

Muscle Synergy Analysis for Rehabilitation

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Abstract

As the population ages globally, the number of patients such as strokes is increasing. Motor function often impaired after a stroke, and QOL is significantly damaged. Therefore, rehabilitation is necessary, but there are few effective methods yet. After the damages to the motor cortex by stroke, some motor functions are affected, but the rehabilitation training can induce the reorganization in the adjacent intact cortex and motor functions may be recovered. The musculoskeletal system plays a role in bridging brain activity and motor function. Even though the movement appears to be the same, the muscle activity may have changed. Muscle synergy plays an important role in visualizing muscle activity because it can express activity patterns that depend on tasks more than muscle activity alone.

Keywords: Muscle synergy; Rehabilitation; Stroke

Introduction

As the population ages globally, the number of patients such as strokes is increasing. Motor function often impaired after a stroke, and QOL is significantly damaged. Therefore, rehabilitation is necessary, but there are few effective methods yet. Rehabilitation is a kind of motor learning and support to acquire the new skill for new environments. It is caused by damage to the brain due to a stroke, and loss of brain function. It means that the body remains healthy, but the motor performance was affected. The brain control many muscles for controlling our body and our body has redundant joint system. It means that even though the hand position is fixed, there are many combination of joints angles to realize same hand position. In order to overcome this problem, the brain coordinates degrees of freedom by changing muscle activities [1]. Muscle activities caused by combination of motor units in spinal cord. A module of motor units in the spinal cord generates a specific muscle activation pattern [2]. Primary motor cortex sends the command to the spinal cord to control these module, but it is still unknown about the mechanisms of coordination of these modules. To reveal this mechanisms, muscle activation patterns are measured and muscle synergy concept is used [3,4]. Some researchers have also been conducted on how motor function recovery occurs during rehabilitation after stroke from the viewpoint of muscle synergy [5,6].

Muscle Synergy

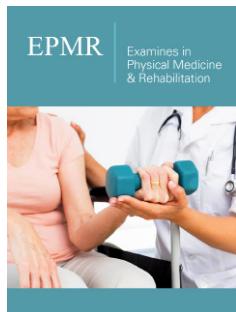
Muscle synergy is coordination of some muscles and a small number of muscle synergies are used to accomplish a task. There are various algorithms can be used to calculate the muscle synergies. A number of different factorization algorithms are assessed to identify muscle synergies [7].

$$\mathbf{m}(t) = \sum_{i=1}^N \mathbf{c}_i(t) \mathbf{w}_i \quad (1)$$

where $\mathbf{m}(t)$ is a vector that species the muscle activation at time t , and $\mathbf{c}_i(t)$ is the time series of muscle synergies. \mathbf{w}_i is a time invariant vector of muscle synergy. They tested Principal Component Analysis (PCA), Factor Analysis (FA), Independent Component Analysis (ICA) and Non-negative Matrix Factorization (NMF). Each algorithm showed different performance for different noise characteristics, NMF was performed well and robust. Recently NMF is frequently used to acquire the muscle synergies. Equation (2) shows the time varying synergies [8].

$$\mathbf{m}(t) = \sum_{i=1}^N \mathbf{c}_i(t) \mathbf{w}_i(t - t_i) \quad (2)$$

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They analyzed the muscle patterns of intact and unrestrained frogs during kicking and showed that combinations of three time-varying muscle synergies required to kick in different directions. Same group tested the time-varying muscle synergies during jumping, swimming and walking using frogs and also showed a small number of synergies were behavior specific [2,9]. These findings indicated that the muscle synergies are related to movement kinematics and dynamics. Cortical damage impairs motor command to the spinal cord and resulting in abnormal movement. Therefore, muscle synergy analysis from stroke patients found the relationship between the muscle activation pattern and the severity of functional impairment [10,11].

Discussion

Where is the source of muscle synergy? This is quite difficult question to answer. Muscle synergy, which is acquired using NMF algorithm, depends on the task. Muscle activation pattern during some task depends on the task. The number of synergy is unknown, so the muscle synergy patterns vary with required accuracy. The index, such as Fugl-Meyer assessment score, Brainstorm stage, Functional Independence Measure (FIM), are widely used for indicating the degree of disability. These indexes are mainly evaluate the motion or range of motion. Muscle synergies will become useful indexes of both kinematics, dynamics and degree of disability. After the damages to the motor cortex, some motor functions are affected, but the rehabilitation training can induce the reorganization in the adjacent intact cortex and motor functions may be recovered using undamaged motor cortex [12]. The musculoskeletal system plays a role in bridging brain activity and motor function. Brain activities are difficult to measure during the rehabilitation, but EMG can be measured. Even though the movement appears to be the same, the muscle activity may have changed. Muscle synergy plays an important role in visualizing muscle activity because it can express activity patterns that depend on tasks more than muscle activity alone.

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