

# **A New Look at Vital Signs**

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# **Road Map**

- Introduction
- Temperature
- Heart Rate
- Respiratory Rate
- Blood Pressure
- Remote Monitoring
- Future Outlook
- Final Case





### Temperature

"<u>Calor</u>, Dolor, Rubor, Tumor" – 98.6°F or 37°C



# Temperature **Physiology**





Dinarello, C. A., Gatti, S., & Bartfai, T. (1999). Fever: links with an ancient receptor. *Current biology*, 9(4), R143-R146 Nakamura, K., Nakamura, Y. & Kataoka, N. A hypothalamomedullary network for physiological responses to environmental stresses. *Nat Rev Neurosci* **23**, 35–52 (2022)

# Temperature **Measurement**

1867	▶ 1960-80	> 2012	Present
Liquid Expansion	Non-contact	Intelligent	Continuous
A State of the sta		Image: Contract of the contract	



Rogers Group. Science **344**, 70 (2014) Rogers Group. Science **333**, 838 (2011) Wright, W. F., & Mackowiak, P. A. (2016). Origin, evolution and clinical application of the thermometer. *The American Journal of the Medical Sciences*.

### Jane

- 35-year-old female with hx of asthma living in NYC. She wants to know what her risk of getting a viral infection is by returning back to work in person.
- 98.6°F





### Temperature **Potential**





Miller, A. C., et al. (2019, November). Improving state-level influenza surveillance by incorporating real-time smartphone-connected thermometer readings across different geographic domains. In <u>Open Forum Infectious Diseases</u> ).

Smarr, B.L., Aschbacher, K., Fisher, S.M. et al. Feasibility of continuous fever monitoring using wearable devices. Sci Rep 10, 21640 (2020).

### **Heart Rate**

60 – 100 beats per minute



# Heart Rate Physiology





Gordan, R., Gwathmey, J. K., & Xie, L. H. (2015). Autonomic and endocrine control of cardiovascular function. World journal of cardiology, 7(4), 204. Heart Rate

### Measurement





# Jane

- 35-year-old female with hx of asthma wants to know why her heart rate is not back to normal after Covid infection 2 months ago.
- HR 80bpm, 98.6°F





# Heart Rate Potential

DETECT Feeling sick? If you're feeling sick, start tracking your symptoms DETECT-AHEAD: New study available You're invited to help us test new technologies **Baseline Survey** Tell us about your respiratory illness history and your demographics Add COVID-19 Test Result Add the results of a swab test, saliva test, or blood test 2/2 Vaccine Doses Received First dose on 9/9/2021 Second dose on 9/30/2021 Edit vaccine information

detect.scripps.edu

My Data Resources Account

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Home

#### **A** Change in RHR for COVID-19-positive vs COVID-19-negative individuals





Quer, G., Radin, et al (2021). Wearable sensor data and self-reported symptoms for COVID-19 detection. *Nature Medicine*. Radin JM, et al. Assessment of Prolonged Physiological and Behavioral Changes Associated With COVID-19 Infection. *JAMA Netw Open*.

# Heart Rate Potential

• Heart Rate Variability

HEART RATE VARIABILITY



#### HEART RATE VARIABILITY





https://ouraring.com/blog/what-is-heart-rate-variability

https://www.hrv4training.com/blog/one-year-of-hrv-data-in-review

# **Respiratory Rate**

**12-16 breaths per minute** 



# Respiratory Rate Physiology

**ACTIONS:** 

Medullary chemoreceptors detect an increase in blood pH (often caused by a decrease in blood  $CO_2$ ), causing a decrease in breathing.



ACTIONS: Medullary chemoreceptors detect a decrease in blood pH (often caused by an increase in blood  $CO_2$ ) causing an increase in breathing. **REACTIONS:** Effectors Respond. Decreased breathing increases blood CO<sub>2</sub>.



**REACTIONS:** Effectors Respond. Increased breathing decreases blood CO<sub>2</sub>.



Scanlon, V. C., & Sanders, T. (2018). Essentials of anatomy and physiology

#### Respiratory Rate

### Measurement





Santos, M. D., Roman, C., Pimentel, M. A., Vollam, S., Areia, C., Young, L., ... & Tarassenko, L. (2021). A real-time wearable system for monitoring vital signs of COVID-19 patients in a hospital setting. *Frontiers in Digital Health, 3*) Chun, K. S., Kang, Y. J., Lee, J. Y., Nguyen, M., Lee, B., Lee, R., ... & Xu, S. (2021). A skin-conformable wireless sensor to objectively quantify symptoms of pruritus. *Science advances,* 7(18), eabf9405.

### Jane

- 35-year-old female with asthma, Covid positive 6 months ago, vaccinated and now getting short of breath again.
- 98.6°F, HR 80, RR 16





# Acoustic Signaling **Potential**



Compound Sound





Rogers, J., Ni, X., Ouyang, W., Jeong, H., Kim, J. T., Tzavelis, A., ... & Xu, S. (2020). Long-term, continuous, and multimodal monitoring of respiratory digital biomarkers via wireless epidermal mechano-acoustic sensing in clinical and home settings for COVID-19 patients.

### **Blood Pressure**

120/80mmHg



**Blood Pressure** 

Physiology

LEFT VENTRICLE

OLE

SYST





Salvi, P. (2017). Vascular Hemodynamics and Blood Pressure. In: Pulse Waves. Springer, Cham.

# Blood Pressure Measurement

- Primary modifiable RF
- 2nd reason for OV
- >1B adults
- ~50% remain uncontrolled
- Cuff based





Pandit JA et al. Snapshot Hemodynamics and Clinical Outcomes in Hypertension: Precision in the Measurements is Key. Hypertension. 2016;67:270-271 Pandit, JA., Lores, E., & Batlle, D. (2020). Cuffless blood pressure monitoring: promises and challenges. *Clinical Journal of the American Society of Nephrology*, *15*(10), 1531-1538.

# Blood Pressure Measurement









Protogerou AD e tal. Central blood pressures: do we need them in the management of cardiovascular disease? Is it a feasible therapeutic target? Journal of Hypertension. 2007;25:265-272. Gescge H et al. Continuous blood pressure measurement by using the pulse transit time: comparison to a cuff-based method. European Journal of Applied Physiology. 2012;112(1):309-315.

### Blood Pressure Optical Sensor Measurement

THE FRONT ROW

at Scripps Research





Gescge H et al. Continuous blood pressure measurement by using the pulse transit time: comparison to a cuff-based method. European Journal of

Applied Physiology. 2012;112(1):309-315.

# Blood Pressure Problem

### Assumptions

- Distance
- Conversion Equations
- Pre-ejection period
  - Electrical to mechanical





Balmer, J et al. Pre-ejection period, the reason why the electrocardiogram q wave is an unreliable indicator of pulse wave initialization. Physiol Meas. 2018 Sept 24:39(9):09505.

Mukkamala R et al. Towards Ubiquitous Blood Pressure Monitoring via Pulse Transit Time: Theory and Practice. IEEE Trans Biomed Eng. 2015. Aug:62(8):1879-901.

### Blood Pressure Solution: Differential Pulse Arrival Time





# Blood Pressure **DPAT Validation**





Study Demographics: n=12, Ages: 25-50, Gender: M/F, Normotensive & Hypertensive Subjects



# Blood Pressure DPAT Validation





# Blood Pressure Prototype





# **Alignment of tech push and clinical pull**





### **Remote Vitals Monitoring**



# **RPM Diagnostics**

Multi-modal, skin conforming, time synchronized wireless measurements of key data streams linked to physiological variables of interest:





Data from the Remote Patient Monitoring Study led by Dr. Pandit, Dr. Ahmad and the Rogers Group.

### **Sensor Capabilities**

Parameters Measured by Consumer Digital Health Devices by Type



Source: IQVIA AppScript Device Database, Mar 2021; IQVIA Institute, Jun 2021

Notes: Chart includes data from 384 sensors. Total exceeds 384 due to multiple measures being tracked by a single sensor. Specific measurement devices include vitals measurement.

Report: Digital Health Trends 2021: Innovation, Evidence, Regulation, and Adoption. IQVIA Institute for Human Data Science, July 2021







# **Our Efforts**



Health

#### PROGRESS

Current points 460pts	
740 points to next reward	*
Tasks	
Collect Blood Sample	>
Collect Saliva Sample	>
Collect Microbiome Sample 225 points   20 min	>
Return Samples 90 points   10 min	•
PRediction Of Glycemic RESponse Study (PR.	. My Projects
	-05-

#### progress.scripps.edu

Precision Nutrition

# Good morning Tasks Sleep Apnea Screening Assess your risk for obstructive sleep apnea O 8 minutes Insomnia Screening

REFRESH

Assess your risk for insomnia 순 Complete sleep apnea screening 

#### Results

Your results will show here once you have completed the above tasks.

#### refresh.scripps.edu

Sleep Medicine



#### Getting Started Welcome to All of Us - to get started, please tell us some basic information about vourself. START THE BASICS $\odot$ 0 1 0/6 0/2 0/2 0/1 Surveys Health **Digital Health** Biosample Records 7/22/2019 Consent Not started The Basics Survey Not started O Order Salivary Kit Return Salivary Kit Not started EHR Consent Link Health Records Not started Share Digital Health Data Lifestyle Survey Not started Not started Overall Health Survey ~ -Dashboard Tasks My Data Profile

#### go.joinallofus.org

Precision Medicine



Diseases

### **Future Outlook**





### What's Next?



Expanding access

From active to passive



From unregulated to regulated



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# Final Case –

- 38- year-old male cardiologist with hx of brain cancer s/p surgery, chemotherapy, and radiation.
- Gets MRIs every 3-4 months for screening because not enough data on risk factors of tumor recurrence.
- Precision health enabled by digital health technology with large longitudinal datasets might hold this answer.



Pandit, J. A. (2019). Finding the Words. *JAMA*, 321(23), 2283-2284.
 Pandit, J. A. (2020). Memento Mori. *JAMA*, 324(17), 1731-1732.
 Pandit, J. A. (2022). The Farewell. *JAMA*, 327(9), 819-820.

# Thank you

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- "If you want to go fast, go alone, if you want to go far, go together." African Proverb
- Digitaltrials.scripps.edu





# Upcoming Lecture



### The hunt for regenerative medicines

#### **Michael Bollong PhD**

Assistant Professor, Department of Chemistry

Wednesday, June 29, 2022 | 1:00 pm PT/4:00 pm ET

Register now at: frontrow.scripps.edu



📜 SCAN ME

