VI International Conference on Biomedical Technology, ICBT 2025
November 17-19, 2025, Hannover, Germany

DATA-DRIVEN FORCE ESTIMATION OF THE QUADRICEPS FEMORIS MUSCLE DURING CONCENTRIC KNEE EXTENSION USING IMPEDANCE MEASUREMENTS

Jacob P. Thönes*, Franziska Geiger†, Judith Osterloh†, Rainer Bader†, Sascha Spors*

* Institute of Communications Engineering, Rostock, Germany
jacob.thoenes@uni-rostock.de

† Department of Orthopaedics, Rostock University Medical Center, Rostock, Germany

Musculoskeletal disorders affecting bones, joints, and muscles, such as osteoarthritis, rheumatoid arthritis, and osteoporosis, have become increasingly relevant nowadays. These diseases often result in chronic pain, restricted mobility, and functional impairments, significantly reducing the quality of life [1, 2]. The measurement of muscle forces plays an important role in understanding and treating these disorders. However, current methods for measuring muscle force, such as dynamometers, are impractical for self-monitoring in daily life.

Electrical Impedance Tomography (EIT) offers a non-invasive, radiation-free, and low-cost approach for capturing tissue conductivity changes associated with muscle activity [3]. In this proof-of-concept study, EIT data were recorded from the quadriceps femoris during concentric knee extensions at predefined torque targets, while an isokinetic dynamometer provided ground-truth force measurements.

Variations in electrical conductivity, influenced by tissue properties and functional states of the muscle, were evaluated by a data-driven model to allow an analysis of internal structures and dynamics of the muscle functionality. Analyzing the measured data using principal component analysis and data-driven models revealed clear patterns that could be directly associated with the applied muscle force, indicating that variations in the force are reflected in the recorded impedance signals.

This EIT approach may provide a non-invasive, portable, and practical method for real-time monitoring of muscle forces, offering significant potential for later application in clinical rehabilitation and sports science.

REFERENCES

[1] Gill, T. K., et al., *Global, regional, and national burden of other musculoskeletal disorders, 1990–2020, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021*, *The Lancet Rheumatology*, Vol. 5, pp. e670–e682, 2023.

[2] Youssef Baby, L., et al., *MUSCLE: Muscle Understanding through Synthetic Computation and Lesion Evaluation A Semi-Synthetic Dataset for Hamstring Injury Prediction Using Electrical Impedance*, *medRxiv*, pp. 2024–11, 2024.

[3] Adler, A., Holder, D., *Electrical impedance tomography: methods, history and applications*, CRC Press, 2021.