Chapter 3
The Next Generation of Health Monitoring: Digital Twins and Medical Wearables

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ABSTRACT

Digital twins and medical wearables are revolutionizing healthcare by enabling personalized, real-time monitoring and predictive insights. Digital twins, virtual replicas of patients, integrate data from wearables to simulate health conditions, predict outcomes, and optimize treatments. Medical wearables such as smartwatches, biosensors, and fitness trackers collect continuous health data, providing insights into vital signs, activity levels, and chronic disease management. Together, they enhance remote patient monitoring, support AI-driven diagnostics, and facilitate early detection of anomalies. This synergy accelerates precision medicine, improves patient outcomes, and empowers proactive healthcare, marking a transformative leap in medical innovation.

1 INTRODUCTION

With the rapid advancements in technology, modern healthcare is expected to leverage the use of relevant tools to streamline patient care and provide better medical solutions. Two technologies garnering interest in this field are digital twins and medical wearables (Singh et al., 2024). In simple terms, a digital twin is a virtual

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representation of a physical asset that can be monitored and analyzed. Medical wearables, or simply wearables, are devices that carry out the mundane task of monitoring human health and recording it (Zhou et al., 2024). Wearables provide real-time health data and other vital parameters that are essential for observation. The use of the digital twin in healthcare is an ongoing research topic where human beings, or a part thereof, are replicated virtually so that researchers can subject the virtual twin to various medical scenarios and experiments, thereby bringing forth new healthcare solutions. The basic proposition of integrating digital twins and medical wearables is to take the data from these wearables, both vital and non-vital, and run it in sync with the digital twin[1] to provide a more comprehensive picture of the patient's current state (Kalyani et al., 2024). Suppose a perturbation or any influencing condition occurs in the digital twin. In that case, it can be gauged to be close to the actual patient's case as well, thereby eliminating the need for costly interventions for the body. The emergence of digital twins in mundane applications and technologies touches all spheres of science and life. In this context, it has percolated into the world of medicine and healthcare (Shafik, 2024e, 2025b). This has given rise to the concept of augmented intelligence as well.

Digital health technologies have been integrated into healthcare practices, and the innovations they are powering are rapidly changing the way disease prevention, diagnosis, and treatment are conducted. One set of digital health primitives – digital twins and medical wearables – are technologies that are enabling people to know about the state of their bodies. Digital twins and wearables can be used to iteratively refine personalized mathematical models of physiology that are unique to the individual over time (Huang & Liu, 2024). They are enhancing our collective capability to manage our lives from a health perspective by acting as tools for proactive and personalized health monitoring. This explores and explains digital twins and medical wearables, outlines their approach, and puts forth an argument for their importance in the present day. The urgency to monitor health beyond the clinical scale has multiplied recently (Khan et al., 2024). The 21st century has been characterized as being disease-burdened with 'lifestyle diseases.' These chronic conditions have assumed significance because of a reduction in infectious diseases and continued investments in research that have extended human life cycles across the globe (Shafik, 2024c). Chronic health conditions are typically lifelong and costly to manage and to respond to the surge of chronic health conditions, people across the globe are warming up to the benefits of normal and continuous health monitoring as a means of better managing personal health goals today to pre-empt tomorrow's diseases (Casas et al., 2024).

A digital twin is a digital representation that simulates a real-world scenario. As such, the twin must be uniquely identifiable, be able to measure data, communicate with its original object, and change its environment. It possesses working