A novel concept of passive knee prosthesis with multiple stiffnesses to support overground walking and sit-to-stand

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Lower-limb amputation severely affect amputees mobility

20 per 100,000 europeans undergo a **lower-limb amputation** yearly.

55% of lower-limb amputations are **transfemoral**.

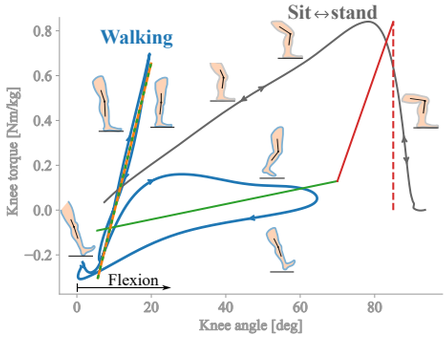
Growing demand for **affordable**, **efficient** and **versatile** prosthetic knee devices offering optimal functionality for daily mobility.

Passive knee prosthesis developed to enhance tasks versatility

Enable **level-ground walking**, capturing natural gait biomechanics **as faithfully as possible**.

Enhance **motion transition** capabilities by providing **passive assistance** while **standing up** and **sitting down**.

Knee biomechanics approximated by various stiffnesses



Walking

High stiffness for stance

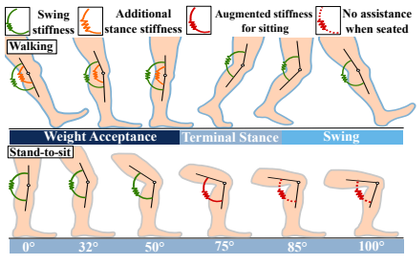
Low stiffness for swing

Sitting

Increased stiffness after swing

Seated drop of assistance

Innovative concept to transition between multiple stiffnesses



Conceptual parallel stiffness states for walking and stand-to-sit

Three distinct **stiffness levels** implemented with **parallel elastic** elements.

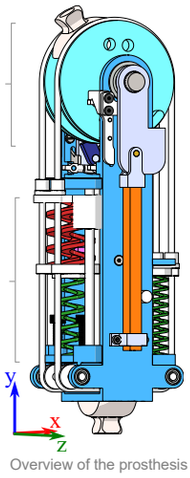
Passively variable **activation states** based on **angular position**.

Prosthesis with two main sub-mechanisms

Monocentric joint with **two pulleys** and transmission cables

Double stiffness mechanism with **knee extension locking** while seated

Stance stiffness engagement mechanism



Overview of the prosthesis

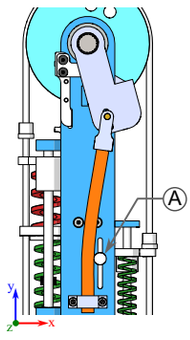
Cam cleat clutch engaging stance stiffness

Stance stiffness implemented via **elastically deformable composite beams**.

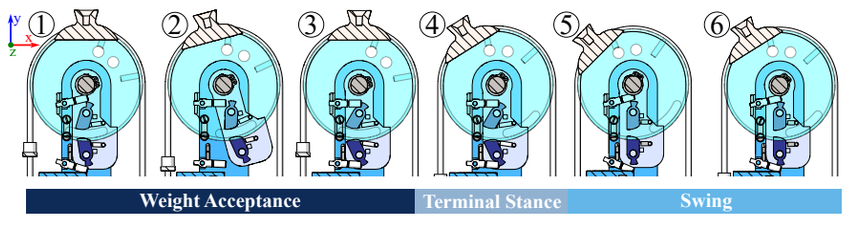
Adjustable stiffness level to user's weight and preference via intermediate **fulcrum position** Ⓐ.

Two **cams** in an overarching configuration **couple the beams to the pulleys** via an intermediate plate.

Stance stiffness engaged between the knee first **full extension at heel strike** and second at the **end of weight acceptance**.



Stance stiffness clutch and beam in the middle of weight acceptance phase



Sectional view of the stance mechanism during an overground gait cycle

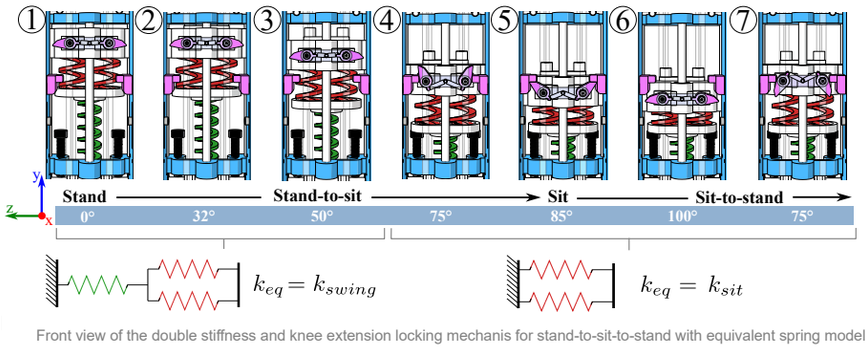
Serial springs to ensure swing to sit transition

①-③ As the knee flexes, the **series springs compresses** rendering **swing stiffness** (k_{swing}).

④ When the intermediate plate contacts stoppers, the **stiffness rises** to the **sitting stiffness** (k_{sit}).

⑤ When seated, the couple of **cams locks knee extension**.

⑥-⑦ Knee extension is **unlocked after an over-flexion** and the previously stored energy is released to **assist standing**.



Front view of the double stiffness and knee extension locking mechanis for stand-to-sit-to-stand with equivalent spring model

Future work

Manufacture and assembly of a functional prototype.

Validation of various sub-mechanisms **on test bench**.

General **validation with healthy subjects** using an adapter.

This work is supported by the French Community of Belgium as part or FRIA grant (1.E014.24F awarded to Julien Guiaux Brinon) from the F.R.S - FNRS.