A Wearable Compression-Based Assistive System for Managing Postural Orthostatic Tachycardia Syndrome (POTS)

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Abstract

Postural Orthostatic Tachycardia Syndrome (POTS) is a disorder of the autonomic nervous system characterized by abnormal cardiovascular responses to postural changes, most notably excessive heart rate increase upon standing. Affecting an estimated 500,000 to 1,000,000 individuals in the United States, POTS significantly impacts daily functioning and quality of life. Current treatment strategies focus on symptom management rather than cure and often rely on lifestyle modifications and pharmacologic interventions. This paper proposes a wearable, sensor-driven compression brace system designed to assist blood circulation in individuals with POTS. By providing adaptive, externally regulated vascular support, the system aims to mitigate orthostatic intolerance symptoms, improve patient independence, and offer a scalable, personalized management approach.

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1. Introduction

Postural Orthostatic Tachycardia Syndrome (POTS) is a chronic form of dysautonomia involving impaired autonomic regulation of heart rate and vascular tone. The autonomic nervous system normally maintains cerebral perfusion during postural transitions by triggering rapid

vasoconstriction in the lower extremities. In individuals with POTS, this compensatory mechanism is delayed or insufficient, leading to venous blood pooling in the lower limbs and reduced cerebral blood flow upon standing. As a result, patients experience symptoms such as dizziness, lightheadedness, palpitations, fatigue, and syncope.

Despite growing recognition of the condition, POTS remains underdiagnosed and lacks a definitive cure. Management strategies are often multifaceted and individualized, underscoring the need for innovative, non-invasive assistive technologies that directly address the underlying circulatory dysfunction.

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2. Pathophysiology of POTS

POTS arises from dysfunction within the autonomic nervous system, particularly its control over cardiovascular responses. Under normal conditions, standing causes a transient shift of blood toward the lower extremities. Baroreceptors signal the autonomic nervous system to constrict blood vessels and increase heart rate, thereby maintaining adequate cerebral perfusion.

In POTS patients, this signaling pathway is impaired. Blood vessels fail to constrict rapidly enough, allowing excessive venous pooling in the legs. To compensate, the heart rate increases abnormally, often exceeding 30 beats per minute within ten minutes of standing. This compensatory tachycardia is frequently insufficient to fully restore cerebral blood flow, resulting in orthostatic symptoms that can significantly impair daily activities.

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3. Limitations of Current Treatment Approaches

Current management of POTS focuses on symptom mitigation rather than correction of the underlying autonomic dysfunction. Common interventions include increased fluid and salt intake, physical reconditioning, compression garments, and pharmacologic therapies such as beta-blockers or vasoconstrictors. While these strategies may provide partial relief, their effectiveness varies widely among patients and often requires continuous monitoring and adjustment by healthcare providers.

Traditional compression garments, although helpful, offer static pressure and lack adaptability to real-time physiological changes. This limitation reduces their effectiveness during dynamic postural transitions, which are central to POTS symptom onset.

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4. Proposed Solution: Adaptive Circulatory Support Braces

4.1 Concept Overview

This paper proposes the development of an adaptive compression brace system designed for the thighs, calves, and biceps. The system functions as an external circulatory aid, compensating for delayed autonomic responses by mechanically regulating blood flow during postural changes.

Each brace consists of an adjustable strap integrated with sensors capable of monitoring blood flow and pressure dynamics. Unlike conventional compression garments, this system actively adjusts compression levels in response to real-time physiological data.

4.2 Design and Functionality

The braces incorporate an adjustable pressure mechanism calibrated by a clinician to ensure both therapeutic effectiveness and patient comfort. Embedded sensors continuously collect data related to blood flow and limb perfusion. Based on these inputs, the system dynamically modulates compression to prevent venous pooling during standing or prolonged upright posture.

The modular design allows selective use across different muscle groups, enabling customization based on symptom severity and patient-specific circulatory patterns.

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5. Monitoring and Intelligent Adjustment System

The brace system is supported by an AI-driven or rule-based control program that processes sensor data and determines optimal compression levels. This program enables continuous, autonomous adjustment without requiring constant clinician oversight. Over time, collected data can be used to identify individual trends, allowing further personalization of therapy.

As patient tolerance or autonomic function improves, compression intensity can be gradually reduced. This adaptive capability supports both short-term symptom control and long-term management strategies.

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6. Benefits and Clinical Impact

The proposed system addresses a key limitation in current POTS management by directly targeting abnormal blood pooling through responsive mechanical intervention. By stabilizing

circulation during postural changes, the braces have the potential to reduce the frequency and severity of dizziness, syncope, and fatigue.

Improved symptom control may enhance patient independence, reduce reliance on pharmacologic therapies, and improve overall quality of life. Additionally, the scalable and wearable nature of the system supports widespread adoption and accessibility.

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7. Broader Implications and Future Applications

Beyond POTS, adaptive compression technology may have applications in other conditions characterized by impaired circulation or autonomic dysfunction, including orthostatic hypotension, chronic venous insufficiency, and select neurological disorders. The integration of wearable sensors with intelligent control systems represents a promising direction for personalized, non-invasive medical devices.

Further research, including clinical trials and long-term outcome studies, is necessary to validate the efficacy and safety of this approach and to refine system parameters for diverse patient populations.

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8. Conclusion

POTS presents a significant clinical challenge due to its complex pathophysiology and lack of curative treatment options. The proposed adaptive compression brace system offers a novel, technology-driven solution that directly addresses the circulatory deficits underlying the

condition. By combining wearable design, real-time monitoring, and intelligent adjustment, this approach has the potential to meaningfully improve symptom management and quality of life for individuals living with POTS.

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