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Designing Wearable Electronic Textiles to Detect Early Signs of Neurological Injury and Disease: A Review

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Abstract

Neurological disorders affect the central and peripheral nervous system covering the brain, spinal chord, cranial nerves, nervous system and neuromuscular junction. There is an unsatisfied need for a non-invasive ambient measuring system which can record patients' vital body levels autonomously and in real-time. There is also an acute need to detect diseases at prodromal stages in patients that may carry asymptomatic characteristics of underlying disease. The opportunities offered through innovations in wearable electronic textiles can provide a solution to this by measuring biomarkers for Alzheimer's disease detection, and other neurological disorders, through a non-invasive biosensor that detects protein levels in saliva. This is an area which has large gaps in research around utilising these technologies for early diagnosis of injury, and for differentiating between stages of illness to provide more accurate and bespoke neurological healthcare.

Keywords: Brain injury; Alzheimer's disease; Wearable Electronics; Biosensors

1 Introduction

Neurological injury covers the areas of the central and peripheral nervous system and can include temporary or permanent damage to the brain, spinal chord and peripheral nerves. Due to the complex and intricate structure of the brain, the responses triggered by injury are equally multifaceted and complex [1]. Severe brain injuries can result from damaged tissues or cells from high-impact blows to the skull, penetrative injury or acceleration and rotational forces. Brain injuries resulting from traumatic brain injury (TBI) can include subdural or epidural hematoma, subarachnoid hemorrhage (SAH), contusion and diffuse axonal injury. Acquired brain injury (ABI) results from injuries suffered by means of stroke, tumors or degenerative diseases [2]. These injuries include anoxia and hypoxia as a result of restricted or low blood pressure to the brain which can starve the organ of oxygen and cause devastating long-term damage [1].

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Severe head injuries also place the patient under high risk of developing neurological diseases such as Alzheimer's disease and dementia. A study produced by the Care Policy and Evaluation Centre at the London School of Economics and Political Science modelled projections of dementia care in England. In 2019, 885 000 people in the UK were diagnosed with dementia [3]. These figures are expected to rise in the future driven by an increasingly ageing population in the United Kingdom. The ONS population projections predicts that between the years 2019-2040 the proportion of people aged 65-74 will increase by 20% and the amount of people above 85 years over will increase by 114% [4]. This leads to an increase in older people suffering from dementia by 80% by the year 2040 affecting 1.6 million people. The costs associated with dementia care are substantial and are expected to rise over subsequent decades. The total cost of dementia care for older people in the UK in 2019 was £34.7 billion and is expected to triple by 2040. The development of a point-of-care, wearable electronic device, which can detect early signs of Alzheimer's disease by measuring Amyloid beta protein in saliva would provide a solution to this. It could assist in early detection of Alzheimer's disease treatment, make healthcare more accessible to lower income households, and move towards a neurological point-of-care health system.

2 Literature Review

This review will outline the developments in wearable technologies in the application of monitoring vital health signs through the application of biosensor materials. There has been increased interest in this area due to their accessibility, affordability and progression towards personalised medical care. This review will cover conductive materials, nanobiosensors, biomarkers, protein detection, sensor device technologies and device applications. The first section will cover critical analysis of conductive materials and their desirable properties as a biosensor component. The second section will cover biomarkers used for protein detection with a summary of the knowledge gaps in this areas. The last section will look at sensor device technology and its applications in healthcare monitoring and e-textile developments. This will be concluded with a summary of the knowledge gaps covered in the review followed with an assessment of how these will be developed into future research objectives.

3 Conductive Biosensing Materials

The key properties that conductive biosensing materials require are to be lightweight, durable, highly sensitive, flexible and hold the ability to be utilised non-invasively. Innovations in novel micro or nanonstructured materials provide great potential for medical applications to monitor physiological changes in the body [5]. The use of graphene or carbon-treated fibres has proven a successful material for monitoring bodily functions in the short-term but remain challenging when worn in the long-term [6]. The promising applications of this technique include treating natural fibres such as cotton, silk and flax with graphene oxide (GO) or novel combinations through reduction (rGO). Further desirable qualities of an effective conductive fibrous medium include breathability for comfort of wear by the user, for example stretchability and moisture wicking capabilities. Within the field of enzyme-based biosensors the area of glucose detection is the most saturated in terms of research. However, the conventional conducting-based glucose sensors has limitations such as unsatisfactory sensitivity or detection limit and relatively high applied