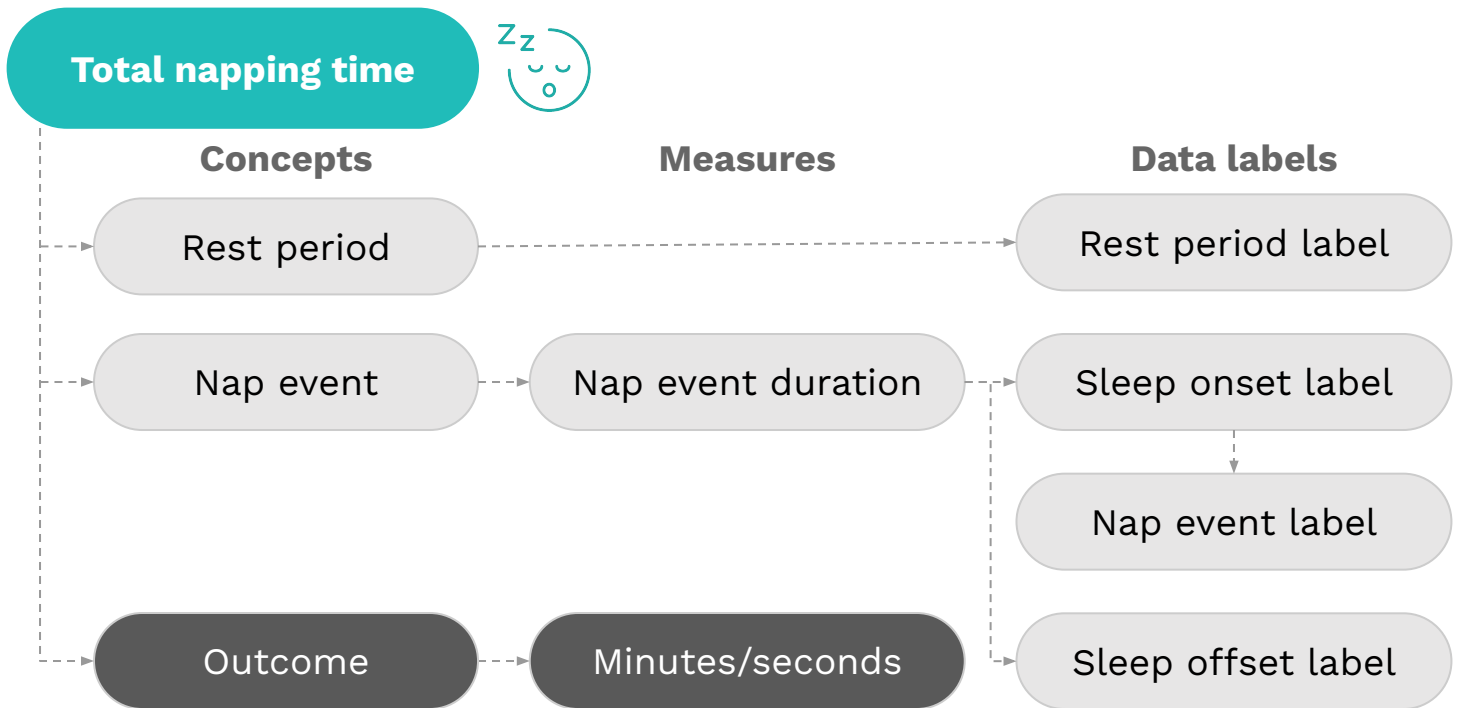
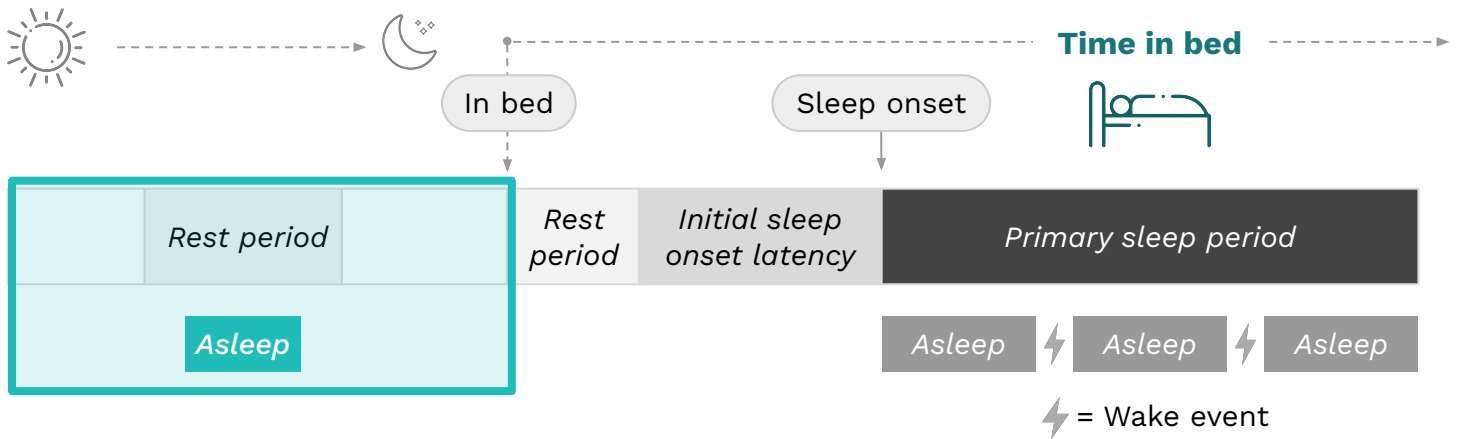


Core Digital Measure of Sleep: Total napping time (Duration)

Also known as: Daytime sleep duration
Type: Duration of time

Definition: The total duration of time spent sleeping outside of the time attempting to sleep, while at rest



Measure considerations

Importance: Sleeping outside of the time attempting to sleep period can be a marker of poor sleep on the prior night or a marker of morbidity and mortality.^{1,2}

Measure considerations (continued)

Measure derivation: A total of all nap event durations occurring during rest periods. A rest period is inferred through a specified low level of activity or other physiological measure for a specified minimum duration. Individuals are often required to confirm a nap occurred.

Optional deviations:

- Nap events are recorded during rest intervals because for some technologies, the sleep/wake algorithms are only active during these periods.
- For researchers who want to collect total sleeping time outside of the primary sleep period, regardless of the presence of the rest periods, technology which continuously monitors sleep/wake will be important to consider. In this event, the rest period is not accounted for.

Rest period label

Description

Epochs covering the primary period of time where the individual is in a resting state that specifically occurs outside of the time attempting to sleep.

It involves and is often detected through a change in physiological metrics, such as reduced activity.

Label definition

A label for each epoch denoting when an individual is recorded to be resting and the time attempting to sleep label=0.

The parameters or algorithms for detecting rest should be clearly defined or referenced.

Why is this important?

The rest period label differentiates from the primary sleep period label in that it occurs outside of time attempting to sleep for the primary sleep event of the day. This difference suggests that it is a period of restfulness where the individual did not intend to start their primary sleep event for the day.

This specification allows for the detection of minor sleep events, or naps, to be measured outside of the time attempting to sleep.

Derived variables

Rest period start time

Variable definition

The **timestamp** of the first epoch in a series of epochs with a rest period label=1 that follow a series of epochs with Rest Period Label=0. The valid minimum length of each series must be specified.

Rest period end time

Variable definition

The **timestamp** of the final epoch in a series of epochs with a rest period label=1. The valid minimum length of each series must be specified.

Rest period duration

Definition: A **time duration (seconds)** calculated as the difference between the rest period start and end times.

Sleep offset label

Description

An epoch where the individual transitions from being asleep to being awake.

Label definition

A label for the first epoch in a series of epochs with an asleep label=0 that follow a series of epochs with asleep label=1 (the opposite of the sleep onset label). The valid minimum length of each series must be specified.

Why is this important?

The sleep offset label can be used to define when individuals wake up from sleep. This may not be the final awakening of a given period of sleep, but could be important for understanding the continuity of an individual's sleep.

For example, the sleep offset label could be used in conjunction with other parameters to understand how many times an individual wakes up during a primary sleep period before their intended wake time.

Sleep offset time

Variable definition

The **timestamp** associated with a sleep offset label.

Sleep onset label

Description

An epoch where the individual transitions from being awake to being asleep.

Label definition

A label for the first epoch in a series of epochs with an asleep label=1 that follow a series of epochs with asleep label=0. The valid minimum length of each series must be specified.

For example, a valid minimum length could be ten 30-second epochs of sleep (5 minutes in total). In this case, where sleep is registered for at least ten consecutive epochs, the first epoch in the series would be awarded the sleep onset label. If a series of epochs is registered for less than ten consecutive epochs, no sleep onset label would be awarded.

Why is this important?

Not all sleep epochs represent a confirmed sleeping bout. Describing, evidencing, and confirming a minimum detected sleep time prior to denoting sleep onset allows for more sensitive sleep measurement.

The sleep onset label can be used to define when individuals achieve sleep and used in conjunction with other parameters to derive important metrics, such as the time it takes for an individual to fall asleep.

Sleep onset time

Variable definition

The **timestamp** associated with a sleep onset label.

Nap event label

Variable definition

An epoch with a sleep onset label=1 and rest period=1

Sleep onset time

Sleep offset time

Nap label

Nap event duration

Variable definition

The **time duration (seconds)** of a sleep event that occurs during a rest period outside of the time attempting to sleep and is followed by a further period of wakefulness.

The duration of each nap is calculated separately as the difference between:

- A sleep onset time of an epoch with rest period=1
- The sleep offset time of the following epoch with sleep offset label=1

Why is this important?

By measuring each nap duration, the sum of these events can be used for total napping time, and the individual nap events can be assessed, if relevant to the research question.

Additionally, nap durations with outlying duration magnitudes can be individually explored as a data quality assurance step.

References

1. Leng, Y., Wainwright, N. W., Cappuccio, F. P., Surtees, P. G., Hayat, S., Luben, R., ... & Khaw, K. T. (2014). Daytime napping and the risk of all-cause and cause-specific mortality: a 13-year follow-up of a British population. *American journal of epidemiology*, 179(9), 1115-1124.
2. Zhong, G., Wang, Y., Tao, T., Ying, J., & Zhao, Y. (2015). Daytime napping and mortality from all causes, cardiovascular disease, and cancer: a meta-analysis of prospective cohort studies. *Sleep medicine*, 16(7), 811-819.