MILLIMAN WHITE PAPER

What is the impact of wearable technologies on life expectancy?

State of the art of the current knowledge

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Wearable technologies are becoming increasingly important, not only in our daily lives but also in medicine, potentially leading to medical breakthroughs, including live health monitoring and individualisation of treatments.

Digitalisation of treatments and patient follow-up could transform the entire health sector, including doctors, the medical profession and life insurers. The latter can consider three points:

1. What are the consequences from the daily or occasional use of these objects in terms of mortality?
2. How can these effects be integrated into mortality projections?
3. How can incentives for their use be incorporated into life and health products?

The aim of this white paper is therefore to study, through the existing literature, the extent to which the different types of wearable technologies can enhance health and life expectancy, whether through the better health management they enable or thanks to the amount of data they provide to compute more accurate predictions for health and life span. Finally, this white paper analyses the treatment of wearables in insurance contracts.

Context

The wearables market is expanding worldwide, with a key question relating to the usefulness of wearables in predicting longevity and their impact on healthcare systems and insurance around the globe.

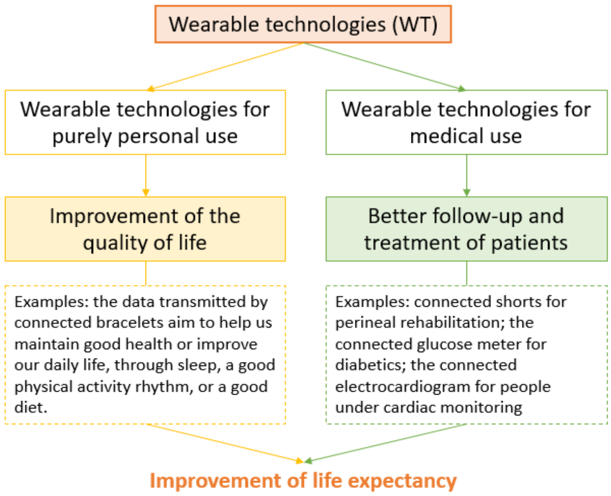
Life span has been increasing steadily since the 1850s. Most of the explanations are related to exogenous factors such as lifestyle and medical advances. Collecting relevant data through wearable technologies may be an opportunity to understand the explanatory variables of longevity in different geographies in greater detail.

Medical devices allow the collection of data which were previously difficult to obtain in real time. Thus, the understanding of certain diseases is improved: treatments can be more personalised, and patients better taken care of.

Everyday connected objects can have diverse roles in medicine, such as encouraging a healthier lifestyle, allowing the implementation of more appropriate treatments, assisting the elderly in their medical monitoring or avoiding accidental deaths in dangerous work areas.

Intuitively, it seems that these technologies contribute to the improvement of life expectancy, as diagrammed in Figure 1. Nevertheless, this intuition will have to be verified and quantified through statistical studies.

FIGURE 1: INTUITIVE IMPACT OF DIFFERENT TYPES OF WEARABLES ON LIFE EXPECTANCY



Source: Milliman

Executive summary

This paper is a review of the literature released before 2022 on the impact of wearables on mortality. Many qualitative studies are available on the subject, but no explicit quantification of mortality impact has been found. Due to privacy regulations, the access to open data remains complex, especially obtaining the consent of the users of wearables in studies of their data. Once relevant data is collected, methodologies can be established to assess the impact on mortality of a type of wearable:

1. **Considering mortality rates by age class** and **cause of death**.
2. **Identifying the main variables** linked to the type of studied wearable (cause of death, lifestyle factors etc.).
3. **Splitting individuals into two groups,** one for users of connected objects and the other for control.
4. **Quantifying the effects of the devices** in terms of life expectancy or mortality, according to the purpose.

Sometimes, only very small samples of data are available. In this case, appropriate statistical hypothesis tests must be used (these are the tests generally used in biostatistics to evaluate the impact of a drug on a sample of individuals, such as the Mann-Whitney test for very small samples, or the chi-square test for larger samples).

Once the mortality adjustment by age group and cause of death is calculated, it can be directly applied to the mortality projections, taking care to multiply this adjustment by the projection of the percentage of the population in the relevant age group that will use the wearable whose impact we are studying.

These objects, which are a rich source of information, could be integrated into insurance contracts. The use of data from wearables would be particularly useful in insurance (to price health or life insurance contracts, for example). However, it remains difficult to access and use data from wearables, because of the various data protection and pricing regulations currently in force as well as the practical challenges of using wearables data.

Definition and classification of wearable technologies

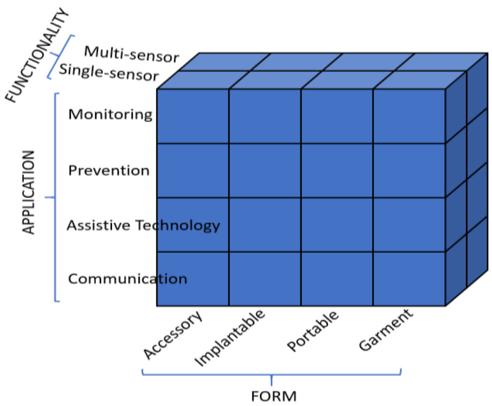
Before studying the impact of wearable technologies on life expectancy, it is necessary to clarify the scope of the study by precisely defining these devices. According to Kurwa et al.,[1] a wearable technology is a computing device with an application which collects and processes data. It often takes the form of a fashion accessory (like a wristwatch), but it can also be on the body (like a smart patch) or in the body (like a monitoring sensor attached to the heart). Besides this basic definition, secondary characteristics have been identified by Çiçek:[2]

- **Interface**, meant to transfer data between the wearer and the device.
- **Communication** through wireless systems such as Bluetooth technology or radio frequencies.
- **Data management:** Data storage and processing.
- **Energy management**.
- **Integrated circuits**.

In fact, each technology is developed for a specific purpose in a certain sector. Therefore, each one has its own characteristics and applications. Diverse classifications of wearables exist in the literature. Thus, Alrige[3] categorises these objects according to three dimensions, schematised in Figure 2:

1. **Application**, which concerns the main purpose of the object. Four levels of applications are defined:
    a. Monitoring
    b. Assistance, mainly used by sick and medically monitored individuals
    c. Prevention
    d. Communication, intended for the healthy population
2. **The form** the object can take (accessory, wearable or implantable).
3. **Functionality**: While certain technologies measure a single parameter and perform a single function, others are able to measure more and perform several functions.

FIGURE 2: TAXONOMY FOR HEALTHCARE WEARABLES



Source: Alrige

Because it focusses only on health-related wearables, this classification is particularly relevant for our study, based on the impact of wearables in terms of life expectancy and health.

We distinguished two classes, based on the previous Alrige classification:

1. **Medical purpose:** These health wearable technologies target individuals suffering from existing diseases.
2. **Daily life** wearable technologies, including wearable textiles, consumer electronics and personal health wearables that are used by the general public.

Collection of new data

AN ACCESS TO NEW VARIABLES

Wearable technologies are particularly interesting because they provide:

- **New data** that cannot be obtained otherwise.
- **Better quality data**: Quantitative data replaces previously declared data, such as sleep quality.
- **More data**, **obtained in real time,** thanks to higher frequencies of measurement.

The data processing cycle of wearable data is complex and not detailed in this paper (see Figure 3 and Ometov et al.[4] for more details).

Nevertheless, it leads to interoperability issues identified by Arriba-Pérez:[5] the variety of devices and operating systems available, the issues related to the data models etc. Another major concern is the exploitation of personal data, developed further in this white paper.

Even though wearable technologies provide massive and relevant amounts of data, multidisciplinary teams are required to store and analyse the measure in a clinically relevant manner. Especially, Liao et al.[6] raises the issue of the cost to handle the treatment and visualisation of this huge volume of data. Today, this topic is still to be investigated.

FIGURE 3: CYCLE OF WEARABLE DATA

Source: Ometov et al.

FREE DATASETS AVAILABLE

Very few databases of wearable device data are available as open access. While technology users can retrieve their own data, databases of all users are not accessible. Yet it would allow for more in-depth studies on the impact of wearable technologies on health and life expectancy. We did not identify any public database on wearables data. Furthermore, studies on wearables are generally based on small samples of individuals, as a table of the main articles on the topic published by Pardamean et al.[7] reveals.

However, we found two relevant databases or concepts of data collection:

1. **Swedish Heart Failure Registry** (SwedeHF):[8] The SwedeHF allows the linking of many very precise medical data points with mortality data. The registry collects information from 65 hospitals and 113 clinics within Sweden. It counts about 130 patient variables including demographic, clinical and laboratory data, and most of them are collected via wearables (Ahmad et al.[9]). The registry can lead to obtaining 1-year all-cause mortality. Nevertheless, the data are not fully open access: a potential user must explain the purpose of the research and obtain authorisation to receive access to these data.
2. **Baseline Project:**[10] A platform where people can sign up for different research projects if they meet specific criteria. Their data is collected for research purposes, and the participants themselves can view their results and analyses. Particularly some projects require the use of wearables, such as sleep sensors, as detailed by Arges et al.[11] Therefore, it is a good way to collect data from these devices.

Wearable technologies in medicine

We discuss below the first category of wearables—wearables technologies for medical use. Typically, they can be classified into three subcategories (Phaneuf[12]):

1. **Patient monitoring**, which includes blood pressure monitors and electrocardiogram (ECG) monitors.
2. **Prevention of medical claims**, like smart health watches or biosensors.
3. **Treatment of medical problems**, as INNOVO products help treating urinary incontinence.

USE OF DATA FROM WEARABLES: IMPACT ON KNOWLEDGE OF DISEASES

The benefits of medical wearables are numerous. First, they allow the collection of more accurate, continuous-time datasets, which gives physicians a better view of a patient's health status. Moreover, they can create alerts in case of anomaly or deterioration in the measures taken (Ramachandran & Karuppiah[13]). Wearable sensors could help physicians monitor patients once they return home. Last but not least, the amount of precise and numerous data they bring (e.g., neurological, motion, cardiac data) leads to a better understanding of diseases. For instance, by monitoring a patient's foot movements in a continuous manner, Varatharajan et al.[14] have shown that they are a relevant indicator for the detection of the early stage of Alzheimer's disease.

In conclusion, early detection of certain diseases would allow for better prevention and management, which may significantly reduce deaths from these causes. In addition, improved knowledge of certain diseases would facilitate the implementation of more appropriate treatments and follow-up of patients, thus potentially extending the life expectancy of these individuals.

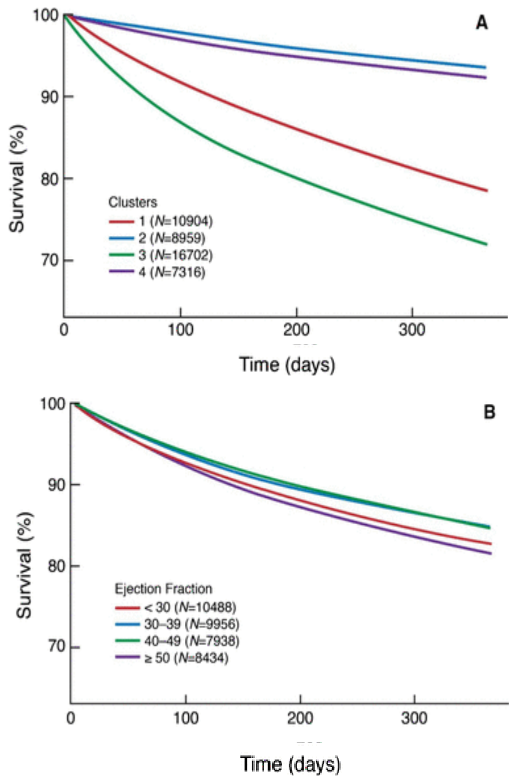
IMPACT ON LIFE EXPECTANCY

Because of the difficulty of systematically collecting medical data, there are few quantitative studies showing an impact of connected wearable objects on health or life expectancy. Furthermore, life expectancy is assessed over the long term; however, when health data is available, we generally only have a few years of history, but not enough to assess the impact on mortality over, for example, a 10-year horizon.

Nevertheless, some insights into the contribution of this type of data in terms of mortality reduction can be gained from some studies, including Ahmad et al.[15] This article highlights the possibility of predicting 1-year mortality of patients with heart failure using specific data, which could be provided by wearables. This work is unique to date, and the outputs of this study are particularly interesting in terms of predictions. Hereunder is detailed the methodology used in Ahmad et al.:

1. **Preprocessing and then training** the SwedeHF data to create a random forest to predict 1-year survival after hospital discharge.
2. **Clustering of patients** in four groups with *k*-means thanks to the eight more predictive variables. The variables are the following: age, creatinine, hemoglobin, weight, heart rate, systolic blood pressure, mean arterial pressure and income. Among these variables, heart rate, systolic blood pressure and mean arterial pressure can be collected by wearables.
3. **Computation of Kaplan-Meier survival curves** to compare the predictive utility of each methodology. The top of Figure 4 shows survival curves for each of the four groups based on data collected from wearables. On the bottom, survival curves are presented for the four groups based on different levels of left ventricular ejection fraction (LVEF), a variable typically used to discriminate the patients.

FIGURE 4: SURVIVAL CURVES ACCORDING TO (A) CLUSTER AND (B) EJECTION FRACTION GROUP



Source: Ahmad et al.

Figure 4 shows that the new segmentation helps to define four groups of individuals with homogeneous characteristics and very distinct survival curves. The typical grouping does not provide large differences in terms of life expectancy. Besides, it appears that the group of people with normal LVEF (above 50) has lower survival curves. In that case, LVEF is not the most determinant variable to use to predict mortality. Thus, this type of study would have several impacts:

- Improving the effectiveness of current treatments and transforming future heart failure clinical trials.
- Predicting 1-year mortality, or even further out if the data are available.

The question then arises as to how to incorporate the observed differences in mortality for specific causes into aggregate mortality predictions. Previous work has been done in Boumezoued et al.[16] on the projection of mortality by cause of death. For each cause, the model of projection is based on the classic Lee-Carter framework but has extended it to a multivariate setting and adapted it to by-cause modelling using a specific calibration of the future trends.

Generally, in the treatment of wearable data, it is impossible to avoid selection bias. Indeed, because wearable users are usually paying more attention to their health, it is hard to distinguish the part of the increase in life expectancy that is due to the use of wearables from the part that is due to the selection bias. But here, in the medical framework, this selection bias could be weaker, because individuals do not take the initiative to use a wearable technology. It is doctors who make the decision to use the wearable technology.

In terms of mathematical models, appropriate statistical hypothesis tests must be used (these are the tests generally used in biostatistics to evaluate the impact of a drug on a sample of individuals, such as the Mann-Whitney test for very small samples, or the chi-square test for larger samples). However, in the next one to five years, as there will be few deaths, one can use credibility theory and relational models to challenge statistical estimators and avoid basing the estimate of the mortality rate solely on the sample.

Besides the anticipation of future mortality, wearables can help in studying the prevalence of diseases, thanks to the very granular information they provide.

Daily life wearable technologies

According to our researches, everyday wearables technologies can be classified into three subgroups:

1. **Encouragement of a healthy lifestyle**, through for instance smartwatches aiming to monitor many variables or smart sleep products to improve sleep quality and habits.
2. **Prevention of injuries,** especially in the world of sport (swimsuits with UV sensor, clothing lines which enhance muscle recovery).
3. **Prevention of specific diseases**, such as G95 filtration clothes to prevent the development of respiratory issues or viral infection.

IMPACTS ON WAY OF LIFE AND LIFE EXPECTANCY

The need for very long-term follow-up data makes the establishment of a direct link between the use of wearable and life expectancy difficult. Nevertheless, lifestyle and life expectancy are closely linked and, beyond the consideration of life span, the enhancement of health span is also at stake (Bolnick et al.[17]). Then, to estimate the impact of wearables on life expectancy, we can proceed in two steps:

1. **Study the impact of appropriate wearables** on smoking, physical activity and other lifestyle factors. Indeed, wearables can play the role of coach for their users by motivating them to adopt healthier lifestyles.
2. **Quantify the impact** of these lifestyle factors on life expectancy.

Beyond that phenomenon, wearables might have an indirect impact on life expectancy. The data they provide can be especially useful to conduct biometric research or to personalise health. For instance, Lim et al.[18] analysed fitness data from a wearable in order to better understand the origin of cardiac diseases. In another paper, wearable data led to identifying risk factors for high stress and poor mental health, by identifying stress schemes whose effects can be mitigated to avoid complication (Sano et al.[19]). In that case, the impact of wearables is beneficial for life span, but nevertheless it is more difficult to quantify properly.

PREVENTION OF ACCIDENTAL DEATHS[20]

Wearable technologies may also have a decisive role to play in everyday safety, especially for professions involving physical risks. For those working in hazardous environments, such as mines, wind turbines or oil rigs, wearable devices could make work safer. For instance, to prevent accidents to truck drivers, an Australian company, SmartCap, has developed a helmet that detects fatigue and alerts the user to the risk of falling asleep. For its part, the Tata group developed, between 2013 and 2015, a smartwatch specifically dedicated to factory workers, which alerts them in case of danger, by measuring heart rate and body temperature and detecting the presence of noxious gases. With more than 2.3 million deaths due to occupational accidents or from work-related disease, these devices could have a real impact on accidental mortality.

Because companies and insurers have a clear business interest in adopting technologies that reduce the risk of injury and death in dangerous places, the use of wearable technologies is becoming more and more prevalent. Nevertheless, this development is hindered by a number of constraints and adaptations to be made:

- **Companies require software** to convert the data from the devices into clear insights on the danger their employees are facing.
- **The battery life** of the wearables can be too restrictive to fully benefit from these technologies.
- **Wireless companies' networks** must be expanded to provide Wi-Fi connectivity to remote workers.
- **Companies must ensure the confidentiality** of the sensitive data they collect and protect it from potential data leakage.

Even though we mentioned the use of wearables in the professional framework, accident prevention can also be done in the context of everyday life. At this stage, no quantitative study has been found to evaluate the impact in terms of mortality of this type of wearable. To quantify the impact of a single technology on mortality, the following approach is proposed by Twentyman:[21]

1. **Define the type of accident** to be prevented and the use of the wearable to do so.
2. **Create a group of individuals** wearing the connected object, and a control group. Over a period of one to five years, we can then count the number of deaths in each group and try to draw conclusions. If equipping only a part of the employees raises ethical issues, then the approach can become historical, comparing statistics before and after the equipment.

However, estimates of work-related accidental deaths require a large sample size to be robust. Due to the scarcity of the phenomenon, one could then look at other impacts of wearables. For instance, some connected helmets alert on the level of toxic gas in an environment to quickly evacuate the workers. One can compare the alert time between the wearable approach and the traditional approach and then try to estimate the accident rate induced by a time lapse equal to the alert time differential.

Impacts for life insurers

OVERVIEW OF THE WEARABLE MARKET WOLRDWIDE[22]

The global wearables market size was estimated to be $61.3 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 15% from 2023 to 2030.[23] Regarding medical devices, the associated global market was value at $28 billion in 2021 and is expected to expand at a CAGR of 13% from 2022 to 2030.[24] The growth of the market should be impacted by the expansion of industries such as home healthcare and remote patient monitoring. Moreover, it should also be impacted by people's growing focus on fitness and healthy lifestyle. In addition, the activity monitor and tracker segment accounts for the largest share of the wearable health devices market. The increasing adoption of sedentary and unhealthy lifestyles has led to increasing adoption of self-monitoring vital signs, increasing prevalence of lifestyle diseases and low costs of activity trackers. The COVID-19 pandemic has also expanded the role of wearable medical devices in the healthcare business, by popularising devices that can detect signs of viral infections.

In 2022, North America dominated the market (accounting for over a 33% share in terms of revenue in 2022), followed by Europe. This technology is in the emerging stage in developing countries.

The characteristics of the consumers depend on the category of wearables we consider. Medical wearables are mainly used by the elderly and people with chronic diseases, while other wearables appeal to younger people. Indeed, in the United States, almost half of the users of smart wearables were under 35 in 2019. Regarding the proportion of elderly, it is expected to grow from 15.9% to nearly one-third in 2026.[25]

LEGAL AND REGULATORY ISSUES

If wearable technologies can bring a real benefit in the management of insurance contracts, they also imply serious privacy risks and raise many legal and regulatory questions, especially on the use of data.

There is no common international regulation. Each state has its own legislation:

- **Europe:** The regulations on data protection and privacy have been strengthened with the General Data Protection Regulation (EU) 2016/679 (GDPR), which sets a new standard for the protection of personal data. It came into effect in the European Union from 25 May 2018. Under this regulation, the collection of data that are not relevant or are excessive to perform the insurer's functions is forbidden.
- **United States:** The Health Insurance Portability and Accountability Act of 1996 (HIPAA) aimed to protect Americans in the digital world. It was then updated by the Health Information Technology for Economic and Clinical Health (HITECH) Act in 2009, to be coherent with the regulation concerning data protection in the health sector. Today, HIPAA and the HITECH Act apply to healthcare providers, health insurance companies and mutuals, as well as to any person or company in business dealings with healthcare providers or others who deal with protected medical information (Grynwajc[26]). More recently, the California Consumer Privacy Act of 2018 (CCPA), inspired by the GDPR, has been strengthened. On 1 January 2023, the California Privacy Rights Acts (CPRA) came into effect, adding new rights to California consumers and new obligations to the companies which sell and share personal data (Leto[27]).
- **In most Asian countries**, the legislative framework seems to be more flexible although, for some of them, the GDPR is a source of inspiration to strengthen their local data protection laws (Rich[28]).

In order to manage the regulatory issues, the Institute and Faculty of Actuaries presents recommendations for insurers in the usage of data from wearables (Spender et al.[29]):

- **Inform** policyholders of the exact use of data even before collection and ensure that customers are comfortable with what data they are sharing and how it is used. This helps enhance trust between the insurer and the insured.
- **Restrict** the collection to only adequate and not excessive data linked to a product.

USE OF DATA FROM WEARABLES FOR LIFE INSURANCE PRICING PURPOSES

According to a Capgemini paper,[30] data from wearables could impact all parts of the insurance process, including specifically underwriting and pricing:

- **Development** of new insurance products based on data analysis from wearable devices.
- **Adjustment** of the premium based on real-time data analysis.
- **Bonus/penalty programmes** based on meeting or not meeting a target.
- **Pricing options** based on how frequently the policyholder is willing to share personal and health data.

To incentivise their clients to adopt a healthier lifestyle, some insurers have developed apps (Osypenko[31]):

- The US insurer Oscar added a step tracker to reward customers who reach their activity goals.
- The US company Aetna uses cross-promotion to attract their customers to other apps meant to control health and be healthier.

Spender et al.[32] emphasise that wearable technology could also lead to improved risk selection and pricing in a continuous underwriting process, by adapting the premiums according to a measure of the health status of the customers. In doing so, wearables could help enlarge the insurance market by enabling acceptance of customers who would otherwise be refused due to their medical condition or who needed to pay large surcharges.

INTEGRATION OF WEARABLES INTO INSURANCE CONTRACTS

According to Spender et al.,[33] published in the British Actuarial Journal in 2019, wearable technology is currently being used in health and life insurance contracts as a financial incentive for customers to live healthier lifestyles. The article provides a non-exhaustive list of applications of wearable technology to reward healthier behaviours, presented in the table in Figure 5.

FIGURE 5: EXAMPLES OF REWARDING HEALTHY BEHAVIOUR USING TRACKING TECHNOLOGY

INSURER	CATEGORY	EXAMPLE
Beam Technologies	Dental insurance	Uses Bluetooth-enabled toothbrushes to reward good brushing habits with discounted insurance premiums and other rewards (Beam, 2018)
Aditya Birla Healthy	Health insurance	Discounts for policyholders who record a specified number of steps using an activity tracker, attend gym sessions or have a health assessment (Aditya Birla Health, 2018)
Oscar Health	Health insurance	Rewards customers who track their fitness data, with gift cards for those reaching their step goals (Oscar, 2018)
Qantas Assure	Health insurance	Policyholders to receive Qantas frequent flyer points if they lead more active lifestyles (Qantas Assure, 2018)
Vitality including AIA Australia and John Hancock (US)	Health insurance	The Vitality scheme provides near-term rewards such as free cinema tickets, coffee, discounted flights and other incentives, plus longer-term discounts on premiums, based on points accrued for health-promoting behaviour (Vitality, 2018); (AIA, 2018); (John Hancock, 2018)
United Healthcare	Managed care provider	Rewards users with healthcare credits

Source: Spender et al.[34]

Conclusions

Finally, wearables could become a useful tool for insurers in the years to come, especially with market shares set to grow even further. The new data they provide could lead to a better understanding of diseases and an improvement of life span. Thus, insurers could refine their underwriting and pricing processes, using specific medical variables that quantify more accurately the state of health of an insured. At the same time, people who were previously rejected by insurers because of their state of health could find new contracts focussing on medical measurements (e.g., body mass index, blood sugar levels etc.) instead of their disease.

Nevertheless, the biggest barrier to their generalised integration concerns regulatory issues regarding the privacy of the collected data. Health data are particularly sensitive and require extra precautions, to assure fairness and equity in the underlying algorithms but also to avoid data leaks due to security breaches. In addition, to achieve the creation of rich databases such as those built for the Baseline Project, a collective effort is required, whether from people who participate in providing data or from the organisations which finance this kind of initiative.

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