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Case Report

Training and Testing Implications Obtained From a Stroke Survivor Following 3 Years of High-Repetition Training

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ABSTRACT

Introduction: Conventional methods of attempted rehabilitation do not typically restore health, full mobility and independence of the more than 6 million stroke survivors in America. Recent studies, much of the problem is apparently related to the limited amount of time and insufficient repetitive movements employed in training whole body and retraining paretic limbs.

Methodology: The current case study identified a 75 year-old male stroke survivor and his 3-year participation in an unconventional university-based rehabilitation program. The training program has earned a registration mark from the U.S. Patent and Trademark Office in Washington, DC. Team Kinesiology® uses trainer/client groups to systematically extend the training time and effort to regain health and improve mobility and independence.

Results: The return to health and the elimination of additional medical care suggests program success. Electromyographic (EMG) responses of unaffected and paretic muscles provided evidence and rationale for extended bilateral training efforts. On-going collaborative studies are underway with the university Schools of Kinesiology and Engineering and the Department of Biology to better document the improvements in wellness and mobility.

Conclusion: Documentation on a larger scale may help establish a new normal for stroke survivor rehabilitation.

Keywords: rehabilitation, adaptive, therapy

INTRODUCTION

Cerebrovascular accident (stroke) is a leading cause of mortality and disability in the U.S., [1] amounting to approximately 800,000 incidences each year. The current state of American health care leaves key segments of this population unserved. While 3-6 months of prescribed physical therapy may be effective at rehabilitation of acute ankle/knee injuries, [2,3] it is wholly inadequate for catastrophic injuries or other severe disabling diseases. Outpatient rehabilitation use among adult stroke survivors was 31.2% (20 states and DC) in 2013 and 35.5% (four states) in 2015. Disparities were evident by sex, race, origin, and level of education. Focused attention on system-level interventions that ensure participation is needed, especially among disparate populations with lower levels of participation. [4]

In animal models, the adaptive capacity of the nervous system often requires the animals to engage in hundreds of repetitions of movement practice daily. To promote adaptive changes in functional movements in humans, it is likely that the number of repetitions is much higher than commonly practiced in physical therapy. It appears that current doses of practice during rehabilitation are not adequate to drive the neural reorganization need to promote functional recovery from stroke. [5]

A systematic review of ten published studies of current practice of acute rehabilitation following stroke reported 4.1 to 36 minutes per session during physiotherapy and 11.2 to 36 minutes during occupational therapy, while another study reported 5.7 minutes per session during physiotherapy only. [6,7] In recent observations of 312 therapy sessions with stroke survivors, the average number of repetitions in the upper extremity was 32. [5] Repetitions per session reported by one study were 23 and 32 repetitions, respectively across PT and OT disciplines; however, evidence from both animal models and human stroke populations, suggests an increased dose (minutes or repetitions) may be responsible for acceleration in the rate of functional recovery. [6] For example, treadmill aerobic training in humans demonstrated metabolic improvement [8,9] and long-term swim exercise enhances whole-animal health parameters including enhanced nervous system health and protecting against neurodegeneration. [10]

Early studies in our lab of passive movement of paralyzed limbs revealed positive adaptive changes following 12-weeks of high-repetition exercise. [11,12] Vast numbers of individuals remain unserved and untreated, leaving them with only pharmaceutical solutions to alleviate their pain and suffering. Therefore, the purpose of this case study is to highlight the success of an unconventional approach to rehabilitation of the stroke survivor.

MATERIALS AND METHODS

Training Regimen

Professors of kinesiology direct the program and senior kinesiology majors supervise training and testing in the Lab for Wellness and Motor Behavior on the campus of Tarleton State University, Stephenville, TX 76402. The training program has earned a registration mark from the U.S. Patent and Trademark Office in Washington, DC. This so-called Team Kinesiology® (TK) attempts to rectify the problems reported in conventional rehabilitation by using trainer/client groups to systematically extend the training time and effort to regain health and improve mobility and independence. The NuStep T5XR exercise device (NuStep, Inc., Ann Arbor, MI) accommodates the hemi-paretic stroke survivor to accomplish continuous repetitive movements by allowing the unaffected limbs to power the whole-body movements.

Unlike conventional therapy, the supervised exercise in our lab occurs in a room with 10 to 20 clients and trainers who are challenged to create a supportive team environment where success and failure is shared. Four of these NuStep devices were utilized in the lab in 2018 training over 80 clients who had various degrees of limb weakness secondary to cerebral palsy, spinal cord injury, Parkinson's disease, traumatic brain injury, and other debilitating diseases and injuries. Volunteer senior trainers value the opportunity to apply their understanding of adaptive training in this controlled and supportive environment.

Performance Testing

After a 50m walk to the lab and 10 minutes of upper body warm-up activities, lab personnel conducted a baseline muscle activity assessment of CY while seated on the Technogym Excite (Technogym USA, Corp., Fairfield, NJ) arm-crank ergometer. The pivot of the crank arms was positioned vertically at the seated level of the glenohumeral joint. The hand on the paretic side was secured to the pedal handle with elastic wrap. Power (average 25 Watts) from the unaffected arm provided continuous bilateral arm-cranking at 24 rpm for the six-minute test. The electrode sites on the anterior deltoid were identified bilaterally and cleaned with alcohol swabs. Recorded muscle activity was transmitted wirelessly 25 feet across the lab to a desktop computer (Dell OptiPlex 5060) utilizing the DelSys software EMGworks Acquisition (version 4.3.2). The DelSys™ Trigno

System (DelSys, Inc., Natick, MA) recorded EMG activity from wireless sensors (SP-W01D) placed bilaterally along the long axis of the anterior deltoids, an agonist in shoulder flexion. Cathode/anode distance was fixed at 10mm. EMG was recorded at 1000 Hz (bandwidth 20-200 Hz) including signal frequency (Hz) and amplitude (μV) and stored electronically in file folders for subsequent analysis.

CASE REPORT

The current case study subject (CY) identified as a highly-motivated, tight-control diabetic, otherwise healthy 75 year-old male (ht. 1.93m, wt. 97.5kg) stroke survivor. His stroke occurred in 2011, causing right-side hemiplegia complicated by aphasia. He was stabilized by medical care and treated with physical therapy (PT), subsidized by insurance. His initial hospital care provided medical stability and prevented further damage. His prescribed physical therapy helped him adapt to a new lifestyle of being paralyzed on one side, established his need to move, albeit in a modified fashion, and released him after the insurance funds were depleted. After two years of self-training, he began training in our university lab.

CY signed Informed Consent and volunteered to participate in physical training and testing approved by the university Institutional Review Board. CY was a member of TK who collectively recorded over 1.55 million steps, thus accomplishing high-repetition rhythmic full-body movements. He actively participated in a 3-year unconventional university-based rehabilitation program alongside many others with similar impairments, recording 523,535 arm/leg "steps" on the T5XR. In the calendar year 2018, CY completed 185,865 steps at an average power output of 50 W at the cycle rate of 133 steps per minute. He completed an average of over 3500 steps at each training session, high volume training by any standard for a stroke survivor. He continued to improve his balance and subsequent walking, progressing from parallel bars to walker, to canes, to independent walking on the treadmill, indoor hallways, outdoor sidewalks, and multiple trips up the stairs in the nearby 4-story science building. His dedication and continuous active participation in rehabilitation served as the basis for his selection as the subject of this case study.

RESULTS

Analysis of the stimulus/reflex activity periods revealed a longer single reflex activation period than the stimulus activation period. Figure 1 compares 6 selected activation periods spaced at indicated time periods over the 6-minute EMG test.

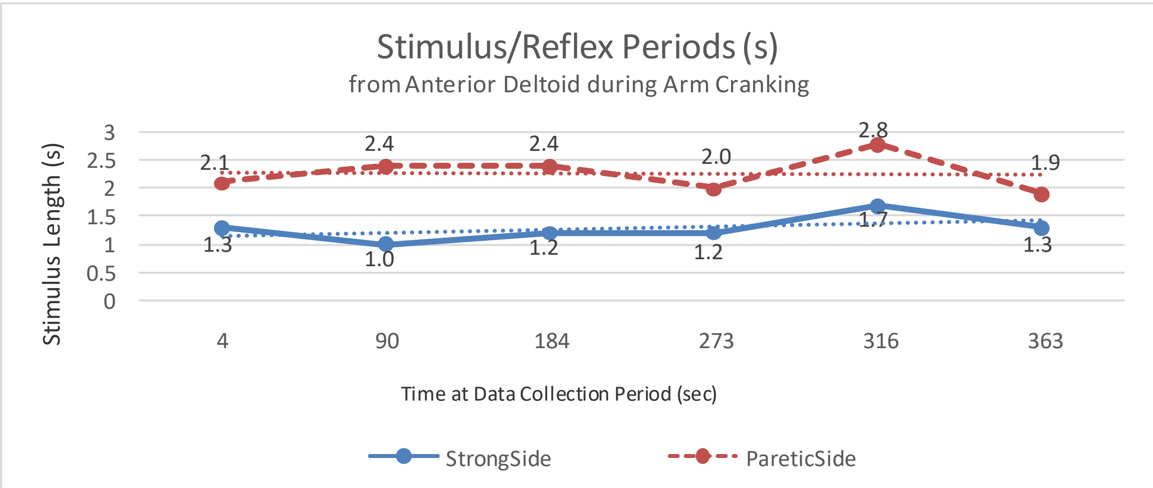

Figure 1. Activation times obtained from electromyography recorded from unaffected and paretic muscles during 6-minutes of continuous 24 rpm arm cycling on the Technogym Excite™.

Although direct comparison of bilateral EMG signals is problematic due to variability in site preparation and electrode placement, separate views of the raw signal illustrate muscle activity periods obtained from the unaffected arm (UA, Fig. 2) and paretic arm (PA, Fig. 3).

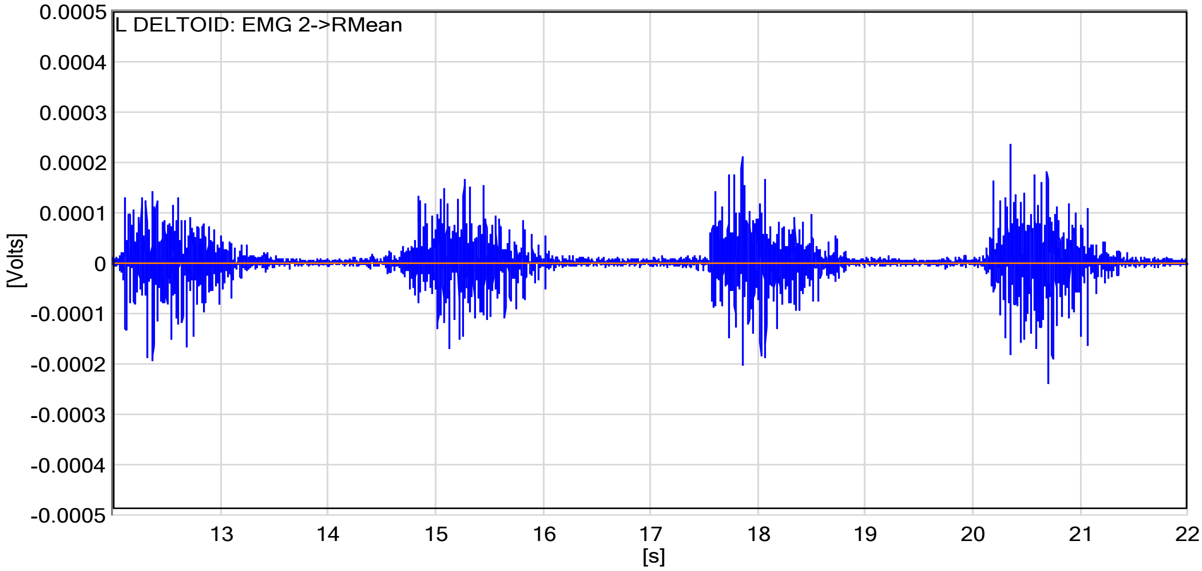

Figure 2. Raw signal obtained from electromyography recorded from unaffected muscles during 10-seconds of a 6-minute continuous 24 rpm arm cycling on the Technogym Excite™.

This 10-second raw EMG signal illustrates the relative timing and signal waveform recorded from UA which provided the power for bilateral arm cycling. During the 6-minute test, the peak-to-peak signal amplitude was consistent with an average voltage of 311 ± 203 µV and an average root mean square of 34.4 ± 12 µV.

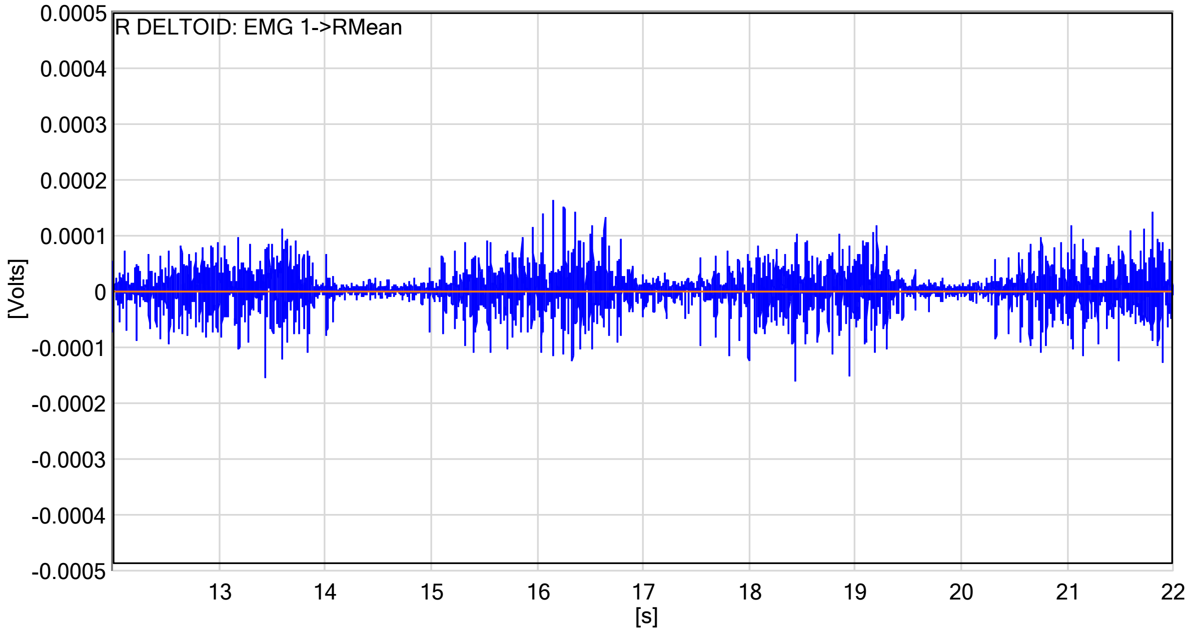

Figure 3. Raw signal obtained from electromyography recorded from paretic muscles during 10-seconds of a 6-minute continuous 24 rpm arm cycling on the Technogym Excite™.

This 10-second raw EMG signal illustrates the relative timing and signal waveform recorded from PA during passive arm cycling powered by the contralateral arm. During the 6-minute test, the peak-to-peak voltage declined from 261 to 80 µV with the average peak-to-peak voltage of 208 ± 175 μV and an average root mean square of 21.4 ± 13.4 μV.

DISCUSSION

With the Technogym crank arms out of sync by 180 degrees, initial muscle activation of the UA occurred simultaneously with the passive stretch of the fibers of the PA. The notable difference was in stimulus length (see Figure 1). The longer activation periods of the PA may be attributed to EMG spectrum shifts as the higher frequency components decrease with acute fatigue and the lower conduction velocity of some or all action potentials. Some authorities would attribute the longer activation times to the nature of the classic stretch reflex. The muscle spindle in the PA generates afferent sensory information on muscle length, which travels in the 1a fiber to the spinal cord, where it synapses with the Aa motor fiber supplying the muscle. In this situation, the muscle contracts against its own stretch, termed the "long-latency" reflex response. [13]

Other investigators have reported motor unit firing behavior alterations following stroke. [14] This alteration was seen in the present case illustrated in the raw EMG signal (Figures 2 and 3). The peak-to-peak voltage demonstrated distinct changes during 6-minutes of continuous arm cycling. The signal strength remained unchanged in the UA and decreased 69% in the PA, indicating no fatigue in the UA and "fatigue" of the motor units in the PA (not shown in Figure 3). The diminished response of the PA indicates that high-repetition movement changed the muscle activation. The motor unit firing frequency decreased in this time period from 68 to 61 Hz in the UA (-10%) and from 67 to 22 Hz in the PA (-67%). The maintenance of tension after the onset of fatigue requires increased motor unit recruitment to compensate for decreased firing rate, [15] reflected in the longer-duration activation periods of the PA.

Recent evidence suggests that neural excitability and muscle strength on the PA can be modulated by training the UA in stroke survivors, [16] lending evidence that supports our bilateral high-repetition training. Kaupp et al. reported that arm cycling alone can activate the neural networks that regulate leg movement and significantly improve performance in walking gait. [17] The EMG evidence presented in the present study supports our earlier findings that high-repetition exercise of paretic limbs is beneficial and may provide a training affect to possibly ameliorate the muscle atrophy associated with lack of movement. [12]

Gordon et al., in a 2004 American Heart Association Scientific Statement, provided extensive evidence that aggressive rehabilitation beyond the typical several months increases aerobic capacity and sensorimotor function of stroke survivors. [18] The case study subject reported here has accomplished a remarkable return to health following his devastating stroke. The weakness/paralysis on his affected side was persistent throughout training along with much improvement in his walking gait. The results of the high-repetition training documented in the present study suggest that the benefits outweigh the risks of engaging this population in such a program.

Over 6 million stroke survivors in America are mostly overlooked and underserved by conventional health care. Time and monetary investment into TK and high-repetition training seems warranted. A local hospital administrator suggested that the savings are significant when hospital revisits within 30 days are reduced or eliminated [19] as a consequence of participation in regular physical activity.

Sun and Zehr [16] concluded that engaging as many limbs as possible may help achieve continuous strength and functional improvement in a community-based chronic stroke population. More than twenty years of experience in TK at our university has provided numerous examples of improved health and mobility in clients after their release from conventional health care. Currently stroke survivors in our country have little if any access to this type of high-repetition, whole-body supervised training. On-going collaborative studies are underway with the University Schools of Kinesiology and Engineering and the Department of Biology to better facilitate and document the improved health and mobility of stroke survivors.

CONCLUSION

From intensive care following his stroke to independent mobility, the return to health of CY as a member of Team Kinesiology® and the EMG evidence of paretic muscle activity suggests that the unconventional program is worthy of consideration for a new normal extension of current health care and rehabilitation.

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