Literature

Caffeine Intake

- **Can it be detected?** This is an **emerging capability** and is **not a standard feature** in any consumer device yet. The literature shows it is scientifically possible and in the advanced research phase.
- **How it's Measured:** This is not *inferred* like stress. Research is focused on creating **electrochemical biosensors** in skin patches or bands. These sensors directly detect the caffeine molecule (or its metabolites) in your **sweat** or **interstitial fluid** (the fluid just under the skin).
- **Accuracy & Real-Time:** This is the key research challenge. Accuracy is improving, and studies are now showing a strong correlation between the sensor's reading from sweat and the "gold standard" measurements from **blood or saliva**. It is designed for *real-time*, continuous monitoring, but it's not yet commercially available or validated for large-scale consumer use.
- **Literature Backing:**
    - **Title:** *Determination of Ascorbic Acid, Acetaminophen, and Caffeine in Urine, Blood Serum by Electrochemical Sensor...*
    - **Finding:** This 2021 study details the creation of an electrochemical sensor that can successfully and simultaneously detect caffeine, acetaminophen, and ascorbic acid in real human samples (blood serum and urine). This type of paper demonstrates the fundamental science of *how* a sensor can be built to accurately identify the caffeine molecule, validating the chemical sensing principle that a wearable device would use.
    - **Link:** https://www.researchgate.net/publication/349495519_Determination_of_Ascorbic_Acid_Acetaminophen_and_Caffeine_in_Urine_Blood_Serum_by_Electrochemical_Sensor_Based_on_ZnO-Zn2SnO4-SnO2_Nanocomposite_and_Graphene

Light Exposure Hours

- **Can it be detected? Yes, absolutely.** This is an **established and accurate** feature in many modern, high-end wearables (e.g., Apple Watch).
- **How it's Measured:** This is a **direct measurement** using a built-in **Ambient Light Sensor (ALS)**. This is the same sensor that adjusts your screen brightness. The device continuously or periodically measures the *illuminance* (brightness, measured in lux) of your surroundings. The "Hours" part is a simple calculation: summing up the total time spent in environments above a certain brightness threshold (e.g., > 1000 lux for "outdoor" or "daylight").
- **Accuracy & Real-Time:** The sensor itself is very accurate for its purpose—measuring the light *at the watch*. It provides real-time data. Its main limitation is *placement*. A watch under a sleeve will read 0 lux, even if you are outdoors. The data is most accurate when the sensor is exposed to your environment.
- **Literature Backing:**
    - **Title:** *Using Wearable Sensors to Measure and Predict Personal Circadian Lighting Exposure in Nursing Home Residents: Model Development and Validation*
    - **Finding:** This 2025 study (PMID: 41055091) did exactly what you're asking about. It *validated* wearable light sensors against professional "gold standard" instruments (spectrometers). The calibration models for photopic lux (brightness) showed **strong accuracy (adjusted R^2 of 0.858)**, confirming that wearable sensors are a "reliable," "effective," and "scalable" method for accurately assessing personal circadian light exposure.
    - **Link:** https://pubmed.ncbi.nlm.nih.gov/41055091/

Heart Rate Variability (HRV)

- **Can it be detected? Yes.** This is a standard and well-validated feature of most modern wearables with an optical heart rate sensor.
- **How it's Measured:** It's measured using the **Photoplethysmography (PPG)** sensor (the green or red lights on the back of the watch). This sensor detects the tiny variations in the time *between* each heartbeat.
- **Accuracy & Real-Time:** Accuracy is highest when you are at rest, particularly during sleep. While a medical-grade Electrocardiogram (ECG) is the "gold standard," high-quality PPG sensors have shown "very good to excellent" correlation at rest. They are highly reliable for tracking your *trends* over time.
- **Literature Backing:**
    - **Title:** *Can Wearable Devices Accurately Measure Heart Rate Variability? A Systematic Review*
    - **Finding:** This review concludes that while accuracy can decrease with intense exercise (due to motion), wearable devices "may provide a promising alternative solution" to traditional ECGs for measuring HRV, especially in resting conditions.
    - **Link:** https://www.researchgate.net/publication/320114620_Can_Wearable_Devices_Accurately_Measure_Heart_Rate_Variability_A_Systematic_Review

Body Temperature

- **Can it be detected? Yes, but with an important distinction.**
- **How it's Measured:** Wearables use **skin temperature sensors**.
- **Accuracy & Real-Time:** These devices are highly accurate at measuring your *skin* temperature. However, skin temperature is not the same as your *core* body temperature (which is what a medical thermometer measures). Your skin temperature changes more rapidly based on your environment. Modern wearables (like Oura, new Apple Watches, etc.) are excellent at tracking your *relative changes* and *trends* (e.g., detecting the onset of a fever or tracking ovulation) rather than giving you a perfect "core" number at any single moment.
- **Literature Backing:**
    - **Title:** *Comparing body temperature measurements using the double sensor method within a wearable device with oral and core body temperature measurements*
    - **Finding:** This 2023 study highlights new methods (like a "double sensor") that are being used to improve the accuracy of wearable estimates. It shows that while there are differences, the wearable data is clinically relevant and shows "high accordance" in tracking changes.
    - **Link:** https://www.frontiersin.org/articles/10.3389/fphys.2023.1279314/full

Movement During Sleep

- **Can it be detected? Yes, this is one of the original and most accurate features.**
- **How it's Measured:** This is done using an **accelerometer**, a sensor that detects motion. The science of using an accelerometer to track sleep/wake cycles is called **"actigraphy."**
- **Accuracy & Real-Time:** It is extremely accurate at detecting *movement*. Its main limitation is that it can sometimes be fooled if you are lying perfectly still but are *awake* (it may count this as "light sleep"). However, when combined with heart rate data (as modern watches do), its accuracy improves dramatically.
- **Literature Backing:**
    - **Title:** *How Is Actigraphy Used to Evaluate Sleep?* (From the Sleep Foundation)
    - **Finding:** This article explains that actigraphy (movement tracking) is a well-established method for analyzing sleep. While the "gold standard" for *diagnosing* sleep disorders is Polysomnography (PSG), actigraphy is "quite accurate at identifying how long healthy people sleep" and is the accepted alternative for real-world, multi-night studies.
    - **Link:** https://www.sleepfoundation.org/sleep-studies/actigraphy

Sleep Duration Hours

- **Can it be detected? Yes, this is a calculated metric, and it's generally very good.**
- **How it's Measured:** This is not a direct sensor reading. Instead, the watch *calculates* your sleep duration by combining data from:
    - **Accelerometer** (Movement)
    - **PPG Sensor** (Heart Rate & HRV)
    - Sometimes **Skin Temperature** The device's algorithm uses the sharp drop in heart rate, rise in HRV, and lack of motion to determine *when you fell asleep* and the reverse to determine *when you woke up*.
- **Accuracy & Real-Time:** Modern, multi-sensor devices are very accurate at estimating Total Sleep Time, often comparable to actigraphy and much more convenient than a lab-based PSG.
- **Literature Backing:**
    - **Title:** *Performance of consumer wrist-worn sleep tracking devices compared to polysomnography: a meta-analysis*
    - **Finding:** This 2025 meta-analysis (a study of many other studies) compared consumer wearables to the "gold standard" PSG. It found that while there are statistical differences (no wearable is perfect), they are effective and valid tools for tracking sleep parameters like total sleep time in real-world environments.
    - **Link:** https://jcsm.aasm.org/doi/10.5664/jcsm.11460

Stress Level

- **Can it be detected? Yes, this is an inferred metric.** The watch isn't reading your mind, it's reading your *body's physiological response* to stress.
- **How it's Measured:** "Stress" is almost always a calculation based on your **HRV**.
    - **High Stress =** Your Autonomic Nervous System is in "fight-or-flight" mode, causing your heart to beat very regularly (like a metronome). This leads to a **low HRV**.
    - **Low Stress (Relaxed) =** Your "rest-and-digest" system is active, causing your heart rate to be more adaptable and varied. This leads to a **high HRV**.
    - Some devices (like Fitbit) also use **Electrodermal Activity (EDA)** sensors, which measure tiny changes in sweat on your skin, another direct indicator of a stress response.
- **Accuracy & Real-Time:** It is an accurate *proxy* for physiological stress. It can't tell you *why* you're stressed (it could be a bad meeting or an exciting movie), but it can accurately tell you *that* your body is in an aroused or stressed state.
- **Literature Backing:**
    - **Title:** *HRV Features as Viable Physiological Markers for Stress Detection Using Wearable Devices*
    - **Finding:** This study confirms that HRV features are "good markers for stress detection." It used machine learning to classify stress from HRV features and concluded that wearables are a "non-invasive and reliable tool for stress monitoring and detection."
    - **Link:** https://www.mdpi.com/1424-8220/21/8/2873

Bed Time Consistency

- **Can it be detected? Yes, 100%. This is a pure calculation.**
- **How it's Measured:** This feature doesn't use a sensor at all. It is simple math performed on your *log* of sleep data. The device's app looks at your "sleep start" and "sleep end" times (from the "Sleep Duration" feature) over the past several days and calculates the *variation* (e.g., the standard deviation) in those times.
- **Accuracy & Real-Time:** The calculation itself is perfectly accurate. Its *usefulness* depends entirely on the accuracy of the underlying "Sleep Duration" detection (which, as noted above, is quite good).
- **Literature Backing:**
    - **Title:** *Sleep and Circadian Wearable Technologies: Considerations towards Device Validation and Application*
    - **Finding:** This paper discusses the importance of using wearables to quantify sleep and circadian rhythms outside a lab. It highlights the value of these devices for "long-term monitoring" to gather data on sleep continuity and rhythm. "Bed Time Consistency" (often called "Sleep Regularity" in research) is a key output of this long-term monitoring.
    - **Link:** https://www.researchgate.net/publication/343938855_Sleep_and_Circadian_Wearable_Technologies_Considerations_towards_Device_Validation_and_Application