



# Development and Validation of a Textile-Based Pressure Sensing System for Lower-Limb Prosthetic Sockets

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## I. ABSTRACT

Ill-fitting prosthetic sockets can lead to health complications and gait abnormalities for lower-limb prosthesis users [1]. To avoid these issues during limb growth, children require socket replacements every 1 to 2 years [2]. The exact frequency depends on the patient's growth rate, making timely replacements challenging during rapid limb growth, particularly for individuals living far from a prosthetics clinic. Additionally, socket shape modifications during and after the fabrication process depend on subjective patient feedback, which can be challenging to obtain from children. Pressure sensors have been used in research to study limb-socket interfaces but remain largely impractical for clinical socket fit assessments and in-community socket fit monitoring [1], [3]. Through a collaboration with Myant Inc. (Toronto, Canada), this project developed textile-based pressure sensors integrated into a prosthetic sock format to address these challenges.

The first step in the development of this system is the selection of the optimal pressure-sensing textile material for the fabrication of the prosthetic sock and the sensors. Myant fabricated six textile pad samples made from different materials, each containing one textile-based pressure sensor. The sensor performance was evaluated using a universal testing machine (ZwickRoell, Ulm, Germany) against a validated commercially available point sensor (SingleTact, Glasgow, UK) [1]. Sensitivity was first confirmed by applying incremental loads of 2 N within a 40 N range and ensuring that the sensor readings increased relative to the applied force. The sensor repeatability was then evaluated by applying five repetitions of eight forces within a 40 N range in a randomized order. The percentage coefficient of variation is used to express the results from this test. Therefore, lower values indicate higher repeatability. Finally, loads of 10 N, 25 N, and 40 N were applied on the sensors for 10 minutes each to assess drift (i.e. measurement consistency over time). The repeatability and drift test sequences were repeated five times on each sensor.

The pad with sensitivity, repeatability, and drift equivalent to or greater than the SingleTact was selected as the optimal material for the sock fabrication. The optimal pad and the SingleTact showed average repeatability of  $0.68 \pm$

$0.05\%$  and  $0.98 \pm 0.25\%$ , respectively. The average drift for the optimal pad and the SingleTact was  $2.56 \pm 0.72\%$  and  $2.43 \pm 1.78\%$ , respectively. These results are comparable to those of other commercially available point sensors [4], [5]. Following this evaluation, Myant integrated 144 textile-based pressure sensors into a prosthetic sock format. The next step is to recruit three prosthesis users to validate the performance and comfort of the system during weight-shifting and walking.

The textile composition of the system will enable comfortable and seamless sensor integration at the limb-socket interface. The sock form factor will allow a high level of usability, enabling pressure monitoring in clinical settings or during daily activities [3]. Continuous socket fit data from free-living environments can help prosthetists intervene earlier to replace sockets, enable remote prosthetic care, and supplement subjective feedback for socket adjustments. The proposed system, therefore, has the potential to address the unique needs of pediatric prosthesis users.

## II. REFERENCES

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