Developing a Novel Fatigue Index: Metrics and Regression Modeling for sEMG-Based Muscle Fatigue Analysis

# Introduction

Muscle fatigue is a critical physiological phenomenon, impacting performance in sports, rehabilitation, and daily activities. Surface electromyography (sEMG) signals are widely used to monitor muscle activity and have shown potential in evaluating fatigue. However, existing methods often rely on indirect or predefined fatigue indicators, limiting their ability to provide a comprehensive measure of fatigue progression.

In this study, we present a two-fold approach to advance the understanding and measurement of muscle fatigue:

1. **Metric Evaluation**: We collected sEMG data from multiple participants performing sustained muscle contractions under continuous fatigue. From this data, we identified and validated custom metrics that reliably correlate with fatigue progression.
2. **Regression Modeling**: Recognizing the absence of a direct measure of fatigue, we explored regression techniques to develop a new fatigue index. By testing different hypothetical fatigue trends over time, we trained models to approximate these trends using the identified metrics, achieving a robust representation of fatigue progression.

This work not only identifies key fatigue-related metrics but also introduces a novel method to quantify fatigue trends, paving the way for more precise applications in monitoring and managing muscle fatigue.

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# 1. Measurement and Metric Evaluation

* **Objective**: To measure sEMG signals from multiple participants while their muscle was under continuous fatigue and identify custom metrics that correlate strongly with fatigue levels.
* **Experimental Setup**:
  + Description of the measurement process using a custom-built sEMG device.
  + Participants performed sustained muscle contractions (e.g., leg extension) to induce fatigue.
* **Data Collection**:
  + Recorded sEMG signals during the task for each participant over time.
  + Preprocessed data to remove noise and extract meaningful features.
* **Metric Analysis**:
  + Researched various sEMG-based metrics and derived custom ones tailored to fatigue analysis.
  + Observed that specific metrics increase proportionally to fatigue, providing a reliable measure of muscle exhaustion.
  + Highlighted the most relevant metrics for characterizing fatigue.

# 2. Regression Modeling for Fatigue Index Creation

* **Objective**: To develop a new fatigue index by combining multiple fatigue-related metrics using regression techniques.
* **Challenges**:
  + Currently, there is no direct way to measure the absolute level of fatigue, so the true fatigue state is unknown.
* **Regression Model Development**:
  + Used the identified metrics as inputs to train regression models.
  + Experimented with various predictions of how fatigue trends over time during the task (e.g., linear increase, exponential decay, or other hypothetical fatigue curves).
  + Designed the model’s output to approximate these expected fatigue trends.
* **Training and Validation**:
  + Experimented with multiple regression techniques (e.g., linear regression, polynomial regression, or machine learning models).
  + Evaluated the models based on their ability to predict trends that best align with fatigue progression.
* **Outcome**:
  + Identified the best-performing regression approach.
  + Demonstrated that the new fatigue index provides an accurate and reliable representation of fatigue progression, even in the absence of direct fatigue measurements.

# PPT Layout

**Slide 1: Title Slide**

* **Title**: "Developing a Novel Fatigue Index: Metrics and Regression Modeling for sEMG-Based Muscle Fatigue Analysis"
* **Subtitle**: "Developing metrics and models to quantify muscle fatigue progression"
* Include your name, affiliation, and any relevant conference/event details.
* A clean background image related to sEMG or fatigue analysis.

**Slide 2: Introduction**

* **Key Points**:
  + Importance of muscle fatigue analysis in various fields (sports, rehabilitation).
  + Role of sEMG signals in fatigue evaluation.
  + Limitation of existing methods (reliance on indirect indicators).
* **Visuals**:
  + A graphic showing muscle activity or an sEMG signal waveform.

**Slide 3: Research Objectives**

* **Key Points**:
  + Two-fold focus:
    1. Identifying fatigue-related metrics.
    2. Developing a new fatigue index using regression modeling.
  + Highlight the novelty of your approach.
* **Visuals**:
  + Simple flowchart outlining the two main parts of your study.

**Slide 4: Measurement and Metric Evaluation (1/2)**

* **Key Points**:
  + Objective: Measure sEMG signals and extract fatigue-related metrics.
  + Experimental setup:
    - Description of custom-built sEMG device.
    - Task performed: Sustained muscle contractions.
* **Visuals**:
  + Diagram or image of the experimental setup (e.g., leg extension exercise).

**Slide 5: Measurement and Metric Evaluation (2/2)**

* **Key Points**:
  + Data collection:
    - Recorded sEMG signals over time.
    - Data preprocessing to remove noise.
  + Metric analysis:
    - Custom metrics increase proportionally with fatigue.
    - Identified key metrics for fatigue characterization.
* **Visuals**:
  + Line graph showing how a specific metric changes with fatigue progression.

**Slide 6: Regression Modeling for Fatigue Index Creation (1/2)**

* **Key Points**:
  + Objective: Combine metrics into a new fatigue index using regression.
  + Challenges: No direct measure of true fatigue state.
  + Regression model development:
    - Tested different hypothetical fatigue trends (linear, exponential).
* **Visuals**:
  + Example of a hypothetical fatigue trend (e.g., a plotted curve).

**Slide 7: Regression Modeling for Fatigue Index Creation (2/2)**

* **Key Points**:
  + Training and validation:
    - Multiple regression techniques (linear, machine learning models).
    - Evaluated models based on alignment with fatigue progression.
  + Outcome:
    - Best-performing model identified.
    - New fatigue index reliably reflects fatigue progression.
* **Visuals**:
  + Table or bar chart comparing model performances.

**Slide 8: Conclusion and Future Work**

* **Key Points**:
  + Summary:
    - Identified reliable metrics for fatigue analysis.
    - Developed a robust fatigue index using regression techniques.
  + Future Work:
    - Validation on larger datasets.
    - Application to real-time monitoring systems.
* **Visuals**:
  + A simple icon-based roadmap for future research directions.