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Development of a Nonmotorized Mechanism for Ankle Rehabilitation

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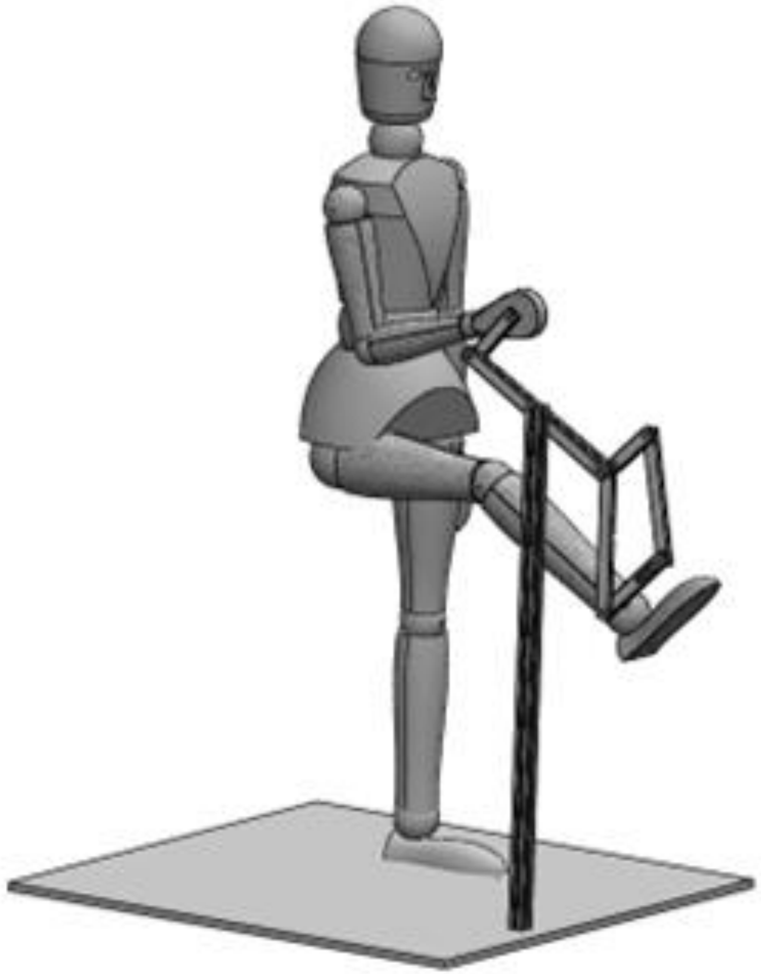
Introduction

Use of robotic structures for rehabilitation:

- Used for different types of treatments
- Reduces costs with active labor
- Allows the execution of new exercises

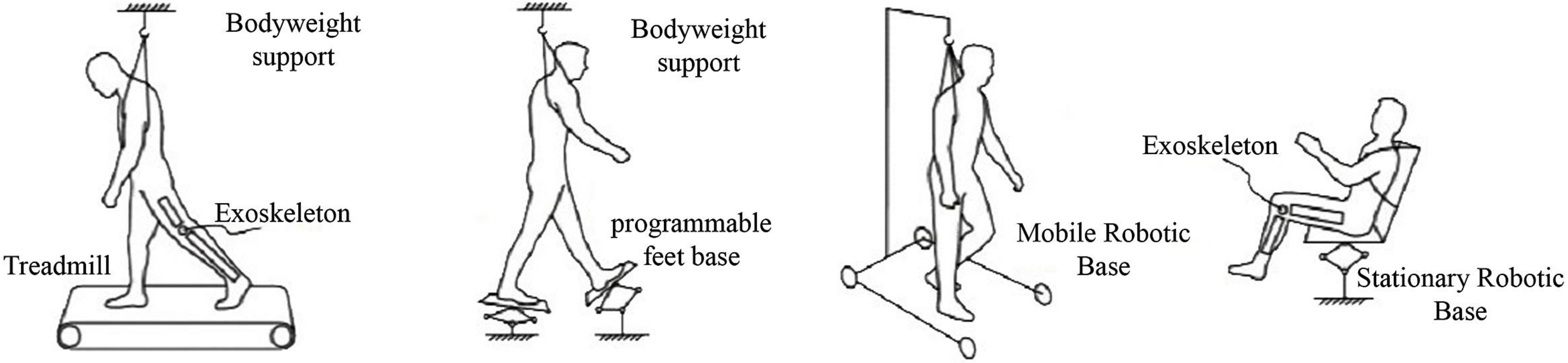


Introduction

Use of nonmotorized devices:

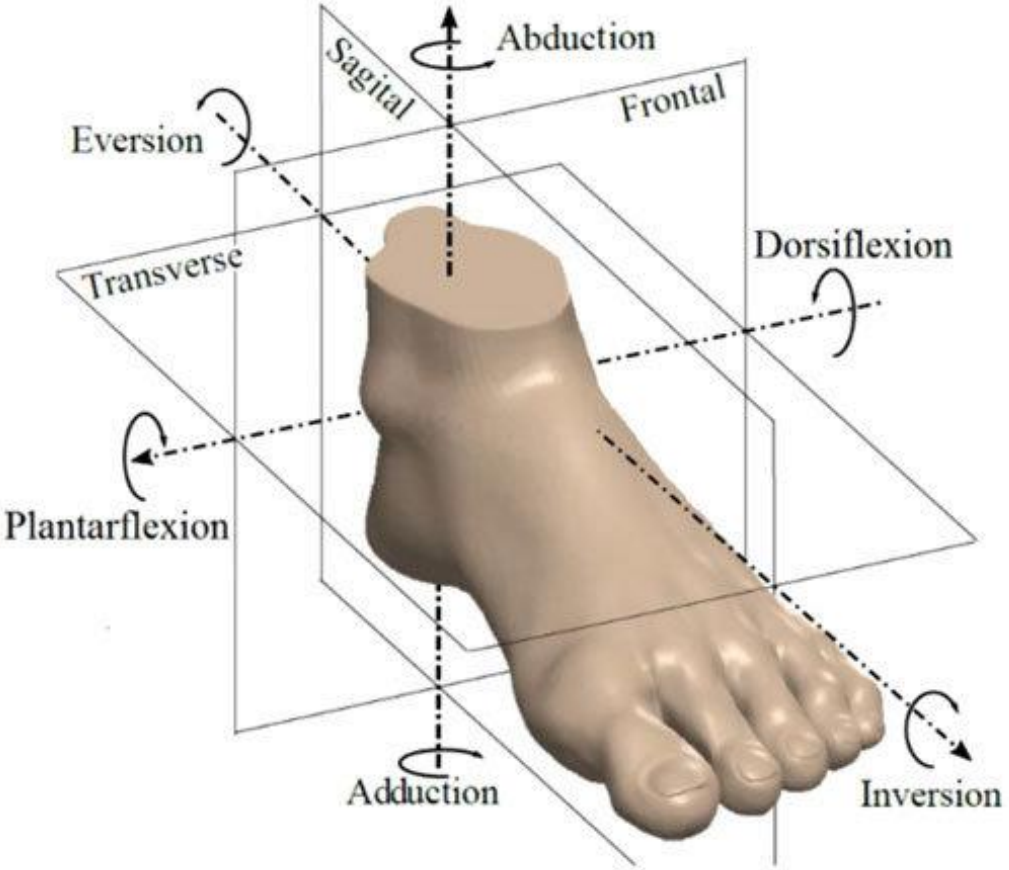
- Easy operation by the end user
- No prior training is required
- Simple functionality
- They are capable of generating positive motivational effects
- Patient independence to perform exercises

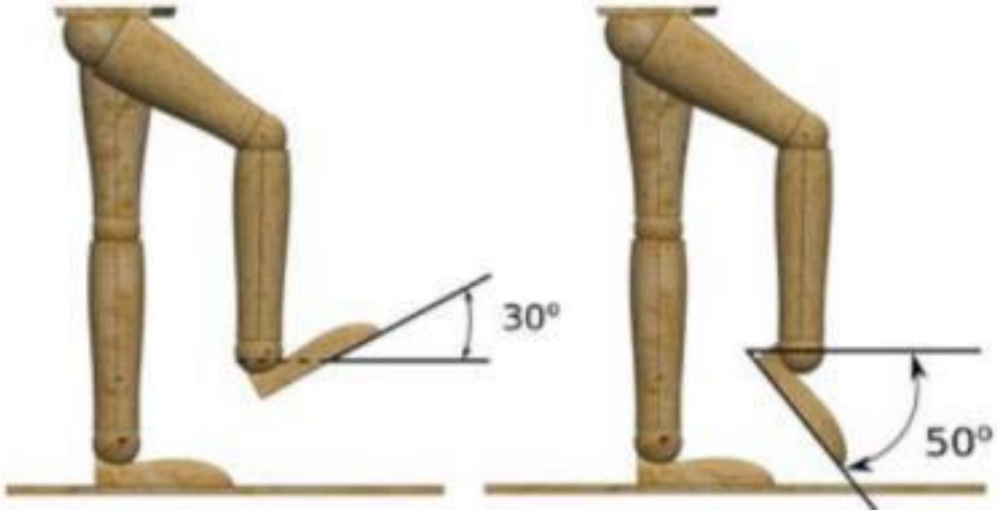
State-of-the-Art: Structures applied to rehabilitation



Generally, the great cost and complexity of the structures for rehabilitation present in the literature is the presence of actuators associated with complex control systems.

Ankle kinesiology





The main action of the ankle joint is to allow dorsiflexion and plantar flexion of the foot

Mathematical Model of the Ankle Device

Mechanism developed based on the planar 4-bar mechanism

Considerations:

- Grashof's Law: Crank-rocker mechanism
- Low speeds and accelerations: Static modeling
- Rigid bars
- Backlash and friction in joints not considered
- Only ankle flexion movements
- Mechanism built from the amplitude of Ankle joint

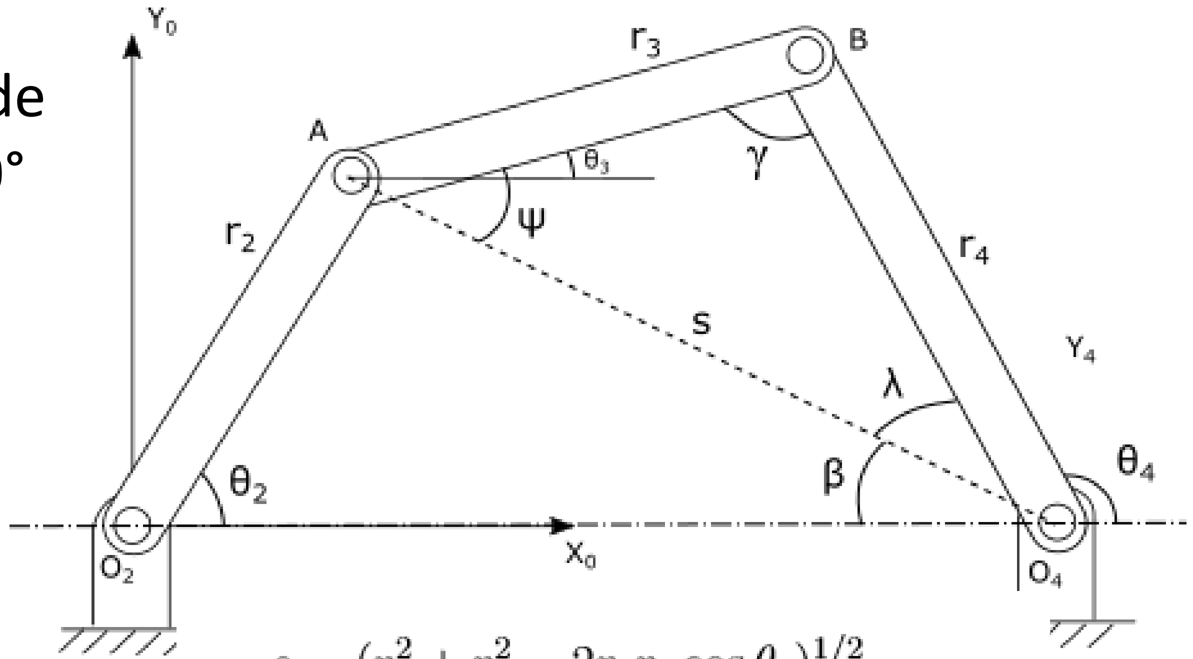
Mathematical Model of the Ankle Device

Use of an evolutional algorithm optimizer to obtain the lengths of the bars;

- Angular output equal to ankle joint amplitude
- Transmission angle (γ) between 30° and 150°

$$\theta_4 = 180° - \lambda - \beta \qquad 0 \leq \theta_2 < 180°$$

$$\theta_4 = 180° - \lambda + \beta \qquad 180° \leq \theta_2 < 360°$$



$$s = (r_1^2 + r_2^2 - 2r_1 r_2 \cos\theta_2)^{1/2}$$

$$\beta = \cos^{-1}[(r_1^2 - r_2^2 + s^2)/(2sr_1)]$$

$$\psi = \cos^{-1}[(r_3^2 - r_4^2 + s^2)/(2sr_3)]$$

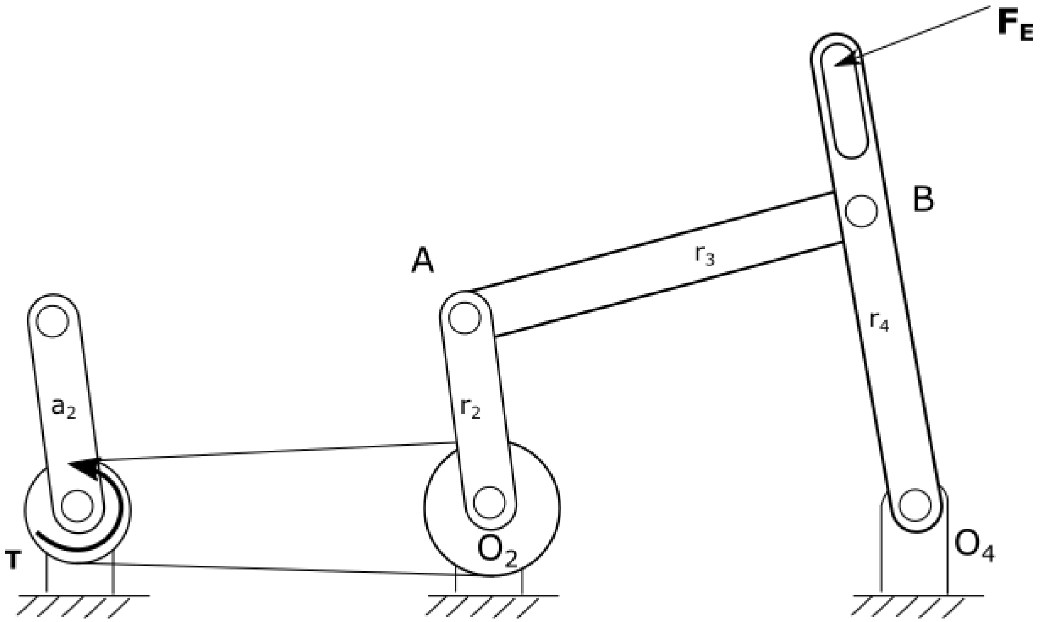
$$\lambda = \cos^{-1}[(r_4^2 - r_3^2 + s^2)/(2sr_4)]$$

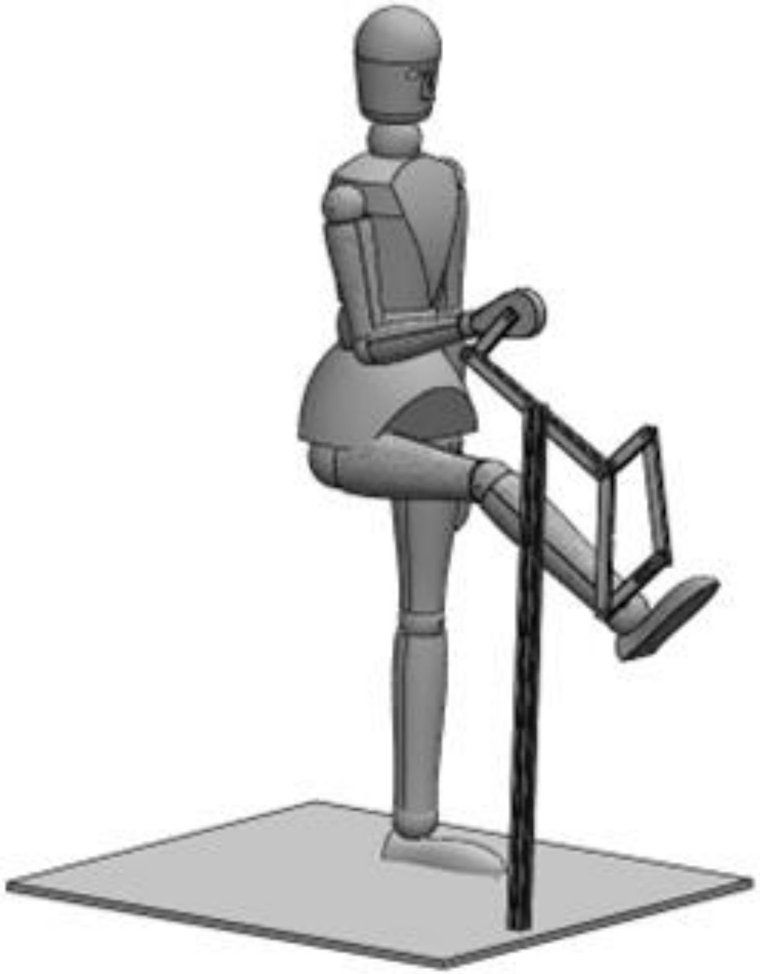
$$\gamma = \pm\cos^{-1}[(r_4^2 - s^2 + r_3^2)/(2r_3 r_4)]$$

The obtained lengths are:
r1 = 273 mm
r2 = 104 mm
r3 = 235 mm
r4 = 164 mm

CAD/CAE Simulations and Results

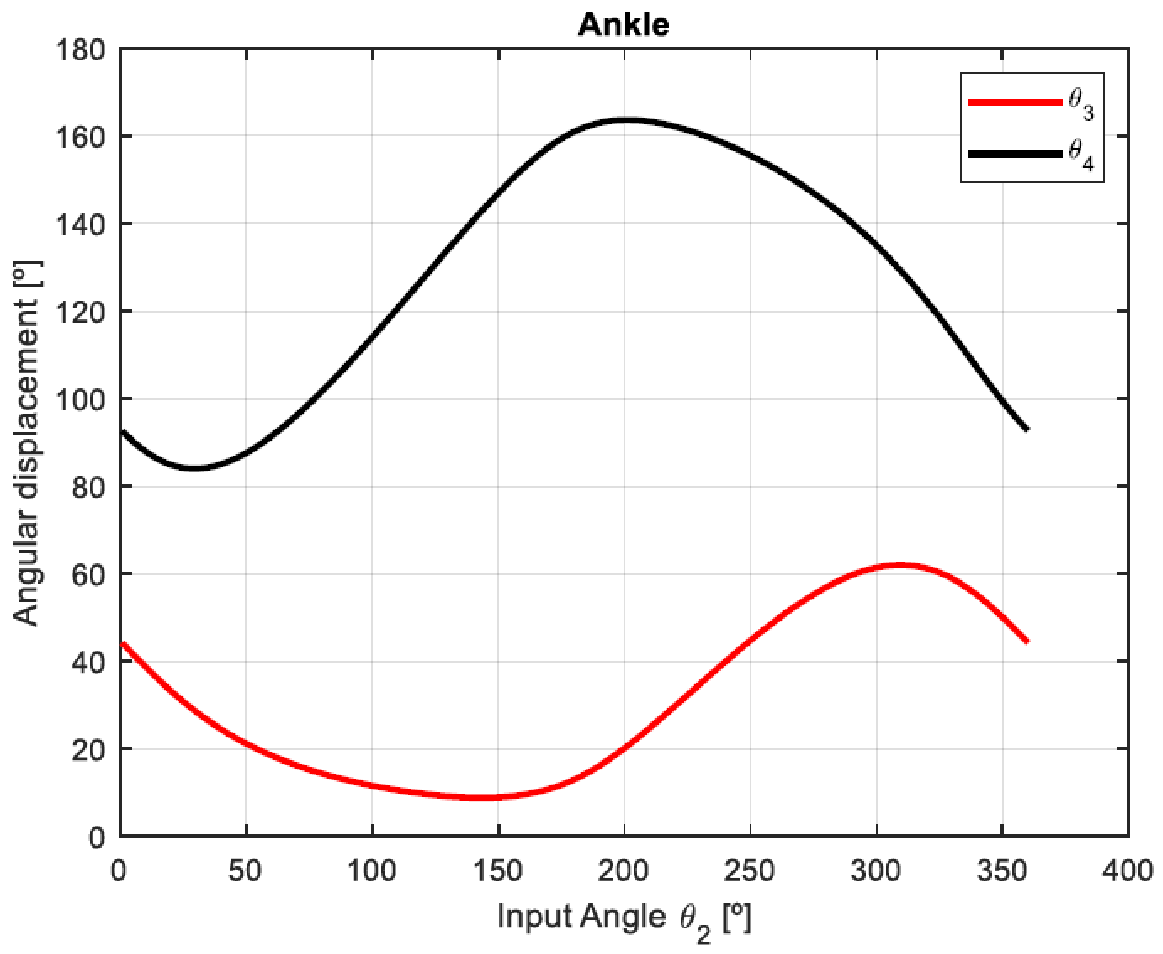
Chain drive mechanism transmission to reduce the patient required effort to a comfortable level

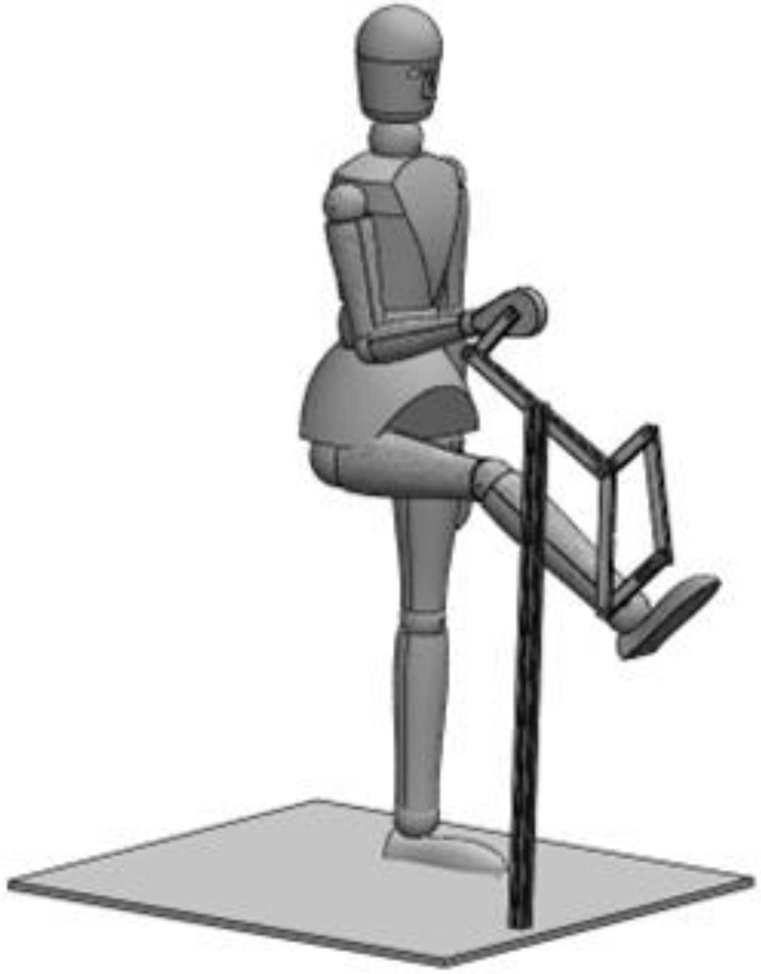




CAD/CAE Simulations and Results

Output amplitude/Angle obtained:





Ankle range: 80°

Obtained: 78.891°

Error: 1.386%

CAD/CAE Simulations and Results

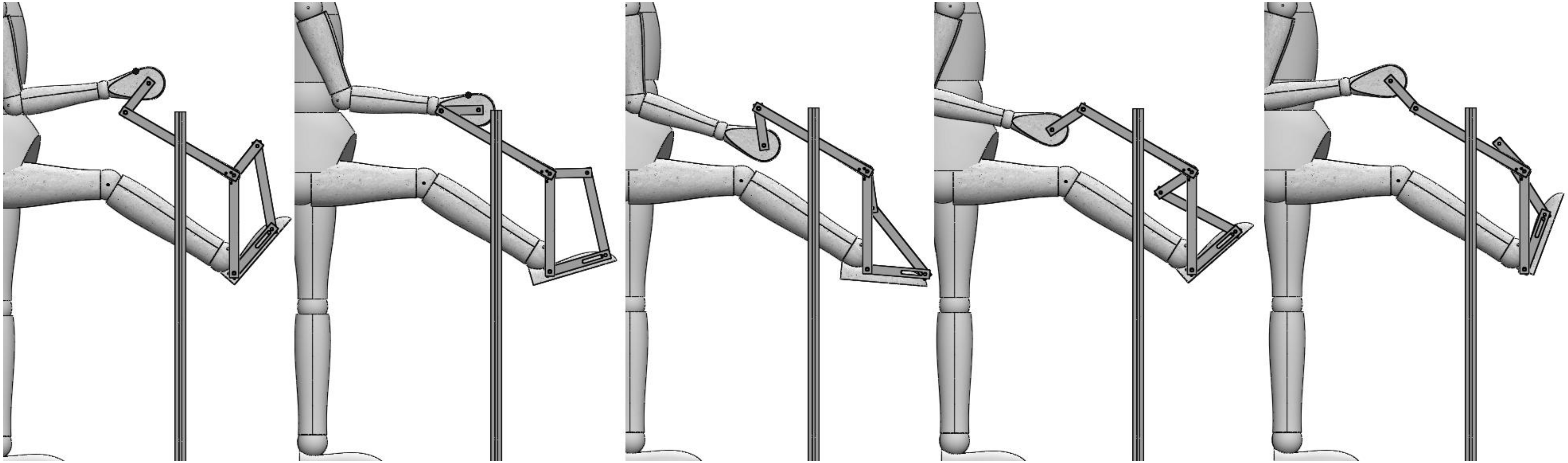
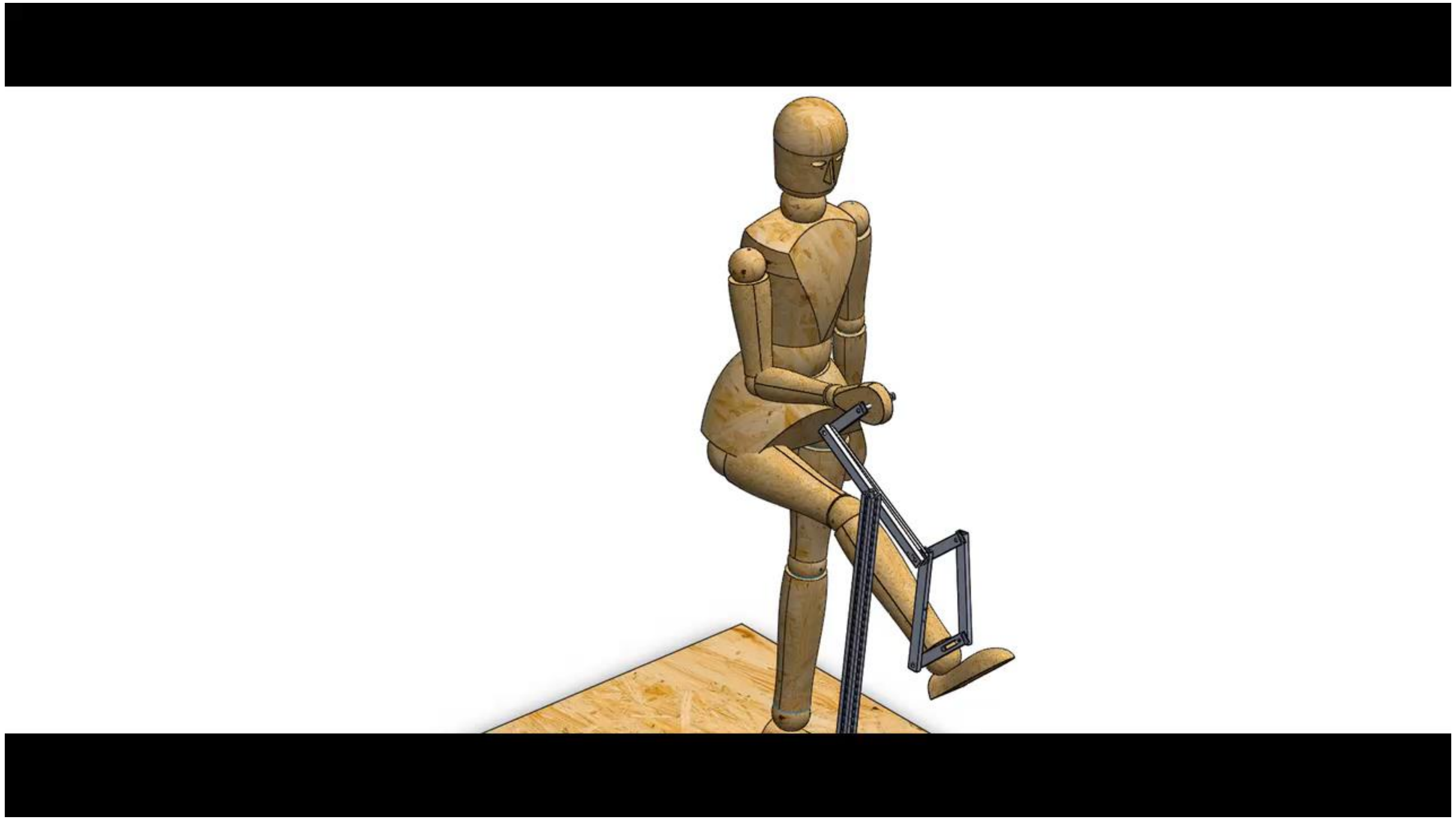


Figure. Sequence of images representing the simulation of motion ankle device.

CAD/CAE Simulations and Results



Conclusions

- In this paper, a simple, yet innovative design of a crank-rocker mechanism is proposed, combined with a chain-drive transmission to ankle rehabilitation.
- This novel structure offers new possibilities to the rehabilitation scenario while being able to assist motor recovery on both paretic limbs of the patients, simultaneously.
- The proposed device was modeled mathematically, and the dimensions were obtained with the aid of an evolutional algorithm.
- Static analysis reveals that the structure can be built using light and easy-to-find materials, thus reducing the costs.
- The graphical simulations shown that the mobility is compatible to the ankle joint movements, while the crank can explore global movements of the upper limb.
- The next step will be construction of the prototype and realize experimental tests with patients.

Acknowledgement

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