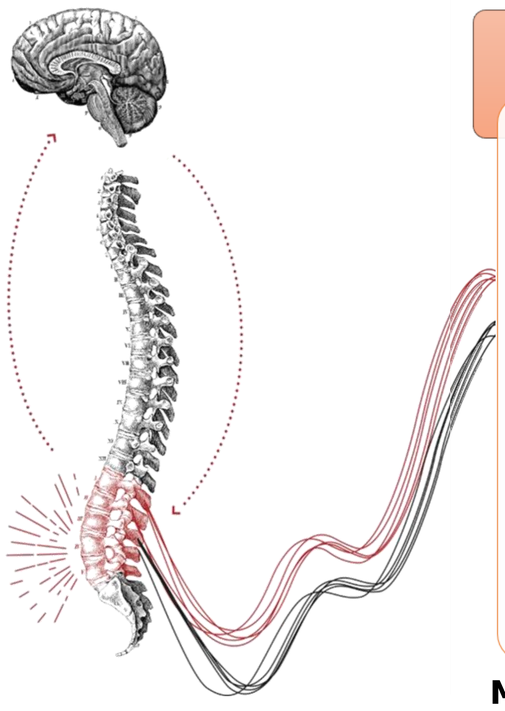
HSLU Hochschule Luzern

Technik & Architektur
Master's Thesis

Master of Science in Engineering, Profile Medical Engineering

Supervised machine learning of lumbar biomechanical features

New insights into lumbar spinal motion of healthy subjects compared to low back pain patients



Machine Learning Pipeline

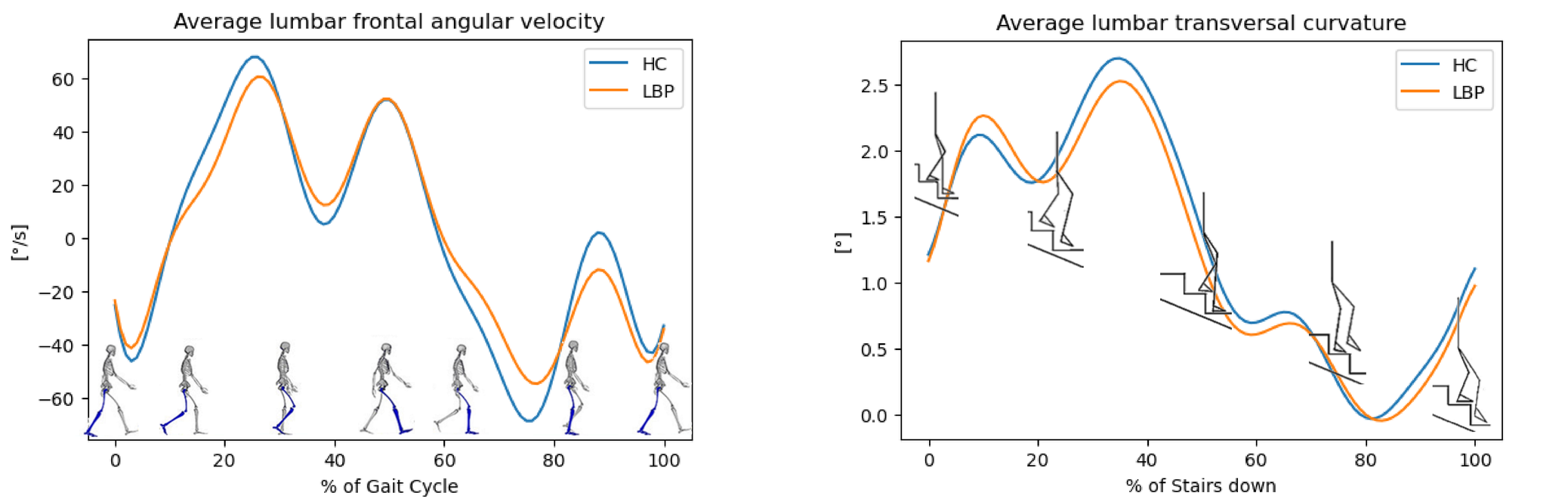
Input
- **Kinematic outputs:** 112 healthy controls and 58 LBP patients
- **Static activities:** Standing, Sitting
- **Dynamic activities:**
→ Standing up and Sitting down (chair)
→ Putting down and Lifting up a box
→ Walking
→ Running
→ Ascending and Descending stairs
- **Questionnaires:** Pain intensity (NRS), pain disability (ODI), pain-related fear (TSK)

Data Preparation
- **Data cleaning and imputation:** Missing activities and single trials
- **Physical outlier detection:** Boxplot Outlier Detector and domain knowledge
- **Treatment of class imbalance:** Proportional stratified random sampling
- **Final dataset**: 51 healthy controls and 48 LBP patients

Feature Extraction
- **Kinematic outputs:** Continuous lumbar angle and angular velocity, variability data
- **Questionnaire scores:**
→ Present pain
→ Average pain
→ Pain duration
→ Pain disability
→ Pain-related fear

Model Training & Evaluation
- **Multivariate Time Series Classification** with Mini- and MultiRocket
- **Multivariate Time Series Extrinsic Regression** with MiniRocket
- Holdout 10-fold cross-validation, nested 10x5 fold cross-validation
- Statistical Inference: Label permutation test
- Permutation feature importance

Model Prediction & Interpretation
- **Classification**: Activity and biomechanical feature that discriminate best between healthy controls and LBP patients
- **Extrinsic Regression:** Prediction of
- pain intensity
- pain disability
- pain duration
- pain-related fear
from motor behaviour
- **Interpretation of results**



Examples of biomechanical features: Average lumbar frontal angular velocities during a gait cycle (left) and average lumbar transversal angles during descending stairs (right); HC = Healthy controls, LBP = Low back pain patients

Background and Purpose

Low back pain (LBP) is one of the major musculoskeletal disorders that affects people of all ages. It is the leading cause of disability globally as well as early retirement in Europe. In order to improve the quality of healthcare of low back pain, gaining a better pathophysiological understanding of this complaint has been acknowledged as a research focus.

A novel cross-disciplinary approach of the Integrative Spinal Research (Balgrist University Hospital, Zurich) and Spinal Movement Biomechanics (Bern University of Applied Sciences, Bern) groups, which combines methods from neuroscience and spinal biomechanics research, strives to fill knowledge gaps in the understanding of LBP. This Master's thesis is to contribute to this new approach and pursues two objectives: First, to provide new insights into possible different lumbar spinal motions of healthy subjects compared to LBP patients during activities of daily life. Second, to acquire new insights into psychomotor interactions in LBP patients.

Methods

Fifty-one healthy individuals and forty-eight LBP patients matched for age, gender and BMI were included in this study. Functional parameters (continuous lumbar angles, continuous lumbar angular velocities, variability data) of different activities of daily life were acquired using state-of-the-art optical motion capture. In addition, scores for pain intensity, pain duration, pain disability and pain-related-fear were obtained. MiniRocket and MultiRocket, two state-of-the-art time series classification algorithms, were used to identify the activity that discriminates best between healthy subjects and LBP patients. The MiniRocket algorithm was adapted for time series extrinsic regression analysis in order to investigate potential relationships between biomechanical mechanisms and pain-related or psychological factors in LBP patients.

Results

In general, lumbar spinal motion does not differ between healthy controls and LBP patients. Among the activities of daily life, walking and descending stairs indicatively discriminate best between healthy controls and LBP patients. Still, with a test accuracy of around 67% for both activities, the result is not statistically significant ($p>0.05$). Furthermore, no association could be found between pain-related or psychological factors and lumbar spinal motion ($R^2<0$).

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