Wearable Technologies for Multiple Sclerosis

The future role of wearable stress measurement in improving quality of life

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Abstract— **Multiple sclerosis (MS) is the most common autoimmune disorder affecting the central nervous system. Most often diagnosed in young adults, MS runs a chronic, unpredictable course, often leading to severe disability: 50% of MS patients are unable to perform household and employment responsibilities 10 years after disease onset, and 50% are nonambulatory 25 years after disease onset. While it is not clear what factors influence the prognosis of MS, exposure to stress has long been suspected as a factor that can aggravate its progression. In this paper, we discuss the opportunities for wearable sensors in the management of stress in multiple sclerosis patients.**

Keywords–multiple sclerosis; stress; wearable; biosensor; electrodermal activity; heart rate variability.

I. INTRODUCTION

Multiple sclerosis (MS) is a chronic inflammatory, demyelinating and neurodegenerative autoimmune disease of the human central nervous system, affecting more than 2.3 million people worldwide. The median clinical onset of MS is approximately 29 years of age, with affected women outnumbering men with a ratio of almost 3:1 [1].

The clinical disease course is variable. In most cases, MS begins with a relapsing-remitting (RRMS) course characterized by periods of exacerbation, lasting from days to weeks, followed by periods of substantial remission, often with some residual disability. In a later stage, anytime between 5-35 years after onset, most patients develop a secondary progressive course (SPMS), marked by a continuous and irreversible neurological decline. A small proportion of patients have a primary progressive course (PPMS) from the onset.

Common symptoms of MS include, but are not limited to, loss of function or feeling in limbs, loss of bowel or bladder control, sexual dysfunction, debilitating fatigue, blindness due to optic neuritis, loss of balance, pain, cognitive dysfunction, and emotional changes [2].

While little is known about its cause or the factors that contribute to its unpredictable course, evidence indicates that both genetic susceptibility and environmental factors play a role [3]. One such factor is psychological stress, which has been implicated repeatedly as a determinant of disease activity ever since MS was first described in the 19th century.

In this paper, we discuss the impact of stress on MS progression and the opportunities for wearable biosensors and and autonomic activity measurement in the management of stress in MS, with the subsequent improvement in quality of life.

II. THE ROLE OF STRESS IN MULTIPLE SCLEROSIS

Stress is a broad concept used to describe conditions ranging from environmental threats to psychological responses relevant to anxiety. Despite the great variability in how people perceive and experience stress, both patients and clinicians note that increased stress increases relapses. In fact, the most recent meta-analysis of studies linking stress and disease exacerbations found that out of the 17 studies reviewed, 15 showed a significant association [4]. Furthermore, acute stressful events or chronic stressful situations have also been associated with the onset of the disease [4].

While relapses are the primary measure in these studies, the count of new lesions on magnetic resonance imaging (MRI) has proven to be a far more sensitive outcome as a measure of disease activity. Although only two studies have studied the relationship of stress and MRI lesion activity, both found that stress increases disease activity on MRI. In one study, the risk development of new lesions 4–9 weeks after a major negative life event was increased, while positive stressful events reduced this risk [5]. A previous smaller study had a similar finding [6].

These findings are not surprising, since neuroendocrine hormones triggered during stress may lead to immune dysregulation or to altered or amplified cytokine production, resulting in atopic autoimmune activity or decreased host defense [7].

III. WEARABLE STRESS MEASUREMENT

Researchers have studied a wide variety of approaches to measure stress, such as self-report measures, collected through retrospective surveys and/or experience sampling, and hormone analysis. However, stress also produces a well-studied set of physiological changes that can be continuously monitored using wearables for the purpose of stress measurement. These physiological changes are controlled by the autonomic nervous system (ANS), which regulates important bodily functions including digestion, thermoregulation, cardiac output, regional blood flow, ventilation, and many aspects of emotional behavior: feelings of fear, anger, happiness, and sadness have characteristic

autonomic manifestations. The ANS is divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). While SNS mobilizes the body's resources in response to a challenge or a threat (e.g., quickens the pulse, deepens the respiration and tenses the muscles), the PNS works antagonistically to control this process.

In the past, to accurately gather measurements of autonomic responses in the midst of daily activity, cumbersome electronics such as sticky electrodes on the chest were usually required. Therefore, so far studies of stress in MS that have looked beyond self-report surveys have relied on single time-point measurements of autonomic responses to a standardized stressor, such as public speaking or a cognitive task [8]. However, the most recent commercially available wearable biosensors can accurately and unobtrusively measure autonomic responses through electrodermal activity and heart rate variability data collected from the wrist:

A. Electrodermal activity

Electrodermal activity (EDA) biosensors measure electrical conductance changes in the skin reflecting eccrine sweat-gland activity. Unlike other bodily functions, EDA is controlled exclusively by the SNS, making it an ideal physiological signal for stress measurement. Using EDA, stress can be distinguished from other similar responses such as cognitive load. As an example of an EDA application, Hernandez et al. discriminated stressful and non-stressful calls at the call center environment using EDA features [9].

B. Heart rate variability analysis

Heart rate variability (HRV) analysis describes the variability of heart rate (HR) over time. In general, HRV analysis takes into consideration the frequency power of low-frequency (LF, 0.01−0.08 Hz) and high-frequency (HF, 0.15−0.5 Hz) bands, which reflects SNS and PNS modulation of HR respectively. HRV can be performed from blood volume pulse (BVP) signals obtained from wrist photoplethysmograph (PPG) sensors and, similar to EDA, used as a biomarker for psychological stress.

IV. Opportunities for Wearable-based Stress Management in MS

Although the studies examining interventions to reduce stress in people with MS are few, it has been shown that stress management programs can result in a significant reduction of both MS symptoms [10] and new brain lesions [11]. While these programs offer great promise, their effect disappear rather quickly after the therapy is stopped. Therefore, there is a need for alternative ways of delivering stress management therapy that can result in longer-lasting effects.

Recent advancements in wearable stress measurement technologies offer an opportunity for the development of biofeedback-assisted stress management therapies that could potentially satisfy this need, resulting in a significant improvement in the quality of life of multiple sclerosis patients. Specifically, we believe the more scalable, adaptive, customizable and interactive behavior interventions that can be achieved with wearable-based behavior intervention technologies tailored to the specific needs of MS patients may result in increased patient engagement, improved stress reduction, and longer-lasting effects.

Acknowledgments

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