Integration of Cardiovascular Activity in Stroke Rehabilitation Therapy

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Abstract— **We aim to optimize post-stroke motor control rehabilitation therapy via integration of cardiovascular activity. Although stroke therapy ranges from months to years for some stroke patients, the majority of neurological recovery occurs within the first three months. Afterwards, neurological recovery occurs at a reduced rate for a period of up to one year. Current studies report that cardiovascular activity increases synaptic plasticity by affecting synaptic structure and potentiating synaptic strength, strengthening neurogenesis, metabolism and vascular function. Integrating cardiovascular activity in post-stroke motor control rehabilitation therapy may help better restore two-way communication between the central nervous system and extremities via growth of alternative central nervous system pathways; thus, resulting in improved motor control in both upper and lower extremities. We hypothesize that the neurotrophic factors engendered by cardiovascular activity significantly fortify descending motor pathways. In part one, functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and load cell readings quantify the level of brain activity resulting from upper extremity movement and lower extremity movement in two cohorts, each cohort consisting of four members. In part two, cohort one will perform 30 minutes of cardiovascular activity prior to 30 minutes of upper and lower extremity strength training five times a week for a total of three months. During this period, cohort two will perform only 30 minutes of upper and lower extremity strength training five times a week. In part three, fMRI and EEG will quantify the level of brain activity resulting from upper extremity movement and lower extremity movement in both cohorts. After data collection, juxtaposition of functional magnetic resonance images in conjunction with electroencephalograms during day one and during day ninety will occur in order to quantify the significance of cardiovascular activity integration in post-stroke motor control rehabilitation therapy.**

Keywords—magnetic resonance imaging; descending motor pathways

I. Background

Every year, roughly 800,000 people in the United States experience a stroke, a serious medical condition caused by a sudden lapse of oxygen-rich blood flow in the brain [1]. Of these 800,000 people, a majority experiences a sudden loss of motor control in both upper and lower extremities [2]. The loss of motor control results from damage to the descending tracts, the central nervous system pathways that permit two-way communication between the central nervous system and extremities [3]. Although rehabilitation methods cannot reverse the damage found in the descending tracts of stroke patients, progressively repetitive upper and lower extremity exercises may restore two-way communication between the central nervous system and extremities via growth of alternative central nervous system pathways; thus, restoring motor control in both upper and lower extremities [4].

In 2007, Christie et al. [3] reported that cardiovascular activity increases synaptic plasticity by affecting synaptic structure and potentiating synaptic strength, strengthening neurogenesis, metabolism and vascular function. A rise in central and peripheral growth factors and growth factor cascades, which instruct downstream structural and functional change, may mediate the benefits of cardiovascular activity on the brain. A common mechanism underlying the central and peripheral effects of cardiovascular activity may result from a reduction in inflammation, which can impair growth factor signaling. In a rodent study by Greenough et al. [4], 30 days of wheel running increased capillary density and 30 days of traversing an acrobatic maze increased the number of synapses per cerebellum primary nerve cell. Similar studies found changes in blood vessel density in motor cortex using both histological [5] and MRI techniques [6]. Although these data suggest that cardiovascular activity increases synaptic plasticity by affecting synaptic structure and potentiating synaptic strength, strengthening neurogenesis, metabolism and vascular function, the significance of neurotrophic factors engendered by cardiovascular activity during a three-month period has yet to be established.

II. MATERIALS AND METHODS

Specific Aim 1: Quantification of Baseline Brain Activity Resulting from Upper and Lower Extremity Flexion and Extension. Specific Aim 1 quantifies baseline brain activity resulting from upper and lower extremity flexion and extension using functional magnetic resonance imaging, electroencephalograms, and load cell readings for all human subjects. In part one, we identify the areas of the brain activated by upper extremity movement using functional magnetic resonance imaging (fMRI), an imaging test that makes use of a magnetic field in conjunction with radio wave energy impulses to construct three-dimensional renderings of the brain. To do so, we ask two cohorts of four test subjects to repeat upper and lower extremity exercises while subjects reside inside of a functional magnetic resonance imaging scanner.

Specific Aim 2: Cardiovascular Activity Integration in Post-Stroke Motor Control Rehabilitation Therapy. Specific Aim 2 integrates cardiovascular activity in post-stroke motor control rehabilitation therapy to test the significance of neurotrophic factors in fortifying descending motor pathways. First, one cohort of test subjects performs 30 minutes of resistance training after completing 30 minutes of cardiovascular activity for a total of 90 days. A second cohort of test subjects completes only 30 minutes of resistance training for a total of 90 days. Studies suggest that resistance training promotes neurogenesis, the growth of new neurons in the brain. In 2013 investigators linked increased levels of the neurogenesis marker known as brain-derived neurotrophic factor (BDNF), a protein of the neurotrophin family of growth factors, to resistance training [7]. We use an MRI scanner and electroencephalograms to detect increased levels of brain activation in the cohort of test subjects after 90 days of progressively repetitive upper and lower extremity exercises. Increased brain activation may indicate fortification of descending motor pathways.

Specific Aim 3: Quantify The Impact of Three Months of Cardiovascular Activity Integration. Specific Aim 3 quantifies the impact of three months of cardiovascular activity integration in subjects who perform 30 minutes of cardiovascular activity prior to 30 minutes of upper and lower extremity strength training versus subjects who only perform 30 minutes of upper and lower extremity strength training. It aims to quantify the effects of brain-derived neurotrophic factor, Insulin-Like Growth Factor-I, and Insulin-Like Growth Factor-Binding Proteins on thirteen weeks of upper extremity resistance training in combination with 30 minutes of cardiovascular activity. Studies show that brain derived neurotrophic factor (BDNF), Insulin-Like Growth Factor-I (IGF1), and Insulin-Like Growth Factor-Binding Proteins (IGFBP) catalyze neurogenesis in the cerebral motor cortex. Studies also suggest that resistance training promotes neurogenesis in the cerebral motor cortex. However, the ability of these factors to enhance the effects of long-term upper extremity resistance training exercise on cerebral motor cortex neurogenesis remains unknown. Our objective is to juxtapose the effect of these factors in subjects who perform 30 minutes of cardiovascular activity prior to upper extremity resistance training and control subjects who do not perform 30 minutes of cardiovascular activity prior to upper extremity resistance training. We identify the areas of the brain activated by upper extremity movement using functional magnetic resonance imaging.

Specific Aim 2: Implementation of an exoskeleton.

Upon establishing increased levels of brain activation, we commence part three of the experiment. Part three of the experiment involves implementation of an exoskeleton that can help a stroke patient integrate cardiovascular activity with post-stroke rehabilitation therapy. The exoskeleton will first assess an individual's mobility. The exoskeleton will assess the amount of force exerted by an individual during an exercise. Once the exoskeleton establishes a baseline, the exoskeleton will help the individual perform repetitive exercises. Each time the individual repeats an exercise, the exoskeleton will assess an individual's progress. Once the exoskeleton detects an increase in strength, the exoskeleton will make progressively resistant adjustments to ensure that the individual always experiences resistance. The exoskeleton will increase the amount of force required to perform each exercise. This ensures improvement in strength, growth signal induction, and activation of signaling cascades (Fig. 1).

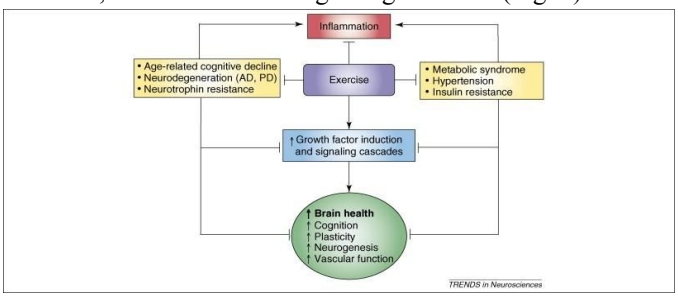

Fig. 1. Exercise induces a central mechanism mediating exercise-dependent benefits synaptic plasticity, neurogenesis and vascular function. (Carl W. Cotman, Nicole C. Berchtold, Lori-Ann Christie Exercise builds brain health: key roles of growth factor cascades and inflammation null, Volume 30, Issue 9, 2007, 464–472 http://dx.doi.org/10.1016/j.tins.2007.06.011)

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