Data-driven Generation of Targeted Biomarkers for Comprehensive Motor Function Assessments

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Summary

Current clinical assessment tools lack the explanatory depth to fully empower clinical decision-making on patient motor function. Leveraging network- and information-theoretic tools and machine-learning, this study extends our recently proposed muscle synergy analysis approach into a fully end-to-end biomarker generation framework. We firstly perform a comprehensive spatio-spectral decomposition of electromyographic (EMG) signals into networks of functionally diverse muscle interactions. Then, by incorporating rigorous feature selection methods and our newly developed clustering algorithm, we identify motor features optimally associated with a chosen clinical measure and cluster participants in a targeted, clinically meaningful way across multiple scales. Framework applications showcased the deep mechanistic insights offered by these biomarkers into the underlying constructs of any established clinical measure, uncovering data-driven milestones of aging and post-stroke impairment chronicity along with novel motor performance characteristics. This adaptable feature engineering framework offers enhanced capabilities to the clinical assessment of motor function.

Introduction

Clinical motion analysis currently relies on physical performance measures that struggle to track genuine motor function into long-term care and/or lack the explanatory depth to offer mechanistic insight into patient condition [1,2]. To address these shortcomings and enhance the clinical assessment of motor function, we propose a fully end-to-end feature engineering framework for the data-driven generation of targeted biomarkers.

Methods

We extend our recently proposed muscle synergy analysis approach to incorporate statistically rigorous feature selection and our recently introduced divisive clustering algorithm (Fig.1) [3-5]. Leveraging network- and information-theoretic tools and machine-learning, we showcase this approach by implementing a comprehensive decomposition of EMG signals to extract networks of functionally diverse (i.e. functionally-similar (redundant), -complementary (synergistic), and -independent (unique)) inter- and intra-muscular interactions both between and within multiple frequency bands and phase-amplitude spectral dynamics. Subsequently, discriminative modular recruitment patterns underpinning healthy young and older adults and acute-chronic stroke survivors performing activities-of-daily-living were identified with respect to established clinical measures and clustered across scales. The certainty of participants' cluster affiliation was quantified using a novel probabilistic metric presented here to aid clinical interpretations.

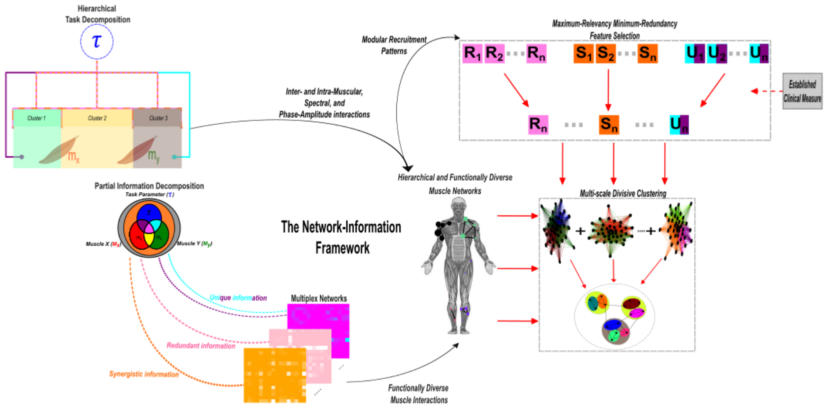

Fig.1: An overview of our proposed approach to generating motor function biomarkers. We extend the Network-Information Framework to incorporate feature selection and divisive clustering across scales [3-5].

Results and Discussion

Two- and three-way participant clusters composed of multiple sub-clusters were identified with high cluster affiliation certainties (~0.8) among participants. The novel mechanistic insights uncovered included:

a) The fifties is a key transitional decade for age-related motor decline which can be avoided.
b) Impairment chronicity milestones were found acutely ~2nd month and chronically ~4 years and beyond post-stroke, representing important transitional stages in motor adaptation that are influenced by patients' age.
c) The delta frequency band contributes in functionally diverse ways to motor performance post-stroke.
d) The EMG phase component provides crucial functional information and should be incorporated into standard analyses.

Conclusion

We present a fully end-to-end feature engineering framework for the data-driven generation of motor function biomarkers. Our approach can target the underlying constructs of any motor function measure, offering enhanced clinical decision-making support through more precise and mechanistically insightful motor function assessments.

References

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