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ORIGINAL ARTICLE

Preliminary Investigation of an Electromyography-Controlled Video Game as a Home Program for Persons in the Chronic Phase of Stroke Recovery

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Abstract

Objective: To investigate the preliminary effectiveness of surface electromyography (sEMG) biofeedback delivered via interaction with a commercial computer game to improve motor control in chronic stroke survivors.

Design: Single-blinded, 1-group, repeated-measures design: A1, A2, B, A3 (A, assessment; B, intervention).

Setting: Laboratory and participants' homes.

Participants: A convenience sample of persons (N=9) between 40 and 75 years of age with moderate to severe upper extremity motor impairment and at least 6 months poststroke completed the study.

Intervention: The electromyography-controlled video game system targeted the wrist muscle activation with the goal of increasing selective muscle activation. Participants received several laboratory training sessions with the system and then were instructed to use the system at home for 45 minutes, 5 times per week for the following 4 weeks.

Main Outcome Measures: Primary outcome measures included duration of system use, sEMG during home play, and pre/post sEMG measures during active wrist motion. Secondary outcomes included kinematic analysis of movement and functional outcomes, including the Wolf Motor Function Test and the Chedoke Arm and Hand Activity Inventory-9.

Results: One third of participants completed or exceeded the recommended amount of system use. Statistically significant changes were observed on both game play and pre/post sEMG outcomes. Limited carryover, however, was observed on kinematic or functional outcomes.

Conclusions: This preliminary investigation indicates that use of the electromyography-controlled video game impacts muscle activation. Limited changes in kinematic and activity level outcomes, however, suggest that the intervention may benefit from the inclusion of a functional activity component.

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In the United States, approximately 795,000 persons sustain a new stroke each year, and 50% of stroke survivors have difficulty using their impaired upper extremity 6 months poststroke.[1] Persons with poor upper extremity motor function after stroke exhibit a variety of impairments, including hemiparesis and spasticity.[2-4] Voluntary selective muscle activation is often difficult because of excessive co-contraction of agonists and antagonists, leading to an inability to achieve movement using typical activation patterns.[2] Impairments in upper extremity motor function are associated with decreased quality of life and difficulty resuming daily activities.[4,5]

While impairments can be severe, stroke survivors can partially improve motor function with therapy and repetitive practice of specific tasks.[6-8] Rehabilitation therapists use a variety of treatment approaches to address hemiparesis and spasticity. Most current approaches to outpatient therapy, however, provide

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too little practice to produce recovery in the chronic phase of stroke for those who actually receive therapy services.[9,10] While clinical practice guidelines strongly recommend follow-up services for persons with residual impairments after acute rehabilitation, only 30.7% of stroke survivors receive outpatient therapy.[11,12] Even for those receiving outpatient therapy the amount is variable, with a median of 6 outpatient therapy visits (interquartile range, 1−21 visits) in the first year after stroke.[13]

In contrast, the amount of practice needed to induce functional improvements for chronic stroke survivors is extensive. A review article[6] reported that a study by Pang et al[14] found that 57 hours of practice was needed to make functional changes that impact performance in self-care and leisure tasks. With this amount of practice suggested in the literature, typical outpatient therapy provides insufficient practice time for motor recovery during clinical sessions. While practice can be extended through home programs, adherence is generally poor with multiple barriers reported.[15,16]

We sought to address the challenges of providing sufficient and specific practice outside the clinic. We developed a home-based program using surface electromyographic (sEMG) biofeedback interfacing with a computer game. sEMG biofeedback has been used in motor rehabilitation after stroke since the 1960s.[17] While the evidence base for sEMG biofeedback is inconclusive, several small studies[17-19] have found it to benefit upper extremity motor recovery of stroke survivors. We used this biofeedback method with an engaging, commercially available computer game in order to increase practice and subsequent repetitions using the impaired upper extremity at home. The use of sEMG biofeedback provides the participant with specific feedback of muscle activation as an agonist/antagonist pair over multiple repetitions. Specificity and repetition are 2 elements found to induce neural plasticity.[8] We tested the hypothesis that use of the electromyography-controlled video game system improves voluntary muscle activation and functional performance on outcome measures for adults in the chronic stage of recovery from stroke.

Methods

Study design

This preliminary study used a single-blinded, 1-group, repeated-measures design: A1, A2, B, A3 (A, assessment; B, intervention). A1 and A2 were scheduled approximately 4 weeks apart, before system use. A3 occurred immediately after completion of system use in the home. This design was selected because of the heterogeneous nature of stroke survivors and the preliminary nature of this investigation. All procedures were approved by the University of Washington Human Subjects Division, and all participants gave written informed consent before participation in the study.

Participants

Participants were a convenience sample of volunteers more than 6 months poststroke with an average age ± SD of 60±8 years. Participants' level of impairment ranged from no active extension in the digits to full digit extension. Participants had vision and hearing sufficient to play a computer game, and were cognitively able to give informed consent. Participants were excluded if they (1) had a skin condition that would interfere with the sEMG assessment or intervention; (2) reported significant pain in their affected upper extremity; (3) had a secondary neurologic diagnosis such as Parkinson's disease; (4) had a contracture at the wrist that would prevent the wrist from being passively extended to a neutral position; (5) had received neurolytic injections in the previous 4 months; or (6) had variations in dosage of oral antispasticity medication in the previous 3 months.

Twelve participants were enrolled, and 9 completed all 3 assessments and the intervention. Two withdrew because they lacked the time to participate, and 1 was asked to withdraw because of a change in his medical condition unrelated to the study. The characteristics of the 9 participants who completed the study are presented in table 1.

List of abbreviations:

CAHAI-9	**Chedoke Arm and Hand Activity Inventory-9**
MVC	**maximum voluntary contraction**
NGT	**NeuroGame Therapy**
sEMG	**surface electromyography**
WMFT	**Wolf Motor Function Test**

Intervention

The electromyography-controlled video game system, called NeuroGame Therapy (NGT), consists of a laptop computer, NGT console, sEMG leads, and disposable electrodes. The NGT system console uses a custom Neurochip circuit to amplify and digitize bipolar analog sEMG signals from 2 muscle groups and transmit these signals via universal serial bus to the computer.[20,21] Custom software converts muscle activity into movements used to control the computer game. The system's sensitivity can be adjusted to detect very low levels of activation, thus allowing persons with minimal muscle activation to participate. The conversion from sEMG activity to game movement was adjusted as needed during the intervention phase to facilitate challenging but successful game play (ie, the "just-right" challenge). If participants had an Internet connection at home, the investigators could make adjustments to game settings remotely.

Participants used the muscle activity in their affected wrist flexors (ie, flexor carpi radialis) and extensors (ie, extensor digitorum communis) to perform pregame maximum voluntary contractions (MVCs) and then to play the commercially available computer game Peggle.[a] For collection of MVCs, participants were instructed to maximally flex or extend their wrist during a 10-second window, followed by a 10-second relaxation period. This was repeated 3 times for flexion, followed by 3 times for extension. In Peggle, participants attempt to clear the board of orange pegs by identifying the correct angle to launch a ball to eliminate pegs. Participants controlled the aim using their affected upper extremity and launched the ball by clicking a button using the less affected hand. The game could be set up in 2 modes. Mode 1 trained selective muscle activation (ie, quieting 1 muscle group while activating the other). Mode 2 trained activation of a weak muscle group independent of the activity of the antagonist group.

Measures

Home therapy outcome measures

The NGT software captured raw sEMG during each home therapy session. To be included in the analysis, home sessions must have lasted at least 5 minutes and have displayed modulations in recorded signals from both muscles to ensure that the sensors were properly connected to the arm. Outcome variables