

# The Voice-EPI Framework: A Novel Voice-Enabled Digital Biomarker Platform for Dynamic Digital Precision Prevention

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## Abstract

Digital biomarkers have become central to the field of precision medicine and preventive care. Using technology to continuously assess behavioral, physiological, environmental, and psychological information can provide insight into the trajectory of a patient's health, which is not possible through routine clinical visits. Digital biomarkers have many applications in cancer prevention, allowing the tracking of modifiable risk factors, screening activities, and health behavior adherence as well as assessing various aspects of the psychological domain. Nevertheless, current digital biomarker systems rely heavily on specific sensors, specialized medical devices, software platforms, and other technical requirements, which increase costs and make scaling difficult. This article presents a review of current methods of collecting digital biomarkers and introduces a novel concept of Voice-Enabled Dynamic Digital Precision Prevention (V-DDPP), which represents a new approach to collecting digital phenotypic information. The V-DDPP method combines voice recording with standardized conversations, reconstructed questionnaires, speech analysis, and artificial intelligence to produce multidimensional digital biomarkers using participant-owned smartphones. The V-DDPP framework provides a highly scalable, affordable, and globally applicable alternative to traditional wearable-based digital biomarker systems. This method will prove particularly valuable in implementing Dynamic Digital Precision Prevention programs in breast (DDPP-BC) and cervical cancer (DDPP-CC).

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## 1. Introduction

The proliferation of digital health tools has led to the development of new ways of collecting and utilizing health information. Smartphones, wearable devices, sensors, cloud computing, and artificial intelligence (AI) now provide means for the constant monitoring of people outside the healthcare setting. All of these advancements have led to the appearance of digital biomarkers, which are objective measures of physiological, behavioral, environmental, or psychological conditions that are collected via technology and analyzed by computational algorithms [1, 2].

As opposed to traditional biomarkers measured during isolated instances of clinical interaction, digital

biomarkers are capable of being collected in an ongoing or repeated manner. This feature is especially beneficial for prevention research since there are many factors involved in determining the risk of developing certain diseases that change constantly. For instance, physical activity, nutritional practices, sleep patterns, psychosocial stressors, healthcare access, exposure to various environmental agents, and compliance with prevention programs keep changing.

Digital biomarkers have been gaining increasing recognition in the field of oncology as methods for achieving personalized prevention, risk stratification, symptom management, and survivorship care. While

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moving from static risk prediction to dynamic risk evaluation, researchers have shown great interest in the concept of Dynamic Digital Precision Prevention (DDPP), where digital data obtained dynamically is utilized in prevention algorithms. Under the framework of DDPP, digital biomarkers play an important role as elements of personalized risk prediction models adaptable to changing lifestyle, biology, behaviors, and environment.

## 2. Importance of Digital Biomarkers in Precision Prevention

Digital biomarkers are among the most significant innovations for precision prevention methodology. The ability to repeatedly measure health-related parameters offers insight into temporal patterns that are impossible to observe with traditional methods employed in epidemiology. In fact, prevention studies based on baseline questionnaires and repeated surveys tend to have a major drawback. Namely, it is quite likely that some relevant changes will happen between measurements, going unnoticed by researchers.

The use of digital biomarkers allows scientists to track health-related behaviors and changes that take place in people's lives outside laboratory conditions. Continuous monitoring of physical activity, sleep, dietary habits, stress levels, and involvement in healthcare activities may offer unique trajectories of risk and help detect signals predicting poor health outcomes. This information is of particular value when discussing cancer prevention since risk factors involved are complex and long-term in nature.

A related concept called digital phenotyping is increasingly used in studies. Digital phenotyping is defined as a second-to-second quantification of human behavior based on data produced by personal devices [3]. Digital phenotyping performed by smartphones shows considerable promise for monitoring mental health, risk factors, healthcare usage, and compliance with preventive strategies [4, 5].

Precision prevention relies on digital biomarkers for transition from population-based prevention strategies to more personalized approaches. Precision prevention does not involve implementing the same prevention strategy across everyone but employs continuously changing risks information to develop the right screening programs, lifestyle changes, behavioral modifications, and clinical care procedures.

## 3. Current Technologies for Digital Biomarker Collection

Modern digital biomarker frameworks depend upon integrations of wearable technology, smartphones apps, electronic health records, imaging devices, and analytical services based in the cloud. The above-mentioned technologies could be broadly grouped into five categories, namely behavioral, physiological, clinical screening, environmental, and engagement digital biomarkers.

Examples of behavioral digital biomarkers would be physical activity, sedentary lifestyle, sleep habits, eating habits, smoking, alcohol use, and psychological wellness. This kind of data is usually generated by accelerometers, smartwatches, mobile phones, ecological momentary

assessment devices, and mobile apps. Many scientific researches have proved the ability of wearable devices to provide accurate assessments of physical activity and sleep patterns [2].

Physiological digital biomarkers can be obtained through wearable devices that are able to measure heart rate, heart rate variability, body weight, glucose metabolism, body temperature, and cardiorespiratory fitness. These measurements offer useful information regarding metabolic health, autonomic function, inflammatory state, and physiological resilience.

Biomarkers of the environment generally depend on smartphone geolocation technologies and geographic information systems. Such systems can provide data on exposure to pollution, mobility behaviors, access to health care services, neighborhood attributes, and determinants of health in the environment.

AI-assisted screening biomarkers include AI analyses of mammograms, cervigrams, histopathology slides, and health service use [6, 7].

Even though these technologies have increased the possibilities for doing research within the field of digital health care, their use involves considerable expense, equipment, software licensing, cloud data storage systems, maintenance services, and more.

## 4. Voice-Enabled Dynamic Digital Precision Prevention (V-DDPP)

Voice-Enabled Dynamic Digital Precision Prevention (V-DDPP) is an innovative method for collecting digital biomarkers that aims at addressing several challenges faced by traditional wearables. The system involves the use of participants' own smartphones and conversations between the participants and the researchers using artificial intelligence technology to capture multidimensional digital biomarkers.

The core assumption of the V-DDPP framework is the possibility of capturing most of the data traditionally collected via questionnaire, diary, wearable device, or interview by means of voice. The participants will be provided with notifications asking them to report on their lifestyle habits, nutrition, sleep patterns, symptoms, medication usage, psychosocial functioning, healthcare access, and screening tests.

First, unlike unstructured dialogues, V-DDPP makes use of verbal reports in which there is enough content for recreating validated measures. For instance, one method of measuring perceived stress is via the use of valid questionnaires like Perceived Stress Scale (PSS). In V-DDPP, subjects give verbal answers to structured questions and, through natural language processing algorithms, their answers are transformed into corresponding questionnaire responses.

This methodology can also be used for several other validated scales like those used for measuring depression, anxiety, sleep quality, quality of life, physical activity, diet, and symptom burden. This, therefore, makes verbal reports digital biomarkers while lowering the burden on subjects.

In addition to self-reports, the voice itself is another potential source of digital biomarkers. Speaking rates,

Table 1. Categories of Digital Biomarkers and Approximate Costs of Conventional Collection Approaches

Category	Example Biomarkers	Hardware Requirements	Software Requirements	Estimated 5-Year Cost per Participant**
Behavioral	Activity, sleep, diet	Smartwatch, smartphone	Health applications	\$300–800
Physiological	HRV, glucose, weight	Wearables, smart scales, CGM	Vendor platforms	\$500–2,000
Clinical Screening	Imaging biomarkers	Imaging systems	AI software	\$200–1,000
Environmental	GPS, pollution exposure	Smartphone	GIS systems	\$50–200
Engagement	App adherence, response patterns	Smartphone	Analytics systems	\$20–100
Integrated DDPP Ecosystem	Combined biomarkers	Multiple devices	Multiple software systems	\$1,000–4,000+

\*\* Cost estimates presented in Table 1 are illustrative estimates derived from representative commercial device prices, software licensing costs, cloud infrastructure requirements, and implementation experiences reported in the digital biomarker literature (Coravos et al., 2019; Goldsack et al., 2020; Hicks et al., 2019)."

pausing, pitch range, vocal effort, articulation, emotional quality, and even vocal consistency have been found to indicate psychological condition, fatigue levels, cognition, and general wellness. Recent programs such as the NIH-funded Bridge2AI Voice Program indicate the scientific appreciation of the clinical significance of the voice as a digital biomarker [8].

Thus, a single voice interaction generates multiple layers of information:

1. Behavioral and health-related self-report data.
2. Reconstructed validated questionnaire scores.
3. Acoustic voice biomarkers.
4. Engagement and adherence indicators.

This multidimensional architecture significantly increases information density while minimizing hardware requirements.

##### 5. Comparison of V-DDPP and Conventional DDPP Systems

Traditional DDPP methods make extensive use of dedicated devices like smartwatches, fitness trackers, smart scales, continuous glucose monitors, and imaging technologies. Although these have their uses, they present considerable expense and logistic problems. Wearer engagement with these devices in the long run can be low owing to the need for frequent charging, loss, discomfort, malfunctioning, and even boredom [2].

In comparison, V-DDPP relies on participant-held phones, saving costs and making involvement more straightforward. Since voice interactions are simple, participant engagement with the system may be high. It will be especially useful for conducting large cohort trials and even in places where the adoption of wearables is logistically impossible.

Data management also differs substantially between the two approaches. Conventional DDPP systems often require integration of heterogeneous data streams originating from multiple vendors, software platforms, and hardware ecosystems. This complexity increases operational costs and creates challenges related to interoperability and data harmonization [1].

V-DDPP centralizes data collection through a unified conversational platform. All information is transmitted through a common pipeline, processed using standardized

AI algorithms, and deposited directly into a central database. This architecture simplifies data management while facilitating longitudinal analyses.

Another key benefit is interpretability. Often, sensor-based digital biomarkers produce high amounts of decontextualized numbers. These, although very useful, are usually difficult to understand without any further processing and explanation. The voice-based report provides not only the numbers but also the context, which helps to understand behavior better and develop individualized interventions based on it.

It should be mentioned that V-DDPP cannot become an outright substitute for wearables. There are certain physiological parameters, such as blood glucose level and heart-rate variability, for example, that would need specific sensors to track. At the same time, V-DDPP could be used as a core digital phenotyping tool, with certain wearables serving only as nested validation tools and biomarkers.

##### 6. Future Applications in Cancer Prevention

The application of V-DDPP would prove very significant in relation to Dynamic Digital Precision Prevention programs that seek to prevent the development of breast and cervical cancers. The two cancers are highly impacted by behaviors, reproductive history, psychosocial and health care utilization determinants that change over time.

In the prevention of breast cancer, the model may be used to track changes in physical activities, weight trends, nutritional behavior, sleep patterns, stress levels, hormonal issues, and screenings. In regard to cervical cancer, the program may be used to determine HPV screening status, vaccination adherence, sexual practices, health care barriers, psychosocial influences, and follow-up care.

Smartphones being common worldwide, V-DDPP provides great possibilities in its adoption in both developed nations as well as other parts of the world.

In conclusion, the development of digital biomarkers is currently an integral part of precision prevention. However, current digital biomarker technology has many limitations including the high cost, the use of advanced technology and devices, and difficulties with scalability. Voice-Enabled Dynamic Digital Precision Prevention (V-DDPP) proposes a revolutionary conversational digital

phenotyping approach, where structured conversations are transformed into multidimensional digital biomarkers using artificial intelligence and natural language processing methods.

The unique combination of questionnaire reconstruction, behavioral data collection, acoustic biomarker analysis, and adaptive risk prediction make V-DDPP a cost-effective and scalable system for precision prevention applications as compared to traditional wearables-based approaches. The proposed approach has specific applications for breast and cervical cancer prevention programs but can potentially become a paradigm for precision prevention of various chronic diseases in the future.

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### *Statement of Transparency and Principles*

- The authors declare no conflict of interest.
- The study was approved by the Research Ethics Committee of the authors' affiliated institution.
- The study data are available upon reasonable request.
- All authors contributed to the implementation of this research.

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