

REDEFINING HEALTHCARE WITH DIGITAL TWIN TECHNOLOGY

Researchers in Japan are seeking to build hugely detailed **VIRTUAL REPLICAS OF HEALTHY INDIVIDUALS TO PREDICT AND PREVENT DISEASES**, and provide more personalized care.

Healthcare digital twins — virtual replicas of specific patients, replete with the characteristics of their own organs — could revolutionize healthcare and medical research. Built from high-resolution MRI and CT scans, clinical records, genetic data, and information from wearable sensors, the resulting 3D computer models provide a highly detailed simulation of a body and how it is functioning.

In recent years, doctors have used digital twins, personalized to each individual, to trial complex procedures before surgery, model disease progression, and explore the effects of different drugs and dosages to determine the best treatment plans for their patients.

But researchers from Nippon Medical School in Tokyo, Japan, hope to push the potential of such replicas even further.

FORECAST TRAJECTORIES

“We are building health digital twins that can forecast individual health trajectories and recommend personalized preventive strategies before disease develops,” explains Akihiko Gemma, the school’s president. He envisions that instead of isolated organs in turn, tomorrow’s virtual models will replicate a person’s entire biological system in much more detail.

As the country’s oldest private medical college, established in 1876, Nippon Medical School has long distinguished itself as

a research facility that tackles medical challenges through cutting-edge research.

Of their visionary digital twin project, Gemma says: “Our goal is to shift healthcare from disease treatment to precision prevention.”

People in Japan have historically had one of the world’s longest life expectancies, with men and women currently living an average of 81 years and 87 years, respectively. But

a person’s twilight years aren’t always healthy ones, says Yoshinori Murakami, a geneticist and molecular pathologist at the school. Some spend as many as 12 years in poor health.

“It’s a burden for people and also for the Japanese government, which is why it’s very important to prevent disease from an early stage so as to decrease this gap between chronological and healthy lifespan,” he explains.

Also an oncologist, Murakami is keenly aware of how early detection and intervention is critical to both improving patient outcomes and reducing healthcare costs. “I’ve also learned that many chronic diseases, like type two diabetes and hypertension are multifactorial and don’t occur suddenly, but gradually get worse and worse,” he says. “This is why it’s very useful to predict the trajectory of a person’s health.”

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▲ Digital twins will be created by combining health check-up data, genetic data and information from wearable sensors to construct a detailed simulation of a healthy individual's body and physiology.

PREDICTING DISEASE RISK

Murakami started building a new kind of health digital twin in 2019 using an AI model, that was later supported by the Japan Science and Technology Agency. The first step was to gather genetic data from large population cohorts, in order to train the model to discern what was normal and abnormal. For this, Murakami was keen to use data collected in Japan.

“More than 80% of genomic data from large scale studies are derived from populations of European descent, but the predictive accuracy of European-derived polygenic risk scores is approximately two-fold lower in people of Japanese and other East Asian descent,” he explains.

So Murakami turned to Biobank Japan (BBJ), in which his school is one of the major participating institutions¹. Established in 2003, BBJ is a repository of biological samples and medical information collected from approximately 267,000 patients, covering 51 diseases.

To obtain information from a healthy patient population, Murakami teamed up with the Japanese telecommunications giant NTT.

“In Japan, we have a unique system where every company has to provide annual health checkups to employees,” explains Michiko Seyama, Murakami’s collaborator at NTT Precision Medicine, the firm’s medical and healthcare branch. “With more than 100,000 participants, the NTT cohort provides an exceptionally rich longitudinal data of healthy individuals, with an average follow-up exceeding 17 years.”

The large scale and long follow-up duration of the cohort stem from the NTT Group’s long-term commitment to employee health and wellbeing. As part of this initiative, the

Genovision genetic analysis programme was developed to provide participants with actionable health-related information and to establish a longitudinal corporate cohort that supports future epidemiological, genomic, and real-world data research.

The health records provide a wealth of information: from lifestyle habits to medical claims and medical treatment and consultation receipt data; blood biochemistry to proteomics and metabolomics, just to name a few.

One of the most useful bits of data is single nucleotide polymorphisms (SNPs), single-letter variations of DNA that occur at specific positions in the genome. By comparing SNP patterns of people in the healthy and disease cohorts, Murakami and his team could calculate a person’s chances, called a polygenic risk score (PRS), of developing a particular disease based on their genetics.

“IT CAN HELP US START INTERVENTIONS PRIOR TO THE ONSET OF THE DISEASE.”

“We looked at SNPs across 11.7 million sites, and obtained the PRS of over 40 diseases in the Japanese population,” he explains. “The scores help us identify people who are at a high risk of getting a disease.”

This identification is critical, says Murakami. “It can help us start interventions prior to the onset of the disease,” which could give doctors a head start.

PERSONAL PREVENTION

The team is now working with collaborators to integrate this risk prediction with longitudinal health records, multi-omics, biological, physiological and



▲ (left-right) Akihiko Gemma, Hiroshi Yoshida, director of the Yaesu Health Checkup Station and Yoshinori Murakami discussing Nippon Medical School’s digital twin research programme.

other data to map out the health trajectory of individuals.

“You can’t predict this simply by using PRS alone,” says Murakami, who says the researchers are harnessing the power of AI and deep learning to develop prediction algorithms. “It’s necessary to combine lifestyle factors and other indicators to determine a person’s risk for each disease.”

Seyama adds: “In the future, we might even be able to use this to evaluate combined disease risk — because people can sometimes have more than one disease, especially for ‘lifestyle’ diseases such as hypertension and diabetes.”

While they are currently focussing on a small number of common diseases, the team plans to expand their study scope to 38. Crucially, the researchers want their digital twins to help them predict how interventions such as exercising more can shift these health trajectories.

NEW FACILITY

In June 2026, Nippon Medical School launched a state-of-the-art health screening facility to further realize its vision of shifting healthcare from disease treatment to prevention. A key plank to this

is personalized preventative medicine.

In the heart of Tokyo, the Yaesu Health Checkup Station offers employees a convenient location to complete their annual medical screenings, while providing “a dedicated setting to receive advanced and personalized prevention,” says Gemma.

“Over the next few years, we’ll evaluate the clinical utility of our prevention precision and digital twin research,” he adds, “as well as determine whether interventions can effectively promote behaviour change and lead to healthier lifestyles.”

Gemma says: “In this way, Nippon Medical School aims to engineer a new and integrated healthcare paradigm of prevention, diagnosis and treatment.” ■

REFERENCE

1. Ishigaki, K. et al. *Nat. Genet.* **52**, 669 (2020).



Nippon Medical School
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