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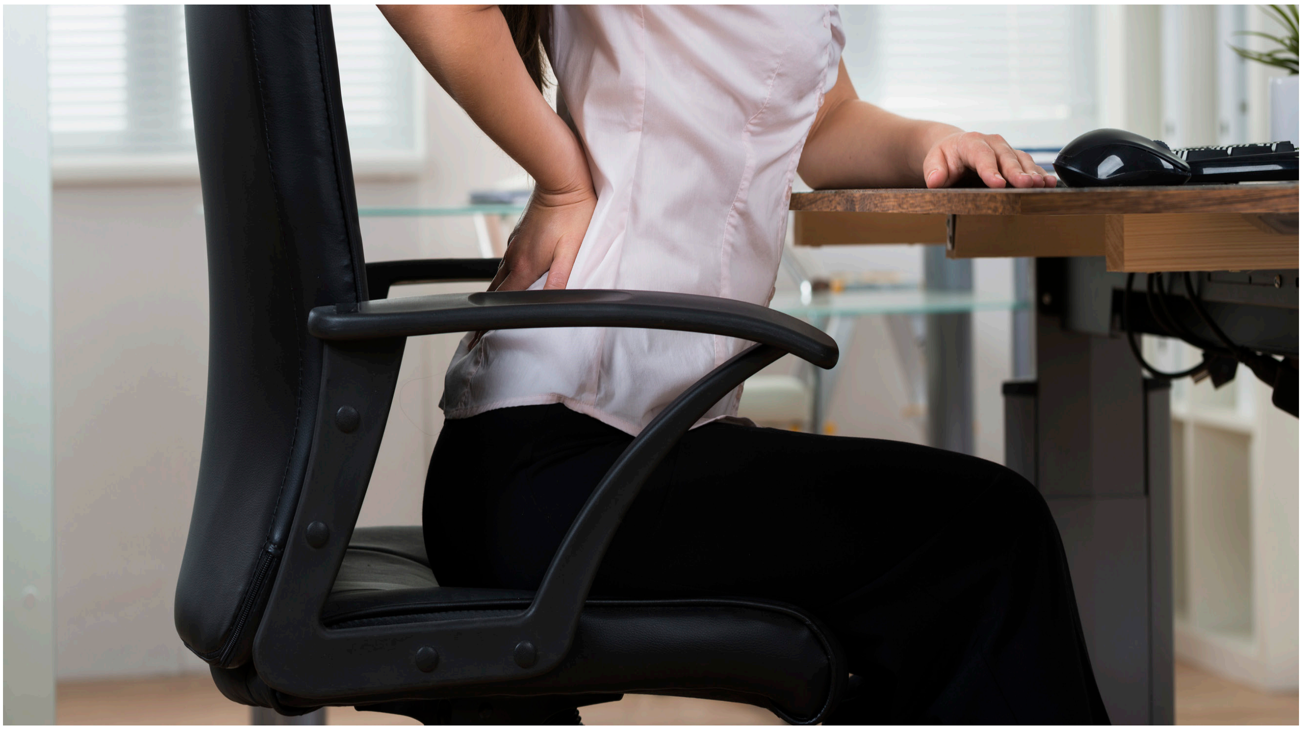
Have difficulty standing up?

Soft exosuitsare here to help!



Soft robotics is a novel disruptive technology that is revolutionizing the fields of robotics. Innovative use of compliant materials by researchers has elevated soft robotics over contemporary technologies. The Computational Sensing and Smart Machines (CSSM) laboratory of the Department of Mechanical Engineering, University of Moratuwa, has been taking strides in the development of soft robotics, ranging from actuators, sensors, and applications. The most recent output in this development is the first soft exoskeleton suit or "exosuit" in Sri Lanka. Researchers from CSSM have developed this exosuit as an orthotic device to aid in the sit-to-stand transition (StSt) of a person with lower limb impairments.

This exosuit focuses on helping a wearer from transitioning to standing posture from a seated position. The exosuit is worn as part of the wearer's pants and can actuate, assisting in parallel to their biological muscles while standing up from being seated. Aging, obesity, paresis, neuromuscular disorders, and trauma-induced lower limb muscle impairments can result in persons being restricted to a bed or a wheelchair. Being limited to such positions will make their lives sedentary, increasing the chances of secondary medical consequences and losing independence and quality

The research team from CSSM has used a novel, vacuum-driven soft artificial muscle actuator (LPVAc) that mimics biological muscle contraction to actuate the StSt assist exosuit.

Figure 1: Sit-to-stand transition assist exosuit

of life. This inspired the research team at CSSM to develop an exosuit that would improve their quality of life through leveraging novel soft robotic concepts.

Population aging results from declining fertility and increasing lifetimes, two trends associated with social and economic development. In the more developed global regions, older people increasingly live either alone or with only a spouse. In contrast, even the aging population would have to contribute financially to the younger generations in developing countries [1]. Sri Lanka's population is among the oldest in the non-developed world. Recent surveys find Sri Lanka as one of the fastest aging countries globally. They predict that Sri Lanka will have an elderly population above 60 years, reaching 30% by 2050 [2].

Another primary reason behind impaired lower limb functionality is paresis (weakened muscle performance) or paralysis (complete loss of motor function). A U.S. study reports that the primary reasons for paralysis were stroke (29%) and spinal cord injury (23%). Most spinal cord injuries were reported due to vehicular trauma. At the same time,

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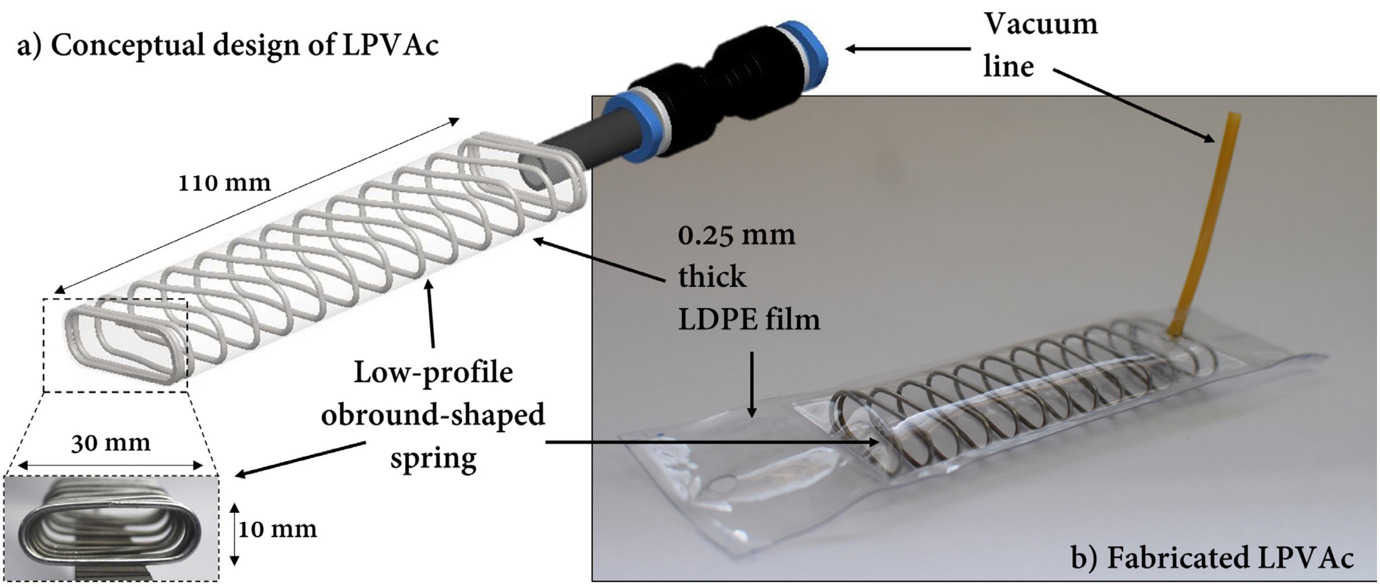

Figure 2: The novel vacuum-driven soft artificial muscle actuator: LPVAc. a) The conceptual design of the LPVAc. b) The fabricated LPVAc.

falls were the primary cause in the elderly population [3]. The most common non-traumatic injury leading to lower limb paralysis is the 'stroke.' In the Sri Lankan context, stroke is the second leading cause of death, with 15,200 recorded deaths in 2012. Stroke and subsequent paralysis were prevalent in about 77,000 persons nationally (2014) (0.37 % out of a total population of 20.77 million) and high as 10.4 per 1000 persons in Colombo [4], [5].

Hence, Sri Lanka faces a need to help those unfortunate to lose their muscle functionality due to the above reasons. Persons in sedentary lifestyles need to be motivated and incentivized to try independent motion. Such attempts will help them regain their lost abilities through rehabilitation or allow them to keep the current state without further deterioration. If they can be motivated to stand up effortlessly, it will promote other attempts at independent motions. This will reduce their reliance on passive-assistive devices (such as canes, walkers) and caregivers. People tend to be stigmatized when seen using such assistance. Hence, they would prefer any such assistive device to be invisible to the public. Therefore, the CSSM lab developed the StSt assist exosuit as an orthotic device that such persons can wear discretely.

The research team from CSSM has used a novel, vacuum-driven soft artificial muscle actuator (LPVAc) that mimics biological muscle contraction to actuate the StSt assist exosuit. This actuator is the first of its kind developed in Sri Lanka and is a lightweight (14 g), low-profile (30 mm x 10 mm) actuator that can lift 4 kg. This means the LPVAc can lift 285 times its' self-weight. The low-profile nature allows for unobtrusive integration to wearable devices. When these characteristics are combined, the LPVAc becomes an ideal actuator for use with wearable devices that need to supply power to aid the motion of human limbs while still being hidden to an observer. The research team integrated the LPVAc into a novel soft wearable exoskeleton suit. This exosuit focuses on augmenting the lifting power of the gluteus maximums muscles of the lower limb. StSt requires the extension of hip and knee joints. The main muscle groups used during these motions are the

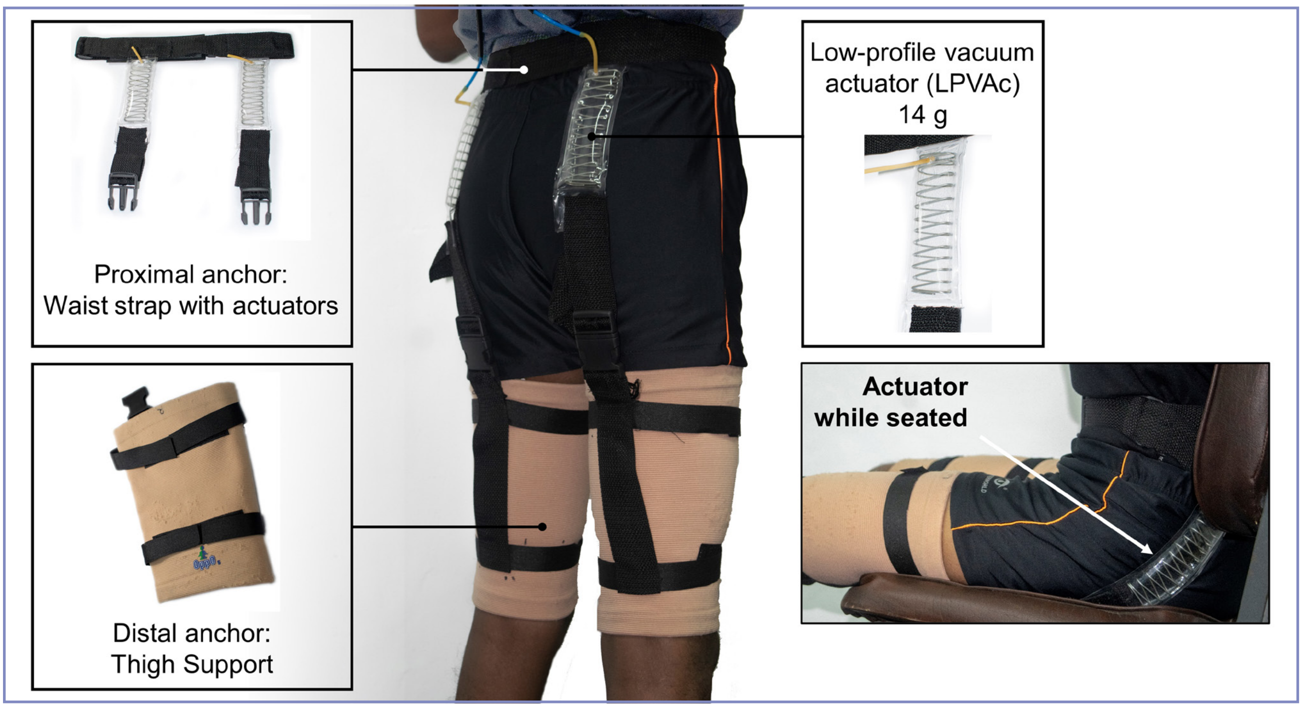

Figure 3: The main parts of the sit-to-stand transition assist exosuit. The inset shows how the LPVAc is unobtrusive during seated posture.

quadriceps femoris (QF) and the gluteus maximus (GM) muscles. The gluteus maximus is the largest muscle in the human body and does most of the heavy lifting of your body during motions against gravity, such as standing up or walking upstairs. Hence, the research team placed the LPVAc parallel to the gluteus maximus muscle to help it lift your body when standing up from a sitting posture.

The exosuit developed by the CSSM team is classified as a mono-articular exosuit as it augments only the singular gluteus maximus muscle in each leg. The research team designed the exosuit using lines on non-extension and anchor point concepts of Wehner [6]. The exosuit is made from soft inextensible webbing straps, which act as anchors and force guides. To make sure the donning and doffing of the suit is made easier for a user with impaired muscle strength, the exosuit is made in parts. The base part is worn around the hip and can be adjusted to the wearer's waist using push-on quick-release buckles. The distal portion is worn as two thigh support sleeves that tighten the suit at the wearer's thighs. The LPVAc is connected in between these two parts using push-on quick-release buckles. The exosuit uses one LPVAc per leg. The complete exosuit weighs only 324 g, and

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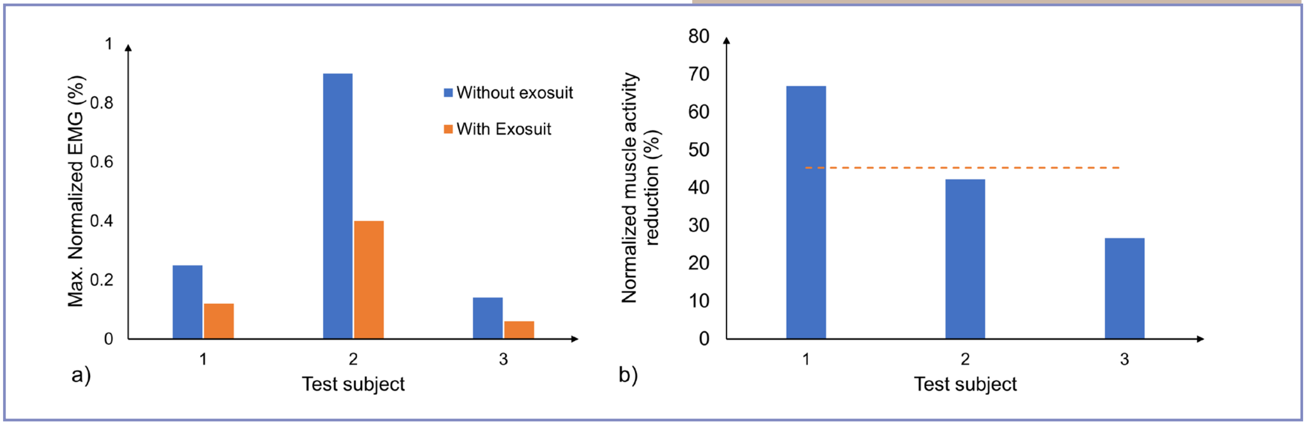

Figure 4: The performance validation of the exosuit. a) The observed normalized EMG readings from the gluteus maximus muscle activity in three test subjects without the exosuit and with the exosuit. b) The observed reduction of EMG activity as a percentage. The dashed line shows the average reduction of 45%.

most of this weight is anchored close to the waist. By positioning most of the weight around the hip anchor, the metabolic penalty of carrying weights distally from the joint is also reduced.

The research team used healthy volunteers to assess the amount of aid provided by the exosuit during StSt. They used electromyography (EMG) signals (EMG tells you how much muscle activity is present by measuring the electrical activity) from the surface of the buttocks to measure the gluteus maximus muscle activity. The results obtained by the research team showed the suit reduced the muscle activity requirement by up to 66%, with an average reduction of 45%.

The researchers of CSSM have presented a comprehensive description of the design, development, and assessment of the StSt assist exosuit in [7].
This exosuit is one of the recent developments presented by the researchers at the CSSM laboratory. Both undergraduate and postgraduate researchers working under the banner of CSSM have actively contributed to the development of many soft robotic actuators, sensors, and systems. These researchers continue to work on the development of novel, smart applications involving these soft robotic technologies.

The members of the CSSM research team continuously strive to provide innovative solutions to improve the quality of life of humans, as shown by the contributions of the exosuit development team.

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