INTERNET OF MEDICAL THINGS – BASED HEALTH RISK INSURANCE MODELING

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Abstract: *When concluding an insurance contract, data collections that convey information about an individual's measurable parameters are vital in assessing the insured's health state. Within the model that relies on data about potential insured, the technical and technological background of solving the health insurance modeling challenge should be found. The data is inherited (historical), previously acquired data, as well as data collected in real time. A body area network is a network of wearable computing devices or devices embedded in the body. These devices can be worn on the body or monitored by equipment in the local surroundings, whether wearable or stationary. The concept of the Internet of Medical Things on and around the human body, such as Wearable Sensors, is increasingly being used for not only monitoring an individual's health state, but also for collecting data that might be used for health risk assessment of insured.*

Key words: Body area network, Health insurance, IoT, Wearable Sensors

1. DIGITAL ECOSYSTEM IN INSURANCE

For a number of years, people have been carrying devices and sensor systems with them that are able to collect and transmit a large amount of data about the person wearing the device, his or her behaviors, and even their health. Such collections can be used for real-time analysis, automatic triggering of actions, or even defining business or operational models. Accurate and precise determination of risk is one of the basic activities of insurers. The more accurate the estimate, the greater the business success. IoT-based systems in insurance are often tasked with interacting with the user, retrieving the necessary information about the client or processing claims. No special explanation is needed for this traditional approach, they naturally occupied a business niche. However, increasingly, IoT systems are changing or completely defining new business logic.

Business models based on IoT are grouped into several current digital ecosystems (Behm et al., 2019):

1. Ecosystem of network-centric organized smart vehicles.
2. Smart housing and smart risk management ecosystem.
3. Smart treatment ecosystem in health management.
4. Ecosystem for business distribution with partners (B2B/B2C).

If it functions and operates in a single instance of the ecosystem, the organization of life and business in habitats created in this way extends to the horizon; if it functions and operates in multiple coexisting instances of the ecosystem, it extends within the intersection of several ecosystems of interest. This type of structure exists in both the physical and digital realms of existence. The commercial dynamics are best illustrated by two examples: the smart housing ecosystem, the most advanced of the four ecosystems, and the smart treatment ecosystem in health management. Ambient Assisted Living is one of the more successful concepts; it mixes smart homes and connected health services and enables corporate integration into the personalized insurance approach market.

1.1 The role of health management ecosystems in the development of health insurance models

The insurance market did not initially recognize smart housing and smart health management as important concepts. This was primarily due to technological but also sociological limitations. The potential new market was too limited for technical reasons and the solutions available on the market were slow to meet technical standards. Fortunately, it didn't stop there. After the big players in the field of IoT services like Google and Amazon, other providers have also offered their digital infrastructure services needed for smart health and treatment management. Such a technological breakthrough has enabled many insurers to launch collaborative models, selling integrated products through Google Nest or a similar service. In 2008, the

number of IoT devices exceeded the current population (Behm et al., 2019) and thus definitely enabled insurance companies to enter the field of personalized life and health insurance (Figure 1).
People who collaborate in an ecosystem based on the Internet of Medical Things idea and use IoT edge devices to monitor their essential functions are now eligible for personalized products and insurance bonus. In addition, insurers offer digital services such as health security and other services whose advantages correspond to consumers' interests based on the data gathered.

2. WEARABLE *DEVICES* IN THE HEALTHCARE ENVIRONMENT

As we've seen, and have known for some time, wearable technology and the related algorithms of the digital ecosystem of smart treatment in health management allow medical professionals to view the individual in a wider context and deliver effective health services. When examining the individual from the perspective of insurance, there aren't many differences. We are particularly interested in wearable devices that enable the collection of contextually organized data on possible insured. Therefore, wearable devices used in the healthcare environment to quantify the health status of the user are also devices of interest to the insurance industry. These devices can be divided and organized into several categories. For example, they can be divided according to the location on the body where they are worn or changes in medical records that device register. The following figure (Figure 2) illustrates wearable gadgets based on their location on the human body.

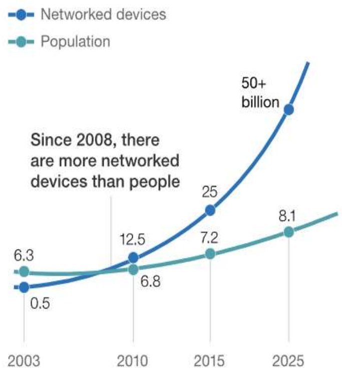


Figure 1: Time distribution of the number of IoT devices and population (Source: Behm et al., 2019)

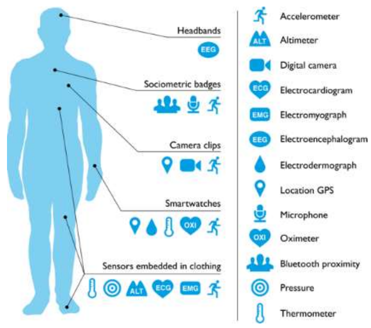


Figure 2: Wearable devices and their attached locations on the human body (Source: Piwek et al., 2016)

Regardless of the perspective, measurement or health condition that device record, we have identified a number of commercially available wearable devices that are used in the healthcare environment and are suitable for health insurance modeling based on the Internet of Medical Things (Table 1).

Table 1. Wearable devices that are used in the healthcare environment and could be used in health insurance modeling

Wearable Device	***Body Location***	***Typical Use Case/Disease Condition***	***Captured Movement***
Smartwatch with chest band (Vijayan et al., 2021)	Wrist and Chest	Multisport overal body condition	Movement, VO2Max, heart rate, oxygen saturation.
Smart Electro-Clothing Systems – SeCSs (Sayem et al., 2020)	Heart	Health Monitoring	Surface electromyography (sEMG); HR, heart rate variability.
Xsens DOT (Xsens, 2015)	All over the body	Healthcare, sports	Osteoarthritis
5DT data glove (Caeiro-Rodríguez et al., 2021)	Fingers and wrist	Robust Hand Motic Tracking	Fibre optic sensors measure flexion and extension of the Interphalangeal (IP), metacarpophalangeal (MCP) joints of the fingers and thumb, abduction and adduction, and the orientation (pitch and roll) of the user's hand.
Neofect Raphael data glove (Shin, 2016)	Fingers, wrist and forearm	Poststroke patients	Accelerometer and bending sensors measuring flexion and extension of finger and thumb.

Polysomnography sensors (Schätz et al., 2020)	Chest, hand, leg and head	Identify sleep apnoea	Breathing volume and heart rate.
Pulse oximetry (Liebling et al., 2018)	Finger	Pulmonary disease	Monitor oxygen saturation, respiratory rate, breathing pattern and air quality.
Eversense Glucose Monitoring, Guardian Connect System and Dexcom CGM (Kumar, 2019)	Hand	Diabetes	Glucose level monitoring.

Although recognized devices are widely distributed among patients with various medical conditions, the most interesting for insurers are those that are commercial and are most commonly worn by the healthy part of the population. Due to this, we will focus on the most commercially viable gadgets, smart watches.

3. SMART WATCHES AS PROVIDER OF PHYSICAL ACTIVITY METRICS IN HEALTH INSURANCE MODELING

The efficiency of physical activity as measured by wearable sensors in stratifying the mortality risk profile of a U.S. population-based dataset derived from a collection of clinical research studies was assessed by Munich Re. The dataset includes each participant's vital status (dead or alive) across a 20-year period, allowing for a comprehensive dive into the association between physical activity and mortality outcomes. The results of the study showed (Figure 3) that those with sedentary lifestyles and low daily step counts have considerably greater mortality risks, whereas people with moderate to high daily step counts have lower risks (Chefitz et al., 2022). The number of daily steps is particularly useful in identifying sedentary behavior that has a high mortality risk. Insurers who want to involve clients in the risk assessment process, improve the healthy lifestyle of policyholders may in the future want to consider the use of physical activity metrics obtained using wearable sensors such as smart watches throughout the insurance period and at different time points of life insurance.

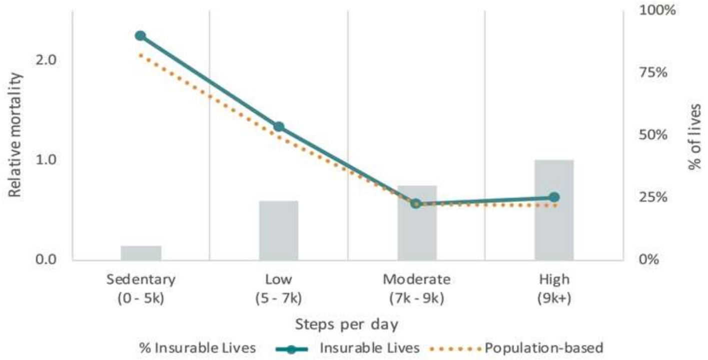


Figure 3: Relative mortality by average steps per day (Source: MunichRe, 2022)

3.1 Health monitoring and activity tracking features of smart watches

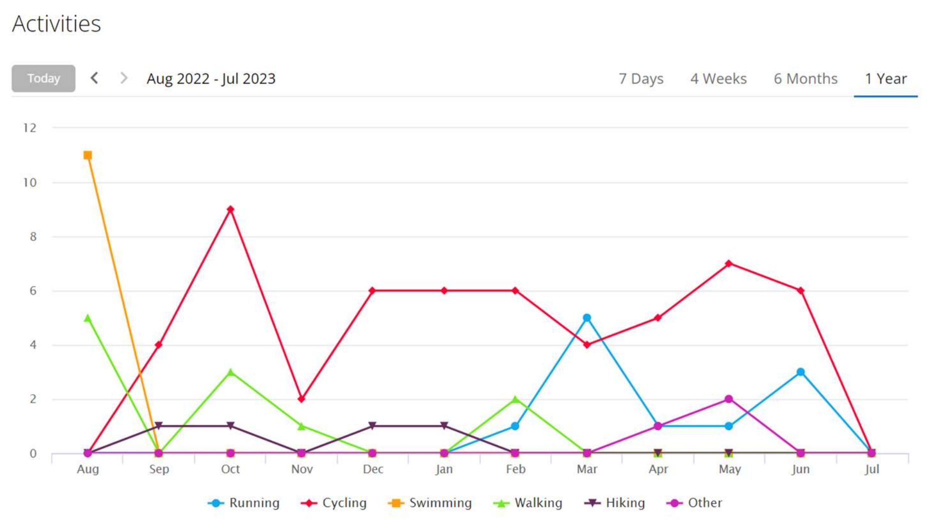
For the purpose of research, we have selected a multisport smart watch, the Garmin Fenix, as a representative example of a device for exploring the features of a fitness tracker that can be useful to insurers when determining and monitoring the health status of the insured.

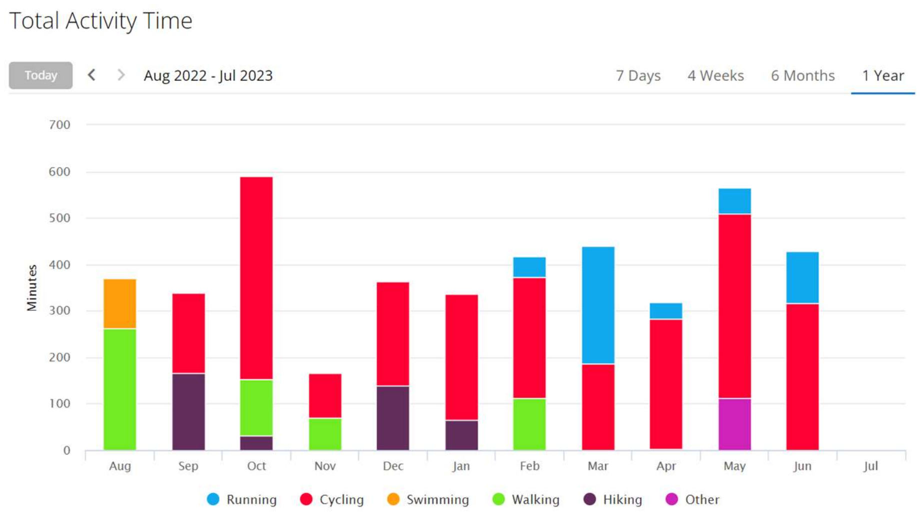
Garmin Fenix, a multisport smart watch, from version 5 to the current version 7, is a device from the category of wearable medical devices that is widely used to monitor the state of training of athletes, their general condition, and critical health indicators. The reports generated by this device can be monitored live on the display of the watch itself, on the local application (bluetooth connected to the logger), and also remotely for the purposes of acquisition or monitoring by trainers and medical staff.

This device can only be used as a smart watch, with the use of a chest strap, or with the use of a logger. Regardless of which configuration is used, the time series of collected data are stored and used locally, both at the time of logging and in subsequent processing. Therefore, this device can be seen as an edge IoT device but also as an edge-to-fog system when it is completed with a logger. When the watch is used only in an isolated device configuration without a logger, data can be stored for 24 hours, after which it must be transferred to either the logger or a computer due to the limitations of the local memory on the watch.

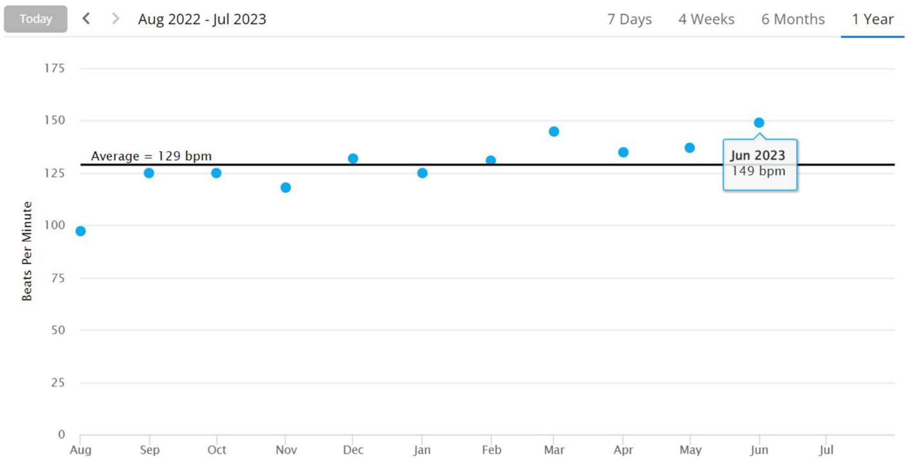
The chest strap does not expand the possibilities but serves to increase the precision and density of data sampling.

Data can be generated to examine the general status of training and vital functions, in addition to GPS, multisport capabilities and sensor data, to track the wearer's present health. Reports intended for subsequent analysis are of particular interest to medical censors in insurance companies. Specifically, in the case of the mentioned smart device, the following reports that could be useful for health risk assessment (Figure 4) are available: Activities; Activity Calories; Average Heart Rate; Average Pace; Average Speed; Calories Consumed; Calories Remaining; Functional Threshold Power; HRV Stress; Max Heart Rate; Total Activity Time; Total Distance; Training Status; VO_2 Max.

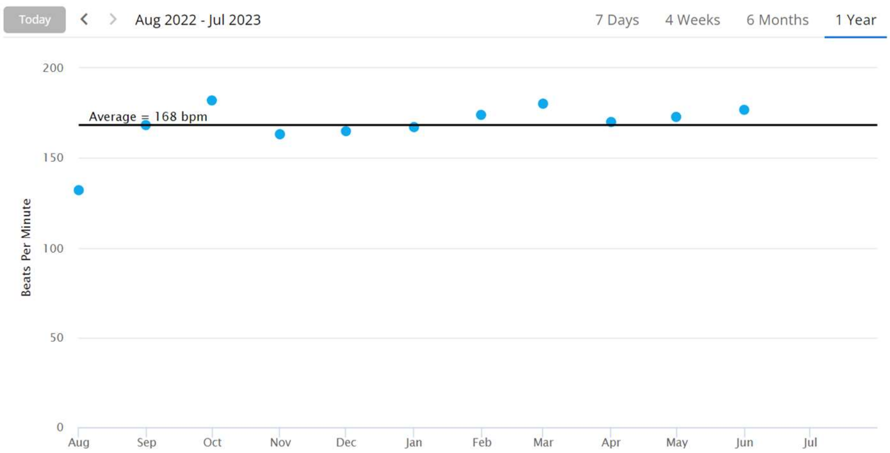




Average Heart Rate



Max Heart Rate



VO_2 Max

Figure 4: Garmin Fenix - Activity and health reports

Of particular interest, for subsequent analysis, can be the monitoring of heart activity (Figure 5).

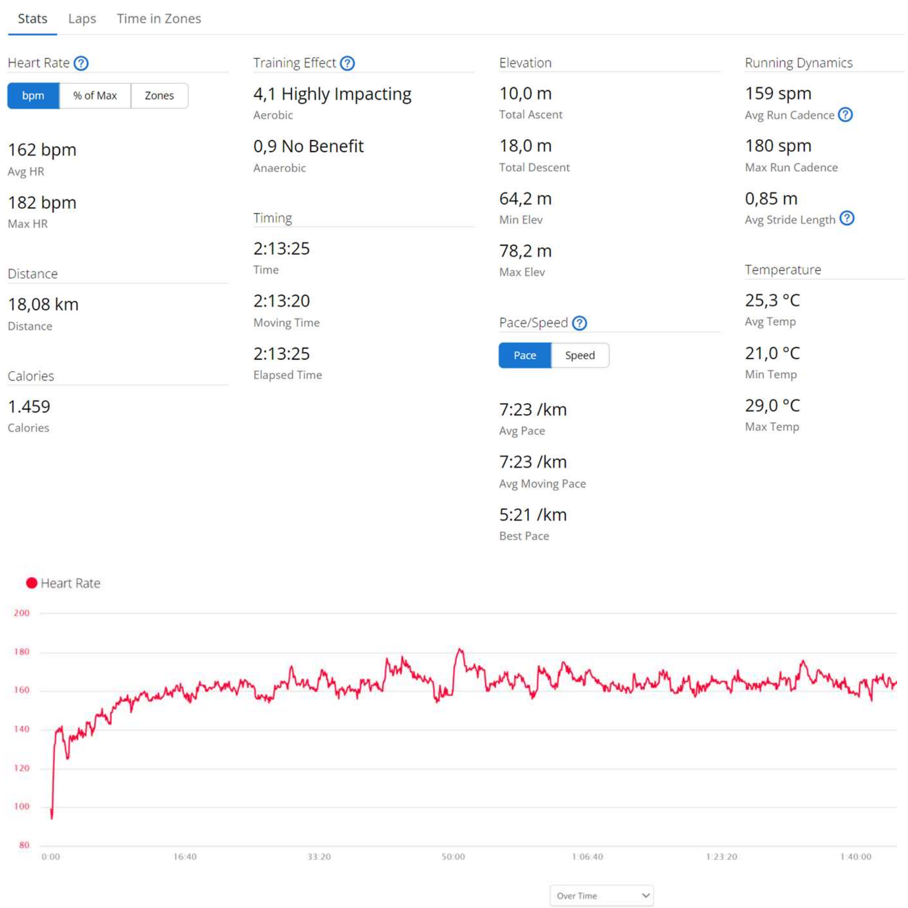


Figure 5: Heart rate report

In order to show potentially dangerous health conditions and situations that can be noticed in the reports and are therefore potentially useful to insurers, we will also list some specific examples.
One of the particularly interesting monitored parameters is the Resting Heart Rate (Figure 6). In a healthy person, this parameter is in the range of 50 to 70 bpm (beats per minute). In the observed series of data, this value deviated from the usual value in November last year. The change was registered and logged. It was subsequently determined that there were health impairments during that period, which were confirmed by laboratory analyses and medical examination later on. In other words, if this parameter had been monitored by a person or healthcare AI in charge of the client's health condition, the client could have been alerted immediately and not later, when the consequences had already occurred.
In the following example of monitoring physical activities, a dangerous situation also occurred (Figure 7). During the activity, the heart rate was in the danger zone for twenty minutes.

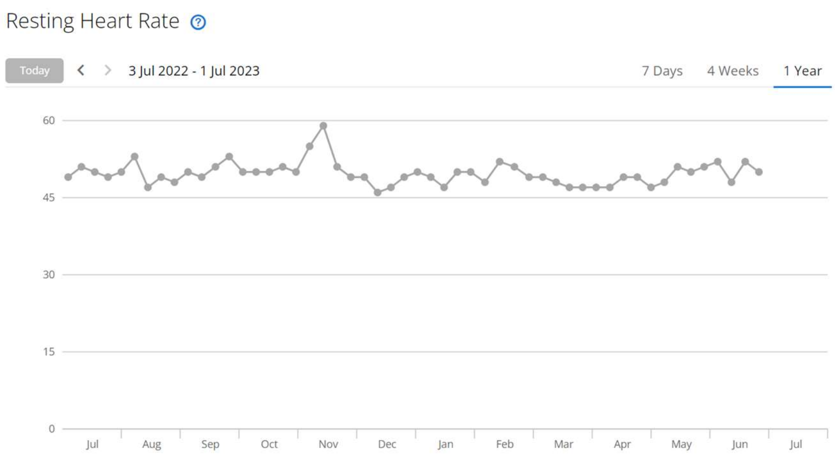


Figure 6: Resting Heart Rate

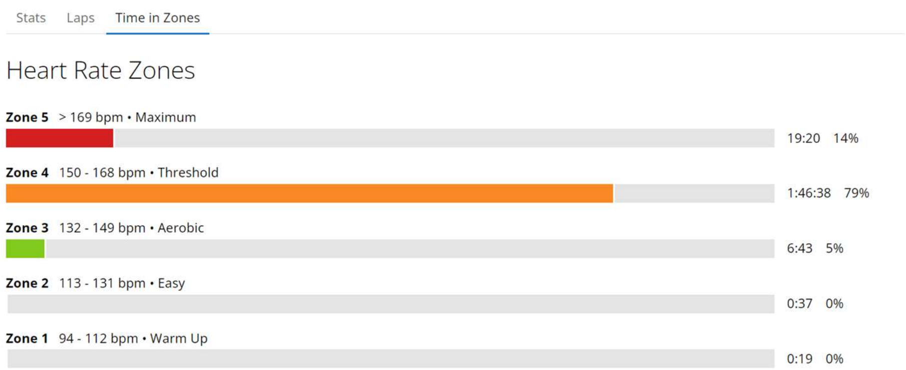


Figure 7: Heart Rate Zones

4. DISCUSSION AND CONCLUSION

Based on the presented case study of the Garmin Fenix multisport smart watch application, two roles for the person or AI who monitors and interprets the data are indicated.
The first roll is related to incidental health conditions and potentially harmful events. In this type of data analysis, the monitoring person or AI recognizes unwanted conditions and informs the insured about the danger.
The second roll is less noticeable but potentially more interesting for further insurance personalization. In this case, the person conducting health surveillance creates a kind of medical data model and projects desirable activities based on that model. Activities can be various, from suggestions for preventive

examinations to recommendations on daily routines that can raise the quality of life of the insured. This increases health resilience and reduces the occurrence of potentially harmful health events. Ultimately, this reduces the insured's claims.

Modeling of health insurance based on the Internet of Medical Things is definitely an aspect of modern technology that brings novelty in the perception of business. Also, to a certain extent, it changes the perspective and the role of the insurance agent. Beside identifying sales opportunities for insurance plans and overseeing a portfolio of clients or tracking claims, the aspect of continuous monitoring of the health parameters of the insured is now being added. A trend that began in professional sports, where the coach received real-time values of the variables of interest and could alter training or even the athlete's behavior during competition, is now spreading to the health insurance industry. Now the insurance agent assumes the role of a supervisor and monitors the client's vital parameters in real time. Based on currently measured values or on the basis of analysis of historically collected data series, a model of the insured's medical assessment is generated, and the agent is able to take pro-active steps and thus influence the insured's health condition and contract terms.

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