

Smartwatches & Biometrics for Personal Health Monitoring

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Disclosures

- Nothing to disclose.
- No potential conflict of interest.
- No companies paying us :(



Disclaimers

- We will be discussing exercise-related topics in this presentation. See your doctor first to see if you are cleared to exercise. We are not doctors.
- The nature of the presentation will involve discussing consumer health products. We will try our best to approach this in an objective and unbiased way.
- We are not experts in all fields.



Objectives

- Overview of Smartwatches & Biometrics
- Discuss Fitness monitoring
- Preventative health & wellness
- Specialized monitoring
- Potential Pitfalls
- Potential Best Uses



WWW.SLI.DO

S for your audience to join in

Image: state contract of the state contract of the

What is a Smartwatch?

Author(s)	Year	Definition
McIntyre	2014	'Smart watch is a multi-functional device that appeals to a broad range of user interests, including not only fitness, health- monitoring, and location tracking but also extended communication and smart features.'
Kim and Shin	2015	'Smart watches serve mostly as satellite devices for amassing useful data from a paired smartphone via wireless Bluetooth connection and providing more convenient, faster, and substitutable access to information, especially as its information processing is less demanding and using a smartphone is sometimes impractical.'
Cecchinato et al.	2015	'A wrist-worn device with computational power that can connect to other devices via short range wireless connectivity; provides alert notifications; collects personal data through a range of sensors and stores them; and has an integrated clock.'
Choi and Kim	2016	'The smartwatch is a unique form of information technology in that its shape resembles an item that has been a close companion to us humans for many centuries, namely the "wristwatch".'
Chuah et al. Hsiao	2016 2017	'A mini device that is worn like a traditional watch and allows for the installation and use of applications.' 'Smartwatch is devices that can connect with smartphones and receive a lot of information, such as time, text messages, schedules, and GPS data. While it can perform basic data and communications tasks, it is also capable of running mobile applications.'

... Many definitions.

What is a Smartwatch?

- <u>Smartwatch</u> Device that is worn that monitors and tracks biometric parameters (Macridis, 2018)
- <u>Biometrics</u> relating to or involving the application of statistical analysis to biological data
- For our presentation, we will be referring to all devices worn on the wrist as being either a "smartwatch" or "wearable"
- Some examples of wearables:
 - Fitbit Charge 2
 - Garmin Vivoactive 3
 - Jawbone Up3
 - Apple Watch Series 3
 - Samsung Gear S3





Smartwatch Components

- Optical sensor
 - Heart rate
- Contact sensor
 - Skin temperature
- Altimeter
 - Altitude gain or loss
- GPS
 - Biking/running route and distance
- Accelerometer
 - Step count
 - worn/not worn state
 - Overall physical activity levels
 - posture
- Gyroscope
 - posture





Purpose of Smartwatches

- Support individuals in becoming <u>more</u> active and <u>less</u> sedentary (little or no physical activity; e.g., sitting)
 - Decreased risk of chronic physical and mental health conditions (Owen, 2010; Warburton, 2006)
 - Cardiovascular Disease, stroke, hypertension, depression, anxiety, cancers, diabetes, etc.
- Recommended 150 mins of Moderate to Vigorous Physical Activity (MVPA) per week (Warburton, 2007)

Evidence-informed physical activity guidelines for Canadian adults (1)

Darren E.R. Warburton, Peter T. Katzmarzyk, Ryan E. Rhodes and Roy J. Shephard

Applied Physiology, Nutrition, and Metabolism. 32 (Dec. 31, 2007): pS16+.

How many Canadians meet the Physical Activity Guidelines?



Percent of Canadians meeting the Canadian Physical Activity guidelines by age and sex, 2013 1

Age groups	Men/Boys	Women/Girls		
5 to 11 years	18%	8%		
12 to 17 years	8%	3%		
18 to 39 years	35%	30%		
40 to 59 years	<u>a</u>	18%		
60 to 79 years	13%	11%		
a too unreliable to report				

Taken from: https://www.canada.ca/en/public-health/corporate/publications/chief-public-health-officer-reports-state-public-health-canada/2016-health-status-canadians/page-13-what-influencing-health-physical-activity.html

Purpose of Smartwatches

- Specialized health monitoring
 - Blood sugar
 - Blood pressure
 - Heart attacks





Uses of Smartwatches in Personal Health Monitoring

- Number of steps
- Weekly MVPA mins
- Sedentary time
- Distance walked or ran
- Heart rate
- Flights of stairs
- Calories burned
- Sleep patterns
- Skin temperature



How many of you wear a smartwatch?



Smartwatch Use



Smartwatch Use

- Danova, 2013:
 - Projected that 373 million units sold in 2020
- Gartner, 2015:
 - Projected that 500 million units sold in 2020

Gartner. 2015. "Wearable Tech way beyond Smartwatcher Available at: https://www.gartner.com/smarterwithgartner/wearabletechnology-beyond-smartwatches-3/ (last accessed March 1., 2018)

Danova, T. (2013), "Why the smart watch market is poised to explode as it draws millions of consumers into wearable computing", Business Insider, pp. 1-18, available at: <u>http://www.businessinsider.com/global-smartwatch-sales-set-to-explode-2013-9</u> (accessed March 11, 2018)

Local Smartwatch Use

- Study in Alberta (Macridis, 2018)
 - 18 years or older
 - 1215 participants



- Comparison of Normal vs. Overweight and between regions (Metro Edmonton + Calgary vs. Rest of province)
- Leisure-time physical activity (LTPA) questionnaire
- Sedentary Behaviour Questionnaire
- Questions related to Physical Activity Tracking Devices

Consumer physical activity tracking device ownership and use among a populationbased sample of adults

Soultana Macridis^{1,2}, Nora Johnston^{1,2}, Steven Johnson³, Jeff K. Vallance³*

1 Alberta Centre for Active Living, Edmonton, Alberta, Canada, 2 Faculty of Physical Education and Recreation, University of Alberta, Edmonton, Canada, 3 Faculty of Health Disciplines, Athabasca University, Athabasca, Canada

Local Smartwatch Use

RESULTS

- Significantly associated with Physical Activity Tracking Devices:
 - Being female
 - <60 years of age
 - Having post-secondary education
 - Meeting PA guidelines
 - Being overweight/obese



What does this mean?

- People in Canada are interested!
- There is a consumer bias.
- There are barriers in using wearables.
 - 37% <1 month
 - 35% 1-6 months
 - 27% >6 months

BMJ Open Interest and preferences for using advanced physical activity tracking devices: results of a national cross-sectional survey

Stephanie Alley,¹ Stephanie Schoeppe,¹ Diana Guertler,² Cally Jennings,³ Mitch J Duncan,⁴ Corneel Vandelanotte¹



What do the people want?!

- Many barriers, but...
- Perceived usefulness is the most significant variable for consumers to adopt and accept wearable technology

People can't use you if you're useless.



Chae, J. M. 2009. "Consumer Acceptance Model of Smart Clothing According to Innovation." *International Journal of Human Ecology* 10 (1): 23–33.

What do the people want?!

A more current framework...



Milad Dehghani 💿

Department of Computer, Control, and Management Engineering, Sapienza University of Rome, Rome, Italy

Quantified Self

https://www.youtube.com/watch?v=8wqC6ad1V_Q



Quantified Self self knowledge through numbers

Questions?



SMARTWATCHES, FITNESS, AND HEALTH



Getting a "STEP" ahead

- Smartwatches have ubiquitous function as a pedometer
 - Counts the number of steps
- Step counting is one of the most accurate features of smartwatches



Richardson et al., 2008, Annal. Fam. Med.

Smartwatches as Pedometers

How does it work?

- Changes in acceleration in various axial planes



- Tracks pattern of movement of swinging arm; used as a proxy for steps
 - Complex algorithm

What is the recommended number of steps per day?

a. 1000
b. 5000
c. 10 000
d. 20 000



Smartwatches as Pedometers

- Most smartwatches have preset goal of **10 000 steps**
 - What does this mean?



Counting Steps

It depends....

Smartwatches as Pedometers

- The effect of walking 10 000 steps (or any number) varies greatly
 - Dependent on duration, intensity, & distance
- Pedometer use has been shown to:
 - Increase physical activity
 - Be associated with moderate weight loss (0.7-1.85 kg)
 - Over 4 wks to 1 yr period
 - Have slight **increases** in cardiovascular performance

Richardson et al., 2008, Annal. Fam. Med.

Smartwatches as Pedometers

- There is more to a healthy lifestyle than 10 000 steps but step goals can help facilitate healthy lifestyle changes



Normal Heart Metrics

Heart Rate (HR)

- Beats per minute

Rhythm

- Should be regular (aka sinus rhythm)

Amplitude

- Size or strength of the pulse
- Not currently monitored by smartwatches



Monitoring Heart Rate (HR)

- Resting HR: **60-100 bpm**
- Maximum HR estimate:
 - 220 age (men)
 - 226 age (women)
- Changes throughout lifespan
- Elevated resting HR associated with increased risk of cardiovascular disease and mortality

Who has taken their heart rate before?

Taking Your Own Heart Rate

- 1. Find your radial pulse
- 2. Feel for the radial artery
- 3. Count the number of beats in a set time interval (20 sec)
- 4. Multiply by 3 to get beats per minute

Monitoring Heart Rate

- Smartwatch monitoring real-time tracking
 - Use an optical sensor to monitor blood flow
- Accuracy varies depending on device
 - Most within 80-90% of actual HR
 - Chest strap > wrist monitoring


Monitoring Heart Rate

Fitness - track heart rate for aerobic vs anaerobic exercise

- Aerobic intensity
 - Light:
- 30-39% HR max
- Moderate: 40-59% HR max
- High:
- 60-85% HR max



- Useful for training and exercise
 - Jogging, walking, cycling, swimming, etc.

Monitoring Heart Rate

Health - general monitoring for healthy patients or patients with known heart conditions (cardiopathies)

- Stay within physician-recommended, safe HR thresholds during rehabilitation and exercise



Monitoring Heart Rhythms

There is more to the heart monitoring than just the rate



Monitoring Heart Rhythms

- There is more to the heart monitoring than just the rate
- Heart rhythm, or the **regularity of the heartbeat**, is an important variable
- Rhythm commonly assessed using an **electrocardiogram (ECG)**

What is an ECG?

- An ECG (or EKG), or an **electrocardiogram**, records the electrical activity of the heart
- Gives information on the **structure and function** of the heart



Monitoring Heart Rhythms

WEARABLE TECH / Leer en español

The new FDA-cleared Apple Watch band adds real-time EKG

The KardiaBand aims to track atrial fibrillation, something that fitness tracker heart rate monitors aren't approved to test (yet).

BY SCOTT STEIN / NOVEMBER 30, 2017 8:26 AM PST

KardiaBand by AliveCor



Monitoring Heart Rhythms

- FDA approval for ECG (EKG) sensor for apple watch (Nov. 2017)
 - Doesn't mean it is a good device
- Pairs with smartphone application
- Can monitor <u>abnormal heart rhythms</u> (arrhythmias) including **atrial fibrillation**

WEARABLE TECH / Leer en español

The new FDA-cleared Apple Watch band adds real-time EKG

The KardiaBand aims to track atrial fibrillation, something that fitness tracker heart rate monitors aren't approved to test (yet).



BY SCOTT STEIN / NOVEMBER 30, 2017 8:26 AM PST

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What is Atrial Fibrillation?

- An irregular heartbeat (arrhythmia) due to rapid, irregular atrial contractions - "quivering"



American Heart Association; Canadian Heart & Stroke Foundation

Importance of Atrial Fibrillation

- Blood stasis in heart can lead to pooling and clot formation
- 1/3 strokes after 60 are caused by A-fib
- A-fib patients have 3-5 times greater risk of ischemic stroke

- Back to the smartwatch ECG.... how well does it work?

- A-fib detection:
 - Good sensitivity (96%) and specificity (94%) for detecting Afib compared to physician-interpreted ECGs
 - n=52; 225 paired ECGs; mean age 68

P4257 Assessing the accuracy of an automated atrial fibrillation detection algorithm using novel smartphone technology @

A. William, M. Kanbour, T. Callahan, M. Bhargava, A. Hussein, N. Varma, J. Rickard, W. Saliba, K. Wolski, O. Wazni ... Show more

- This means that the smartwatch ECG was able to accurately detect both the presence and absence of atrial fibrillation

- Accurate detection compared to physician interpreted ECGs
- 96% of ECGs were interpretable by physicians
- 85% symptom-rhythm correlation (Newham et al., 2017)
 - Pts. recorded when they were having symptoms
- Patients found device easy to use & lessened anxiety about Afib

Drawbacks

- Device is expensive (~\$200) and requires a subscription for full range of features (\$99/yr)
 - Limited accessibility to user
- Current studies limited by small sample size and potential bias
- Cannot replace current diagnostic standards but may complement as a tool to monitor patients with known A-fib or arrhythmias

UPDATE NOVEMBER 30, 2017

Apple Heart Study launches to identify irregular heart rhythms

Apple Smartwatch Study

- Partnered with Stanford Medicine
- Via "Apple Heart Study" app,
 - Data is collected on irregular rhythms
- Users notified if A-fib detected



Apple Heart Study

TODAY AT 10:09 AM Your Statistics Heart Rhythm Data Contributions 122 Days in Study 10

Samples will be collected when you are wearing your Apple Watch. Depending on how active you are, one or more samples may be collected per day.

11/29/17

Welcome and Thank You

Implications

- Exciting technology and may have future implications in monitoring of patients with heart problems
- May allow for rapid treatment of patients experiencing A-fib

- Sleep disorders seriously affect quality of life
 - Insomnia associated with impairments in daytime functioning (Baglioni, 2013)
- Polysomnography is used for sleep monitoring (Kuo, 2017)
- Limitations of polysomnography (Kuo, 2017; Schute-Rodin, 2008)
 - Must be in lab setting
 - Electrodes and wiring
 - Expensive equipment



- Wearables (actigraphy) in sleep research and sleep medicine
 - Measures movement, activity, and sleep
- Several algorithms proposed; each device has its own measurement characteristics (Tilmanne, 2009; Jean-Louise, 2001; Sazonov, 2004)
 - Validation and reliability studies required
 - Studies have established this in infants, children, and adults (Sadeh, 2011; Domingues, 2014; Ustinov, 2013)
 - Biggest issue is detecting wakefulness within sleep periods (Kuo, 2017)

What about validity and reliability for individuals with **sleep**related disorders?

- Kuo et al. (2017):
 - actigraphy recorder with low sampling rate
 - 81 participants
 - Polysomnography compared to proposed actigraphy recorder
 - Objective sleep measurements:
 - Sleep efficiency
 - Total sleep time
 - Sleep onset time
 - Wake after sleep onset

Development and Evaluation of a Wearable Device for Sleep Quality Assessment

Chih-En Kuo, Yi-Che Liu, Da-Wei Chang, *Member, IEEE*, Chung-Ping Young, *Member, IEEE*, Fu-Zen Shaw, and Sheng-Fu Liang*, *Member, IEEE*



Fig. 3. Accuracy changes in utilizing various window sizes for the sleep-wake staging of data from subjects with different sleep efficiencies.

- 22 subjects used to develop sleep-wake algorithm
- 43 subjects with 'good' sleep + 16 subjects with 'poor' sleep
 - <85% sleep efficiency</p>
- Demonstrated reliability using limited information to estimate wake-sleep stages during overnight recordings





- Limitations for this study:
 - Unable to classify light sleep, deep sleep, and rapid eye movement
 - Involuntary body movements could be misclassified as a wake stage
 - Subjects with a long quiet-wake interval can be misclassified as sleep
- Potential use for:
 - In-home screening
 - Evaluation of sleep
 - Measurement and tracking with treatment

Weight Loss

- Tracks calories burned (**energy expenditure**) via accelerometer algorithms
- Can use in conjunction with phone calorie tracking applications (e.g., MyFitnessPal) and body weight scale
- Calories in, calories out



Weight Loss



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Weight Loss

- Stanford University School of Medicine researchers (May 2017) looked at energy expenditure of 7 devices (Apple Watch, Fitbit Surge, Samsung Gear)
 - 31 women and 29 men
 - Compared energy expenditure to gold standard
 - Most accurate device off by 27%
 - Least accurate off by <u>93%</u>



OTHER HEALTH PARAMETERS



Monitoring Blood Pressure

- Omron BP Monitor
- FDA Approved
- Accuracy: +/- 3 mmHg or 2%
- Hypertension is the "silent killer"
- Diagnosis is most accurate when home blood pressure monitoring is used.
- Trends in BP can be useful
- Physician review of data



Monitoring Hypertension



Does "Hidden Undercuffing" Occur Among Obese Patients? Effect of Arm Sizes and Other Predictors of the Difference Between Wrist and Upper Arm Blood Pressures

Hardik Doshi MD, Alan B. Weder MS, Robert L. Bard MS, Robert D. Brook MD

First published: 17 November 2009 Full publication history

Diabetes

- Monitoring Glucose levels
- Less invasive than current options?
- Continuous glucose monitoring vs. on-demand
- Newer models anticipated to be release soon; 10-day wear.





Falls in the Elderly

- Many apps.
- Often used in conjunction with sensors In smartphone.
- Can notify family.
- Reduces fears of falling.
- Accuracy not well known.



Friedman SM, Munoz B, West SK, Rubin GS, Fried LP. Falls and Fear of Falling: Which Comes First? A Longitudinal Prediction Model Suggests Strategies for Primary and Secondary Prevention. J Am Geriatr Soc. 2002;50:1329–1335. doi: 10.1046/j.1532-5415.2002.50352.x. [PubMed] [Cross Ref]

Epilepsy

- "Neutun" Software
- Medication Reminders
- Journal Log
- Notifies family during emergencies.





Medication management Track, manage and fulfill your medications



Health insights

Reduce and prevent seizures with the best research



Care-circle Share your journey with your loved ones



Log seizures

Maintain a complete log of all of your seizure activity

Heart Monitoring





eCor

Respiratory Diseases

• No good current options on market.



American Journal of Respiratory and Critical Care Medicine 2016;193:A1695

Feasibility of Using Smartwatches and Smartphones to Monitor Patients with COPD

Robert Wu , Eyal De Lara , Daniyal Liaqat , Ishan Thukral , Andrea S. Gershon ,

Support Networks

- Online Communities
 - Fitness
 - Diseases
- Physician Review
- Family Oversight



EVALUATING SMARTWATCHES

Accuracy and Validity

Reliability

Privacy and Security
- Devices are marketed under premise that they will improve health & fitness
- **<u>But</u>** majority of manufacturers provide no empirical evidence
 - Reliant on external institutions for proper evaluation



Steps > Distance > Physical Activity > Energy Expenditure > Sleep

Evenson et al., 2015, J. Behavioural Nutrition and Physical Activity

Heart Rate



Wang et al., 2017, JAMA Cardiology

- In medicine, we only perform a test if we believe it will be useful
- With wearables, patients will be able to monitor themselves constantly
- This will increase the amount of **false positive** and **false negative** results

- An effective medical tool must be reliable
- A number of pitfalls plague smartwatches in regards to reliability

Limited Battery Power

- Reported issue in many studies
 - Battery life variable; 2 7 days with use
- Speculated that power consumption will only increase



Reeder et al., 2016, J. Biomedical Informatics

Watch Placement



- HR not collected when sensor is not in contact with skin
- Variations in HR even with skin contact
- Detection difficulties with hand-limited activities (biking) or tasks with high levels of wrist action (washing hands)

Kamdar et al., 2016, Pac. Symp. Biocomput.

Data Quality

- Data must be interpretable to be useful
- Gaps in data due to:
 - Charging
 - Short breaks
 - Missed data

Interdevice reliability

How consistent are two of the same devices?



- High interdevice reliability for steps, distance, and energy expenditure
- High variation between devices when sleeping
 - Evaluated when wearing two devices

Privacy & Security

• What are your concerns?

sli.do



Privacy & Security

- Data Ownership
- Insurance Companies
- Personal Safety especially in children
- Employee Monitoring
- Local vs. Cloud data storage



Privacy & Security

- Data Ownership
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Smartwatch Summary

Today we have discussed the many applications of smartwatches

Future applications are exciting but caution should be used when using smartwatches for medical purposes

- Further research and validation is required

Currently, smartwatches cannot replace standard healthcare but may be complementary

Acknowledgments

Thanks to Dr. Gair & Let's Talk Science for letting us put on this talk

let's talk Scrence inspiring discovery

Thank You!

Questions?



