Design and Development of a Modular Compression Test Rig for Simulating Human Limb Pressurisation under Wearable Garments

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Abstract. This study presents the development of a modular experimental platform to assess mechanical interactions between compression garments and human soft tissue analogues under physiologically relevant boundary conditions. The work aims to support garment innovation for military and healthcare applications by enabling systematic benchmarking of commercial and bespoke compression textiles.

Introduction

Compression garments are widely used in clinical, sports, and performance contexts to improve circulation, aid recovery, and manage swelling. However, understanding the real-time pressure distributions they exert on human limbs under anatomically realistic and dynamic loading conditions remains a challenge. Most characterization efforts rely on uniaxial testing of fabric swatches, which fails to replicate the circumferential and complex geometries of the limb. To bridge this gap, we present a modular experimental test rig capable of simulating lower limb segments and measuring garment-induced pressures under quasi-physiological configurations.

Methodology

A lower-limb analogue test rig has been designed and fabricated with an adjustable geometry spanning five anthropometric stages (XS to XL), simulating diameters from 60 mm to 165 mm. The rig incorporates modular silicone soft tissue layers to replicate mechanical compliance and allows mounting of compression garments (e.g., sports, clinical). Real-time interface pressure mapping is achieved via arrays of capacitive sensors (accurate to ±1 mmHg) positioned radially and longitudinally across the limb surface. Concurrently, 3D Digital Image Correlation (DIC) is deployed to track garment strain and deformation. A complementary uniaxial tensile test protocol was also implemented to characterize stress-strain profiles of the garments under controlled extension, providing baseline mechanical behavior (e.g., ultimate stress >1.5MPa; strain >180%).

Results & Ongoing Work

Preliminary trials using commercially available 15–40 mmHg compression garments reveal heterogeneous pressure profiles across the limb, with measured values ranging between 12–32 mmHg depending on limb size and garment design. Notably, pressure gradients were more pronounced in anatomically shaped garments. Data from the uniaxial and circumferential rig tests are being used to parameterize finite element simulations of limb-tissue-garment interactions, including vessel compression scenarios and poroelastic tissue deformation. Integration into FEBio and ANSYS for simulation is in progress, with future work planned on dynamic compression modes and longer-duration wear testing.

Conclusion

This study introduces a robust experimental platform for evaluating compression garment mechanics under realistic boundary conditions. The combination of uniaxial tensile characterization, whole-limb pressure mapping, and advanced imaging offers a comprehensive dataset to inform both garment design and computational modelling. The system supports future research into physiological impact modelling, garment optimization, and validation of pressure simulation frameworks.

References

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