Protocol: STEP

Objectives

There hasn't yet been a systematic study to determine whether digital biomarkers are affected by skin variations, including natural tone/freckling, subcutaneous fat, hair, tattoos, etc. The ability to develop and use digital biomarkers in underserved populations is dependent on this technology working across all skin and body types. The central hypothesis of Aim 1 is that we can characterize deviations in digital biomarkers such as heart rate and blood oxygen saturation due to PPG inaccuracies across diverse skin and body profiles.

Background & Significance

PPG measures changes in blood volume under the surface of the skin through changes in light absorption. There have been several studies showing that skin tone, thickness of subcutaneous fat, and skin ink (tattoos, henna) affect light absorption, leading to inaccuracies in PPG measurements. Darker skin tones in particular effect sensor readings because they absorb more green light. This previous body of work provides evidence that PPG inaccuracies across diverse skin and body profiles exist and we can characterize deviations in the digital biomarkers.

Design & Procedures

Aim 1.1 Recruit up to 75 subjects with equally distributed skin tones on the Fitzpatrick skin tone scale.

We will recruit up to 75 participants that have an equal distribution of skin tones based on the Fitzpatrick skin tone scale, the gold standard for classifying skin tones on a scale 1-6. The von Luschan scale will also be measured by the study coordinator during the study, which is a more sensitive scale with 1-36 skin tones. For further granularity, spectroscopy measurements of skin tone color will be taken with a Linksquare handheld spectrophotometer. The subjects will be selected to provide a normal distribution of values on the von Luschan skin tone scale. Selection will occur after potential subjects complete a short visual survey that compares their skin tone to the von Luschan scale.

Aim 1.2 Monitor heart rate and blood oxygen saturation using both research and consumer grade PPG devices and clinical PPG and ECG devices in 50 subjects with equally distributed skin tones.

In the subjects recruited in Aim 1.1 , we will measure heart rate (HR) and blood oxygen saturation (SPO2) at rest, while performing a physical activity such as walking for 5 minutes (or until heart rate is elevated to 50% of maximum heart rate, where maximum heart rate is participant age subtracted from 220 bpm), and while performing a wrist-dominant task such as typing on a keyboard. Measurements will be taken simultaneously with consumer PPG devices, research-grade PPG devices, clinical PPG (pulse in tones on the von Luschan skin tone scale and BMI will be oximetry), and electrocardiogram (ECG). Skrecorded for each patient to categorize subjects by skin tone and body profile.

The consumer-grade PPG devices we will utilize to take PPG measurements include: Apple Watch, Fitbit, Garmin, and XiaoMi MiBand. The research-grade PPG devices we will utilize to take PPG measurements include the Empatica E4, the Biovotion Everion. For the ECG, we will make measurements with the Bittium Faros, Preventice BodyGuardian, Welch Allyn Tagecg, or the Alivecor Kardia, and Polar chest strap. All of the devices listed in this study are FDA-cleared.

Aim 1.3 Compare resting heart rate (RHR), HR during movement, and heart rate variability (HRV) metrics from research, commercial, and clinical PPG devices and ECG across different skin tones and body profiles.

Building upon our previous work describing metrics of RHR, heart rate during activity, and HRV using PPG and ECG, we will compare these metrics and statistically validate our comparisons with multiple t-tests and post-hoc tests. This will provide metrics of variability across various skin tones, body profiles defined by BMI, and different PPG devices.

Selection of Subjects

Inclusion Criteria:

We will consider all participants who do not meet the exclusion criteria below.

Exclusion criteria:

Participants will be excluded who:

Anyone who self-reports skin conditions that may be exacerbated by participation in the study (including, but not limited to: skin sensitivities, rash, contact dermititis, hypersensitivity of the skin, and all inflammatory skin disorders)

Anyone who self-reports taking medications that affect heart rate, including Adderall, performance-enhancing drugs, human growth hormones, and illegal substances

Subject Recruitment & Compensation

We will recruit from the undergraduate and graduate student populations. Subjects will be recruited through recruiting materials (flyers) posted around the Duke University student campus. The recruiting materials will have potential participants complete a brief online survey asking for skin tone, body mass index (height and weight), exclusion criteria questions, and potential participant contact information. Study research team will select participants in order to select subjects that represent the relevant demographic groups with a diversity of skin tones and body profiles. The research team will contact selected participants.

Participants will be compensated with $20 for their time and travel.

Subject’s Capacity to Give Legally Effective Consent

Subjects who do not have the capacity to give legally effective consent will not be approached for participation in this study.

Risk/Benefit Assessment

Risks of PPG and ECG sensors:
Risks of wearing the sensors are minimal and may include irritation around the wristband, armband, or finger holder. Risks associated with ECG sensing includes skin irritation at the site of chestband.

Risks to Confidentiality: Participation in research involves some loss of privacy. We will do our best to make sure that information about the participant is kept confidential, but we cannot guarantee total confidentiality. Personal information may be viewed by individuals involved in this research and may be seen by people including those collaborating, funding, and regulating the study. We will share only the minimum necessary information in order to conduct the research. A participant's personal information may also be given out if required by law.

Risks specific to Device Data:
Data collected by devices is streamed via secure Bluetooth (BLE) technology and/or via USB cable to mobile and/or web-based applications. Each device/application we are using claims to be secure, compliant with federal privacy regulations, and used and tested by other academic centers. Data may be stored in servers that are external to Duke. We seek to minimize risk by using subject identification numbers so there will be no personal identifiers associating the participant with the data being collected.

Benefits to Taking Part in the Study:
There will be no direct medical benefit to subjects participating in the study. In the future, the knowledge generated from this study may help to develop PPG sensors that work across all skin tones and body profiles.

Data Analysis & Statistical Considerations
We based our power estimates on a small pilot study done on skin type and PPG wavelength (Fallow, et.al.). Our power calculations with alpha=0.5 and Power=0.8 require 48 participants normally distributed among the skin tone categories as described by the von Luschan skin tone chart and the Fitzpatrick skin category.
We plan to enroll up to 75 participants but only use data from 50 participants because we expect some errors in data collection. Based on previous experiments, we expect approximately 30% of data collected from PPG and ECG to have missing values. Thus, we will enroll 75 and expect to have 50 participants without missing data. Our target accrual will be 75 participants. We anticipate an accrual rate of 5 participants per week for 4 months. By recruiting students, we are confident that this accrual target will be met.

Data & Safety Monitoring
Safety concerns in this study include standard risks for undergoing ECG and PPG, including skin irritation at sensor or wristband/chestband sites. The PI will review adverse events as they occur to determine if there are any unexpected risks or if events are occurring at a higher than the expected rate. Events will be recorded in the study documentation and reportable events will be submitted to the Duke Health System Institutional Review Board. A data safety monitoring committee will not be used in this feasibility study. Internal monitoring of data may occur as required by Duke for investigator-initiated clinical research.