Master Thesis Proposal Nr:

Topic: Classification of inflammatory arthritis patients based on forearm muscle activity patterns during different grasp types

In the pursuit of improving disease management and gaining an understanding of the functional impairments associated with chronic diseases, research into musculoskeletal and neurological dysfunction in rheumatoid arthritis (RA) and psoriatic arthritis (PsA) patients holds clinical importance. RA and PsA patients commonly experience impaired musculoskeletal function, which contributes substantially to their overall disease burden [1, 2]. Despite its clinical relevance, functional impairments are often assessed through subjective questionnaires rather than objective, data-driven measurements [3, 4]. While questionnaires provide valuable insights into patient-perceived impairments, they fail to capture the underlying physiological changes and lack the precision needed for a comprehensive evaluation of disease-related dysfunction [5, 6].

Moreover, the neurological impairments and chronic dysfunction associated with arthritis remain poorly understood, particularly in patients who do not exhibit concurrent inflammation. This gap in knowledge hinders the development of targeted therapeutic strategies. Surface electromyography (EMG) emerges as a promising, non-invasive tool to bridge this gap, as it allows for the quantification of muscle activity patterns and provides insights into neuromuscular adaptations and impairments [7,8]. By analyzing muscle activity in the forearm, EMG can uncover disease-related patterns that go beyond the limitations of conventional assessments, offering a unique opportunity to explore the mechanisms underlying muscle arthropathy and neuromuscular changes in chronic arthritis patients [4, 6].

Despite its potential, systematic research leveraging EMG for the assessment of functional impairments in arthritis patients is limited. Particularly, little is known about how muscle activity patterns differ between patients with and without concurrent inflammation or between different disease groups such as RA and PsA. Identifying these patterns is crucial, as it would not only enhance our understanding of disease mechanisms but also contribute to the development of objective, data-driven functional assessments that can inform more personalized and effective disease management strategies [9].

The goal of this master's thesis is to classify RA and PsA patients, as well as healthy controls (HC), based on forearm muscle activity during grasping different-sized and weighted cylinders, using EMG as a non-invasive data collection tool. To achieve this, a processing pipeline for analyzing EMG data will be developed, using normalized and raw data [9]. Furthermore, the work will focus on identifying features that reflect disease-related changes in muscle activity [10, 11].

A machine learning-based classification framework to distinguish between patient groups (RA, PsA) and healthy controls will be developed [12]. This classification will not only help to identify disease-related muscle activity patterns, but it will also provide information about the specific tasks and distinguish between these patterns. Additionally, a regression model including clinical scores of disease activity and concurrent hand inflammation will be developed. By understanding the neuromuscular differences between RA and PsA patients, as well as between patients and healthy individuals, this research aims to better understand the different disease pathologies and related impairments (especially at the neurophysiological systems), with the overall aim to contribute to improve the disease management of these two chronic conditions.

The proposed work consists of the following parts:

- Literature research of relevant work in the field of hand and neurophysiological impairments in RA and PsA, EMG usage as measurement and analysis tool, and common EMG post-processing and analysis methods, resulting in a comprehensive understanding of the research topic and data
- Research of existing algorithms with a focus on machine and deep learning models for the classification of EMG signals of hand dysfunction, resulting in a comprehensive list of existing approaches and analysis methods
- Development of a data processing pipeline for data cleaning, post-processing (filtering, normalization), and application on existing data set (73 RA, 76 PsA, 76 HC).
- Development of a data processing pipeline for task segmentation (different sized cylinders, 3 attempts each) and extraction of meaningful EMG features.
- Implementation and evaluation of feature-based machine learning models as well as deep learning models to classify patients (RA and PsA) from HC and PsA from RA.
- Detailed evaluation of the different machine learning models in terms of classification performance, and to identify the most informative tasks/task combinations and features for group differentiation.

Optional:

- Statistical analysis of extracted features to understand their association with clinical scores of disease activity and active inflammation.
- Classification based on stratified groups by gender.

The thesis must include a detailed description of all developed and utilized algorithms, as well as an in-depth evaluation and discussion of results. The implemented code must be thoroughly documented and provided. Extended research on literature, existing patents, and related work in this field will also be conducted.

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