

# Semester Project

# Final Presentation

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TEST AND EVALUATION OF A SIMULATION MODEL OF UPPER BODY  
MOVEMENT WITH KINETIC ASSISTANCE

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# Contents

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## 1. Introduction

## 2. External Forces

## 3. Open-loop

## 4. Closed-loop

## 5. Conclusion



[1] Illustration: <https://media.istockphoto.com/photos/question-mark-blue-3d-interrogation-point-punctuation-mark-asking-picture-id943657262>

[visited: 11.06.2018]



# Fly Jacket

## Goals:

- Control drone with upper body movements
- Implement haptic feedback
- Be comfortable for users

## Open questions:

- Determine where to apply the forces
- Find the right force magnitude

## Needed:

- Experimental data from real setup on human subjects
- **A model to simulate human upper body**



[2] Illustration: Alaa Bakr Maghrabi. Simulation model of upper body movement with kinetic assistance, 2017, p.10

# Objectives

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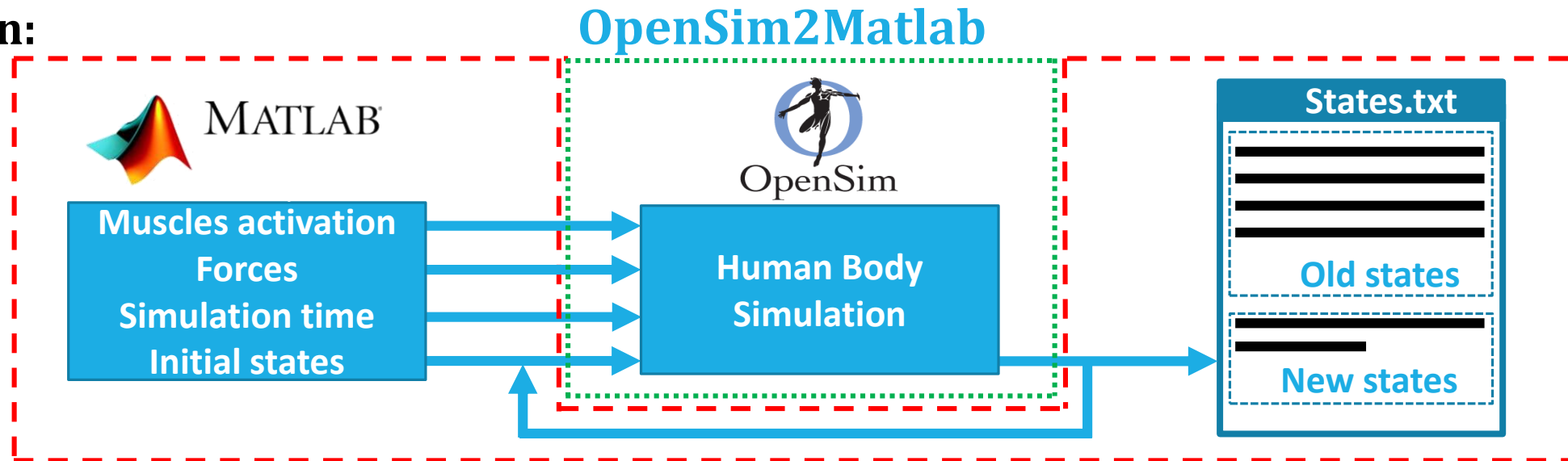
- ❑ Model and simulate the Fly Jacket setup
- ❑ Implement haptic guidance forces by the Fly Jacket on users
- ❑ Implement internal forces exerted by users (muscles)
- ❑ Observe the effect of varying the different force parameters
- ❑ Identify the human-in-the-loop upper body dynamics

# OpenSim

## Limitation:

- External loads cannot be changed during a simulation
- Specific controller law to activate target muscles cannot be directly implemented

## Solution:



[3] Illustration [left]: [https://www.cfn.group.cam.ac.uk/images/1428080879907.png/image\\_view\\_fullscreen](https://www.cfn.group.cam.ac.uk/images/1428080879907.png/image_view_fullscreen) [visited: 11.06.2018]

[4] Illustration [right]: <https://simtk-confluence.stanford.edu/display/OpenSim/OpenSim+and+NCSRR+Logos> [visited: 11.06.2018]

# Fly Jacket: Real Setup



# Fly Jacket: Simulation Setup



# Contents

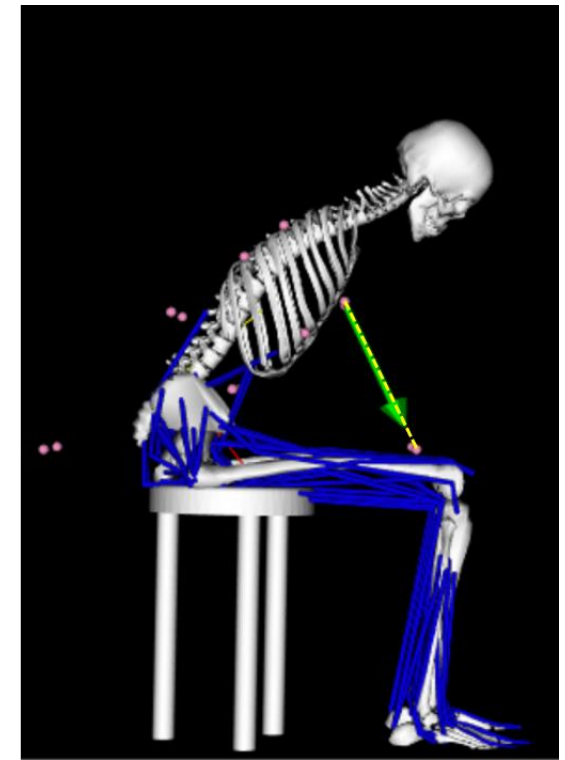
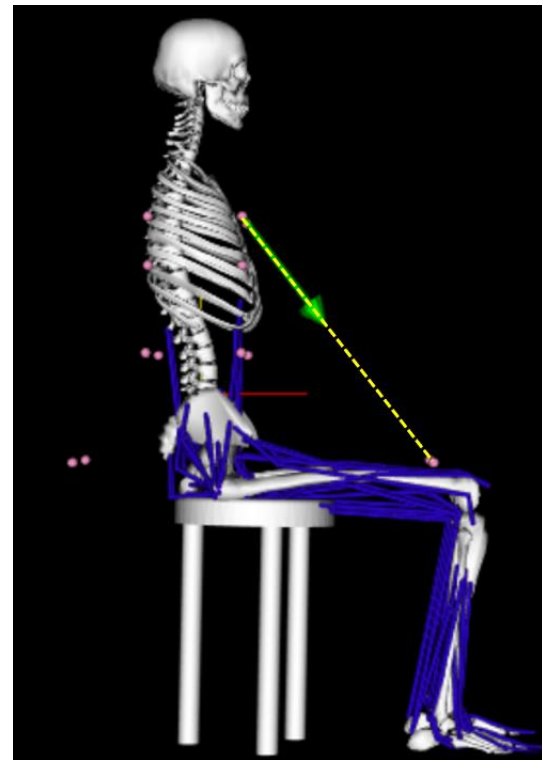
1. Introduction

**2. External Forces**

3. Open-loop

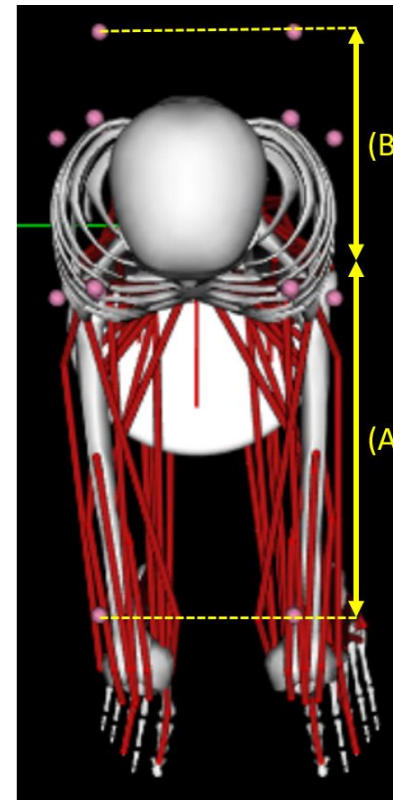
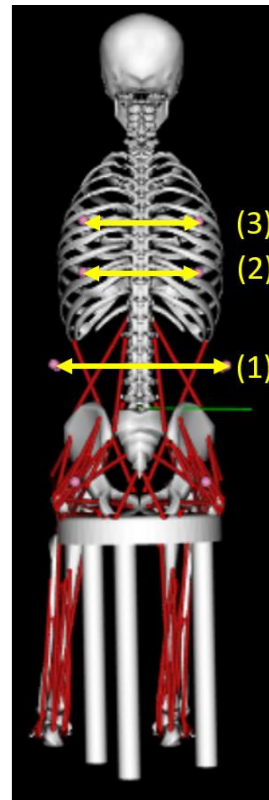
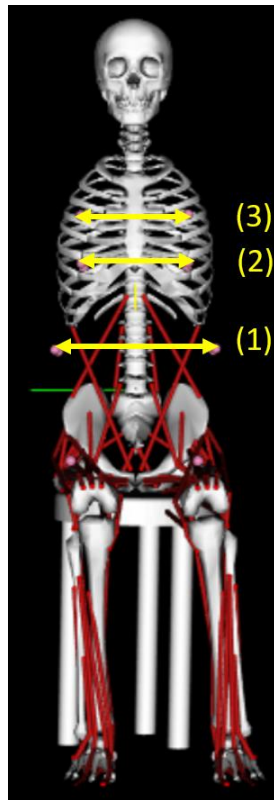
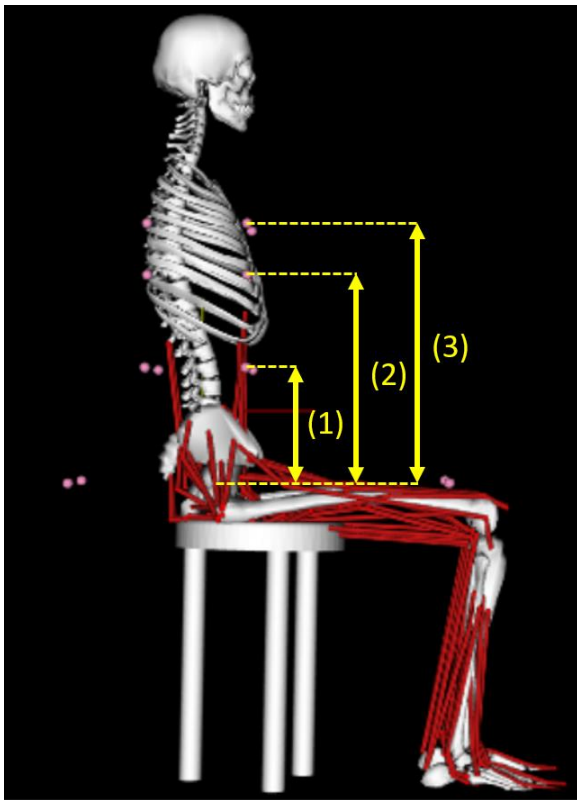
4. Closed-loop

5. Conclusion





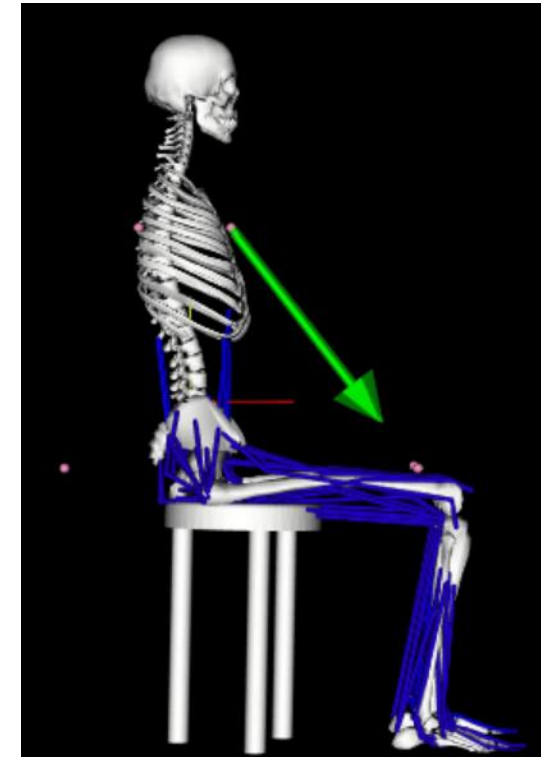
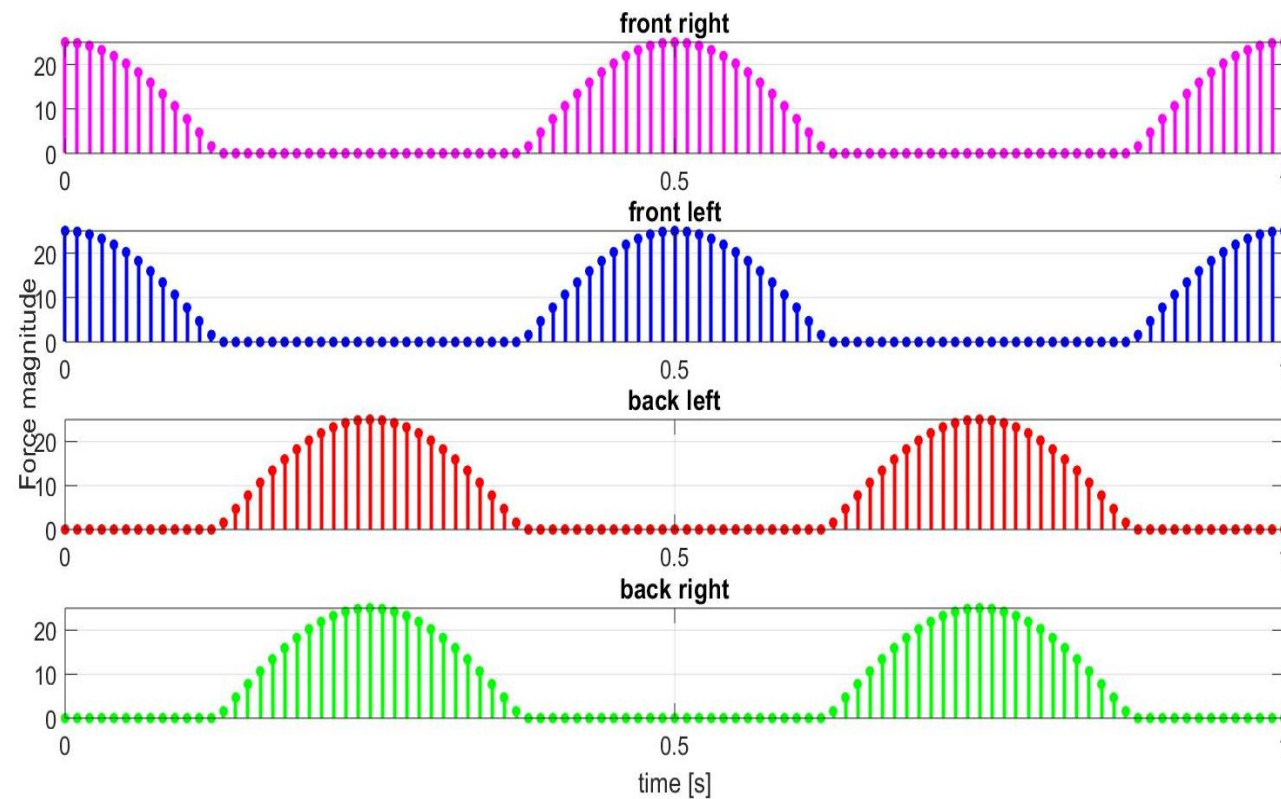
# Torso Placement: Low, Medium, High



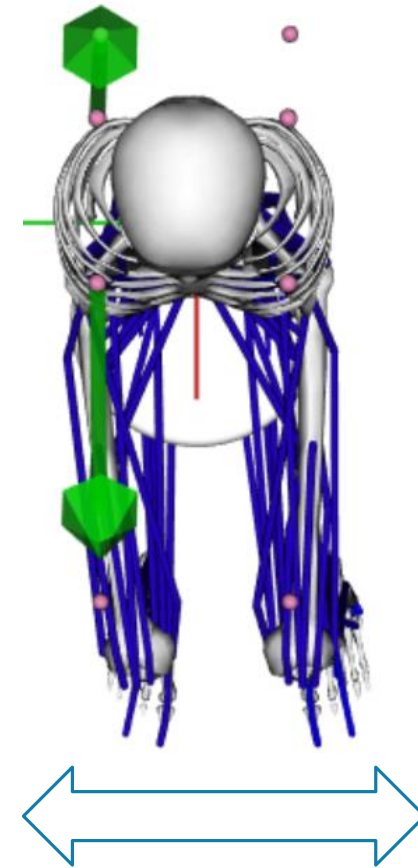
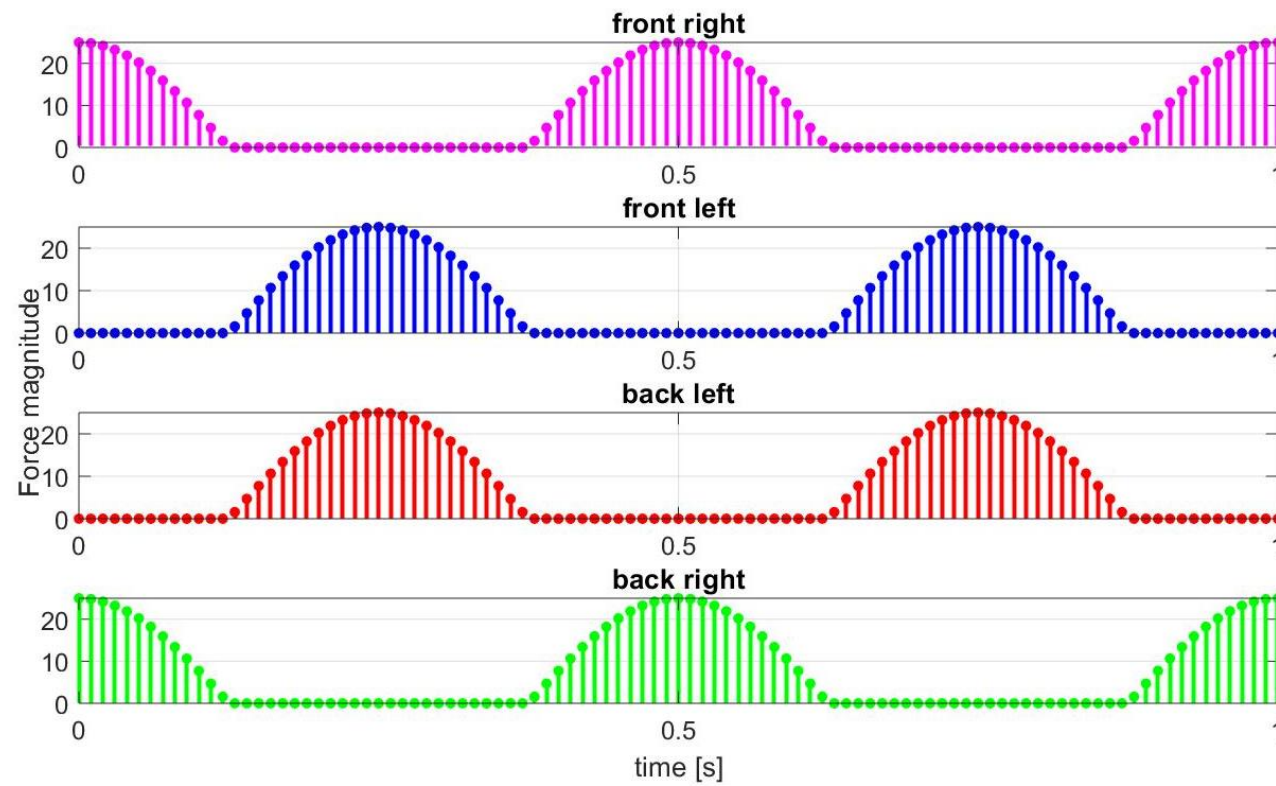
- Three sets of Markers {1;2;3}
- Four move with the torso
- Four others are fixed (based on the placement of motors)

Left/Right side	Front	Back	Top
(1) = 27 cm	(1) = 30 cm	(1) = 30 cm	(A) = 43 cm
(2) = 43 cm	(2) = 20 cm	(2) = 20 cm	(B) = 23 cm
(3) = 52 cm	(3) = 20 cm	(3) = 20 cm	

# Types of Movement – Extension/Flexion



# Types of Movement – Lateral Bending



# Contents

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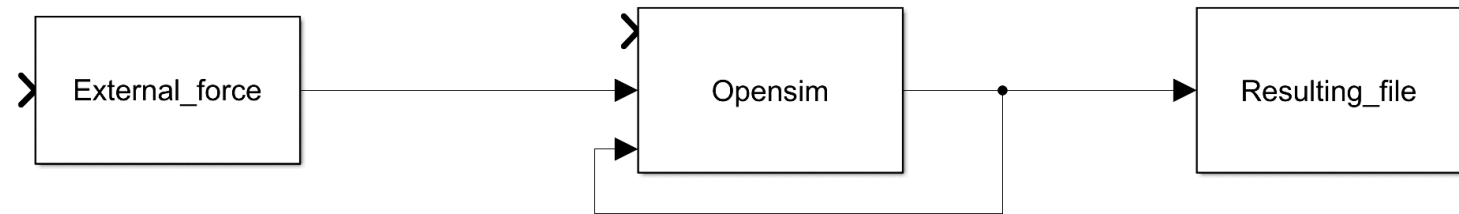
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2. External Forces

**3. Open-loop**

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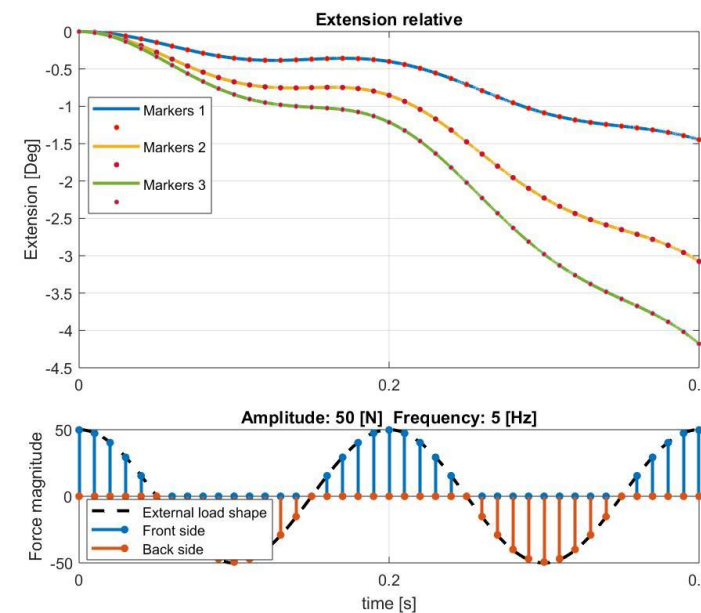
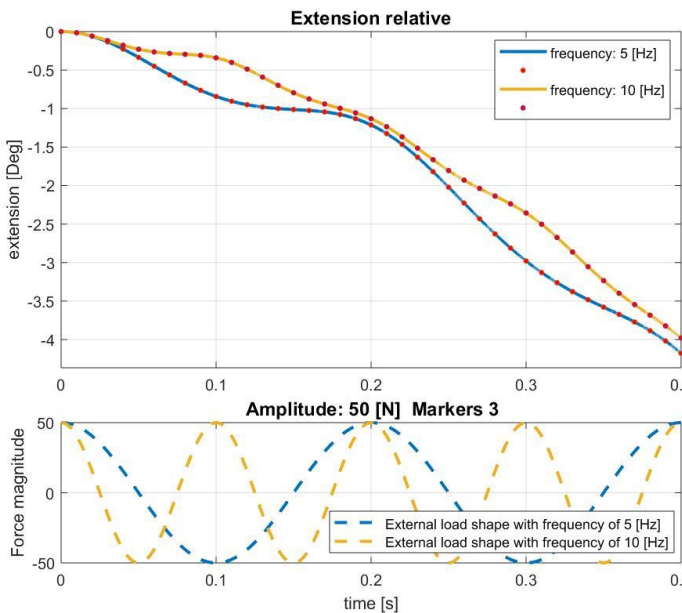
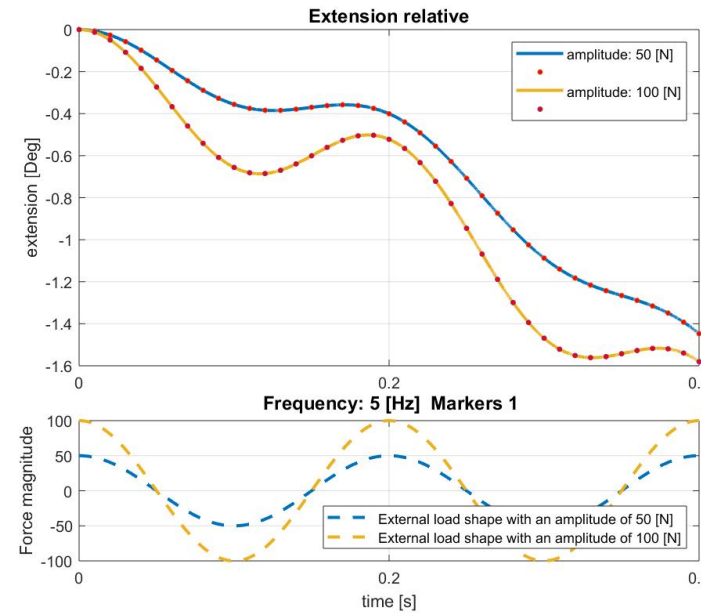
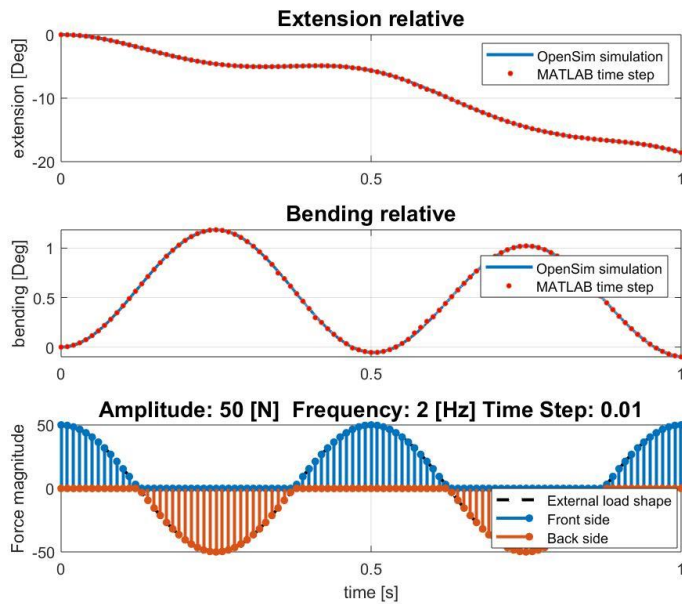
# Forces parameters

Type of movement

Magnitude

Frequency

Markers set





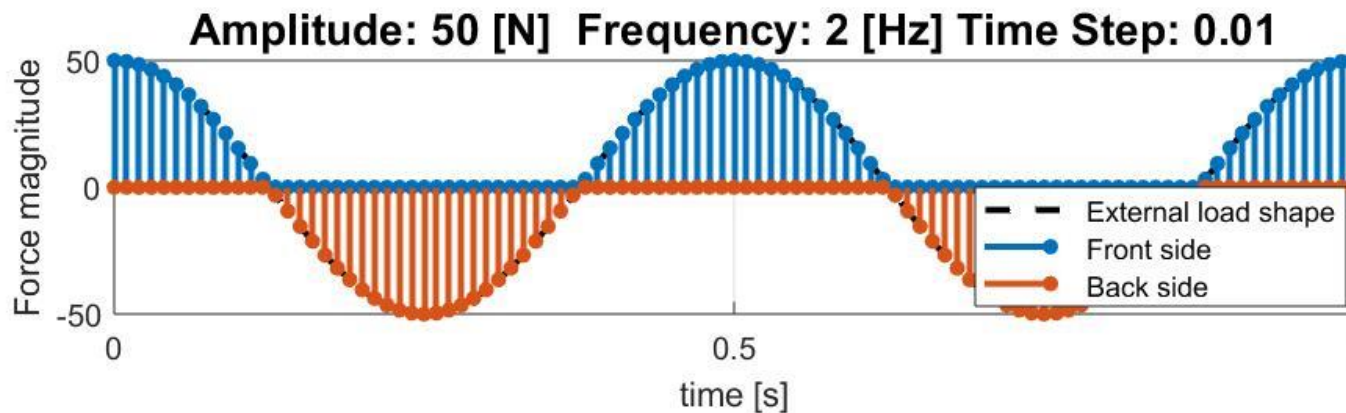
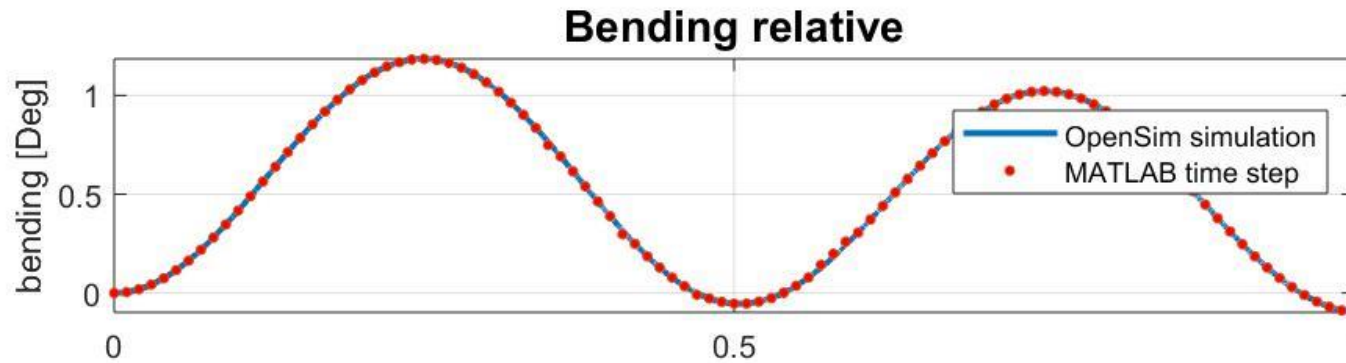
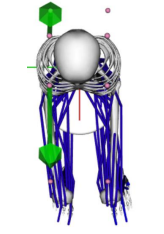
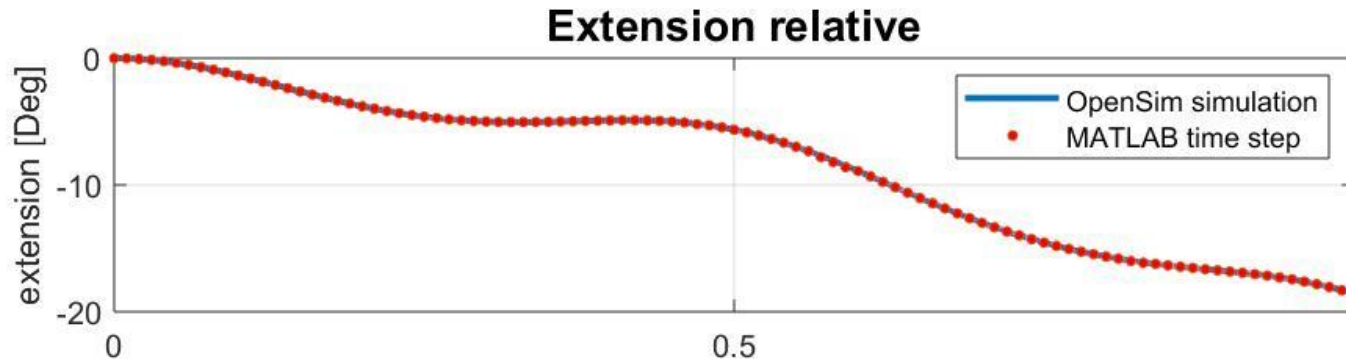
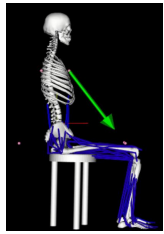
# Forces parameters

Type of movement

Magnitude

Frequency

Markers set



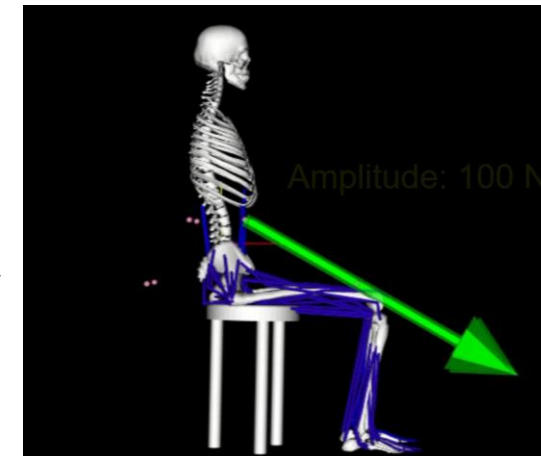
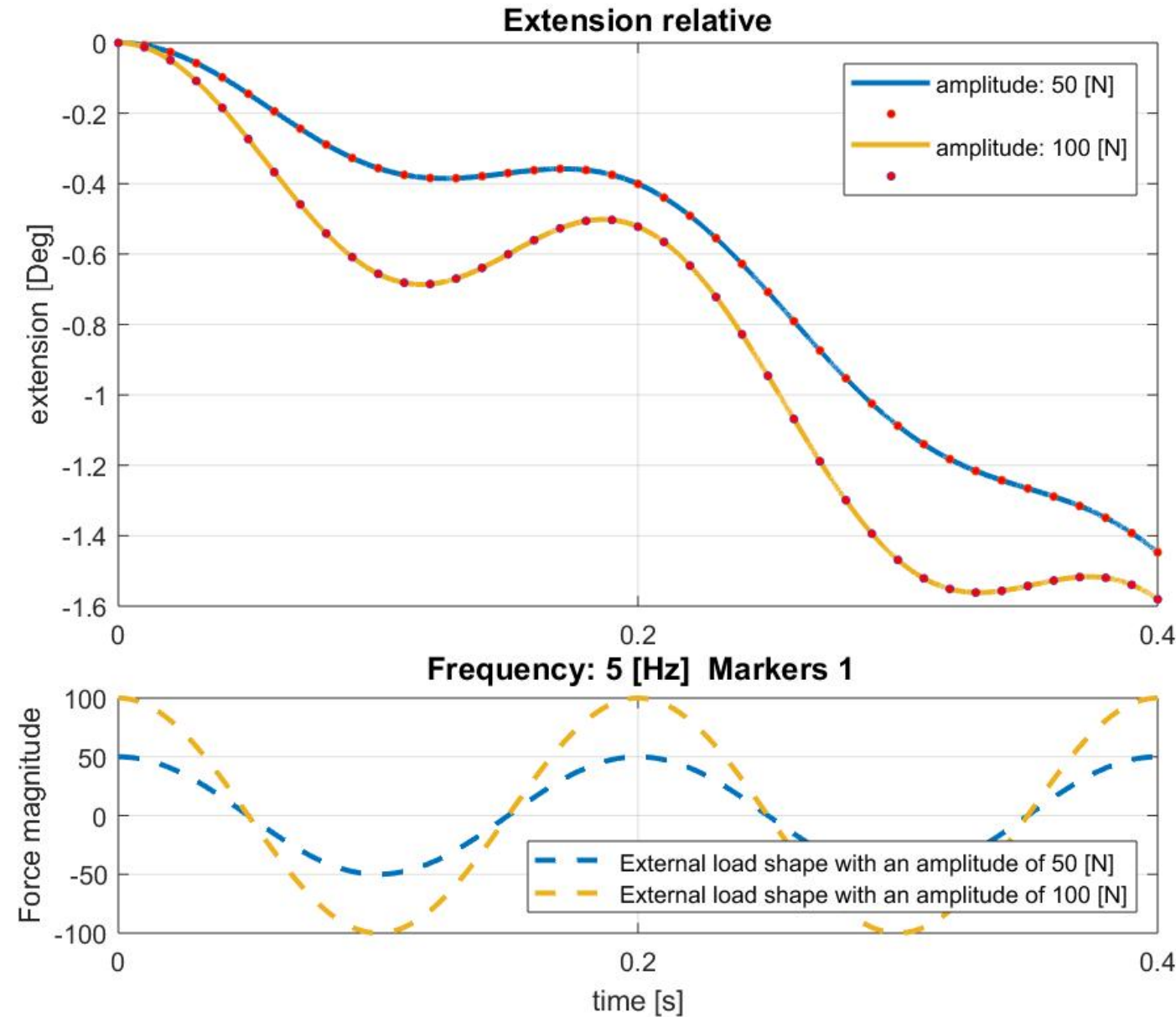
# Forces parameters

Type of movement

**Magnitude**

Frequency

Markers set



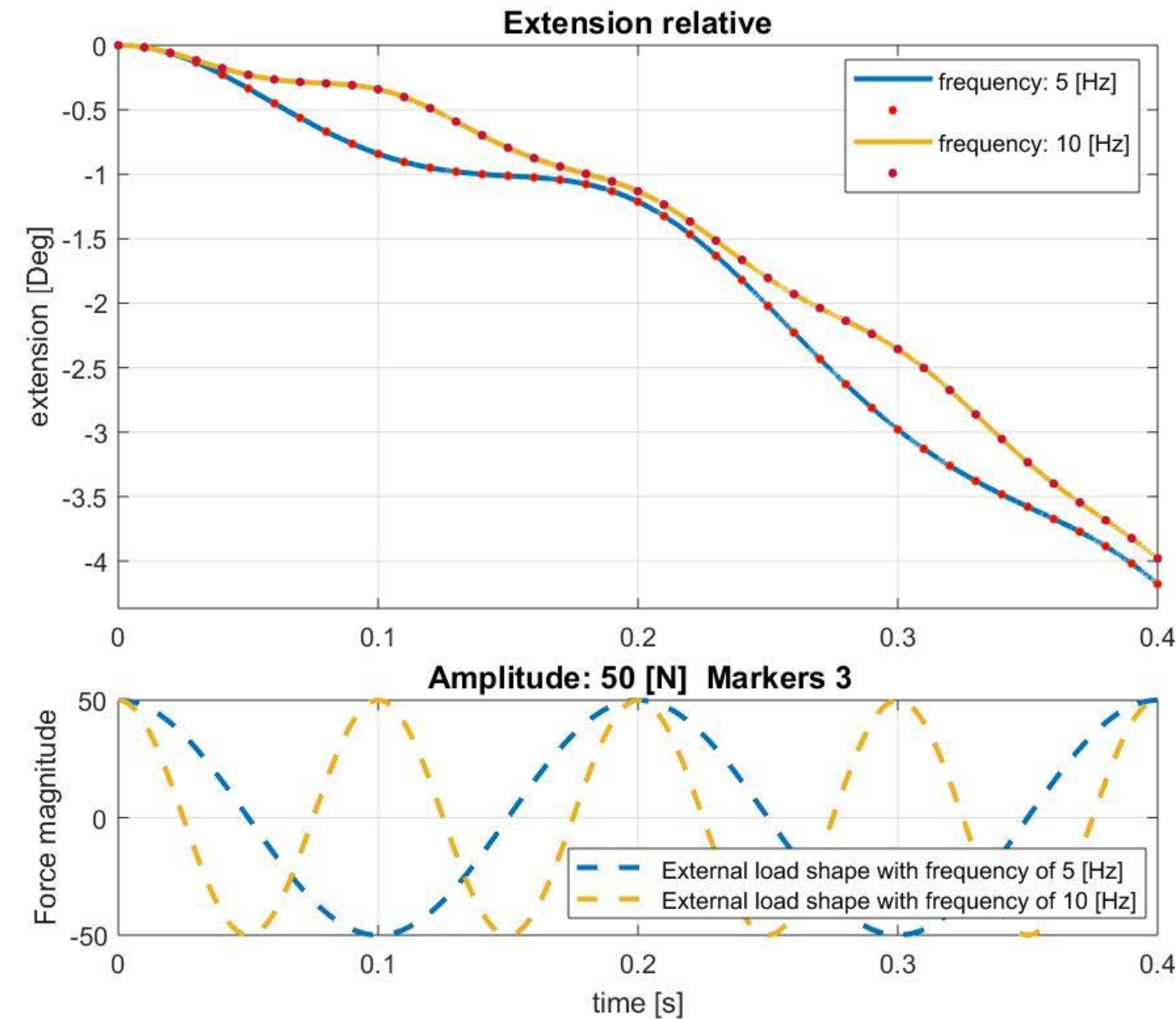
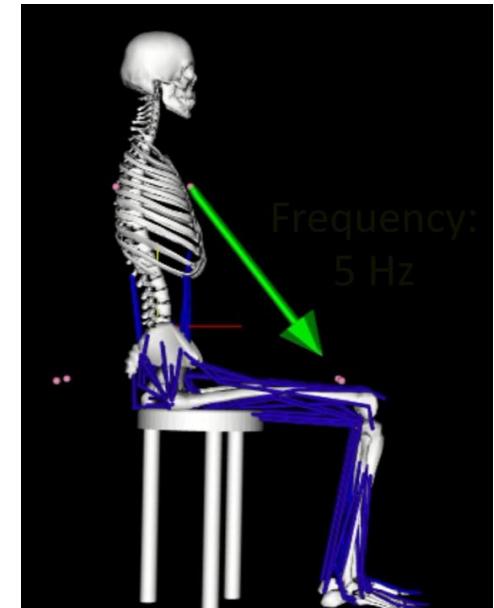
# Forces parameters

Type of movement

Magnitude

**Frequency**

Markers set





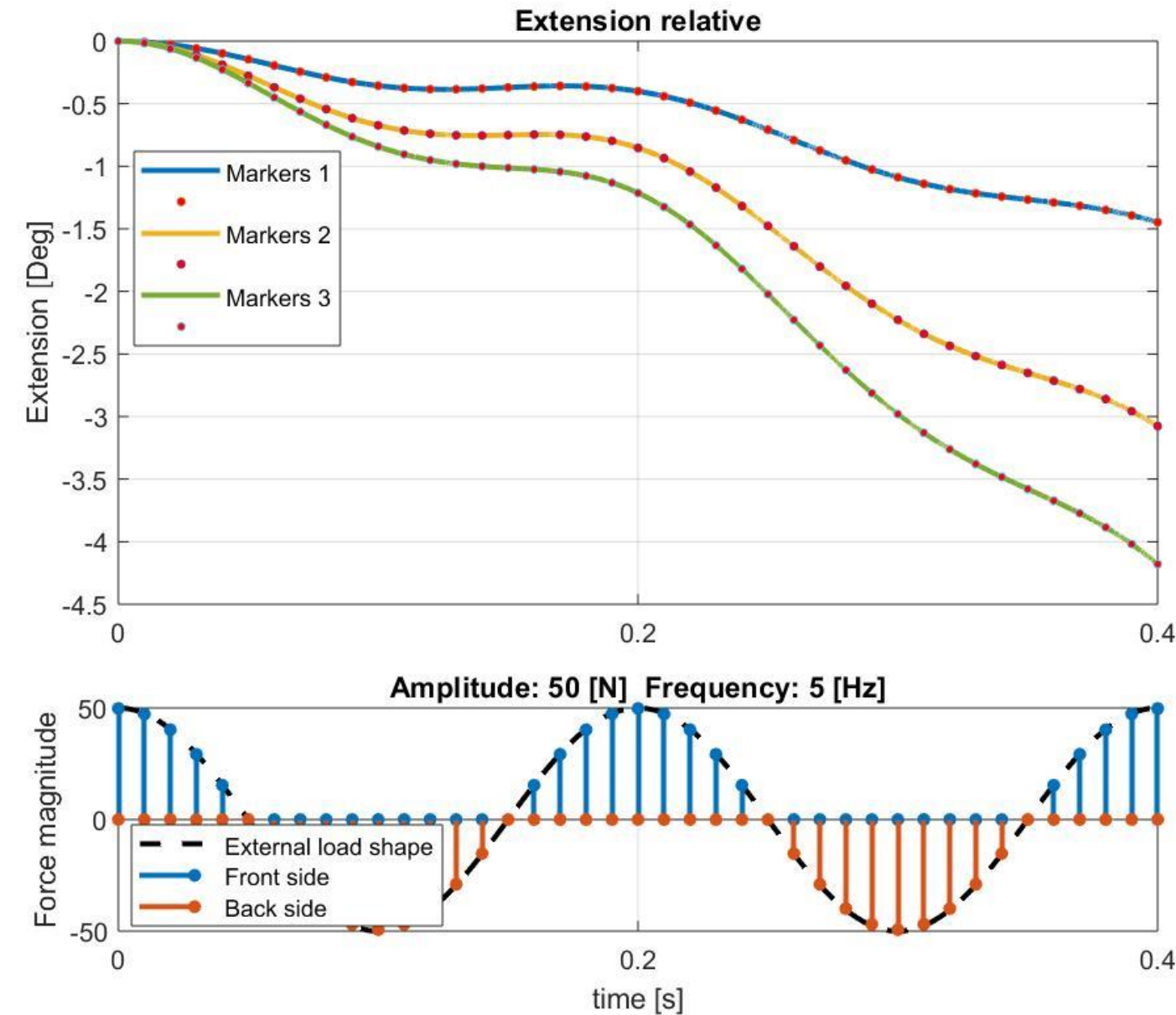
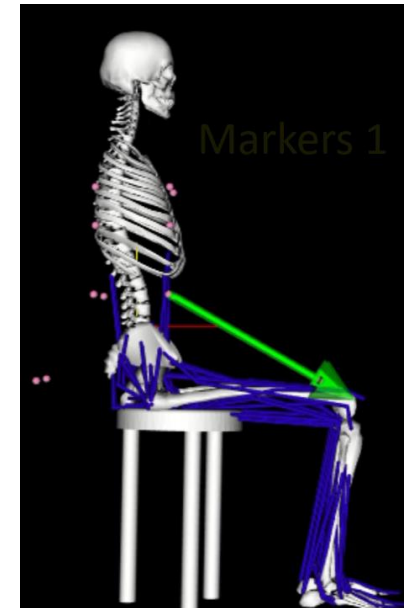
# Forces parameters

Type of movement

Magnitude

Frequency

Markers set



# Contents

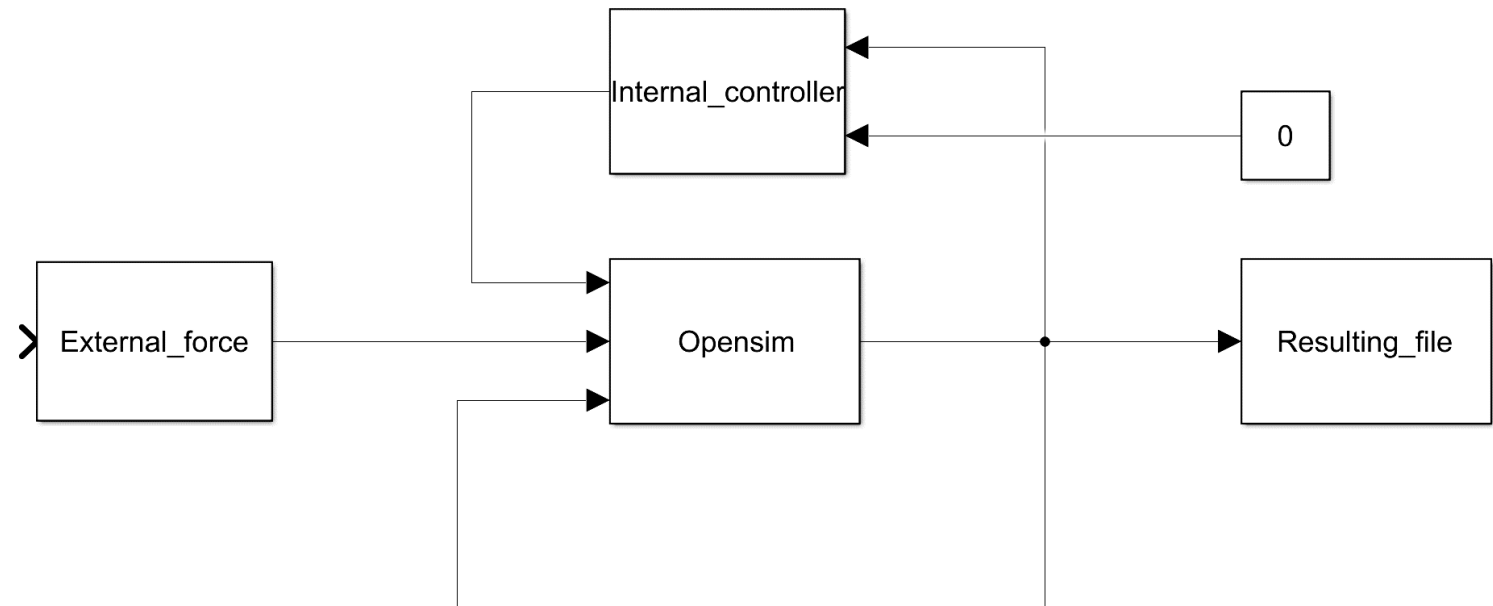
1. Introduction

2. External Forces

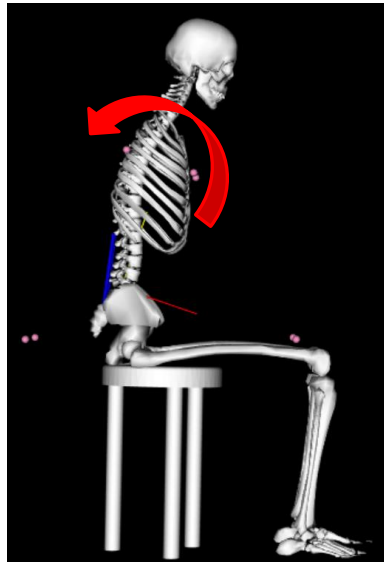
3. Open-loop

**4. Closed-loop**

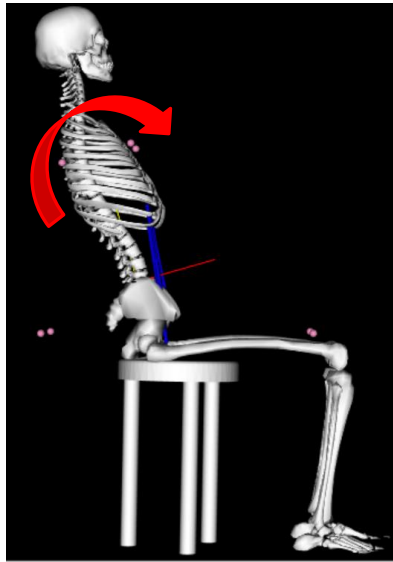
5. Conclusion



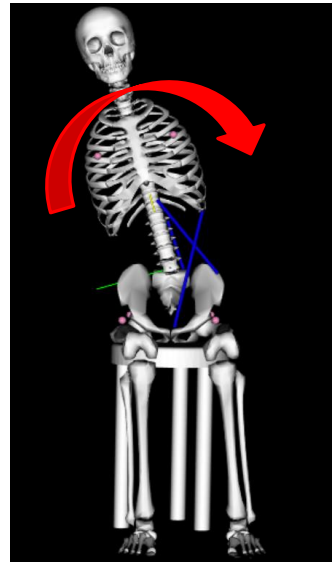
$\kappa_{ext} < 0$



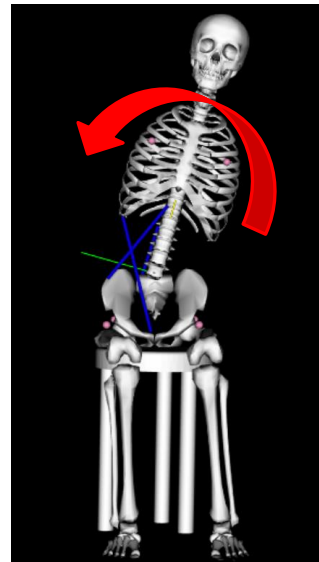
$\kappa_{ext} > 0$



$\kappa_{bend} < 0$



$\kappa_{bend} > 0$



## Controller law

$$\kappa_{ext}[n] = K_p e[n] + K_d \frac{e[n] - e[n-1]}{T_s}$$

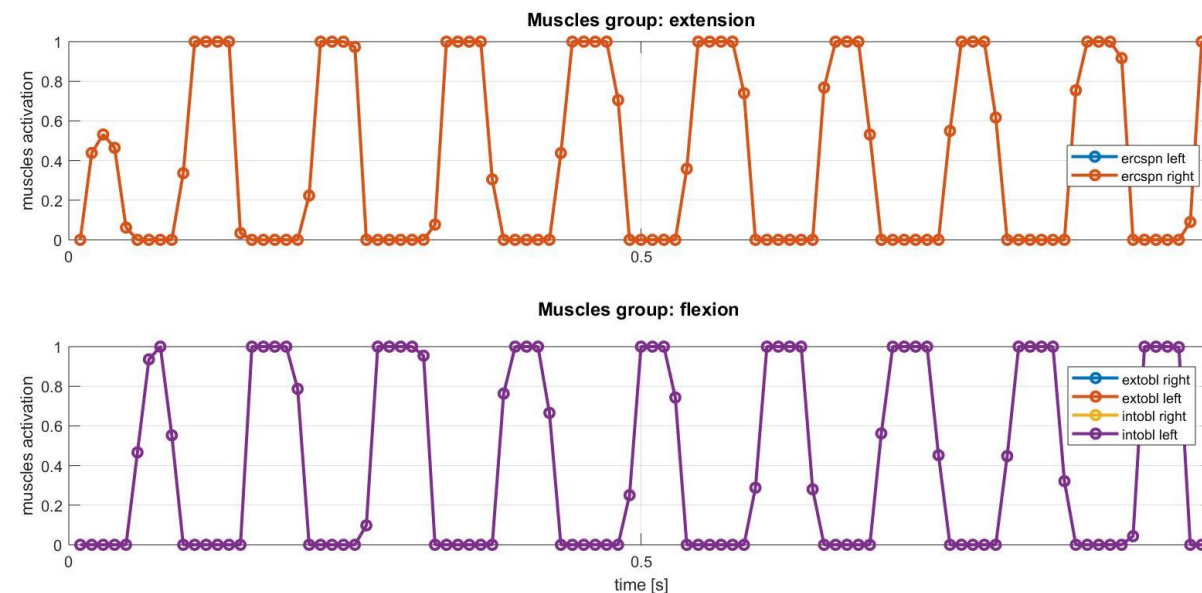
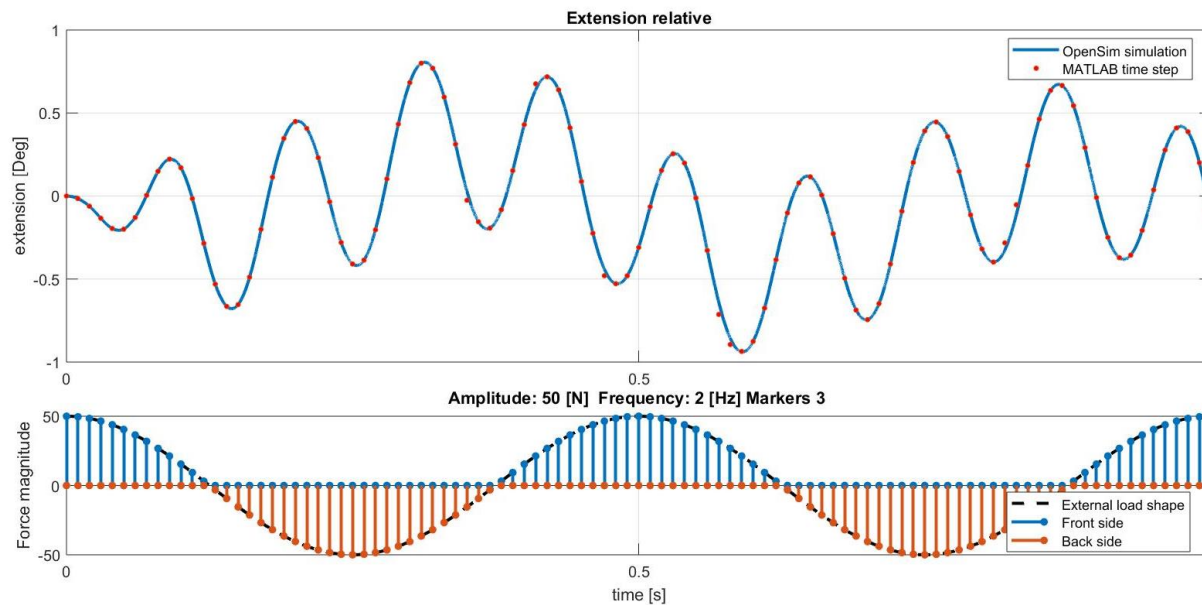
$$K_p = 10 \quad K_d = 4 \quad T_s = 0.01 \text{ s}$$

		Extension controller		Bending controller	
Muscles Name	Shortened	$\kappa_{ext} < 0$	$\kappa_{ext} > 0$	$\kappa_{bend} < 0$	$\kappa_{bend} > 0$
Erector spinal left	ercspn left	Activated	0	0	Activated
Erector spinal right	ercspn right	Activated	0	Activated	0
External oblique muscle left	extobl left	0	Activated	0	Activated
External oblique muscle right	extobl right	0	Activated	Activated	0
Internal oblique muscle left	intobl left	0	Activated	0	Activated
Internal oblique muscle right	intobl right	0	Activated	Activated	0

# First Experiment

Relative extension

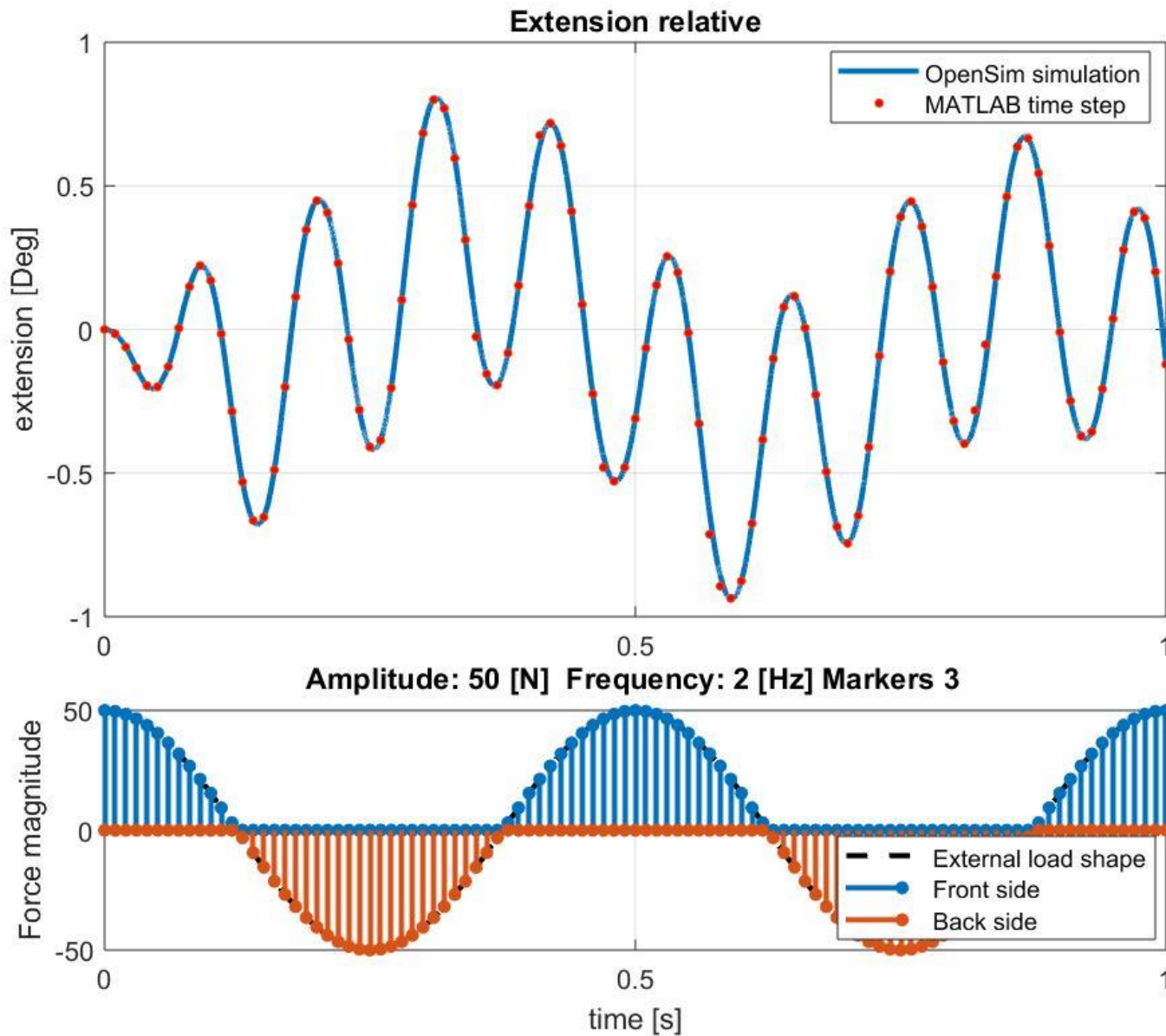
Muscles activations



# First Experiment

Relative extension

Muscles activations

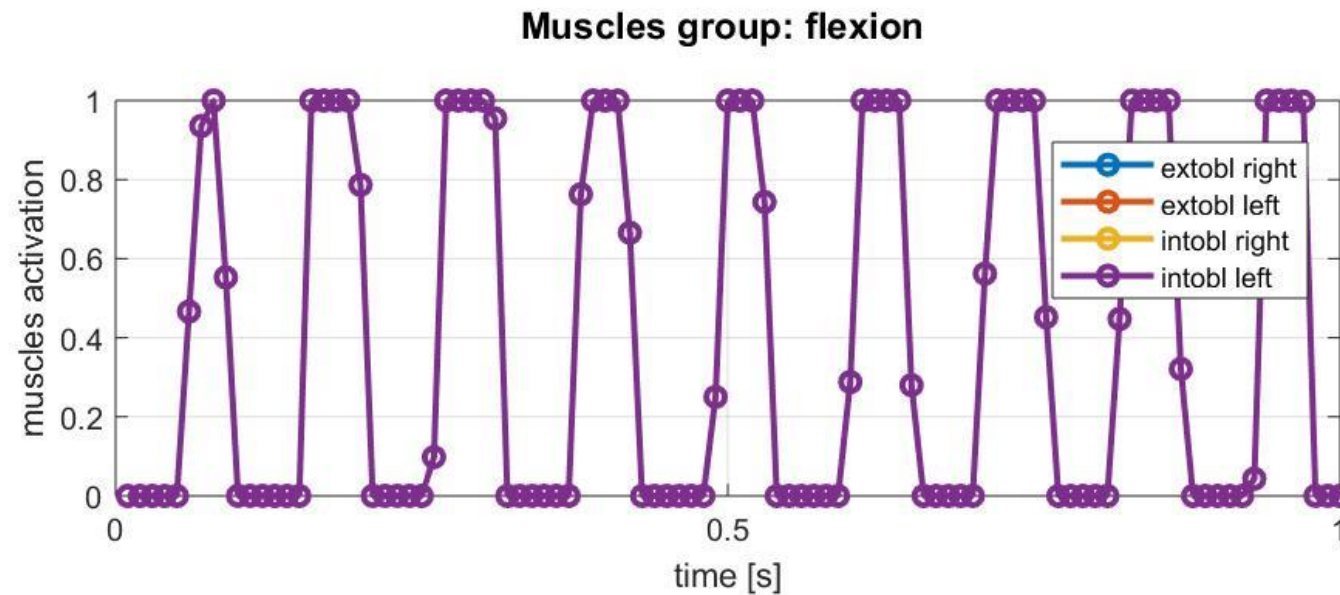
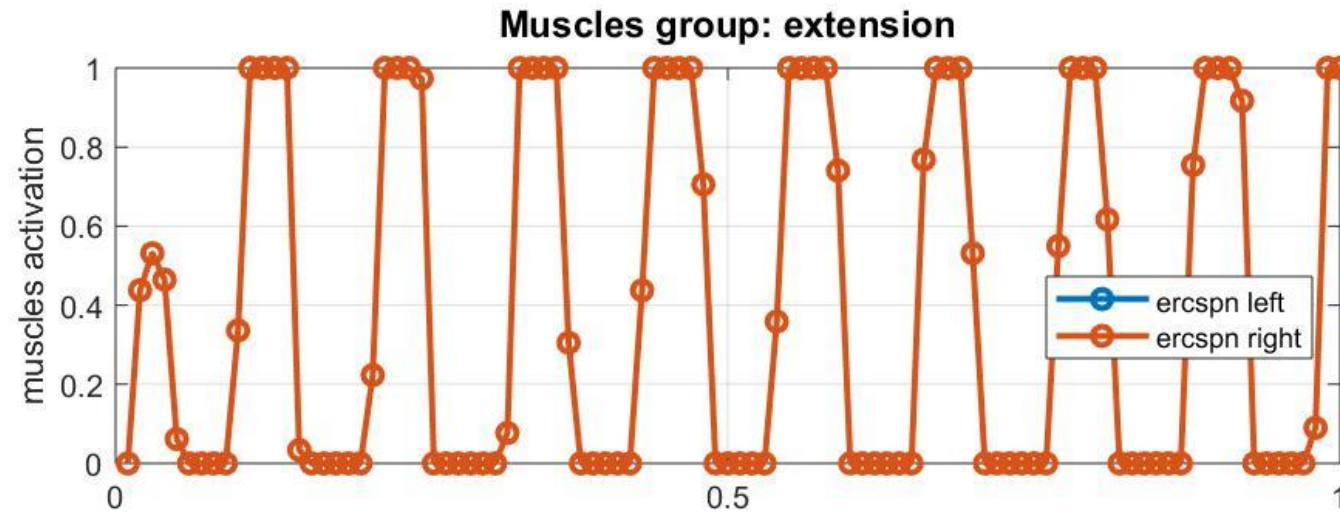




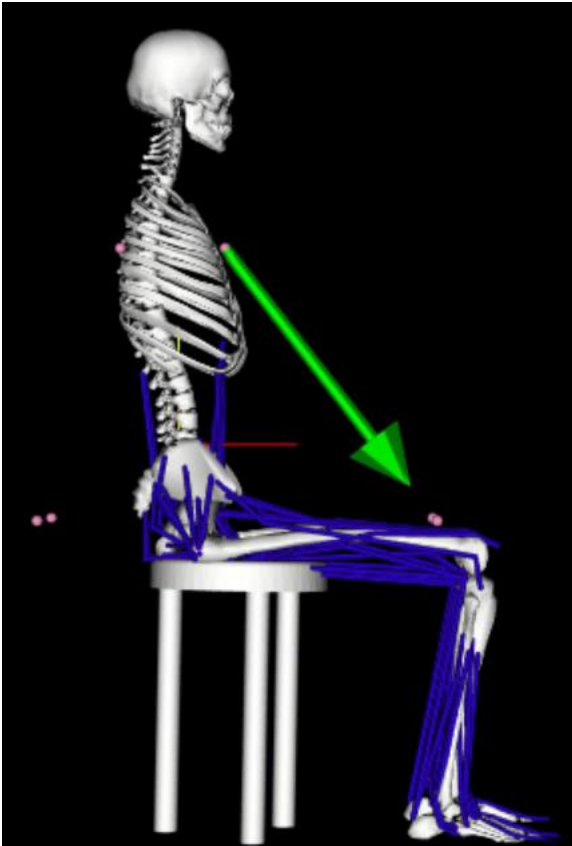
# First Experiment

Relative extension

Muscles activations



# OpenSim visualisation

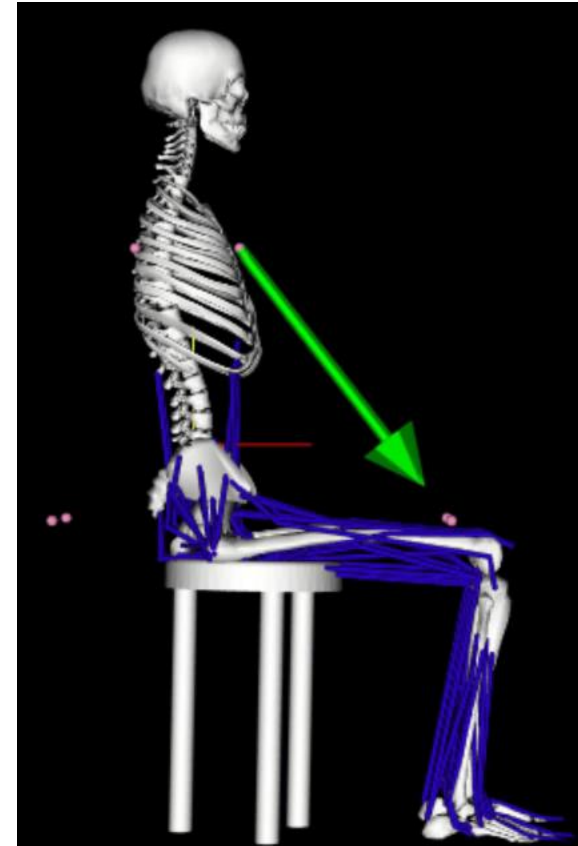


**Gains:**

$$K_p = 10$$

$$K_d = 4$$

⇒ **Unstable**



**Gains:**

$$K_{p1} = \frac{K_p}{16}$$

$$K_{d1} = \frac{K_d}{16}$$

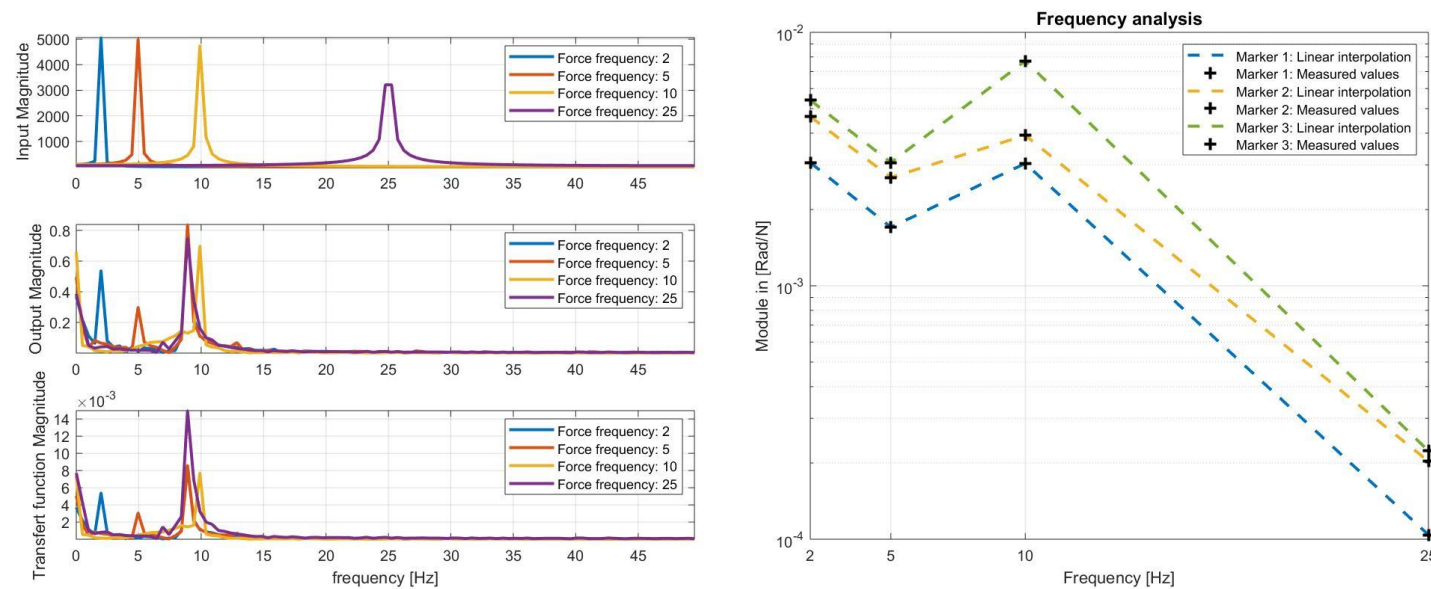
⇒ **Stable**

# Frequency Analysis

Approach

Measures

Result



	Markers 1			
Frequency [Hz]	2	5	10	25
Measured peak value [Rad/N]	3,06E-03	1,70E-03	3,04E-03	1,04E-04

	Markers 2			
Frequency [Hz]	2	5	10	25
Measured peak value [Rad/N]	4,65E-03	2,68E-03	3,92E-03	2,03E-04

	Markers 3			
Frequency [Hz]	2	5	10	25
Measured peak value [Rad/N]	5,40E-03	3,07E-03	7,72E-03	2,23E-04



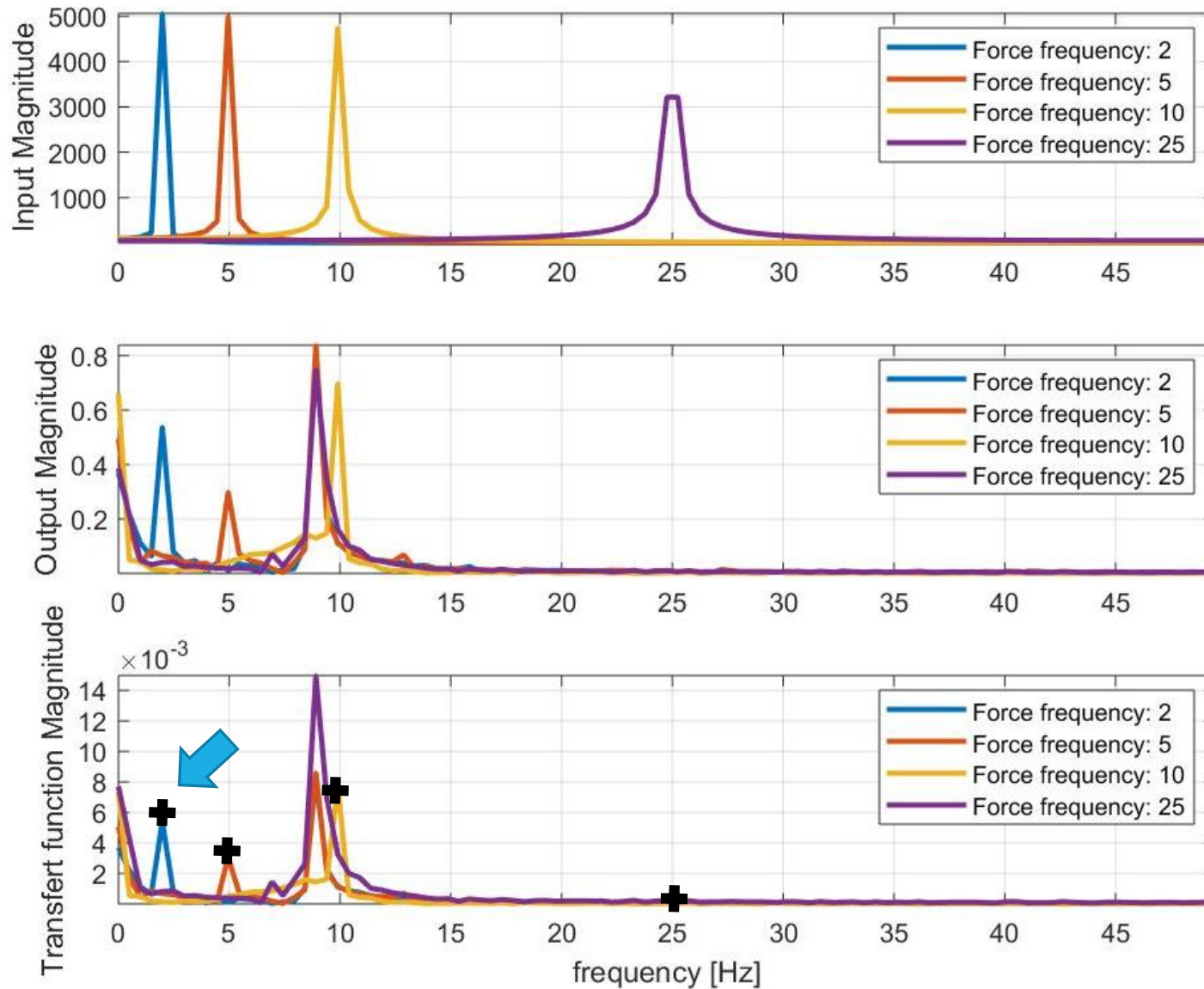
## Markers 3

# Frequency Analysis

Approach

Measures

Result



# Frequency Analysis

Approach

Measures

Result

	Markers 1			
Frequency [Hz]	2	5	10	25
Measured peak value [Rad/N]	3,06E-03	1,70E-03	3,04E-03	1,04E-04

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Frequency [Hz]	2	5	10	25
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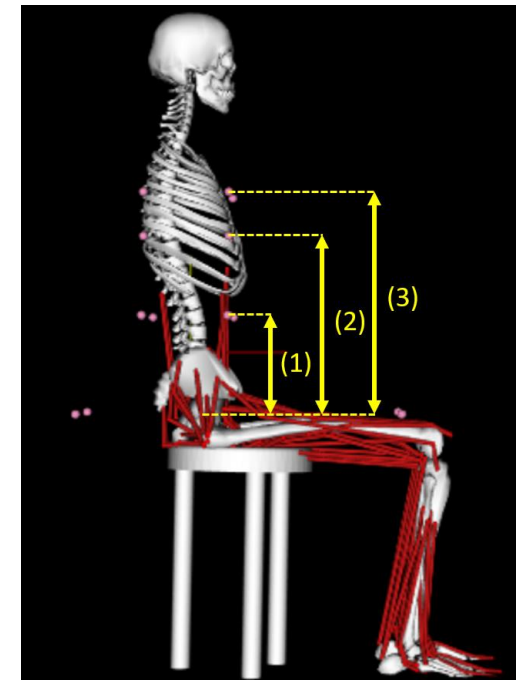
	Markers 3			
Frequency [Hz]	2	5	10	25
Measured peak value [Rad/N]	5,40E-03	3,07E-03	7,72E-03	2,23E-04

# Frequency Analysis

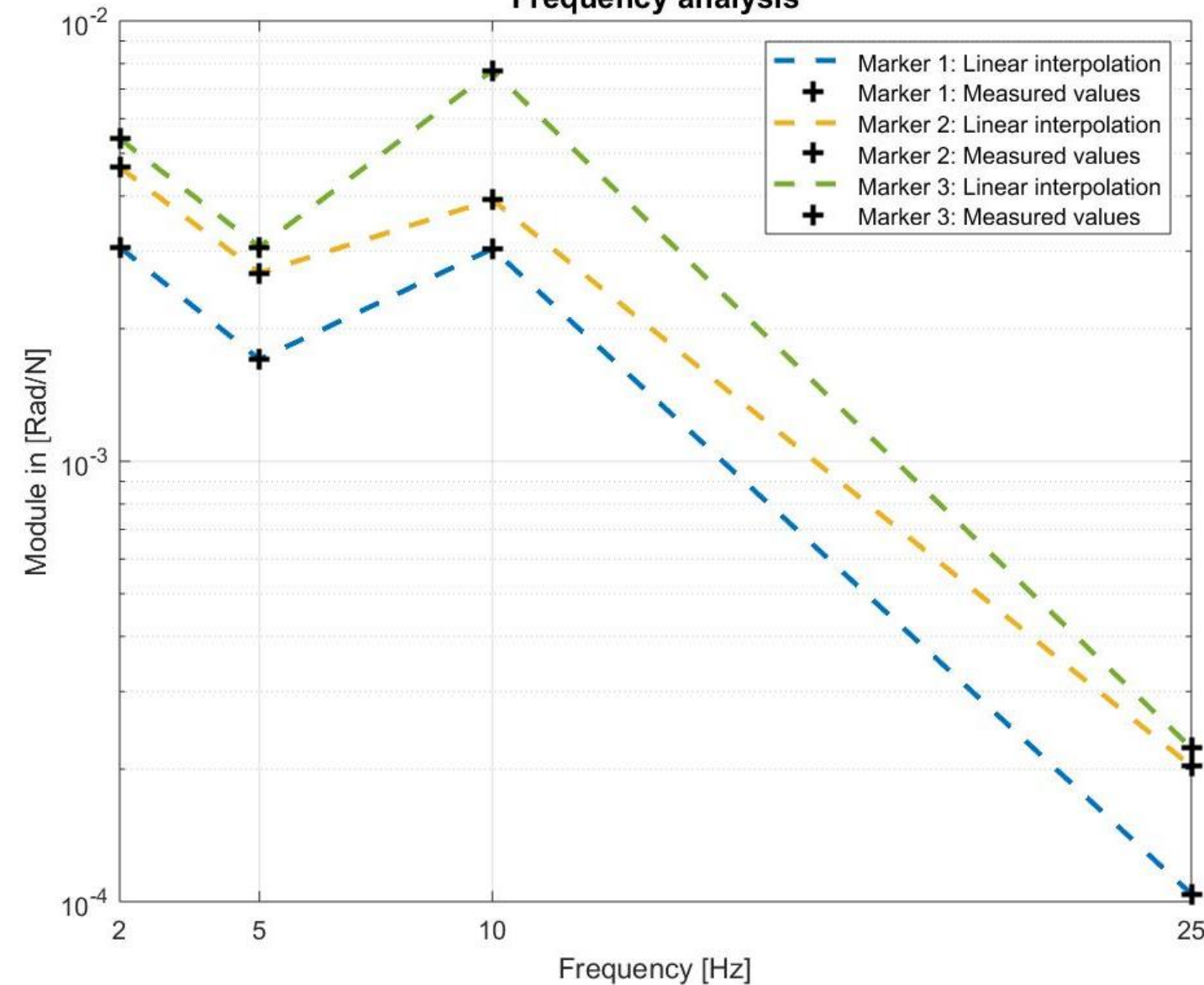
Approach

Measures

**Result**



Frequency analysis



# Contents

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1. Introduction
2. External Forces
3. Open-loop
4. Closed-loop
- 5. Conclusion**



[5] Illustration: [http://permisautomoto.com/wp-content/uploads/sites/88/2016/05/Fotolia\\_10083216\\_Subscription\\_XL.jpg](http://permisautomoto.com/wp-content/uploads/sites/88/2016/05/Fotolia_10083216_Subscription_XL.jpg)

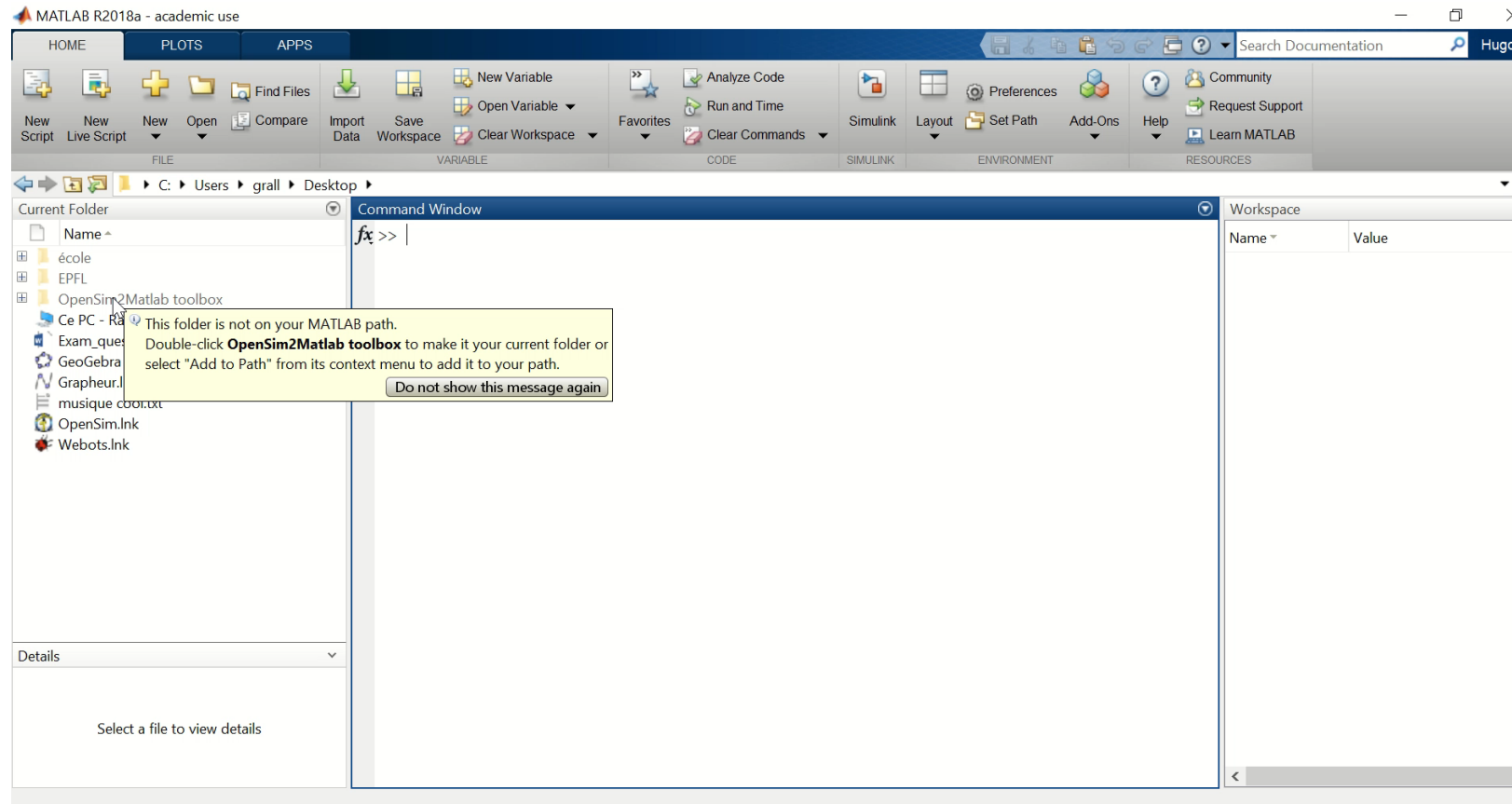
[visited: 11.06.2018]

# Objectives - Results

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- ✓ Model and simulate the Fly Jacket setup
  - ✓ Implement haptic guidance forces by the Fly Jacket on users
  - ✓ Implement internal forces exerted by users (muscles)
  - ✓ Observe the effect of varying the different force parameters
  - ✗ Identify the human-in-the-loop upper body dynamics → **To improve in future work**
- ⇒ ✓ Simplify the use of the OpenSim2Matlab toolbox

# OpenSim2Matlab toolbox



# Questions?

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[6] Illustration: <https://learn-marketing.org/wp-content/uploads/2017/07/question-mark.jpg>

[visited: 11.06.2018]

# References

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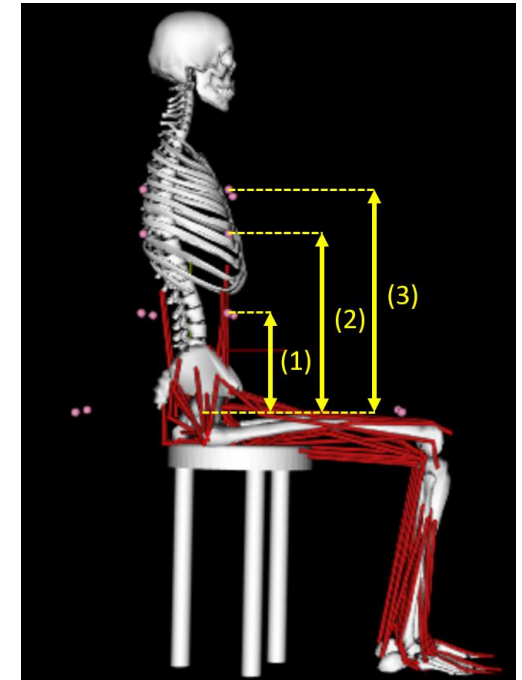
- [1] **Illustration p. 2:** <https://media.istockphoto.com/photos/question-mark-blue-3d-interrogation-point-punctuation-mark-asking-picture-id943657262> [visited: 11.06.2018]
- [2] **Illustration p. 3:**  
Alaa Bakr Maghrabi. Simulation model of upper body movement with kinetic assistance, 2017, p.10
- [3] **Illustration p. 5 [left]:**  
[https://www.cfn.group.cam.ac.uk/images/1428080879907.png/image\\_view\\_fullscreen](https://www.cfn.group.cam.ac.uk/images/1428080879907.png/image_view_fullscreen) [visited: 11.06.2018]
- [4] **Illustration p. 5 [right]:**  
<https://simtk-confluence.stanford.edu/display/OpenSim/OpenSim+and+NCSRR+Logos> [visited: 11.06.2018]
- [5] **Illustration p. 28 :** [http://permisautomoto.com/wp-content/uploads/sites/88/2016/05/Fotolia\\_10083216\\_Subscription\\_XL.jpg](http://permisautomoto.com/wp-content/uploads/sites/88/2016/05/Fotolia_10083216_Subscription_XL.jpg) [visited: 11.06.2018]
- [6] **Illustration p. 31 :** <https://learn-marketing.org/wp-content/uploads/2017/07/question-mark.jpg> [visited: 11.06.2018]



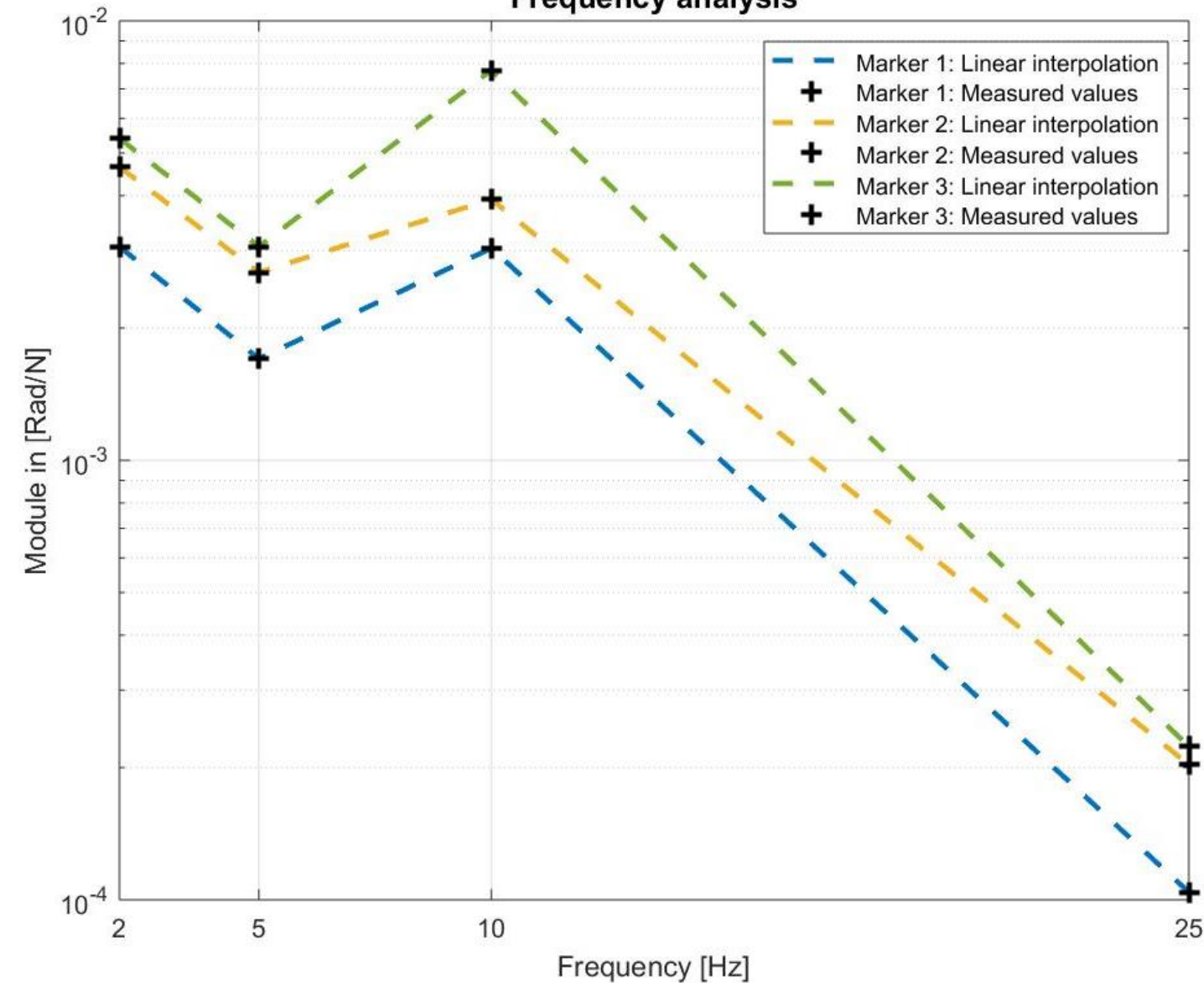
# Frequency Analysis

Simulation

Real



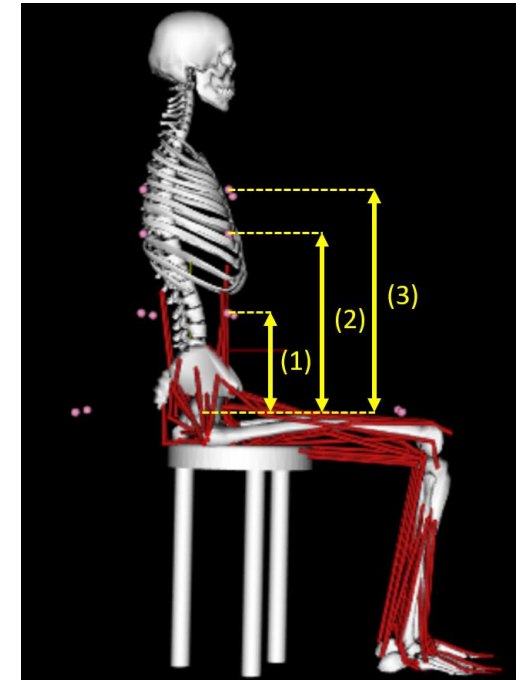
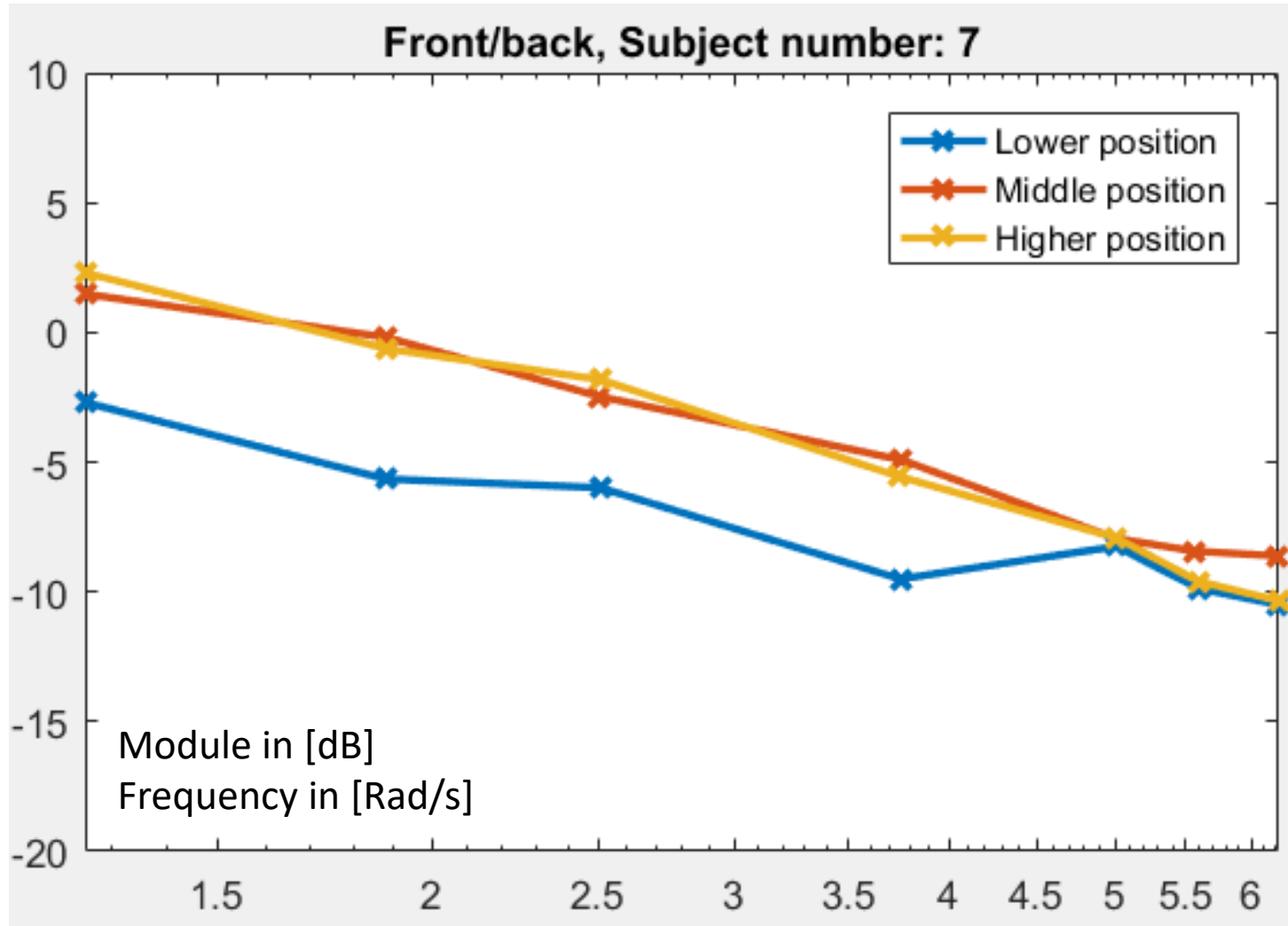
Frequency analysis



# Frequency Analysis

Simulation

Real



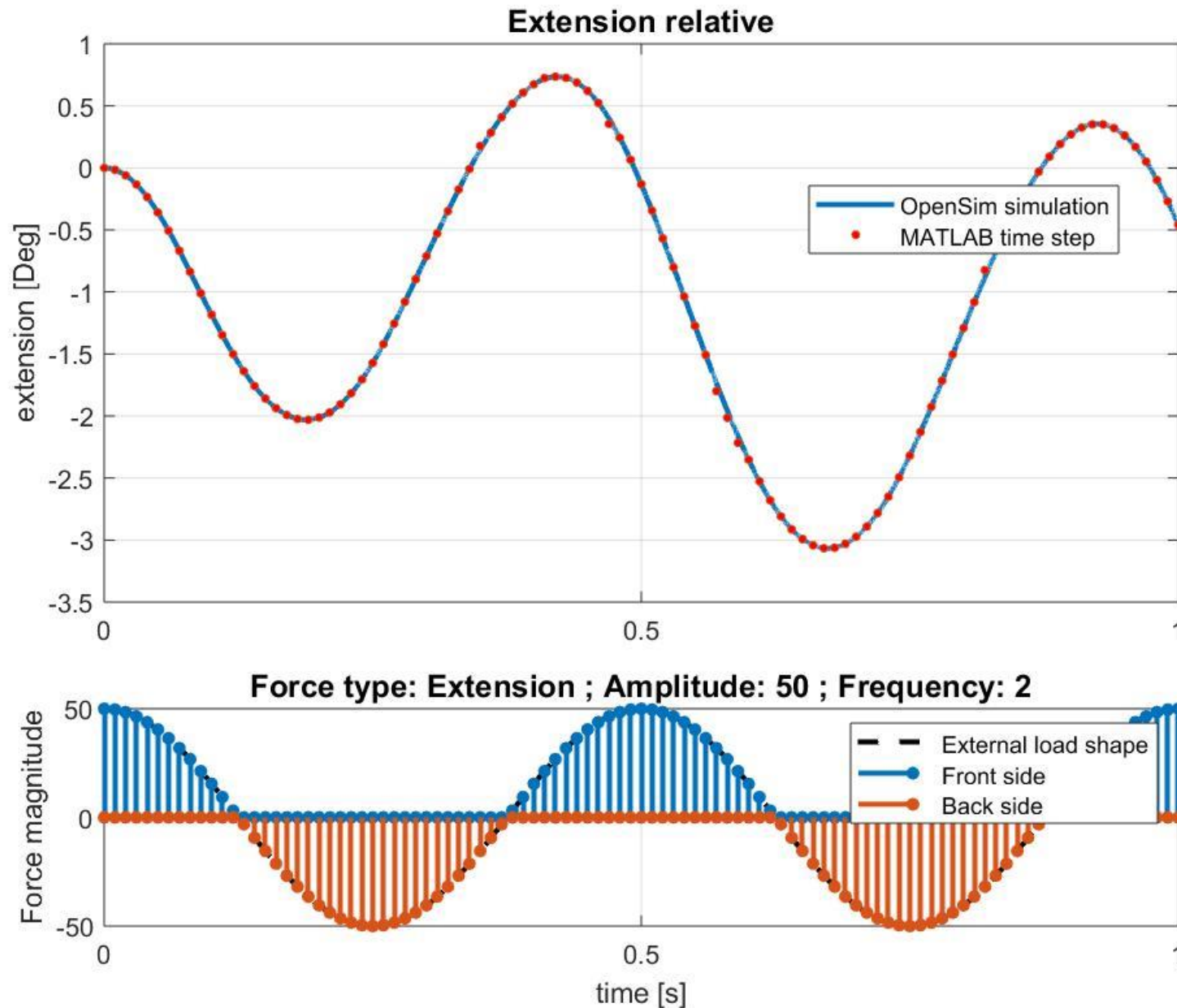
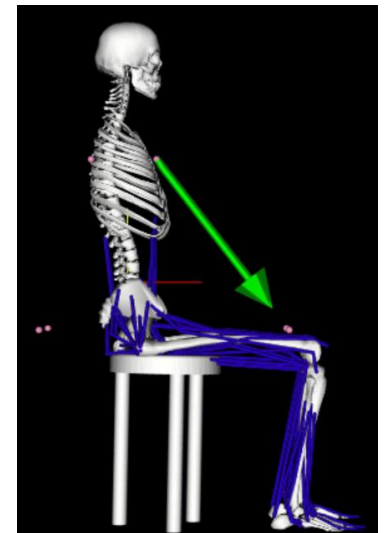
# Stable Controller

## Relative extension

## Muscles activations

## Frequency

## Analysis



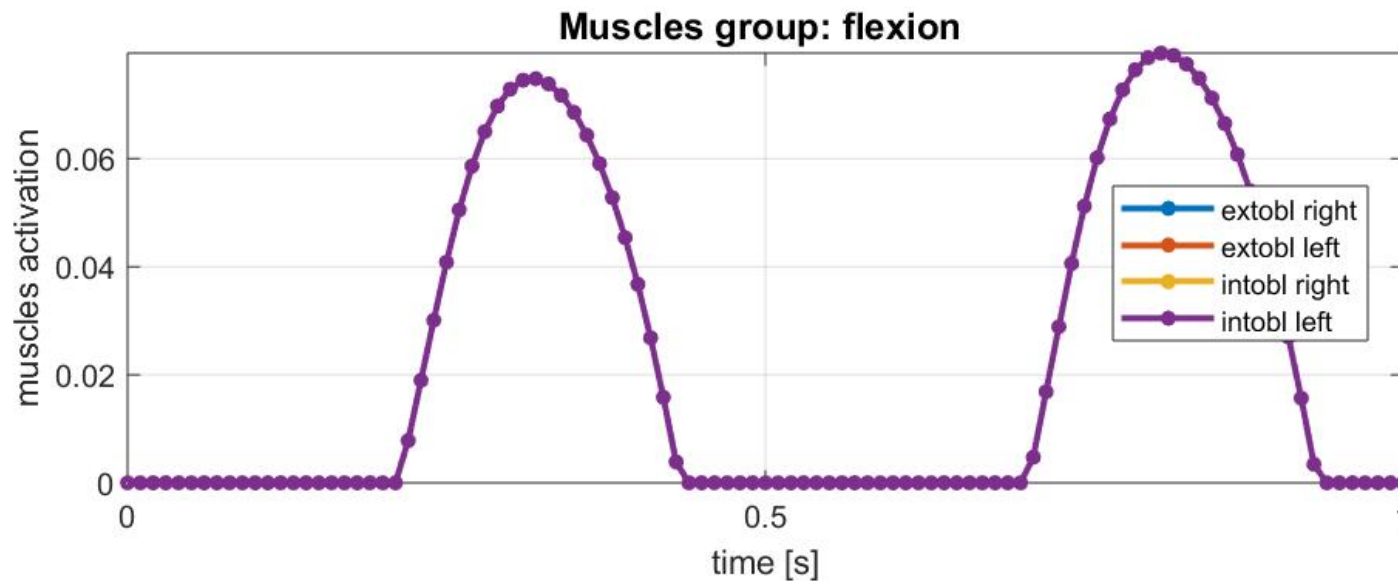
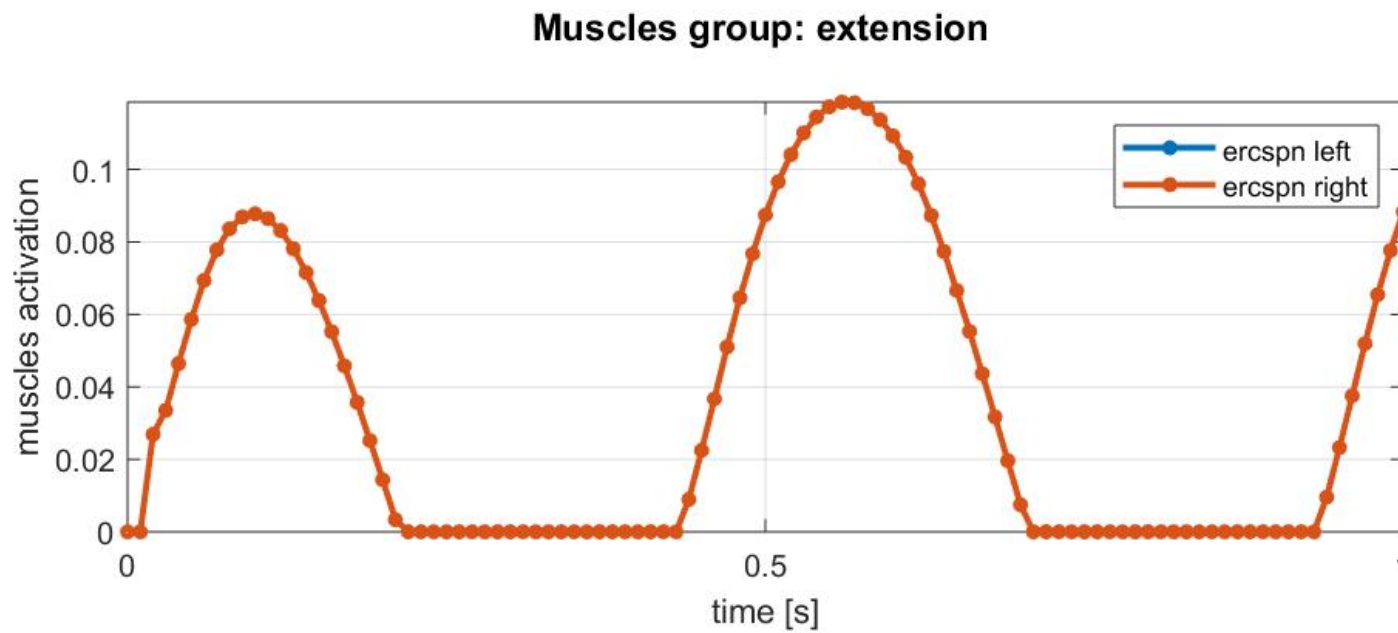
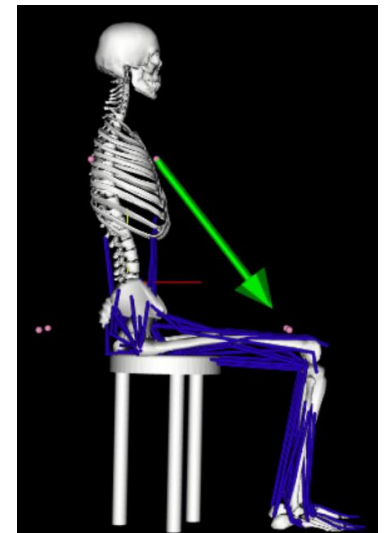
# Stable Controller

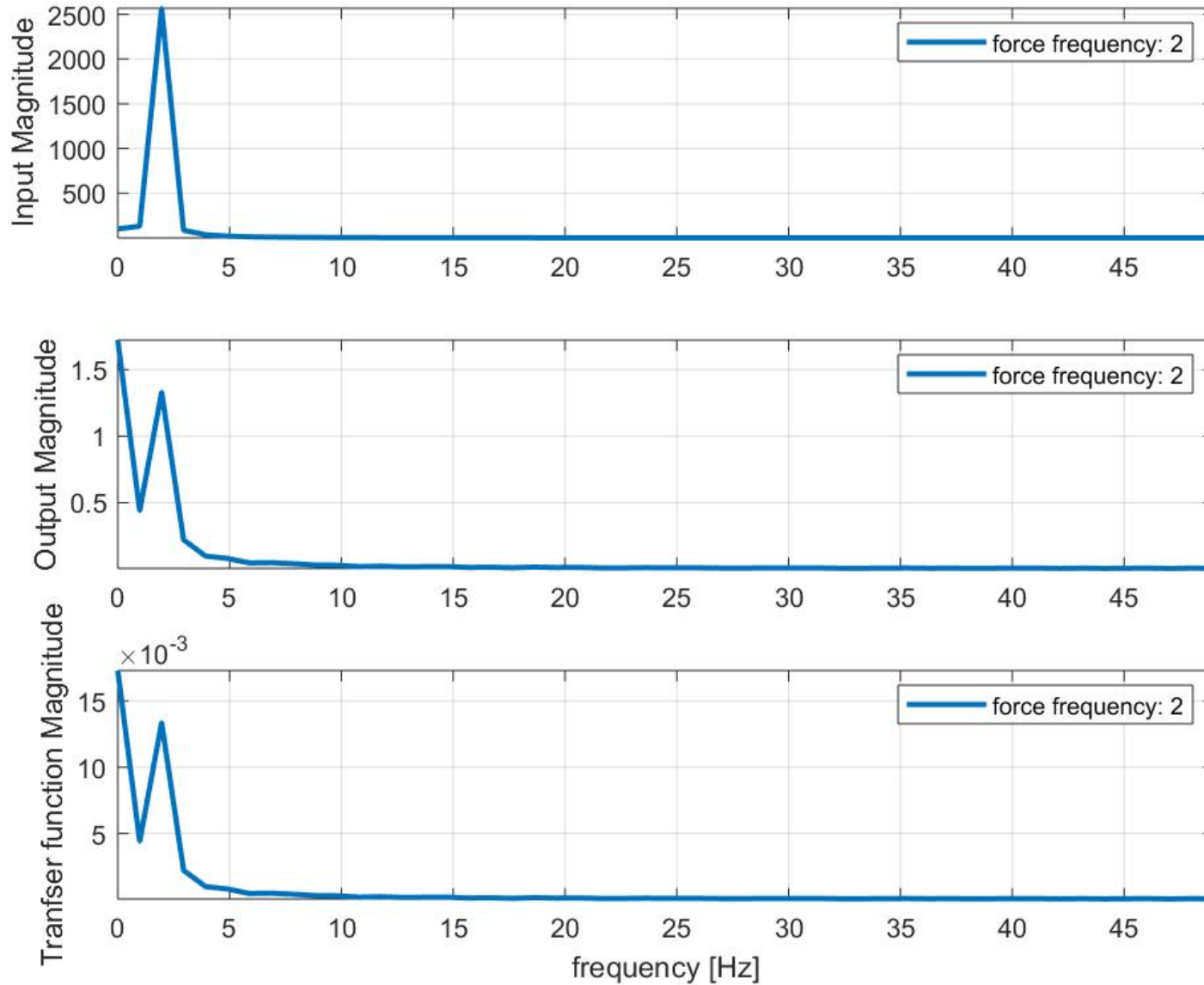
Relative extension

Muscles activations

Frequency

Analysis





# Stable Controller

Relative extension

Muscles activations

**Frequency  
Analysis**

