Helo
GUIDES

SLEEP

Monitoring with Helo
Wearables Devices

Version 1.0 - 1.2023

Abstract

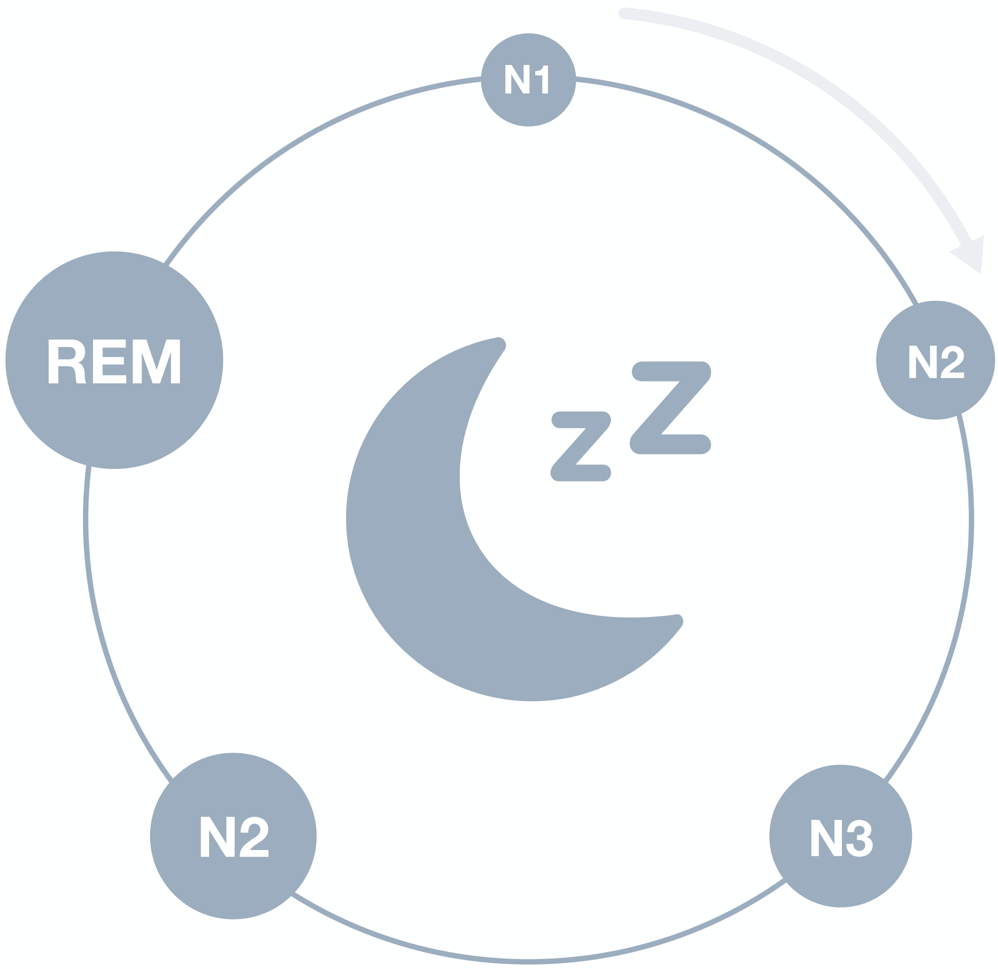
High-quality sleep is important in maintaining health, as this “down time” is necessary for the body to restore and repair bodily systems. Short and poor-quality sleep have been directly linked to a series of chronic health problems, including weight gain and obesity, insulin resistance, hypertension, depression, adverse cardiovascular consequences, weakened immune response, and more. Among all stages of sleep, rapid eye movement (REM) sleep is the key factor in determining sleep quality. The most effective traditional method of sleep monitoring is spectral analysis of the sleep electroencephalogram (EEG), but there is a strong relationship between EEG and the cardiac autocorrelation coefficient of RR intervals (rRR). RR intervals can be measured by photoplethysmography (PPG), which is widely used in wearable devices, such as those produced by Helo, which are suitable for use during sleep.

Sleep Patterns

Sleep is a naturally recurring state that serves several functions, including restoration of bodily systems and memory processing. It is divided into two very distinct types, non-rapid eye movement (NREM) sleep and rapid eye movement (REM) sleep. Non-REM or deep sleep, which occurs first, is characterized by reduced body temperature and heart rate, and less energy use by the brain. REM sleep, known as the dream state, represents a smaller percentage of overall sleep. It involves fast brain waves, eye movements, and relaxed muscle tone.[1]

The American Academy of Sleep Medicine further divides NREM sleep into three stages, N1, N2, and N3 (the deepest level of sleep). A sleep cycle of alternate NREM and REM sleep typically lasts 90 minutes, with four to six such cycles every night.

A sleep cycle "normally proceeds in the order: N1 → N2 → N3 → N2 → REM. REM sleep occurs as a person returns to stage 2 or 1 from a deep sleep. There is a greater amount of deep sleep (stage N3) earlier in the night, while the proportion of REM sleep increases in the two cycles just before natural awakening."[2]



The Importance of REM Sleep

While the general populace will not be familiar with N1, N2, and N3, most will have heard of REM sleep. In this stage, the brain is highly active, the eyeballs will move quickly back and forth, and it's easy to achieve a dream state, including vivid dreams. In addition to the eye movement that gives this sleep stage its name,

> *REM sleep is … characterized (and hence differentiated from wake and non-REM sleep) by other defining physiologic and behavioral features, including a reduced amplitude and faster frequency cortical electroencephalogram (EEG) that is reminiscent of waking, high-amplitude theta waves in the hippocampal EEG, active suppression of skeletal muscle activity, intermittent muscle twitches, autonomic and respiratory activation, fluctuations in brain/body temperature, and an elevated arousal threshold.*[3]

Functionally, REM sleep has been shown to play an important role in mood regulation, learning, memory, and stress management.[4,5] Further research points to additional benefits from REM sleep, including facilitating cortical plasticity[6], restoration of aminergic cell/receptor function[7], and heightening general creativity.[8] Research also shows that REM sleep is "regulated by sensitive homeostatic mechanisms."[9]

The amount of REM sleep experienced during sleep depends on various factors, such as age. For example, the REM sleep of infants accounts for 50% of the total sleep, while for adults it is only about 20%.[10, 11]

To maximize REM sleep, individuals should keep a regular routine, focused on early bedtimes and early wake times, and reducing mental stress. Avoiding caffeine, alcohol, cigarettes, and other chemicals that interfere with REM sleep is critical.

Sleep Quality and Health

Short and poor-quality sleep have been directly linked to a series of chronic health problems, including weight gain and obesity, insulin resistance, hypertension, depression, adverse cardiovascular consequences, weakened immune response, and more.[12, 13] Research shows that excessive sleep can contribute to health concerns as well, with one study recommending that the optimal amount for adults is seven to eight hours nightly.[14]

Numerous factors can contribute to lower quality sleep, including diet, use of caffeine and alcohol, poor sleep environments, and physiological concerns, such as obstructive sleep apnea (OSA) or restless legs syndrome (RLS). OSA is a major form of sleep-disordered breathing (SDB), with a potential prevalence of up to 38% in the general population.[15] It increases the risk of cardiovascular disease and causes hypoxemia, hypercapnia, nocturia, sleep fragmentation, morning headaches, and excessive daytime sleepiness.[16]

Sleep Monitoring via Photoplethysmography

Spectral analysis of the sleep electroencephalogram (EEG) is a traditional useful tool for quantitative and precise analysis and description of the sleep processes.[17] The drawback with EEG is that, in its typical format, it involves numerous electrodes placed on the head, making it highly unsuitable for daily use by consumers.

However, a useful proxy is the strong relationship between EEG and the cardiac autocorrelation coefficient of RR intervals (rRR). Otzenberger et al found “beat to beat heart rate variability and EEG activity are closely linked during sleep in normal man.”[18] This correlation is ultimately unsurprising as both REM and rRR are highly determined by the activity of the vagus nervous system.

Electrocardiogram (ECG) RR intervals can be measured with high accuracy using photoplethysmography (PPG) peak-peak intervals (see Fig. 1). Because PPG is widely and maturely used in wearable devices, these can be used to accurately monitor sleep. Fig. 2 displays the relationship between rRR and EEG, and Fig. 3 displays the relationship between rRR and REM.

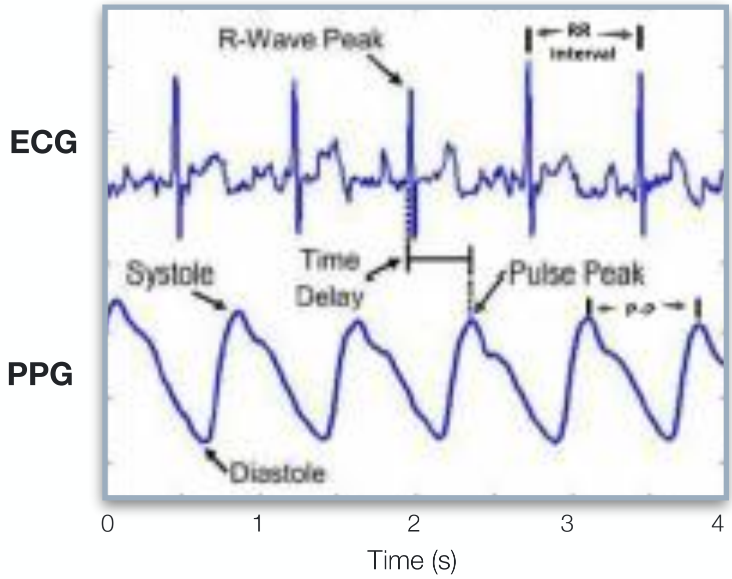


***Fig. 1**: ECG RR interval and PPG peak-peak interval.*

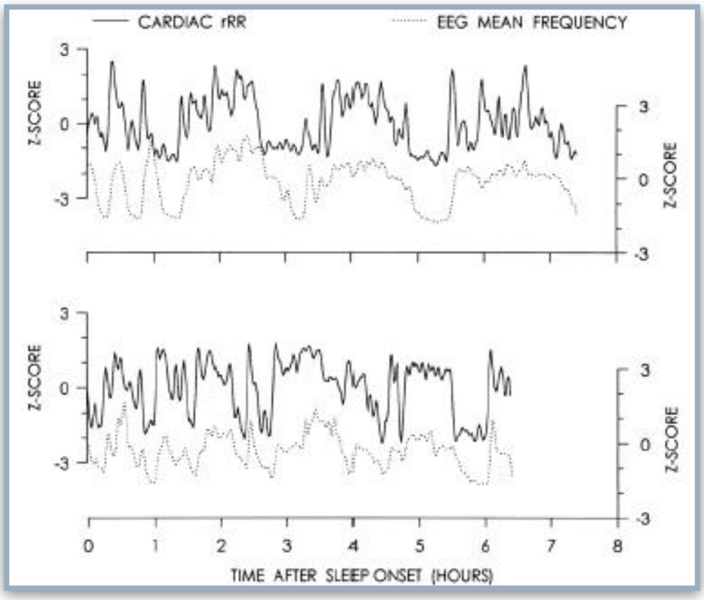


***Fig. 2**: Concomitant profiles of minute EEG mean frequency and of interbeat autocorrelation coefficient (rRR) after z-score transformation in two representative subjects during night-sleep. rRR and EEG mean frequency curves were smoothed using the moving average method over a five-point span.*[19]

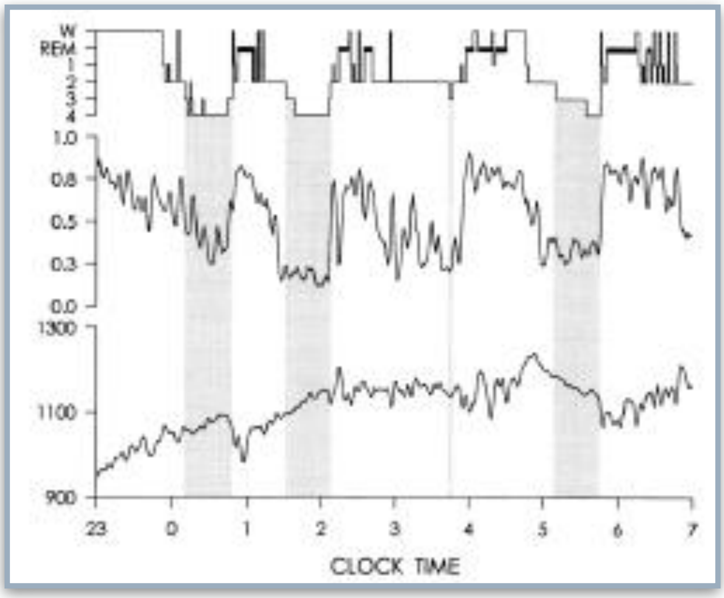
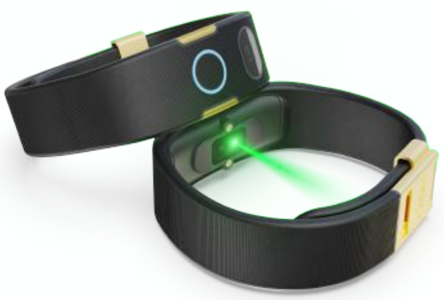


***Fig. 3**: Profiles of minute interbeat autocorrelation coefficient (rRR) and of RR interval together with sleep stage pattern in one subject. Slow wave sleep (stage 3 and 4) lies in shaded areas. rRR and RR curves were smoothed using the moving average method over a five-point span.*[20]

Sleep Monitoring with Helo Wearables

As reviewed above, PPG is a convenient and effective method for monitoring and reporting sleep quality, but wrist PPG quality is far lower than finger PPG quality. Helo wearables utilize the highest quality wrist PPG sensors and most powerful Analog Front End chips, paired with the most advanced Digital Signal Processing technologies. This enables the best possible wrist-based PPG. Also equipped with a motion sensor, Helo wearables employ actigraphy for improved, more accurate sleep monitoring.



Through PPG sensors and a proprietary back-end algorithm, Helo wearables also obtain and record accurate results of respiration rate, heart rate, heart rate variability (HRV), SpO2, etc., during sleep. With a built-in temperature sensor, the wearables record tiny changes of the user's body temperature during sleep. Users and medical professionals alike can review all data and results recorded during sleep for further analysis. Helo's AI summarizes all results captured by Helo wearables, providing accurate sleep analysis results and professional insight. With Helo, it's impressively easy for users to monitor and improve their sleep quality.

Legal Disclaimer

Unless otherwise specified, Helo wearables and related services are not medical devices and are not intended to diagnose, treat, cure, or prevent any disease. With regard to accuracy, Helo has developed products and services to track certain wellness information as accurately as reasonably possible. The accuracy of Helo's products and services is not intended to be equivalent to medical devices or scientific measurement devices.

Consult your doctor before use if you have any pre-existing conditions that might be affected by your use of any Helo product or service.

Useful Terms

Actigraphy: The use of wrist-worn accelerometry devices that measure movement to estimate sleep.

Electrocardiogram (ECG): Used to measure and analyze electrical activity of the heart to detect abnormalities or heart arrhythmias.

Heart Rate Variability (HRV): Variation in the time interval between heartbeats, measured in milliseconds. High variability — for example a low heart rate upon waking and a higher rate during exercise — is considered a hallmark of good health.

Photoplethysmography (PPG): An optical way to measure blood volume changes in a bed of tissue, such as a finger or earlobe. Obtained by illuminating the skin and measuring light absorption.

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