



# Case study: Non-invasive and continuous elevated body temperature detection with greenTEG core body temperature sensor solution

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## 1. Abstract

In this study we present a unique method for detecting elevated body temperature by **continuous and non-invasive measurement of the core body temperature** using greenTEG's gSKIN® heat flux sensors.

greenTEG provides sensor solutions which can be easily integrated into **any wearables**, such as

- patches
- chest and arm straps
- wrist bands
- smartwatches
- textiles

This enables devices to **detect elevated core body temperatures** in **real-time** without repeated measurements using conventional (infrared, rectal) techniques. This has potential to **improve patient monitoring** for various applications, such as

- hospital and ambulatory patient care
- baby and infant monitoring
- elderly care
- consumer-based devices for everyday life

In this study, the sensors are integrated into a patch which is worn on the torso (slightly caudal of the armpit) during sleep and daily life. greenTEG's algorithm then outputs a temperature signal which successfully reproduces the temperature progress during elevated body temperature and successive intakes of antipyretics with an accuracy of 0.24 °C.

## 2. Experimental setup

### 2.1 Equipment

The greenTEG gSKIN® BodyTemp demonstration and test patch used in this study (Figure 1) contains the gSKIN® XU 2mm x 2mm SMD mountable sensor (Figure 2, greenTEG's product), together with ultra-high precision temperature sensors, an accelerometer, a flash storage and a BLE wireless module. It possesses logging capability for up to 4 days of continuous data collection. Thanks to its internal storage, the patch collects data completely autonomously without the need for a constant wireless connection to a host device. At the end of the measurement the data can be downloaded via Bluetooth to a smart phone using an android app.



Figure 1 – The logging device: gSKIN® BodyTemp patch



Figure 2 - gSKIN® heat flux sensor for wearable integration; the core element for accurate CBT measurement

## 2.2 Measurement procedure

The study contains measurements of a 40-year-old male subject with a BMI of 27.4. The measurement lasted approximately 38 hours. The subject developed a fever while at work. At this point the measurement was started. After returning home the rest of the measurement time was spent mainly in bed. The e-Celsius Performance Pill system from BodyCap was used to obtain the reference core temperature. It consists of an [ingestible radio pill](#) that wirelessly transmits core body temperature to an [external receiver](#). The tympanic reference measurements were taken with a commercial Braun infrared thermometer.

## 2.3 Data analysis

At the start of the measurement the algorithm was provided once with the current core body temperature (tympanic measurement) for calibration. Then, the raw measurement values were recorded during the study and downloaded afterwards via the greenTEG app. Finally, greenTEG's algorithms were applied to the raw data and plotted against the temperature reference. The algorithm combines the sensor signals to yield a temperature output every second while at the same time compensating for physiological thermoregulation.

## 3. Results and discussion

greenTEG's algorithm accurately predicts the temperature variations due to elevated body temperature and antipyretic medication by leveraging the information of the gSKIN® heat flux sensor and the temperature sensor. The combination of both is needed to compensate spurious environmental and physiological effects. For this study, the **mean absolute** deviation of greenTEG's prediction to the reference is **0.24 °C**.

The following observations can be made

- greenTEG's sensor solution correlates very well with the reference core body temperature
- Skin temperature alone does not reliably reproduce the variations in core temperature
- greenTEG's algorithm predictions and the tympanic control measurements show comparable deviations to the reference

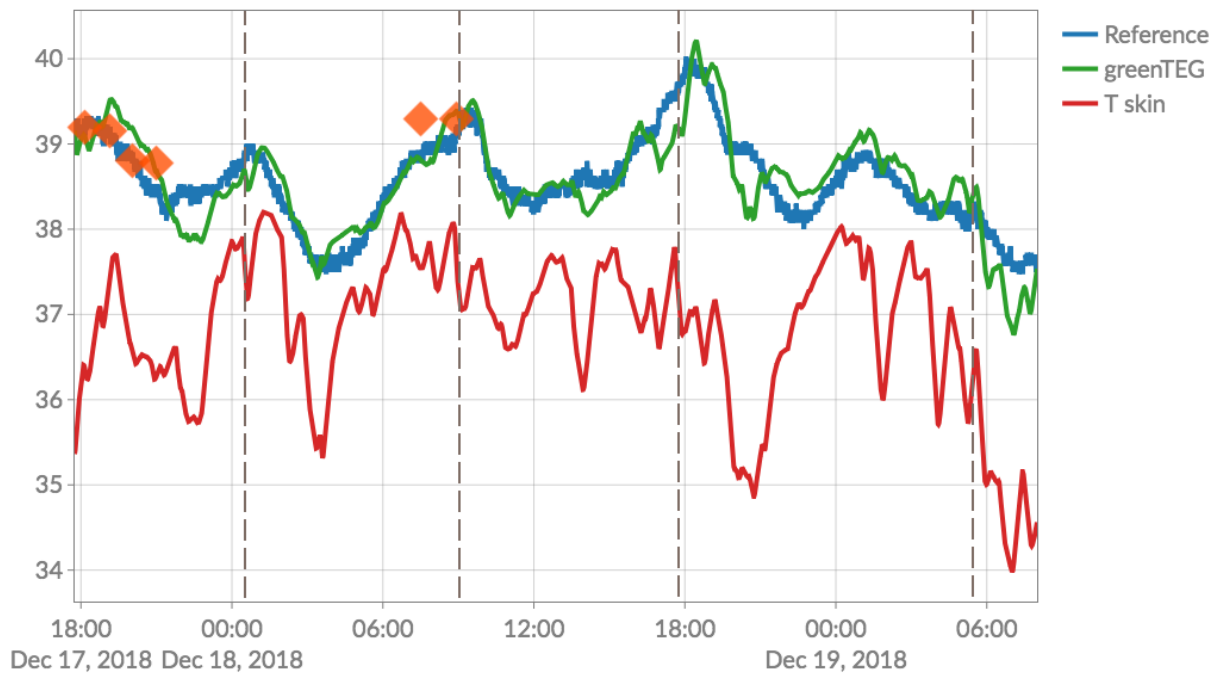


Figure 3 – Reference core body temperature (blue curve), greenTEG's algorithm output (green curve), and skin temperature (red curve). Indicated are also tympanic temperature measurements (orange diamonds) and intakes of 500 mg paracetamol (dashed lines). Vertical axis indicates temperature in °C.

## 4. Conclusion

This study shows the viability of greenTEG's solution to detect elevated body temperature with a patch on the torso by correctly reproducing variations in core body temperature. The strength of the gSKIN® heat flux sensor used here is its high sensitivity and small footprint enabling flexible integration into any wearable device. This will enable future wearables to track elevated body temperature non-invasively and continuously.

We gladly help to adapt our method to your use case. Furthermore, our engineers at greenTEG are happy to support you in integrating the sensors into your device. For further information, please contact [lukas.durrer@greenteg.com](mailto:lukas.durrer@greenteg.com)