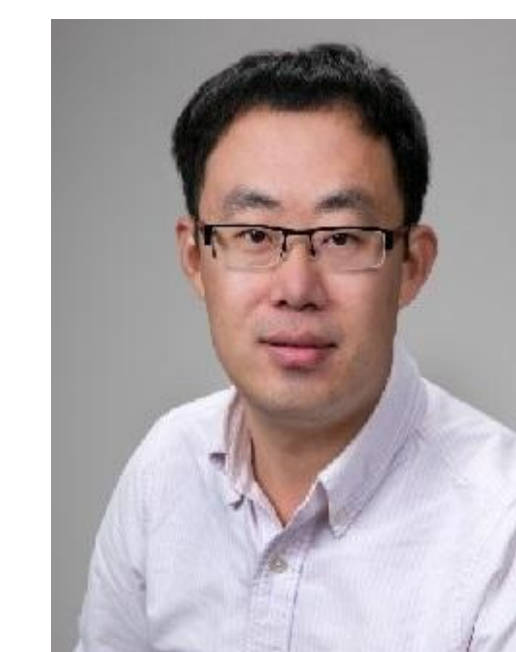


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# Knee Plug & Play Exoskeleton for Knee Osteoarthritis

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## Background and Opportunity

**Knee Osteoarthritis (OA):** A common condition causing pain, functional limitations, and reduced quality of life. Knee braces are explored as potential interventions to alleviate symptoms and improve joint function.

### Overall Literature Review Findings:

- Soft knee braces reduce pain, improve walking performance, and enhance knee stability and confidence [1].
- Unloader braces reduce pain, improve functional outcomes, and increase joint space during gait [2].
- Knee braces are promising non-surgical interventions to alleviate pain and improve mobility in individuals with knee OA [3].

### Existing Solution: University of Michigan Study [4] Comparison with Our System:

- Michigan's system uses custom-manufactured links, adding complexity, cost, and manufacturing time.
- Our system is designed to be plug-and-play: users can attach the actuator to any commercially available knee brace, eliminating the need for custom parts or specialized braces.
- Our goal: Offer a simpler, more cost-effective, and adaptable solution for users to integrate the technology into existing equipment.
- Their Exo: 2.8 kg vs. Our Exo: 1.5 kg (without battery/electronics)



Figure 1: University of Michigan Knee Exo (left) vs. Our P&amp;P Exo (right)

## Design Specifications

The following details the preferred design specifications for our Knee Plug & Play Exoskeletal System:

Specifications	
Total Mass	< 3 kg
Form Factor	~ 50 mm
Brace Hinge	Single
Peak Torque	18 Nm
Battery Life	3 hours

The main goals of the design is to limit the weight (total mass) and provide a low profile that does not stick out far from the user's leg (form factor).

## The Plug & Play System

### Knee Exoskeleton:

- Exoskeleton designed to be attached to pre-existing soft brace solutions.
- Mounted mechanically to the knee brace and connected electrically to the PCB

### Overall Design Considerations:

- Focus on functionality, accessibility, and ease of use.
- Designed to offer minimal bulk, intuitive controls, and a user-centric experience.



Figure 2: P&amp;P Knee Exo Gait Cycle

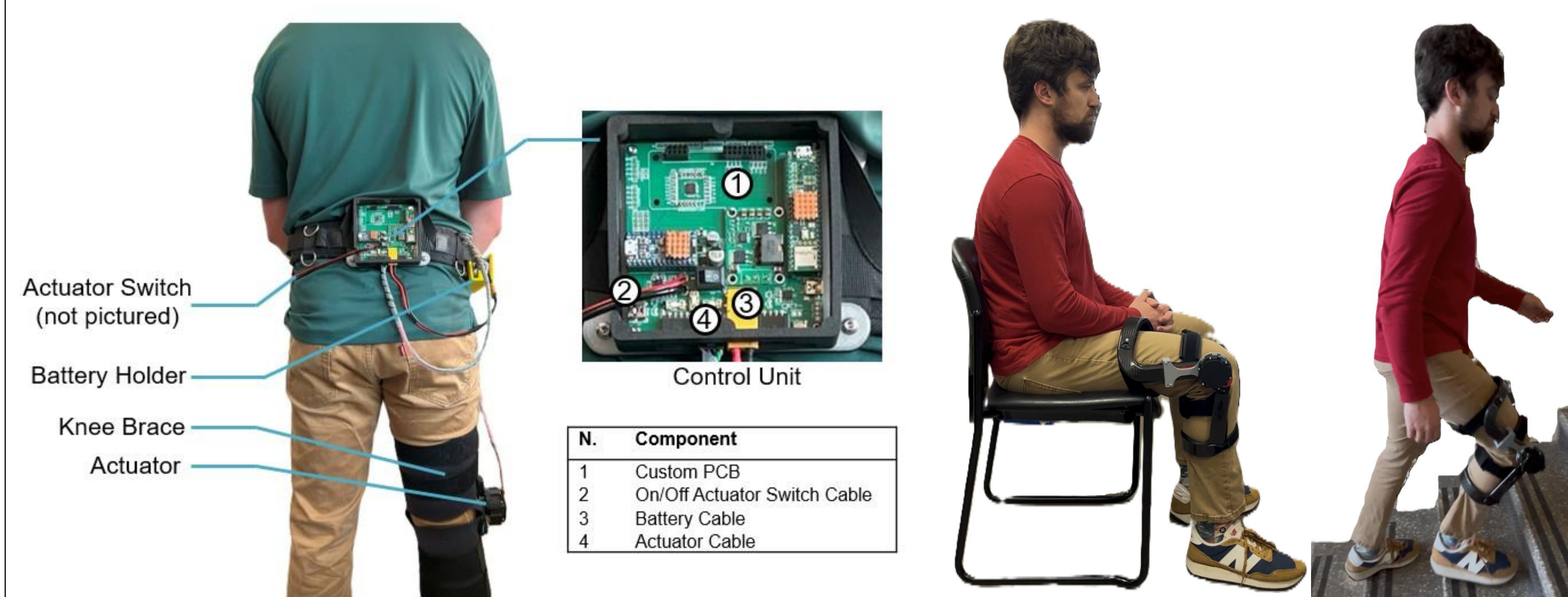


Figure 3: System Components



Figure 4: Sitting and Stair Climbing

## References

- [1] T. Cudejko, M. van der Esch, M. van der Leeden, J. C. van denNoort, L. D. Roorda, W. Lems, J. Twisk, M. Steultjens, J. Woodburn, J. Harlaar, and J. Dekker, "The immediate effect of a soft knee brace on pain, activity limitations, self-reported knee instability, and self-reported knee confidence in patients with knee osteoarthritis," *Arthritis Research Therapy*, vol. 19, 2017.
- [2] P. Thoumie, M. Marty, B. Avouac, A. Pallez, A. Vaumousse, L. PhamThi Pipet, A. Monroche, N. Graveleau, A. Bonnin, C. Ben Amor, and E. Coudeyre, "Effect of unloading brace treatment on pain and function in patients with symptomatic knee osteoarthritis: the rotor randomized clinical trial," *Scientific Reports*, vol. 8, 2018.
- [3] K. Nagai, S. Yang, F. H. Fu, and W. Anderst, "Unloader knee brace increases medial compartment joint space during gait in knee osteoarthritis patients," *Orthopaedic Journal of Sports Medicine*, vol. 6, 2018.
- [4] N. V. Divekar, G. C. Thomas, A. R. Yerva, H. B. Frame, and R. D. Gregg, "A versatile knee exoskeleton mitigates quadriceps fatigue in lifting, lowering, and carrying tasks," *Science Robotics*, 2024.
- [5] Neo-G. (2025). *Knee supports & braces*. Neo-G. Retrieved April 6, 2025, from [https://www.neo-g.com/collections/knee-supports-braces?gad\\_source=1&gclid=CjwKCAjwzMi\\_BhACEiwAX4YZULfixibHGExitoSej8qw1AcyhQg2C8Si\\_p-WSaBMSwSdWpmWdJ1NqRoCboKQAvD\\_BwE](https://www.neo-g.com/collections/knee-supports-braces?gad_source=1&gclid=CjwKCAjwzMi_BhACEiwAX4YZULfixibHGExitoSej8qw1AcyhQg2C8Si_p-WSaBMSwSdWpmWdJ1NqRoCboKQAvD_BwE)
- [6] Spring Loaded Technology. (2024). *Home*. Spring Loaded Technology. Retrieved April 6, 2025, from <https://www.springloaded.com/>

## NeoG Adjusta Fit Hinged Open Knee Brace [5]

The NeoG knee brace was selected for our initial Plug & Play design. The goal of this design is to enable users to purchase an existing knee brace and easily attach our exoskeletal system to it, providing a seamless and accessible solution.



### Features:

- Shank brace link is directly driven by the actuator.
- Actuator is mounted to the thigh brace link for natural force transmission.
- C-clamps secure the exoskeleton to existing braces from the underside.



Figure 5: Close-Up View of Link Attachment



Figure 6: NeoG P&amp;P Actuator

## Spring Loaded Knee Brace [6]

The Spring Loaded knee brace was selected for our second Plug & Play design. The current iteration is less of a plug-&-play model than the NeoG exoskeleton, but offers a direct-drive approach to the knee joint.



### Features:

- Shank with a direct drive from the actuator.
- Assembly replaces the current plating and bearings at the joint.
- Actuator mounted directly to the brace at the joint.
- An additional c-clamp secures the assembly to the thigh link, can be hand tightened from the outside.

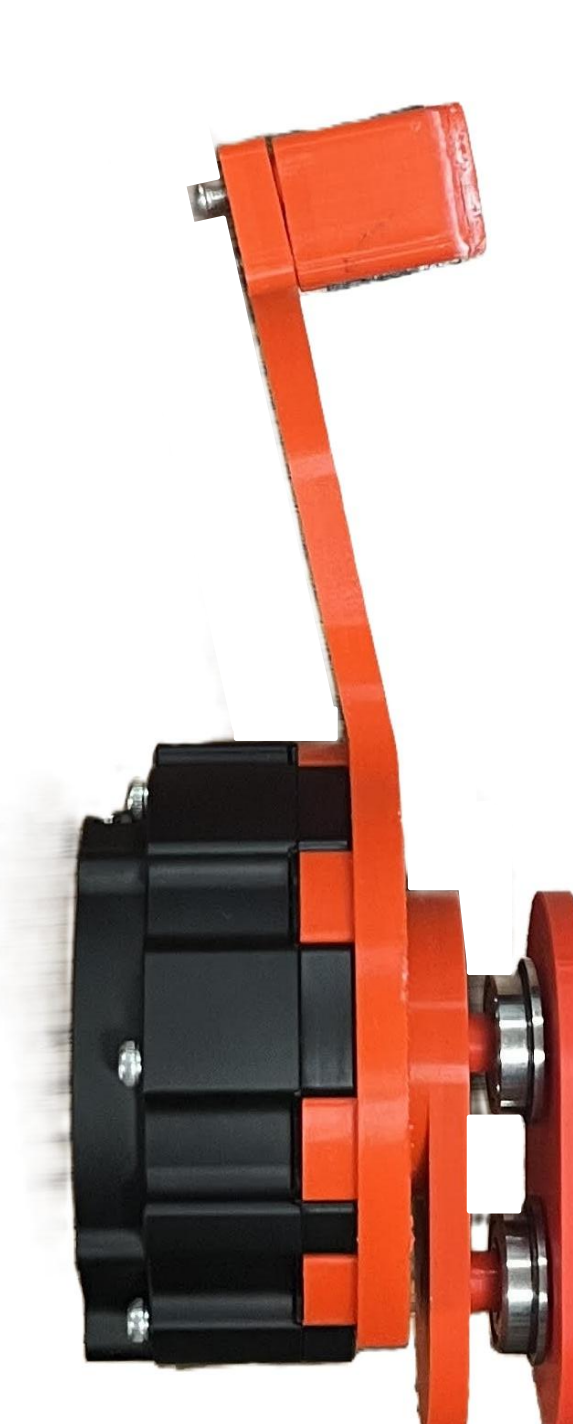


Figure 7: Close-Up View of Direct Attachment



Figure 8: Spring Loaded P&amp;P Actuator