ANSI/CTA Standard

Methodology of Measurements for Feature In Sleep Tracking Consumer Technology Devices and Applications

ANSI/CTA/NSF-2052.2-A

September 2024

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(Formulated under the cognizance of the CTA **R11 Health, Fitness & Wellness Technology Committee**.)

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FOREWORD

This standard was developed by the Consumer Technology Association's R11 Health, Fitness and Wellness Technology Committee WG 1 Sleep Monitors.

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Methodology of Measurements for Features in Sleep Tracking Consumer Technology Devices and Applications

1 SCOPE

This voluntary standard defines the methodology for measuring elemental parameters used in consumer technology devices and applications designed to evaluate sleep. The measures covered within this standard are contained within ANSI/CTA-2052.1, *Definitions and Characteristics for Wearable Sleep Monitors*.

2 REFERENCES

2.1 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed here.

2.1.1 Normative Reference List

1. ANSI/CTA/NSF-2052.1-A, *Definitions and Characteristics for Wearable Sleep Monitors Performance Criteria,* September 2022, https://cta.tech/standards.

3 COMPLIANCE NOTATION

CTA defines the following compliance terms for use in its documents:

shall	This word indicates specific provisions that are to be followed strictly (no deviation is permitted).
shall not	This phrase indicates specific provisions that are absolutely prohibited.
should	This word indicates that a certain course of action is preferred but not necessarily required.
should not	This phrase means a certain possibility or course of action is undesirable but not prohibited.
may	This phrase indicates that a certain course of action is optional.

need not This phrase indicates that a certain course of action is not required (i.e., optional), and this document does not express a recommendation as to preference.

3.1 General Remarks/Caveats

NOTE 1: Sustained is a general term and is not quantified because the specific criteria will be sensor and sensitivity dependent. However, the term is used here to differentiate it from transient changes.

4 DESCRIPTION OF MEASURES

- Directly Measured (D)
- Inferred from measure indicated (I)
- Standard for sleep medicine (S)
- Calculated from other measures (C)
- Newly defined terms (N)
- Standard technique using EEG (electroencephalographic), EOG (electro-oculographic), and EMG (electromyographic) (polysomnography, PSG)
- Heart Rate, Respiration, Blood Pressure, Electrodermal Activity, Pulse Volume, Pulse Transit Time (autonomic nervous system, ANS)
- Core Body Temperature (Body Temp)

5 ELEMENTAL AND DERIVED MEASUREMENTS

Recommended terminology covered in this document falls into five general categories as shown and color coded in Table 1.

For the purposes of this document, all timestamps for time elemental measures should be recorded with a minimum precision of one second and expressed with respect to Universal Coordinated Time (UTC). When storing signals recorded by devices which are not directly aligned with UTC, an estimated offset to UTC may be supplied. In such a case, the temporal alignment should be made objectively, e.g., the clocks should either be synchronized, or their offset should be determined beforehand and applied when comparing the signals.

Table 1 - Sleep Terminology Categorization (derived from ANSI/CTA/NSF-2052.1-A)

Notation:

D- Directly Measured

I- Inferred from measure indicated

S- Standard for sleep medicine

PSG- Standard technique using EEG, EOG, and EMG

ANS- Heart Rate, Respiration, Blood Pressure, Electrodermal Activity, Pulse Volume, Pulse Transit Time

Body Temp- Core Body Temperature

	Self-Report	Observation	Room/Bed Sensors	Actigraphy	PSG	ANS	Body Temp	Endocrinology
TATS Start Time	D	I	I	I	I			
TATS End Time	D	I	I	I	I			
TIB Start Time	I	D	D	I				
TIB End Time	I	D	D	I				
Awake	D	D	D	I	S	I	I	
Asleep		I	I	I	S	I	I	
Awakening from Sleep		D	D	I	S	I		
Brief Awakening				I	S			
Initial Sleep Onset Time		I	I	I	S	I		
Final Awakening Time		I	I	I	S	I		
Brief Moment of Sleep (Dozing)		I	I		I	I		
REM Sleep					S			
N1 Sleep					S			
N2 Sleep					S			
N3 Sleep					S			

CNS Arousal					S			
Sleep-Wake Regularity			I	I				
Sleep-Wake Fragmentation			I	I				
Sleep-Wake Amplitude			I	I				
Circadian Phase				I			D	D
Circadian Phase Angle				I			D	D
Circadian Period Length (tau)							D	D
Circadian Amplitude							D	D
All of the other terms listed in the glossary (ANSI/CTA/NSF-2052.1) are calculated from the parameters in the above table.								

5.1 General Terms Describing the Temporal Frame Containing a Sleep Episode

5.1.1 Time Attempting to Sleep (TATS) Start Time (Elemental Measure)

Direct Measurement: Self-report by the subject that he or she intends to begin a sleep period (e.g., pushing a button on the device, activating application, provides notice to test observer, or adding the sleep diary entry).

Inferred Measurement: Observation can be achieved by video or direct surveillance (e.g., by a person looking at the subject and recording the start time) or with room/bed sensors (e.g., person lying still in bed, putting lights and/or TV off, closing eyes). In laboratory PSG recordings, this is recorded as “lights off” time.

Remarks/Caveats: Time in Bed (TIB) is often used as a surrogate for this measurement and can be inferred from actigraphy (inferred when a person becomes inactive and lying down). However, strictly speaking, TATS is differentiated from time in bed (see definition of TIB). TATS is differentiated from TIB because an individual might lie down in bed without attempting to sleep. Additionally, the term addresses the issue that not all individuals sleep in bed (i.e., they can attempt to sleep in other locations; for example, in a chair or on a couch).

5.1.2 TATS End Time (Elemental Measure)

Direct Measurement: Self-report by the subject that they are finished with their sleep period (e.g., pushing a button on the device, activating application, provide notice to test observer, or adding the sleep diary entry).

Inferred Measurement: Observation can be achieved by video or direct surveillance (e.g., by a person looking at the subject and recording the start time) or with room/bed sensors (e.g., person being more active, getting out of the bed, putting lights and/or TV on). In laboratory PSG recordings, this is recorded as “lights on” time.

Remarks/Caveats: TIB is often used as a surrogate for this measurement and can be inferred from actigraphy (inferred when a person becomes inactive and lying down). However, strictly speaking, TATS is differentiated from time in bed (see definition of TIB). TATS is differentiated from TIB because an individual might lie down in bed without attempting to sleep. Additionally, the term addresses the issue that not all individuals sleep in bed (i.e., they can attempt to sleep in other locations; for example, in a chair or on a couch).

5.1.3 TIB Start Time (Elemental Measure)

Direct Measurement: Observation can be achieved by video or direct surveillance (e.g., by a person looking at the subject and recording the start time) or with room/bed sensors (e.g., pressure transducers in an air filled or fluid filled mattress, infrared sensors, location detector, bio-signal bed sensor).

Inferred Measurement: Self-report by the subject (e.g., pushing a button on the device, activating application, or provide notice to test observer) or actigraphy that has posture sensor that estimates if the person is lying down in bed.

Remarks/Caveats: TIB is differentiated from time attempting or engaging in sleep (see definition of TATS). The term addresses the issue that not all individuals sleep in bed (i.e., they can sleep in other locations; for example, in a chair or on a couch). Additionally, TIB is differentiated from TATS because some individuals engage in other activities (with minimal movement) in bed, other than attempting to sleep (e.g., reading or watching television).

5.1.4 TIB End Time (Elemental Measure)

Direct Measurement: Observation can be achieved by direct or video surveillance (e.g., by a person looking at the subject and recording the end time) or with room/bed sensors (e.g., pressure transducers in an air filled or fluid filled mattress, infrared sensors, location detector, bio-signal bed sensor).

Inferred Measurement: Self-report by the subject (e.g., pushing a button on the device, activating application, or providing notice to test observer) or actigraphy that has a posture sensor that estimates if the person is lying down in bed.

Remarks/Caveats: When using an instrumented approach (e.g., a bed sensor), the specific parameters concerning weight, duration of detected entity's presence on the bed's surface, and possibly the presence of a confirmatory biological signal (e.g., heartbeat) will vary from device to device. TIB is differentiated from time attempting or engaging in sleep (see definition of TATS). The term addresses the issue that not all individuals sleep in bed (i.e., they can sleep in other locations; for example, in a chair or on a couch). Additionally, TIB is differentiated from TATS because an individual might lie down in bed without attempting to sleep.

5.2 General Terms Describing Basic Features of Wakefulness and Sleep

5.2.1 Awake (Elemental Measure)

Direct Measurement: Purposeful motoric and coherent verbal activity occurs in association with wakefulness. When either of these are present, wakefulness is present (except under extraordinary circumstances). The amount of activity can range along a spectrum. This spectrum varies from quiescent wakefulness to active wakefulness.

Active wakefulness can be determined directly

(a) By observing purposeful behavior,
(b) By observing coherent verbalizations, and/or
(c) From self-report momentary assessment.

Quiescent wakefulness can be more difficult to determine when observable purposeful behaviors are not present. It can be determined directly by self-report but not necessarily with observation.

Inferential Measurement: Wakefulness can be inferred from

(a) Measurements made using movement sensors placed in the bedroom or the bed indicating activity persisting over a sustained period of time,
(b) Actigraphic measures indicating movement over a sustained period of time,
(c) Changes in autonomic activity (e.g., faster heart rate and/or respiration, higher and varying blood pressure), and/or
(d) Sustained high body temperature.

Remarks/Caveats: Some of the inferential measures rely on relative quantity. For example, activity measures may decline but not cease when a person is still awake. Thus, cutoff values must be determined for a specific device because different devices with different sensitivities and values will differ. Similarly, many ANS measures decline at sleep onset. Such measures include heart rate, respiration, and blood pressure. When at high levels one may infer that the individual is awake, unless they have a particular pathophysiology that alters this pattern. By contrast, electrodermal activity remains at a low-level during REM, N1, and N2 sleep. Most of its activity occurs during wakefulness and during N3 sleep; thus, if heart rate and respiration are high and electrodermal activity is also high, one may infer that the individual is awake (unless they routinely suffer with sleep terrors).

Often times Sleep Onset, even in the laboratory, is determined as much but a change in bioelectric patterns as it is by detecting an absolute level of activity. Therefore, relying on relative measures may not be able to differentiate awake from sleep at a particular point in time but rather can provide useful ancillary data. For example, body temperature declines and reaches its nadir during sleep and this information can be paired with actigraphy to help identify awake periods. In sleep medicine, determining when an individual is awake relies on polysomnography, however, polysomnography works best when a person has well defined, clear EEG alpha activity. Wakefulness is scored when half, or more, of a 30-second epoch (time domain) has EEG alpha activity when a person’s eyes are closed and they are not engaging in

strenuous mental activity (e.g., counting backwards by 7's). Opening one's eyes or engaging in strenuous mental activity blocks EEG alpha activity and can masquerade as sleep if background EEG does not also show an increase in high-frequency activity. Additionally, about 10% of healthy individuals have poorly formed or absent EEG alpha activity. Finally, severely sleep deprived individuals may emit alpha activity when awake with eyes open. See Note 1.

5.2.2 Asleep (Elemental Measure)

Direct Measurement: There are no direct measures of sleep. A person in a quiescent state may be either in quiescent wakefulness or asleep. Under normal circumstances, a person cannot by self-report say that they are asleep while they are asleep, however, they may indicate having been asleep when questioned immediately post hoc during wakefulness. In general, individuals are less responsive to most environmental stimuli when sleeping than during wakefulness, however, the arousal threshold varies greatly between individuals, as a function of the environmental stimulus's salience, and the underlying sleep process ongoing at the time the stimulus occurs.

Inferential Measurement: asleep can be inferred from

(a) Measurements made using movement sensors placed in the bedroom or the bed indicating sustained episodes without movement,
(b) Actigraphic measures showing sustained[1] periods with minimal or no movement,
(c) Detection of snoring or changes in breathing sounds (due to airway resistance when asleep vs. awake),
(d) Changes in autonomic activity (e.g., slowing of averaged heart rate, stabilization of respiratory rate, decreased of respiratory tidal volume, and/or decreased blood pressure). It should be noted that there may be transient changes in the opposite direction at the moment of sleep onset or when certain events occur during sleep (e.g., changes in sleep position),
(e) Decreased damping of evoked potentials' later components (e.g., very large N2 amplitudes to sounds; that is, the "evoked" K-complex),
(f) Sustained low body temperature.

Remarks/Caveats: Some of the inferential measures rely on relative quantities. For example, activity measures may decline when a person is asleep. Thus, some cutoff value must be determined for a particular device because different devices have different sensitivities. Similarly, ANS measures (e.g., heart rate, respiration, and blood pressure) decline as sleep begins. When at low levels one can infer the individual is asleep, unless they have a particular pathophysiology that alters this pattern. By contrast, electrodermal activity remains at a low level during REM, N1, and N2 sleep. Most electrodermal activity occurs during wakefulness and during N3 sleep; thus, if heart rate and respiration are high and electrodermal activity is also high, one may infer that the individual is awake (unless they routinely suffer with sleep terrors).

Although some relativistic measures cannot differentiate awake from sleep at a particular moment in time, they can provide useful ancillary data. For example, core body temperature declines and reaches its nadir during sleep and this information can be paired with actigraphy to help identify asleep periods. In sleep medicine, determination when an individual is asleep relies on polysomnography. However, polysomnography works best when a person has well-defined, clear EEG alpha activity. Sleep is scored when half, or more, of a 30-second epoch (time domain) has either a low voltage, mixed frequency EEG alpha activity; when sleep spindles or K-complexes are present; or when EEG slow wave activity is present. It should be noted that even with full polysomnography, precise differentiation between wakefulness and stage N1 sleep can be difficult and inter-scorer reliability is low. See Note 1.

5.2.3 Awakening from Sleep (Elemental Measure)

Direct Measurement: The one direct measure of an awakening from sleep is if a person reports having just awakened. Assuming the individual is not in a fugue state or having a parasomnia episode, behaviors indicating Awakening from Sleep include an individual opening their eyes, sitting up, getting out of bed, and/or beginning to engage in a purposeful activity (e.g., answering their cell phone or reading), after having been asleep. By definition, in order to "awaken from sleep" the individual must have been sleeping when this event occurs; therefore, measurement of "Awake" by observation must be preceded by a period of time determined to be sleep.

Inferential Measurement: Wakefulness (i.e., being awake) can be inferred from

(a) Measurements made using movement sensors placed on the individual, in the bedroom, or the bed indicating a transition from a sustained period without movement to significant activity. For example: (a) purposeful movement continuing for more than 15 seconds in duration or (b) movement with intensity exceeding some magnitude threshold.
(b) Changes in respiratory sounds,
(c) Changes in autonomic activity (e.g., sudden increased heart rate and/or respiration, increased blood pressure),

Remarks/Caveats: Some of the inferential measures rely on relative quantity (see discussion above concerning Awake and Asleep Methods and Measures). Although some relativistic measures cannot differentiate awake from sleep at a particular moment in time, they can provide useful ancillary data. In sleep medicine, determination when an individual is asleep relies on polysomnography. However, polysomnography works best when a person has well-defined, clear EEG alpha activity. Wakefulness is scored when half, or more, of a 30-second epoch (time domain) has EEG alpha activity. See Note 1.

5.2.4 Brief Awakening (Elemental Measure)

Direct Measurement: There are no direct measures for brief awakenings. Self-report conflicts with one of the characteristics of brief awakening which is non-awareness. Nonetheless, observation as described in “Awake” in combination with self-report (“I did not awake”) would be possible.

Inferential Measurement: A brief awakening can be inferred from:

(a) Measurements made using movement sensors placed in the bedroom or the bed indicating a transition from a sustained period without movement to a brief bout of movement,
(b) Changes in respiratory sounds,
(c) Actigraphic measures showing relatively short periods (e.g., 3-15 seconds) of movement arising from sustained periods without movement,
(d) Short duration changes in autonomic activity (e.g., sudden increased heart rate and/or respiration, increased blood pressure),

Remarks/Caveats: The main challenge to inferentially determining a brief awakening’s occurrence lies with whether the sleep process is interrupted when the above indicators manifest. For example, when an individual changes sleep position, there may be transient increased heart rate and overall body movement. The question then becomes whether that constitutes an “activation” or an “awakening”. This issue is not completely resolved in the scientific arena. Furthermore, some of the inferential measures rely on relative quantity (see discussion above concerning Awake and Asleep Methods and Measures). Although some relativistic measures cannot differentiate awake from sleep at a particular moment in time, they can provide useful ancillary data. In sleep medicine, determination when an individual had a brief awakening relies on polysomnography. However, polysomnography works best when a person has well-defined, clear EEG alpha activity. A brief Arousal is scored 3-15 seconds of EEG alpha activity occurs from N1, N2, or N3 sleep. To qualify as a brief arousal from REM sleep there must also be accompanying increased submentalis (chin) muscle (EMG) tone. The Brief Awakenings based exclusively on motion can be difficult to differentiate between movements in sleep. See Note 1.

5.2.5 Brief Moment of Sleep (Dozing) (Elemental Measure)

Direct Measurement: There are no direct measures for brief moment of Sleep (Dozing) as there is no direct measurement for “Asleep”. Under normal circumstances, self-report is not possible as the individual might be unaware of the sleep episode.

Inferential Measurement: 3-30 seconds of being “Asleep” (measured as described in 4.3.2) preceded and followed by sustained episodes of being ‘awake’. These short episodes of “dozing” may occur intermittently but may increase in frequency and finally lapse into sustained sleep.

Remarks/Caveats: There are no sleep medicine standards for defining brief moments of sleep (dozing); however, the term “micro-sleep” exists in the literature related to sleep deprivation and hypersomnolence. Nonetheless, the concept of dozing and attentional lapses is central to the occupational medicine field’s focus on fatigue and fatigue-related accidents. For further discussion, see sections above describing methods and indicators for ‘Awake’ and ‘Asleep’. See Note 1.

5.3 Terms Derived from Basic Features of Wakefulness, Sleep as they relate to the Sleep Episode and its Surround

5.3.1 Initial Sleep Onset Time (Elemental Measure)

Direct Measurement: Initial Sleep Onset Time needs the detection of ‘asleep’ per 4.3.2. There is no direct measurement of ‘asleep’ therefore Initial Sleep Onset Time cannot be measured directly.

Inferential Measurement:

a) Initial Sleep Onset Time measured with TATS Start Time: This is the preferred method as the definition of Initial Sleep Onset Time is based on TATS Start Time. Therefore, the first occurrence of ‘asleep’ measured as described in section 4.3.2 after passing one epoch of TATS Start Time measured as described in 4.2.1 without passing an epoch of TATS End Time as described in 4.2.2 defines the Initial Sleep Onset Time.
b) Initial Sleep Onset Time measured with TIB Start Time: This is a further method as TATS Start Time might not be available as data. In this case, the first occurrence of ‘asleep’ measured as described in section 4.3.2 after passing one epoch of TIB Start Time measured as described in 4.2.3 without passing an epoch of TIB End Time as described in 4.2.4 defines the Initial Sleep Onset Time. See Caveat for this method on limitations.
c) Initial Sleep Onset Time measured without TATS start Time or TIB Start Time: This is the least preferred method but possible. In case neither TATS Start Time nor TIB Start Time data are available the Initial Sleep Onset Time is the first occurrence of ‘asleep’ measured as described in 4.3.2 following at least one epoch of ‘Awake’ as described in 4.3.1., both of these being the first occurrences in a measurement cycle.

Remarks/Caveat: The method described in paragraph a) is the most exact one. Sleep Latency (see 4.4.3) can safely be calculated if this method is used. In case method b) **i**s used the Initial Sleep Onset Time had been measured precisely but a sleep latency calculation has limitations as any activity after TIB, i.e. reading a book or watching TV would be added to sleep latency time, which is incorrect. In case method c) is used no sleep latency can be determined.

5.3.2 Final Awakening Time (Elemental Measure)

Direct Measurement: Final Awakening Time needs the detection of ‘asleep’ per 4.3.2. There is no direct measurement of ‘asleep’ therefore Final Awakening Time cannot be measured directly.

Inferential Measurement:

a) Final Awakening Time measured with TATS End Time: This is the preferred method as the definition of Final Awakening Time is based on TATS End Time. Therefore, the final occurrence of ‘asleep’ measured as described in section 4.3.2 before passing one epoch of TATS End Time measured as described in 4.2.2 without passing an epoch of TATS Start Time as described in 4.2.1 defines the Final Awakening Time.
b) Final Awakening Time measured with TIB End Time: This is a further method as TATS End Time might not be available as data. In this case, the final occurrence of ‘asleep’ measured as described in section 4.3.2 before passing one epoch of TIB End Time measured as described in 4.2.4 without passing an epoch of TIB Start Time as described in 4.2.3 defines the Final Awakening Time. See Caveat for this method on limitations.
c) Final Awakening Time measured without TATS End Time or TIB End Time: This is the least preferred method but possible. In case neither TATS End Time nor TIB End Time as data are available the Final Awakening Time is the final occurrence of ‘asleep’ measured as described in 4.3.2 before at least one epoch of ‘Awake’ as described in 4.3.1., both of these being the final occurrences in a measurement cycle.

Remarks/Caveat: The method described in paragraph a) is the most exact one. Latency to arising (see 4.4.4) can safely be calculated if this method is used. In case method b) is used the Final Awakening Time had been measured precisely but a latency to arising calculation has limitations as any activity before TIB, end time i.e., reading a book or watching TV would be added to latency to arising time, which is incorrect. In case method c) is used no latency to arising can be determined.

5.4 Specific Terms Describing Processes Occurring during Sleep based on Polysomnography

5.4.1 REM Sleep (Elemental Measure)

Sleep Medicine Standard: REM sleep is scored when all of the following activities are present in any specific 30-second epoch (time domain):

1. Low amplitude, mixed frequency EEG activity without K complexes or sleep spindles.
2. Low chin EMG tone for the majority of the epoch and concurrent with rapid eye movements.
3. Rapid eye movements at any position within the epoch.

Additionally include epochs as part of REM sleep, even when they do not have eye movements, when they are contiguous with or preceding epochs of REM sleep (as indicated above) if:

1. The EEG shows low-amplitude, mixed frequency activity without K complexes or sleep spindles.
2. The chin EMG tone remains low (at stage REM sleep levels).
3. There are no intervening central nervous system arousals.
4. Slow eye movements following an arousal or wakefulness are absent.

The above designation for REM sleep uses the following definitions: rapid eye movements are conjugate, irregular, sharply peaked with the initial polygraph deflection lasting less than 0.5 seconds and low chin EMG refers to submentalis muscle activity that is not higher than in any other sleep stage (and is usually the lowest during the entire recording).

Remarks/Caveat: This is a specific definition that was derived from PSG recordings and is used as a standard in sleep medicine. However, there are many other activities that occur during REM sleep and those measures have been used to detect REM sleep. Nonetheless, it is recommended that consumer device manufacturers adhere to the strict definition to avoid ambiguity.

5.4.2 N1 (Elemental Measure)

Sleep Medicine Standard: N1 sleep is scored when all of the following activities are present in any specific 30-second epoch (time domain):

1. Low amplitude, mixed frequency EEG activity without K complexes or sleep spindles.
2. No rapid eye movements.
3. No contiguous epoch scored as REM sleep.

N1 Sleep may also contain:

1. Slow eye movements
2. EEG Vertex Sharp Waves

5.4.3 N2 (Elemental Measure)

Sleep Medicine Standard: N2 sleep is scored when the following activities are present within a specific 30-second epoch (time domain):

1. EEG spindle activity or K complexes.
2. No rapid or slow eye movements.
3. Less than 6 seconds of 70 microvolt (or greater) EEG slow wave activity.

5.4.4 N3 (Elemental Measure)

Sleep Medicine Standard: N3 sleep is scored when the following activities are present within a specific 30-second epoch (time domain):

1. 6 seconds (or more) of 70 microvolt (or greater) EEG slow wave activity.

An epoch of N3 sleep may also contain sleep spindles and other EEG waveform activities; however, it is indicated by the presence of slow waves.

5.4.5 CNS Arousal (Elemental Measure)

Sleep Medicine Standard: A Central Nervous System (CNS) Arousal is indicated by a burst of EEG alpha activity with a duration of 3 seconds (or longer) but less than 15 seconds occurring in stage N1, N2, or N3 sleep. To be considered a CNS arousal from REM sleep, the burst of EEG alpha activity must also be accompanied by an increase in submentalis (chin) EMG activity. Persistent EEG alpha activity for 15 seconds (or longer) is considered an awakening rather than an arousal.

5.5 Terms used to describe the Sleep-Wake Cycle over Time Periods Exceeding 7 Days

5.5.1 Sleep-Wake Regularity (Elemental Measure)

Direct Measurement: It is theoretically possible to record 24-h PSG for a week to determine the regularity of the timing of sleep and wake over 24-h periods.

Inferential Measurement: Sleep and Wake inferred from ambulatory devices (e.g., actigraphy) are commonly used to determine Sleep-Wake Regularity. Bed- or room-based sensors and direct observation can be used in cases in which the individual is confined to bed or a single room.

5.5.2 Sleep-Wake Fragmentation (Elemental Measure)

Direct Measurement: It is theoretically possible to record 24-h PSG for a week to determine the fragmentation of sleep and wake over 24-h periods.

Inferential Measurement: Sleep and Wake inferred from ambulatory devices (e.g., actigraphy) are commonly used to determine Sleep-Wake Fragmentation. Bed- or room-based sensors and direct observation can be used in cases in which the individual is confined to bed or a single room.

5.5.3 Sleep-Wake Amplitude (Elemental Measure)

Direct Measurement: It is theoretically possible to record 24-h PSG for a week to determine the amplitude of the sleep and wake rhythm.

Inferential Measurement: Sleep and Wake inferred from ambulatory devices (e.g., actigraphy) are commonly used to determine Sleep-Wake Amplitude. Bed- or room-based sensors and direct observation can be used in cases in which the individual is confined to bed or a single room.

5.5.4 Circadian Phase (Elemental Measure)

Direct Measurement: Under very specific, highly controlled, laboratory environments, the timing (phase) of the central circadian clock can be determined through examination of specific variables under direct control of the clock (e.g., melatonin, core body temperature, cortisol).

Inferential Measurement: As the timing of the central clock is set by light exposure patterns, these 24-h patterns could be used to infer the position of this clock.

Remarks/Caveats: Phase cannot be determined using a direct method under an ad libitum, ambulatory environment as variables such as light exposure, sleep, and activity can all influence the variables controlled by the circadian clock.

5.5.5 Circadian Phase Angle (Elemental Measure)

Direct Measurement: The relative timing of two different events controlled by the circadian clock (e.g., sleep onset and melatonin onset) can be determined through direct measurement of these events (e.g., PSG determination of Initial Sleep Onset Time and Circadian Phase determination through dim light melatonin onset).

Inferential Measurement: Measurements that can infer different circadian clock outputs (e.g., light sensor to determine Circadian Phase and accelerometer to determine Sleep Onset Time) can be used and are specific to the outputs being examined.

5.5.6 Circadian Period Length (tau) (Elemental Measure)

Direct Measurement: Under very specific, highly controlled, laboratory environments, the Period Length of the central circadian clock can be determined through examination of specific variables under direct control of the clock (e.g., melatonin, core body temperature, cortisol).

Inferential Measurement: Given a data set of sufficiently large size, it may be possible to infer Period Length from an ambulatory data source that is controlled by the circadian clock (e.g., sleep patterns).

5.5.7 Circadian Amplitude (Elemental Measure)

Direct Measurement: Under very specific, highly controlled laboratory environments, Circadian Amplitude can be determined through examination of the amplitude of the first harmonic of a fit to core body temperature or the duration of melatonin secretion.

Inferential Measurement: Given a data set of sufficiently large size, it may be possible to infer Circadian Amplitude from the oscillation amplitude of multiple ambulatory data sources that are partially controlled by the circadian clock.

Consumer Technology Association Document Improvement Proposal

If in the review or use of this document a potential change is made evident for safety, health or technical reasons, please email your reason/rationale for the recommended change to standards@CTA.tech.

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