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Smartwatch-Based Data Analytics and Feature Selection for Heart Failure Assessment

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ABSTRACT

Patients with heart failure require long-term or frequent hospitalization, which places a heavy burden on medical resources. The six-minute walk test is a simple and cost-effective method for assessing aerobic capacity and endurance. It does not require specialized personnel or sophisticated equipment and involves recording walking distance, blood pressure, heart rate, and oxygen saturation level within a fixed time interval. In this study, we provided patients with heart failure with a smart watch and an application tool, enabling them to perform the six-minute walk test at home. The application allowed patients to upload their test data on cloud storage, which were examined using feature correlation analysis, regression modeling, and other techniques. The goal was to explore the most influential features that correlated with outpatient records and provide effective reminders to patients with heart failure to monitor their health status during their daily lives, which would reduce medical resource consumption.

KEYWORDS

Cardiopulmonary Exercise Test (CPET), Machine Learning, Heart Failure, Six-Minute Walk Test (6MWT)

1. INTRODUCTION

According to statistics from the Taiwan Ministry of Health and Welfare, in 2022, heart disease was the second leading cause of death after cancers among the population (Ministry of Health and Welfare, Taiwan, Republic of China, 2022). Heart failure (HF) is the final consequence of all types of heart diseases (Yancy et al., 2013). The causes of left-sided HF include coronary artery disease, valvular problems, hypertension, and cardiomyopathy. Right-sided HF is caused by conditions such as Cor Pulmonale (CP), Anemia, Arrhythmia, and Hyperthyroidism. Various factors lead to changes in the structure or function of the heart, resulting in multiple clinical syndromes (American Heart Association, 2017). The prevalence of multiple chronic diseases and the proportion of people with HF is gradually increasing. The risk of death within five years of the diagnosis of HF is approximately 50% (Khan et al., 2022).

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Furthermore, patients with HF require frequent follow-up visits to the hospital. Severely affected patients require weekly appointments, and the high-frequency medical visits impose a significant burden on healthcare resources. The cardiopulmonary exercise test (CPET) (Dafoe, 2007) is one of the common methods used to assess the exercise capacity of patients with HF, providing an accurate assessment of their status. However, the test is expensive. Healthcare personnel, expensive equipment, and specific testing locations are required to perform CPET. Owing to the COVID-19 pandemic, CPET tests at Keelung Chang Gung Memorial Hospital, Taiwan, have been suspended for a long time. Moreover, CPET is unsuitable for real-time patient monitoring. The ability to track a patient's physical condition at home is important.

Therefore, to overcome the constraints of the cardiopulmonary exercise test (CPET), This study aims to improve heart failure (HF) monitoring by integrating the six-minute walk test (6MWT) with machine learning in a smartphone-based application, includings:

- Develop an intelligent application that uses 6MWT data collected by a smartwatch to enable real-time health monitoring.
- Implementing machine learning algorithms for predictive modeling and feature extraction to identify key physiological markers such as heart rate dynamics and step patterns.
- Provide early warning alerts to patients and healthcare providers, facilitating timely intervention and improving remote disease management

The 6MWT The 6MWT is widely used to assess functional capacity in HF patients by measuring walking distance, which is particularly valuable for assessing functional capacity in HF patients because it effectively measures the distance walked in six minutes which is a metric that indirectly measures the heart's efficiency in pumping blood (Enright & Sherrill, 1998). Declining performance on the 6MWT often reflects worsening heart function and increased severity of HF symptoms, such as fatigue and shortness of breath. The 6MWT provides important prognostic information, helps to monitor disease progression and assists in the evaluation of treatment efficacy. Its simplicity and practicality make it a valuable tool for both clinical and home monitoring, especially when compared to the more complex and resource-intensive CPET.

Meanwhile, in this study, machine learning algorithms were used to analyse the data collected during the 6MWT, enabling advanced predictive modelling and feature extraction. This approach not only improves the accuracy of cardiac status assessment but also enables the identification of key health markers that can provide early warnings to patients and healthcare providers. We aimed to identify key features that correlate with the health status of heart failure (HF) patients using a convenient smartwatch device. These key features were used to generate early and accurate alerts for patients, enabling timely health management and intervention. By combining machine learning with the 6MWT in an intelligent application, the proposed solution enables continuous and personalised monitoring, enabling patients to take a more active role in managing their condition. This, in turn, will reduce the need for frequent hospital visits and help reduce the burden on healthcare systems, while ensuring that patients receive timely interventions when needed.

2. MATERIALS AND METHODS

2.1. Six-Minute Walk Test (6MWT)

The 6MWT was developed by Dr. R. Bruce Balke and Dr. Robert W. Ware at the University of Belgrade in 1963 (Balke, 1963) and was originally used to assess exercise endurance and cardiorespiratory function in patients with heart diseases. The 6MWT is widely used to evaluate various chronic diseases owing to its convenience, reliability, and repeatability. Several rules apply when conducting the 6MWT: (1) The test should be conducted on a flat path at least 30 m long; (2)