# Supplementary Information

# Supplementary Figures

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| **A** |
| **B** |

**Supplementary Figure 1. Detailed user interface for both heart rate (HR) and respiratory rate (RR) measurements.**





**Supplementary Figure 2. Number of participants enrolled and data analyzed in (A) the heart rate (HR) study and (B) the respiratory rate (RR) study.** \*Failed study application data collection due to signal-to-noise ratio <0; \*\*Failed reference HR collection.

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| --- |
| **A** |
| **B** |

**Supplementary Figure 3. Additional Bland-Altman plots for the heart rate (HR) study (see Figure 2), for participants (A) at rest and (B) post-exercise.** Left to right: plots from the full study followed by subgroups based on skin type (see Figure 1). The reference HR was obtained from a pulse oximeter (see Methods). Dots represent individual participants; blue lines indicate the mean difference; red lines indicate the 95% limits of agreement (mean difference ± 1.96 standard deviations).



**Supplementary Figure 4. Participants’ survey results after the respiratory rate (RR) study.** The exact survey questions are provided in Supplementary Table 7.

# Supplementary Tables

**Supplementary Table 1A. Eligibility criteria of the heart rate (HR) study.**

|  |  |
| --- | --- |
| **Inclusion criteria** | * Age > 18 years
* Participant is able and willing to provide written informed consent (Attached document: GH-VV-002 [ICF Heart Rate Study])
* Reads and speaks English. (Spanish speaking participants may be enrolled based on IRB requirements and/or availability of bilingual clinical study staff)
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|
| **Exclusion criteria** | * Unwilling or unable to remove makeup or face covering for study participation
* Pregnancy - Women who are, or believe they might be, pregnant
* Inability to understand study procedures and/or the informed consent process
* Other medical complications that preclude completion of the study as determined by the principal investigator at each study site
* Significant tremor that is present while seated at time of study as determined by the study coordinator (upper chest or face)
* Ineligibility for physical activity based on interpretation of PAR-Q by the site’s principal investigator. Study participants who answer yes to one or more of the PAR-Q questions should be further assessed for eligibility by the site’s principal investigator.
 |
| **Enrollment requirements** | **Age*** ≥25% between 20–39 years old
* ≥25% between 40–59 years old
* ≥25% greater than 60 years old

**Skin Tones**Measured by Pantone Device; see Supplementary Table 2 for details* ≥30% Very light, light, intermediate (minimum 10 participants from each group, maximum 40 participants in total)
* ≥20% Tan, brown (minimum 10 participants from each group, maximum 30 participants in total)
* ≥30% Dark (minimum 30 participants)
 |

**Supplementary Table 1B. Eligibility criteria of the respiratory rate (RR) study.**

|  |  |
| --- | --- |
| **Inclusion criteria** | * Age > 18 years
* Participant is able and willing to provide written informed consent
* Reads and speaks English. (Spanish speaking participants may be enrolled based on IRB requirements and/or availability of bilingual clinical study staff)
 |
| Healthy cohort (n=10) | * No respiratory symptoms at time of study and no history of chronic respiratory conditions.
 |
| Cohort of chronic respiratory conditions (n=40) | * COPD of moderate severity as defined by at least one of the following:
	+ hospitalized for exacerbation within 1 year
	+ received oral steroids for COPD within 3 months
	+ Current use of supplemental oxygen at home.

 AND* + A Modified Medical Research Council (mMRC) breathlessness scale score of > 26
* Asthma that is not currently well-controlled, as determined by by one or more of the following;
	+ Emergency department visit and/or hospital admission for asthma within the preceding 3 months
	+ Use of oral corticosteroids for > 3 days for treatment of asthma within the preceding 3 months
	+ Use of a short acting beta agonist (SABA) for > 2 days during the preceding 7 days
 |
| **Exclusion criteria** | * Pregnancy - Women who are, or believe they might be, pregnant
* Inability to understand study procedures and/or the informed consent process
* Medical or other complications that preclude completion of the study as determined by the principal investigator at each study site
* Significant tremor that is present while seated at time of study as determined by the study coordinator (upper chest or face)
 |
| **Enrollment requirements** | Age* > 20% between 20–39 years old
* > 20% between 40–59 years old
* > 40% greater than 60 years old

Race/Ethnicity* > 20% self-identifying as of Hispanic/Latino ethnicity
* > 20% self-identifying as White
* > 20% self-identifying as African American/Black
 |

**Supplementary Table 2. Objective skin tone information was objectively measured by applying a Pantone RM200QC Spectro to each participant’s cheek and mapping the parameters to a Fitzpatrick skin type.** The numerical parameters were in the CIELAB color space, and the L\* and b\* parameters were converted to an individual typology angle (°ITA) as defined by the function [arctan(L\* - 50)/b\*] x 180/3.14159.

|  |  |  |
| --- | --- | --- |
|  **°ITA** | **Skin Tone Classification** | **Mapped to Fitzpatrick Skin Type** |
|  °ITA > 55° | Very Light | 1 |
| 41° < °ITA ≤ 55° | Light | 2 |
| 28° < °ITA ≤ 41° | Intermediate | 3 |
| 10° < °ITA ≤ 28° | Tan | 4 |
| -30° < °ITA ≤ 10° | Brown | 5 |
| °ITA ≤ -30° | Dark | 6 |

**Supplementary Table 3. Participant race and skin tone group stratified by signal-to-noise ratio (SNR) readings < 0 for the heart rate (HR) study.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | No. of participants with SNR<0 | No. of participants with SNR≥0 | P value\* |
| Age | 45.5 ± 16.4 | 41.2 ± 14.7 | 0.372 |
| Sex\*  Female Male | 11 (15.4%)3 (12.5%) | 60 (84.5%)21 (87.5%) | >0.99 |
| Race/ethnicity\*  White, non-Hispanic Black, non-Hispanic Asian / pacific islander Multiple races, non-Hispanic Multiple races, Hispanic | 5 (20.0%)8 (13.1%)1 (14.3%)0 (0.0%)0 (0.0%) | 20 (80.0%)53 (86.9%)6 (85.7%)1 (100%)1 (100%) | 0.798 |
| Measured skin tone\*\* 1 (Fitzpatrick types 1-3) 2 (Fitzpatrick types 4-5) 3 (Fitzpatrick type 6) | 5 (16.1%)4 (12.5%)5 (15.6%) | 26 (83.9%)28 (87.5%)27 (84.4%) | 0.938 |
| Fitzpatrick type 1 (Very light) 2 (Light) 3 (Intermediate) 4 (Tan) 5 (Brown) 6 (Dark) | 0 (0.0%)1 (6.3%)4 (28.6%)2 (40.0%)2 (7.4%)5 (15.6%) | 1 (100%)15 (93.8%)10 (71.4%)3 (60.0%)25 (92.6%)27 (84.4%) | 0.194 |

\* P values were calculated by Fisher’s exact test comparing participants with SNR<0 and those with SNR≥0

\*\* Fitzpatrick determination based on measurement with Pantone device and conversion to Fitzpatrick scale

**Supplementary Table 4. Detailed results of the heart rate (HR) study.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Session | Number of participants | Number of data points | Reference HR(beats/min) | MAE(beats/min) | MAPE |
| Mean ± SD | Range | Mean ± SD | Mean ± SD | Median (IQR) | 95th percentile |
| Total population | 95 | 352 | 79.8 ± 14.6 | 54–134 | 1.32 ± 3.92 | 1.63 ± 4.27 | 1.14 (0.0–1.64) | 4.84 |
|  At rest, flash on, regular light | 95 | 89 | 75.6 ± 11.1 | 55–113 | 0.87 ± 1.06 | 1.16 ± 1.38 | 1.22 (0.0–1.47) | 3.97 |
|  At rest, flash off, regular light | 95 | 92 | 74.8 ± 11.0 | 54–111 | 1.23 ± 3.01 | 1.64 ± 3.60 | 1.20 (0.0–1.64) | 4.77 |
|  At rest, flash off, dim light | 95 | 85 | 75.6 ± 11.2 | 55–110 | 0.96 ± 1.26 | 1.33 ± 1.77 | 1.18 (0.0–1.67) | 5.19 |
|  Post-exercise | 94 | 86 | 93.9 ± 15.4 | 59–134 | 2.23 ± 7.05 | 2.39 ± 7.45 | 1.02 (0.0–1.75) | 5.42 |
| Subgroup 1: very light, light, and intermediate skin tone | 31 | 119 | 81.0 ± 17.4 | 56–129 | 1.53 ± 4.73 | 1.77 ± 4.46 | 1.27 (0.0–1.83) | 4.84 |
|  At rest, flash on, regular light | 31 | 30 | 74.5 ± 11.8 | 58–113 | 1.03 ± 1.16 | 1.40 ± 1.56 | 1.28 (0.0–1.69) | 4.49 |
|  At rest, flash off, regular light | 31 | 31 | 74.0 ± 11.6 | 58–111 | 1.00 ± 1.15 | 1.36 ± 1.57 | 1.27 (0.0–1.64) | 4.59 |
|  At rest, flash off, dim light | 31 | 28 | 74.2 ± 12.3 | 56–110 | 1.04 ± 1.23 | 1.43 ± 1.72 | 1.23 (0.0–1.74) | 5.13 |
|  Post-exercise | 31 | 30 | 101.0 ± 15.9 | 63–129 | 3.03 ± 9.15 | 2.90 ± 8.46 | 1.09 (0.82–2.09) | 4.36 |
| Subgroup 2: tan and brown skin tone | 32 | 113 | 78.8 ± 12.7 | 54–107 | 1.04 ± 2.87 | 1.32 ± 3.30 | 0.98 (0.0–1.37) | 4.86 |
|  At rest, flash on, regular light | 32 | 28 | 76 .0± 11.3 | 55–97 | 0.86 ± 1.15 | 1.14 ± 1.40 | 1.23 (0–1.43) | 2.32 |
|  At rest, flash off, regular light | 32 | 29 | 75.2 ± 11.4 | 54–96 | 1.59 ± 4.98 | 1.97 ± 5.68 | 0.0 (0.0–1.35) | 4.93 |
|  At rest, flash off, dim light | 32 | 29 | 75 .0± 11.3 | 55–96 | 0.86 ± 1.27 | 1.20 ± 1.78 | 0.0 (0.0–1.72) | 5.35 |
|  Post-exercise | 32 | 27 | 89.5 ± 11.3 | 59–107 | 0.85 ± 2.28 | 0.93 ± 2.43 | 0.0 (0.0–1.10) | 1.35 |
| Subgroup 3: dark skin tone  | 32 | 120 | 79.7 ± 13.3 | 58–134 | 1.37 ± 3.89 | 1.77 ± 4.87 | 1.15 (0.0–1.64) | 4.48 |
|  At rest, flash on, regular light | 32 | 31 | 76.2 ± 10.6 | 61–110 | 0.71 ± 0.86 | 0.95 ± 1.17 | 0.91 (0–1.49) | 3.24 |
|  At rest, flash off, regular light | 32 | 32 | 75.3 ± 10.4 | 58–108 | 1.12 ± 1.66 | 1.61 ± 2.50 | 1.22 (0–1.93) | 3.71 |
|  At rest, flash off, dim light | 32 | 28 | 77.5 ± 10.0 | 60–107 | 1.00 ± 1.31 | 1.35 ± 1.87 | 1.19 (0–1.41) | 3.99 |
|  Post-exercise | 31 | 29 | 90.6 ± 15.9 | 61–134 | 2.69 ± 7.51 | 3.22 ± 9.27 | 1.12 (0.0–2.17) | 6.27 |

Abbreviations: HR, heart rate; MAE, mean absolute error; MAPE, mean absolute percentage error; SD, standard deviation; IQR, interquartile ranges

**Supplementary Table 5. Detailed results of the respiratory rate (RR) study.**

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroups | N | Reference RR(breaths/min) | MAE (breaths/min) |
| Mean ± SD | Range | Mean ± SD | Range | P value |
| Algorithm version A | 50 | 15.5 ± 3.6 | 8–22 | 0.84 ± 0.97 | 0–6 | <0.001 |
|  Healthy | 10 | 16.0 ± 3.7 | 10–20 | 0.60 ± 0.52 | 0–1 | 0.001 |
|  Chronic respiratory conditions | 40 | 15.4 ± 3.6 | 8–22 | 0.90 ± 1.05 | 0–6 | <0.001 |
| Algorithm version B | 50 | 15.3 ± 3.7 | 8–26 | 0.78 ± 0.61 | 0–2 | <0.001 |
|  Healthy | 10 | 16.4 ± 3.7 | 12–22 | 0.70 ± 0.67 | 0–2 | <0.001 |
|  Chronic respiratory conditions | 40 | 15.1 ± 3.7 | 8–26 | 0.80 ± 0.60 | 0–2 | 0.001 |

Abbreviations: RR, respiratory rate; MAE, mean absolute error; SD, standard deviation

**Supplementary Table 6. Subgroup analysis for algorithm version B of the respiratory rate (RR) study.**

|  |  |  |  |
| --- | --- | --- | --- |
| Subgroups | N | Reference RR(breaths/min) | MAE (breaths/min) |
| Mean ± SD | Range | Mean ± SD | Range | P value |
| Age subgroups |  |  |  |  |  |  |
|  <40 years old | 17 | 15.8 ± 4.4 | 10–26 | 0.79 ± 0.64 | 0–2 | <0.001 |
|  40–59 years old | 21 | 15.3 ± 3.1 | 10–22 | 0.79 ± 0.60 | 0–2 | <0.001 |
|  ≥60 years old | 12 | 14.8 ± 3.8 | 8–22 | 0.75 ± 0.62 | 0–2 | <0.001 |
| Race/ethnicity |  |  |  |  |  |  |
|  White, non-Hispanic | 18 | 15.4 + 4.1 | 8–26 | 0.72 + 0.67 | 0–2 | <0.001 |
|  Black, non-Hispanic | 6 | 18.0 + 4.0 | 12–22 | 0.83 + 0.41 | 0–1 | <0.001 |
|  Hispanic/Latino ethnicity | 23 | 14.5 + 2.6 | 10–19 | 0.83 + 0.63 | 0–2 | <0.001 |
|  Other  | 3 | 16.3 + 6.8 | 12–24 | 0.67+ 0.58 | 0–1 | 0.010 |

**Supplementary Table 7. Participant experience survey on the respiratory rate (RR) measurement algorithm.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| How easy do you believe it would be to find a place to prop the phone up at home? | ☐Easy\* | ☐Somewhat Easy\* | ☐Neither easy nor difficult | ☐Somewhat difficult  | ☐Difficult |
| How would you rate the experience of following instructions in this application? | ☐Easy\* | ☐Somewhat Easy\* | ☐Neither easy nor difficult | ☐Somewhat difficult  | ☐Difficult |
| How much do you agree with the following statement, I would feel comfortable using this application to assess my general wellness? | ☐Strongly agree\* | ☐Agree\* | ☐Neither agree nor disagree | ☐Disagree | ☐Strongly disagree |
| How well do you feel you could teach another person to use this application?  | ☐Easy\* | ☐Somewhat Easy\* | ☐Neither easy nor difficult | ☐Somewhat difficult  | ☐Difficult |
| If you needed to use this app several times per day do you think there would be any problems? | ☐Yes | ☐No\* |  |  |  |
| (Optional) Do you have any other feedback you’d like to give on this application? | (Free description) |

\* These responses were considered a “positive” response, and excludes neutral responses: “neither easy nor difficult” and “neither agree nor disagree”.