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Demystifying Geolocated Health Data

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ABSTRACT

The biggest companies in the world are tracking your personal health data and using it to improve their bottom line. Apple, Amazon, and Google each have products that collect billions of personal health data points every minute of every day, and the public willingly pays for that "privilege". This report explores the idea that the Nova Scotia Health Care system could be strengthened by engaging with the citizens who are collecting data concerning their own health and making some of their own health decisions based on the information they are monitoring. The future of healthcare is digital. Using personal health data in innovative ways provides additional tools for citizens to use to improve their own physical and mental health.

Background

Support for this research comes from Research Nova Scotia's Scotia Scholars Award, funded by Nova Scotia Department of Health & Wellness. Awarded to research trainees who are engaged in a health research project at participating Nova Scotian institutions. A gracious thank you is given to Research Nova Scotia and the Nova Scotia Department of Health and Wellness for making this work possible.
This research is focused on the "Improve Systems & Resources" and "Innovate for the Future" missions, under the "Healthy People & Health Care Systems" strategy of Research Nova Scotia.

Methods

This report is the integration of a detailed technology review, media review and a broad-ranging literature review. The technology review began with compiling data sheets from a selection of the most popular wearable and personal technology devices on the market today. The actual sensors, inside the devices, being used to generate this data were then analyzed. The literature and media reviewed included research using data collection devices and their impact on health outcomes, geolocated health data and Covid-19. This research also included involving Doctor-Patient interactions with 3rd party health data, health data in the Nova Scotia context, and available market data on the growing proliferation of wearable and personal technology.

Results

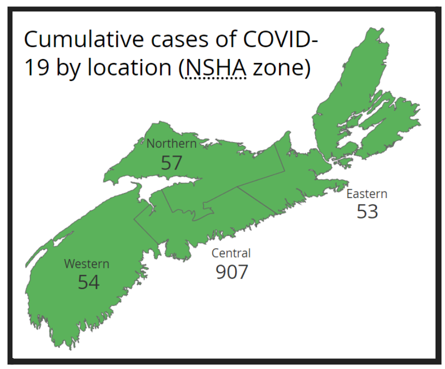
An abundance of personal health data is being collected with ever-increasing and sophisticated technology. This data has wide-ranging application in both personal and population health care.

Conclusion/Discussion

Health data is misunderstood and under-utilized. It is a classic example of analysis-paralysis, where the overwhelming amount of data created in this digital age makes it difficult to make important health-related decisions. Most people in Nova Scotia have taken some steps towards recording (albeit, not always knowingly) and monitoring some aspects of their own personal health data through our FitBits, cell phones, GPS devices and fitness trackers. These empowered patients are at a severe disadvantage in Nova Scotia where this patient generated data goes unused and unshared with care providers.

Introduction

The 1854 Broad Street cholera outbreak in the City of Westminster, London, England, killed 616 people. A physician at the time, John Snow, studied the cause of the outbreak and determined that contaminated water was the source of the cholera. The dot map, produced by John Snow (shown at the right) is credited as one of the earliest examples of using location mapping to influence public health decisions. The term "focus of infection" later became used to describe particular sites where conditions favoured the spread of infection. (1854 Broad Street Cholera Outbreak, wikipedia).



In strangely analogous circumstances, public health data has become a mainstream topic in Nova Scotia, as it has around the world. The Covid-19 pandemic has illustrated how important it is to communicate clear information to the public to keep them safe, but also to satisfy their thirst for knowledge. Although world Covid events often garnered the headlines, Nova Scotians demanded data that is relevant to their own personal situation, that is, health information about their community and even their close contacts. (image from CTV Atlantic, August 2, 2020).

Health data related to an individual has historically been produced through doctor, hospital, and other health care provider visits. Population health data is generated by compiling these sources of individual data and relating the information to specific regions, or communities or even to demographic traits. Now we have patient created data, collected through wearable devices, computer applications and cell phones. A wide variety of sensors can be employed, depending on the device themselves and patient preference. These sensors can measure heart rate, heart rate variability, heart rhythm (ECG), step count, distance traveled, movement, body temperature, skin temperature, sleep patterns, blood oxygen saturation, blood pressure, blood sugar level, oxygen uptake, and location. In this report, personalized health data that can be connected to a particular location, such as this, is called "Geolocated Health Data", (GHD).

When you enter a hospital, your health record becomes tied to that hospital, that information is used to track where healthcare is being consumed to efficiently allocate resources where needed. Individuals have multiple methods of creating their own GHD, the 2 most common being Smartphones and Wearables (Fitbits, Apple Watch, etc).

GHD plays a very important role in the delivery of healthcare to Nova Scotians. Incorporating location-based information can allow us to better understand risk factors for disease and identify novel targets for prevention efforts (Kamel Boulos et al., 2019). GHD helps to determine where new healthcare facilities and infrastructure is located. Visualization of GHD informs citizens of their relative risk of novel infectious diseases. GHD allows researchers to study discrete populations to track and better understand geographic trends. And GHD allows individuals to track and monitor their own health.

GHD is a rapidly growing area of interest in health care *(Phaneuf, 2022)*. The technology supporting GHD is rapidly growing and becoming more common. Basically, every citizen of Nova Scotia has a digital health footprint, whether they know it or not. This GHD is being used by multinational companies to improve their bottom line. This GHD can also be used to improve our healthcare system in Nova Scotia. This report provides a window into how this improvement can be made.

With an abundance of new wearable technologies on the market every year individuals and medical workers are inundated with users' health data. The future of health will be technology driven and personal wearable devices represent a tremendous wealth of information that remains underutilized. Imagine a population health researcher knowing where and when their subjects became infected with a pandemic virus. Or which regions of the province experience lower physical activity rates, or more heart rate abnormalities. GHD could allow a doctor to treat their patient more effectively by easily identifying whether their medications are wearing off too soon or too late, or that a patient's activity level was interfering with their optimum recovery. This research looks at the different impacts geolocated health data can have on our provincial health care systems. It is a review of the current technologies on the market with descriptions to help understand the data, the technology used to collect the data, the technology used to store the data and the technology solutions needed to access the data. The results of this review will provide answers to the questions of; what data is available? Where is it stored? How can it be accessed? What technology is needed to create workable solutions?

We must also recognize that there can be a downside in the drive to access personal information. Caution must be taken to avoid being seen as ‘Big Brother” watching over the population.


THE ROLE OF GHD IN HEALTH CARE
LOCATION OF HEALTH FACILITIES
GHD helps to determine where new healthcare facilities and infrastructure is located.
INFORMS CITIZENS
Visualization of GHD informs citizens of their relative risk of novel infectious diseases
BETTER UNDERSTAND GEOGRAPHIC TRENDS
GHD allows researchers to study discrete populations to track and better understand geographic trends
INDIVIDUALS MANAGING THEIR OWN HEALTH
GHD allows individuals to track and monitor their own health
Made By Andrew MacCulloch

Literature Review

GHD for the Individual

Health Care Practitioners widely believe the data that patients collect using wearable devices and smartphone apps impacts their clinical practice (Andrews, 2021).

Wearable device activity tracking allows customers to better self-manage their health. These devices remain in contact with our bodies for extended periods of time, collecting reams of data. individuals are interested in their activity levels and monitoring vital signs.

Surveys have found that diabetes apps are used by over half of those with type 1 and one third of those with type 2 diabetes (Kebede 2019). In another study, just under half of respondents with high blood pressure reported using apps to help manage it (Langford, 2019). In relation to mental health issues, apps and wearable technology have been used in the management of depressive and bipolar disorders (McIntyre 2017, Brick 2020), and a systematic review of depression apps identified the main medical functions of a selection of apps available for this market (Qu 2020).

User Data:

Individuals are already paying major technology companies like Google and Apple to collect and store their personal health data. Many people don't even realize this data is being collected (Apple's IPhone does it automatically) and how valuable it is. By purchasing and using smartphones, smartwatches, wearable devices, and smart home accessories we are agreeing to the terms and conditions and freely sharing this personal health data. A big part of the data that is being collected is gps enabled. As more devices become available and are connected to the internet of things, it will become impossible to not have a digital data footprint. Megabusiness is using this data to better market products to us and are using it in ways we don't even know about. It's a byproduct that users have access to their own data.

Better understanding of the user and non-user profiles of mobile health technologies may inform medical practitioners how best to target interventions to reach more of the population and improve health outcomes (Rising C, 2020).

GHD for Locating Facilities

Targeted Healthcare:

People need to access healthcare that is relevant to them. When reviewing the location components of patient data, we can make more accurate decisions about what type of healthcare needs to be offered and where. Understanding the location component allows us to make decisions on where to place new doctors' offices, ambulance bays, and hospitals. By looking at demographics we can better understand the age of the population, where people are located, what types of sicknesses they are dealing with. Understanding what types of illnesses are prevalent in certain areas is the first step in being able to provide proper care. How can health geomatics improve our understanding of the relationship between location and health?

GHD for Communication

Health Communication:

People want to know what is happening in their community. At the start of Covid-19 people expected to see confirmed cases mapped out. This was a new expectation from the public and something the province needed to provide quickly. People used these maps in a dramatic way, using them to make many decisions about their day-to-day life. It influenced where and when they would go grocery shopping, what doctors' office to visit, if they would visit family or stay home, and more. How can we use a similar approach to other illnesses, and inform our communities what is happening around them? Data maps related to certain cancers, drug deaths, MS, tracing colds and flus could begin influencing the way communities start noticing related illnesses in specific locations and which management strategies are most impactful. Families might use health maps to plan where they will settle in the province, and towns would be able to notice these trends sooner and relocate people faster to avoid illness.

GHD for Health Study and Demographics

Marra et al. (2020) reviewed 18 years of work (2000-2018) and found that clinical trials have been increasing their use of "connected digital products" at an annual growth rate exceeding 34%.

What would be the benefit if doctors had access to this GHD? If Health Nova Scotia could access everyone's health data there would be a daily, hourly, minute to minute snapshot of the current state of the province. You would see the entire province's mobility, heart rates, blood pressure, oxygen levels etc. There is a sense of how drastically this data will impact the future of health care, but it is so unused that trying to make predictions as an individual is back-breaking.

Covid has forced a more robust switch to virtual medical appointments. The NS public has accepted this new treatment pathway and will support it in the future.Crawford (2022)
Locally, Dr. Knapp is interested in examining geospatial differences in receipt of breast cancer surgery in Nova Scotia (Knapp 2022).

Technology Review

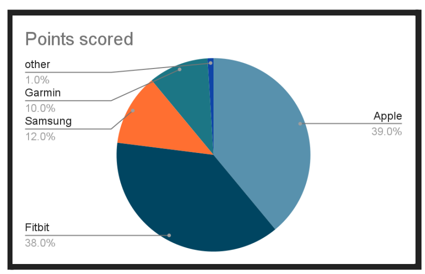
Every moment of everyday, phone applications, and wearables, are collecting detailed location data. Most of us only need to look at our wrist or scroll through our phone to get a glimpse of what health data is being collected all day and all night, wherever we are, when we are asleep, awake, working out or just hanging around.

Smart phones and smart watches collect this user data by being equipped with a variety of sensors. A sensor is a device which detects or measures a physical property and records, indicates, or otherwise responds to it (Merriam-Webster, 2022). Our fitness trackers, smart phones, apps and wearable devices are using a combination of sensors to collect health related data on: heart rate, heart rate variability, heart rhythm (ECG), step count, distance traveled, movement, body temperature, skin temperature, sleep patterns, blood oxygen saturation, blood pressure, blood sugar level, oxygen uptake, and more.

The sensors listed below may not be present in every smartwatch on the market but is instead intended to be a comprehensive list of the most common sensors found in consumer smart watches. Users are already collecting personal health data and it’s important to understand what is being collected. It is always advisable that if users are having health issues to contact a medical professional and not rely on their personal devices. Users who monitor their vitals and activity with sensors should only do so to have a general idea of their health and fitness.

In Canada there were 92.53 mobile subscriptions per 100 inhabitants in 2020. That percentage correlates to 898,932 mobile phone users in Nova Scotia. Apple alone holds seven of the top ten spots on the top selling smartphone list 2020. There are approximately 2.95 million smartwatch users in Canada 2022.

This year the top four eHealth trackers/ smartwatch brands constitute 99% of the market, Apple 39%, Fitbit 38%, Samsung 12%, Garmin 10% (Kunst, 2022).



Apple Watch Breakdown:

Apple watch is currently leading in the global market having sold over 100 million apple watch products (HKT, 2020). Since being launched in 2015 there are currently six series of Apple Watch models spread over many generations. Apple currently equips these devices with up to nine sensors: Optical heart sensor (ECG, EKG), Electric heart sensor, blood oxygen sensor, Satellite Navigation (GPS, GLONASS, Galileo, QZSS and BeiDou), Accelerometer, Gyroscope, Ambient light sensor, Altimeter, and Compass.

Apple has been building a system with their technology to assist health care providers. They make claims of helping health care providers work more effectively in hospitals, connecting remotely with patients, and contributing to medical research. They promote the sensors within their devices as giving patients an early warning sign of further evaluation being needed. They also have a dedicated app where researchers can enroll patients to capture consent and gather medical information more frequently (ResearchKit). To access Apples medical research network, you must contact an Apple Business Team Professional via their website or business phone number (https://www.apple.com/ca/healthcare/).

FitBit Breakdown:

Fitbit has 30 different product ranges including fitness trackers, smart watches, smart headphones, clip on trackers, wristband trackers, and smart scales. Fitbit has sold 93 million devices globally (Why Fitbit?, 2021). The newest of the smart watch product line is the Fitbit Versa 3 which comes equipped with six sensors: 3-axis accelerometer, Altimeter, Navigation (GPS, GLONASS), Optical heart-rate tracker, Device temperature sensor, and an Ambient light sensor. (Fitbit Inc, 2020)

Fitbit has been contributing to health research for over ten years (Why Fitbit?, 2021). They have a dedicated health solutions website - *healthsoultions.fitbit.com*, with an entire Fitbit publication library hosting over 1400 different studies. The most popular areas of interest are physical activity, sleep, chronic pain, and mental health. This website is also where researchers and organizations can contact a Fitbit Expert to access one of the largest databases of validated health data in the world. This database hosts 181 billion hours of heart rate data, 9 billion nights of sleep, 175 trillion steps, 457 billion minutes of exercise, and more (Why Fitbit?, 2021).

Definition of Sensors:

To be used in a medical setting doctors must understand the data that is being collected, what information each of the sensors collecting, what environmental factors influence the data, and overall accuracy of the data.

Optical Heart Sensor:

How does optical heart rate monitoring (OHRM) work? Most wearables measure heart rate using photoplethysmography (PPG). PPG is a technical term for shining light into the skin and measuring the amount of light that is scattered by blood flow. Light entering the body will scatter in a predictable manner, as the blood flow dynamic changes, like changes in blood pulse rates or with changes in blood volume we are able to measure this.

How does the technology work?
There are four primary technical components to measure heart rate: Optical emitters, Photodetectors, Accelerometer, and Algorithms.

1. Optical emitters - Both Apple and Fitbit use green LEDS to detect the amount of blood flowing through your wrist. Red light is reflected by blood and green light is absorbed. With an increased heart rate there is more blood flowing, and thus more absorption of green light. The most state-of-the-art optical heart rate monitors use multiple light wavelengths that interact differently with different levels of skin and tissue.
2. Photodetectors - A photodetector captures the light refracted from the user of the device and translates those signals into binary code to be calculated into meaningful heart rate data.
3. Accelerometer - the accelerometer which measures motion is used in combination with the photodetector signal as inputs for photoplethysmography algorithms.
4. Algorithms - the algorithms process signals from the photodetector and the accelerometer into heart rate data, calories burned, heart rate variability, blood oxygen levels, and blood pressure.

Electric Heart Sensor:

Electric heart sensors in wearables became widespread in 2019 after being included in the Apple Watch Series 5. It is now available in many more devices including the new series of Samsung Galaxy Watch, and Fitbit lineups. Rather than measuring blood flow like the optical heart sensor, electric heart sensors use the electrocardiogram to measure how well the heart is working. Wearable devices work differently than the same sensor found in a medical setting. By placing your finger directly on the sensor your heartbeat will be measured for 30 seconds and will indicate whether you have a normal sinus rhythm, or whether there are signs that you might have atrial fibrillation, or an inconclusive reading. The biggest difference between an electrocardiograph at a hospital and the ECG technology in your Apple, Fitbit or Samsung smartwatch is the first is a 12 lead and the latter is a single lead. The 12 lead is taking lots of readings about your heart - the single lead is taking one. The single lead has limited capabilities and offers a single view of your heart. There are some benefits of having this technology at home, users could detect irregular and abnormally fast heartbeats. These being the early symptoms of several heart related issues. For people who have palpitations or other symptoms, ECG can be a reassurance and lets users have better informed conversations with their doctors.

Blood Oxygen Sensor:

Smartwatches use the Reflectance Oximetry technique to measure oxygen saturation levels of the body. By using the same optical emitters for measuring heart rate, blood oxygen levels can be determined based on the difference between injected and reflected light. The reflected oximetry technique projects red and infrared light into the wrist. The red light enters the blood tissues containing oxygen, reflecting the light back to the sensor. The difference between the level of injected light and reflected light is shown as the SpO2 level of the body. The American FDA - National Centre of Biotechnology warns against smartwatch SpO2 monitors for medical reasons as the readings are not as accurate as an Oximeter, they recommend the device only be used for casual tracking.

Satellite Navigation:

Smartwatch satellite navigation uses GPS and GIS to provide data on location of the device, distance traveled, pace, and route mapping. Some smartwatches work in collaboration with the cellphone, but most can operate independently. The smartwatch captures the signal data and uses a triangulation method to pinpoint your exact location. GPS receivers must detect at least three satellites for latitude and longitude and four satellites to measure your altitude. An internet connection is not required since the receiver in a smartwatch uses the GPS satellite network. The watch is a signal receiver which sends out and receives a signal from satellites. The amount of time for an exchange of signals to occur is how GPS watches track movement (Parnell, 2020).

Accelerometer:

The 3-axis accelerometer is one of the most common sensors found in wearable devices. This sensor tracks forward and backward movement, determines the body's orientation, position, and changes in speed. With this information we can track whether the user is walking, running, cycling, or involved in other activities based on the speed of the individual.

Gyroscope:

Gyroscopes measure angular velocity and are used to detect motion. It is the primary sensor for determining exercise. Because this sensor detects motion it can differentiate from running or simply jogging on the spot. By detecting motion, you can track specific types of movement, such as arm movements made during a workout. This device's outputs are often accompanied by information from the accelerometer for tracking rotation and twisting.

Ambient Light Sensor:

The primary job of the ambient light sensor is to detect ambient light around the display and to adjust display brightness based on this amount. This provides users with a better viewing experience and aids in saving battery life.

Altimeter:

An altimeter is a sensor that helps measure altitude and detects changes in height. It works by having a built-in pressure sensor that can measure ambient air pressure resulting in barometric altitude measurements. It is used for tracking exercise and calorie counting, by determining if you are going up and down stairs or a slope. It remains on to provide real-time elevation information and becomes more accurate when combined with other GPS data.

Compass:

A compass helps map applications run on the smartwatch and gives the device a sense of direction. The compass in most watches is a digital compass, or magnetometer, that measures the earth's magnetic field to determine the direction to the magnetic poles.

Summary of Technology:

The benefits of these technologies are helping us paint a more accurate picture of our health and fitness. They can assist us in understanding our bodies and how it responds to exercise and daily life. The data recorded can be influenced by environmental factors and may not always be accurate. If there is a reading you are concerned about, one should see a medical professional for further examination. Users who monitor their conditions should pay attention to all signs and symptoms of their condition and communicate any concerts to their health care provider. If you are having health issues it is advised to use medical-grade equipment over any smart-wearables.

Conclusions

- Geolocated Health Data is a very valuable data source.
- GHD is big business.
- GHD is collected in different formats, different systems and by different sensors, or by unique user input.
- GHD is often misunderstood by the individual creating it and by health care practitioners.
- GHD is often freely shared by its creator.
- GHD may not be equally available across underrepresented populations.

- Self-generated health data is increasingly important in individual health care decisions.

- Nova Scotia has commercial expertise in many aspects of the pertinent technology.
- Nova Scotia has research expertise studying this technology and applications.

- It will be easier and more effective to “keep up” than to “catch up” with this technology.
- Select regions are using GHD in their healthcare systems at present.
- Future uses of GHD will be wide ranging and impactful.

Most market forecasts predict that there will be over 1 billion wearable devices in use around the world in the next few years. This is a huge opportunity to use technology to improve our healthcare system, both by using the data to create better individual and community outcomes, and by supporting future innovators and entrepreneurs in our province.

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