results are promising and demonstrate that the Basis Band provides a level of sleep analysis previously unavailable outside a sleep laboratory.

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References


