Realising the potential of wearables for health monitoring

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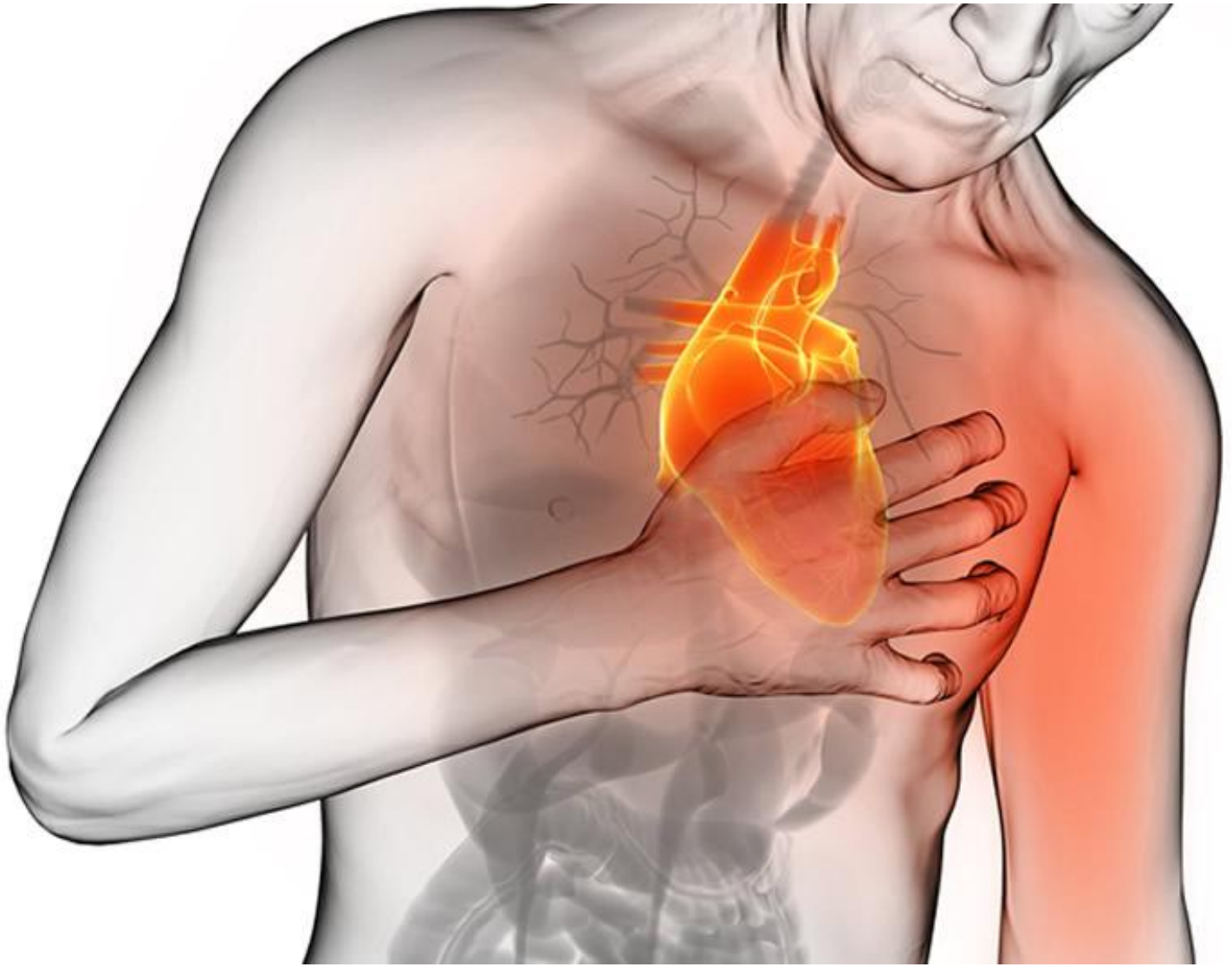
https://doi.org/10.5281/zenodo.4616718 (CC BY-SA 4.0)

Every 15 mins in UK:

3 hospital admissions

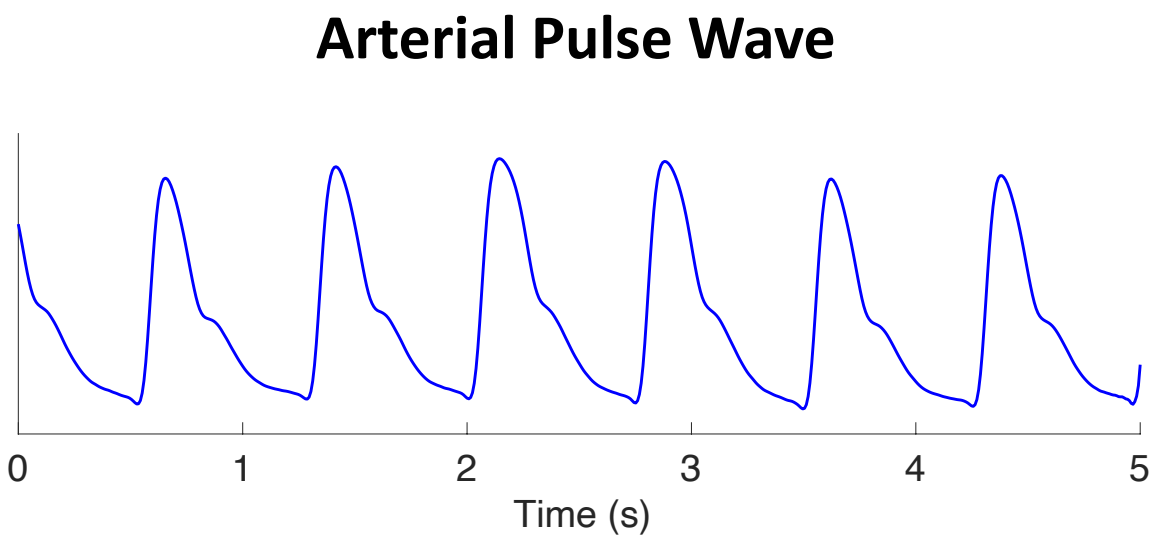
5 deaths

£250k healthcare costs



BHF Statistics Factsheet – UK, 2020: https://www.bhf.org.uk/what-we-do/our-research/heart-statistics

German Tenorio, https://www.flickr.com/photos/germantenorio/18459649560/ (CC BY SA 2.0)

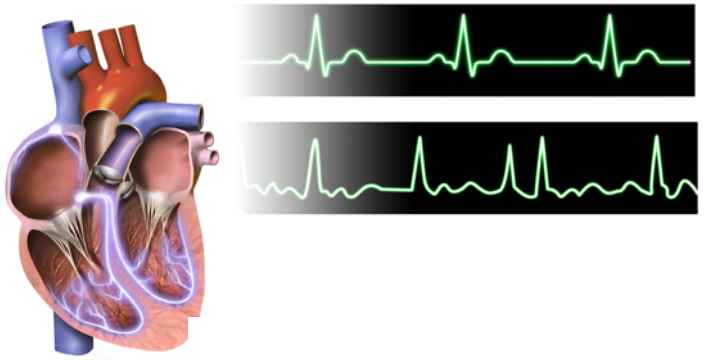


Ellywa,
https://commons.wikimedia.org/wiki/File:Fitbit_versa.jpg (CC BY SA 4.0)

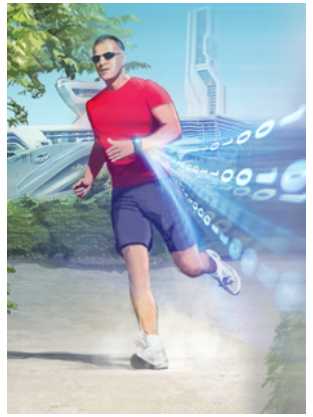
St. Thomas' Hospital
St. Thomas' Hospital

Development of Wearables

Clinical Applications



Next Steps



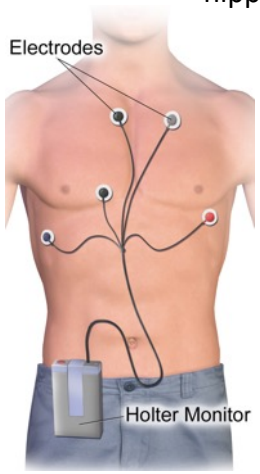
BruceBlaus,
https://commons.wikimedia.org/wiki/File:Atrial_Fibrillation.png (CC BY SA 4.0)

Luke Chesser,
https://commons.wikimedia.org/wiki/File:Apple_Watch_user_(Unsplash).jpg (CC0 1.0)

Brother UK,
https://www.flickr.com/photos/brother-uk/31501281284/in/photostream/ (CC BY 2.0)

Clinical

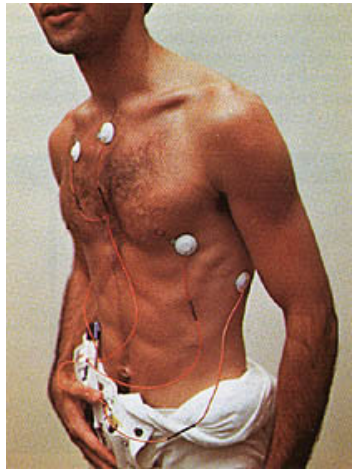
BruceBlaus, https://commons.wikimedia.org/wiki/File:Holter_Monitor.png (CC BY-SA 4.0)

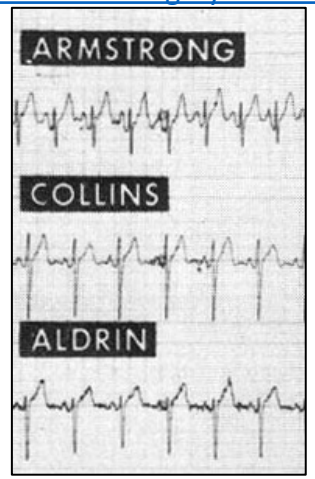


Holter Monitor, 1963

hippopx, https://www.hippopx.com/en/hospital-bed-doctor-surgery-healthcare-and-medicine-indoors-hospital-ward-90160 (CC0)

NASA, https://history.nasa.gov/SP-368/s6ch3.htm (Public Use Permitted)





Apollo Missions, 1968-72

ECG Telemetry, 1980s with SpO2, 2010s

Electronic Pedometer, 1965

ECG Chest Strap, 1978

Tiia Monto, https://commons.wikimedia.org/wiki/File:Polar_H10.jpg (CC BY-SA 3.0)

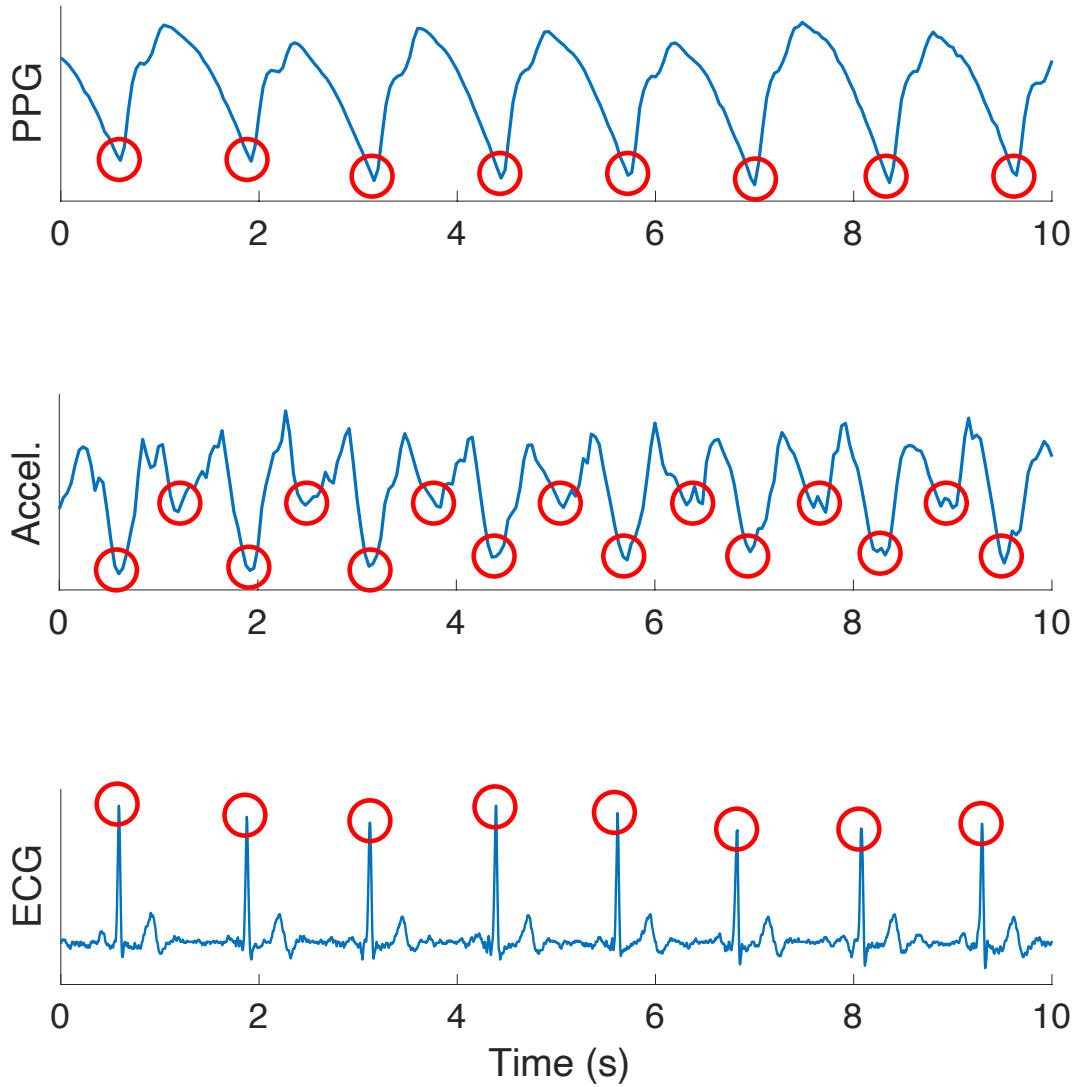
Optical Heart Rate Monitor, 2013

Consumer

Adam Engelhart, https://www.flickr.com/photos/tellumo/354630079 (CC BY-SA 2.0)

Global Panorama, https://www.flickr.com/photos/121483302@N02/15489204048 (CC BY-SA 2.0)

A **Fitness tracker** which acquires photoplethysmography (PPG) and accelerometry (Accel.) signals



Pulse waves used to:
- estimate heart rate
- identify an irregular pulse
- assess pulse rate variability

Steps used to:
- estimate step count

Heart beats. Signal used to:
- estimate heart rate
- (potentially) diagnose arrhythmias

A **Smartwatch** which acquires electrocardiography (ECG) and accelerometry (Accel.) signals

Peter H Charlton, https://doi.org/10.5281/zenodo.798234 (CC BY 4.0)

Functionality

		Using PPG					Using PPG and Accel.			Using other sensors			
Wearable	**Form factor**	**Heart rate**	**Irregular pulse**	**Oxygen saturation**	**Respiratory rate**	**Blood pressure**	**Sleep**	**Calories**	**VO2 max**	**ECG**	**Steps**	**Elevation**	**Temperature**
Apple Watch Series 6	wrist watch	✓											
Withings Scanwatch	wrist watch	✓											
Samsung Galaxy Watch3	wrist watch	✓											
Fitbit Sense	wrist watch	✓											
Biostrap Evo	wrist band	✓											
Oura Ring	finger ring	✓											

Functionality

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Apple Watch Series 6	wrist watch	✓	✓										
Withings Scanwatch	wrist watch	✓	✓										
Samsung Galaxy Watch3	wrist watch	✓	X										
Fitbit Sense	wrist watch	✓	X										
Biostrap Evo	wrist band	✓	X										
Oura Ring	finger ring	✓	X										

Functionality

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Apple Watch Series 6	wrist watch	✓	✓	✓									
Withings Scanwatch	wrist watch	✓	✓	✓									
Samsung Galaxy Watch3	wrist watch	✓	X	✓									
Fitbit Sense	wrist watch	✓	X	✓									
Biostrap Evo	wrist band	✓	X	✓									
Oura Ring	finger ring	✓	X	X									

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Apple Watch Series 6	wrist watch	✓	✓	✓	X	X							
Withings Scanwatch	wrist watch	✓	✓	✓	✓	X							
Samsung Galaxy Watch3	wrist watch	✓	X	✓	X	✓							
Fitbit Sense	wrist watch	✓	X	✓	✓	X							
Biostrap Evo	wrist band	✓	X	✓	✓	X							
Oura Ring	finger ring	✓	X	X	✓	X							

Functionality

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Withings Scanwatch	wrist watch	✓	✓	✓	✓	X	✓	✓	✓				
Samsung Galaxy Watch3	wrist watch	✓	X	✓	X	✓	✓	✓	?				
Fitbit Sense	wrist watch	✓	X	✓	✓	X	✓	✓	✓				
Biostrap Evo	wrist band	✓	X	✓	✓	X	✓	✓	X				
Oura Ring	finger ring	✓	X	X	✓	X	✓	✓	X				

Functionality

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Wearable	**Form factor**	**Heart rate**	**Irregular pulse**	**Oxygen saturation**	**Respiratory rate**	**Blood pressure**	**Sleep**	**Calories**	**VO2 max**	**ECG**	**Steps**	**Elevation**	**Temperature**
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Withings Scanwatch	wrist watch	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	X
Samsung Galaxy Watch3	wrist watch	✓	X	✓	X	✓	✓	✓	?	✓	✓	X	X
Fitbit Sense	wrist watch	✓	X	✓	✓	X	✓	✓	✓	✓	✓	✓	✓
Biostrap Evo	wrist band	✓	X	✓	✓	X	✓	✓	X	X	✓	X	X
Oura Ring	finger ring	✓	X	X	✓	X	✓	✓	X	X	✓	X	✓

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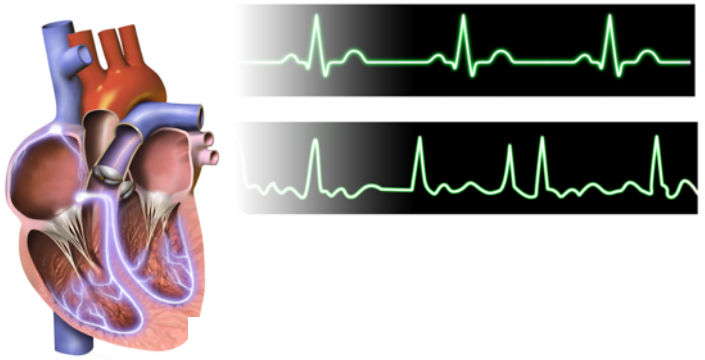
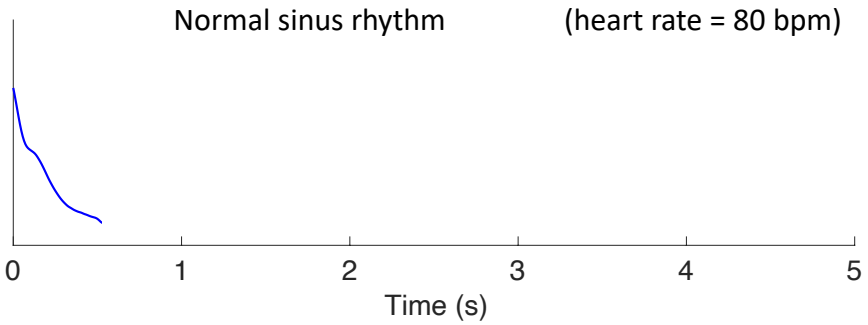
Development of Wearables

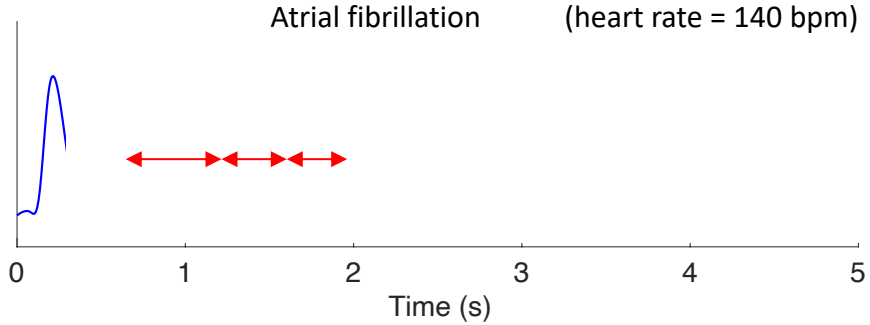
Clinical Applications



Identifying Atrial Fibrillation

Perez M.V. *et al.* Large-scale assessment of a smartwatch to identify atrial fibrillation. *N. Engl. J. Med.* **2019**, *381*, 1909–1917, doi:10.1056/NEJMoa1901183





Irregular beat-to-beat intervals

0.5% alert rate

84% positive predictive value

117 days monitoring per individual

Infectious Disease

Resting heart rate

Sleep duration

Radin, J.M. *et al*. Harnessing wearable device data to improve state-level real-time surveillance of influenza-like illness in the USA: a population-based study. *Lancet Digit. Heal.* **2020**, *2*, e85–e93, doi:10.1016/S2589-7500(19)30222-5

Resting heart rate

Sleep duration

Step count

Heart rate to steps ratio

Mishra, T. *et al.* Pre-symptomatic detection of COVID-19 from smartwatch data. *Nat. Biomed. Eng.* **2020**, *4*, 1208–1220, doi:10.1038/s41551-020-00640-6

Quer, G. *et al*. Wearable sensor data and self-reported symptoms for COVID-19 detection. *Nat. Med.* **2020**, *27*, doi:10.1038/s41591-020-1123-x

Additional Potential Applications

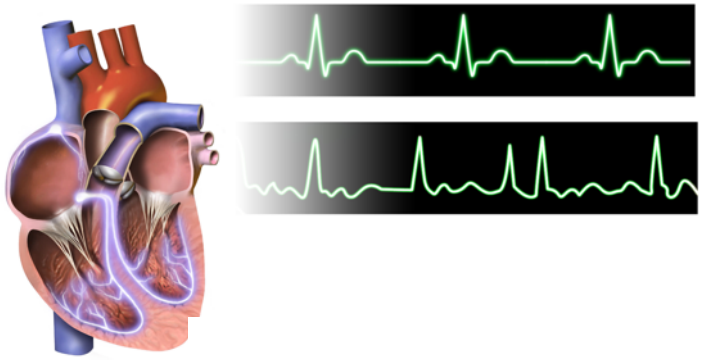
- Identifying obstructive sleep apnea
- Assessing stress levels
- Assessing vascular age
- Identifying clinical deteriorations
- Cardiovascular risk prediction
- Assessing response to exercise
- Identifying sepsis
- Identifying heart failure
- Identifying pre-eclampsia
- Menstrual cycle monitoring
- Identifying orthostatic hypotension
- Seizure detection in epilepsy
- Chronic kidney disease monitoring
- Biometric authentication
- Health insurance

See:

1. Charlton, P.H. *et al.* Wearable photoplethysmography for cardiovascular monitoring. *[under review]*
2. Charlton, P.H. and Marozas, V. Wearable photoplethysmography devices. *[under review]* In *Photoplethysmography*; Elsevier

Development of Wearables

Clinical Applications



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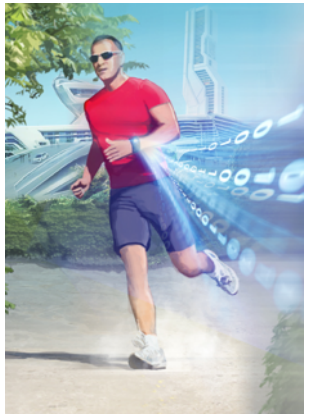

Next Steps

Provide best possible signals

Provide accurate parameters

Provide clinically useful information

Tailor wearables to intended users

Specific applications to improve outcomes

Resources

http://peterhcharlton.github.io/

Contains:

- Datasets
- Signal processing algorithms
- Presentations (including this one)
- Publications

With thanks to…

Panicos Kyriacou

Jonathan Mant

Vaidotas Marozas

Jordi Alastruey

Phil Chowienczyk

British Heart Foundation

Peter Charlton

pc657@medschl.cam.ac.uk

http://peterhcharlton.github.io

Bertrand Semelet,
https://commons.wikimedia.org/wiki/File:Abseilen_jumelle.jpg (CC BY-SA 2.0 FR)

Consumer wearables now have a wide functionality

Clinical applications are emerging, including detecting atrial fibrillation

When used clinically, wearables should be like a harness:

- highly reliable
- for specified purposes

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http://peterhcharlton.github.io