

Force Myographic Interface for Ankle Rehabilitation

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ABSTRACT

Neuromuscular rehabilitation regimens can be demanding and tedious for users. Programs that link physical exercise with game playing or simulated activities within virtual reality environments attract many users. Herein we describe a non-invasive interface to a computer mouse emulator using force myography (FMG). The interface consists of a pressure-cuff around the calf, and can be used to control the cursor for game playing and computer utility.

KEYWORDS

Neuromuscular, force myography, muscle, biofeedback, ankle

BACKGROUND

Neuromuscular rehabilitation is necessary for many populations including those with stroke and cerebral palsy. To restore mobility therapists have used several approaches including muscle strengthening, biofeedback, anti-spasticity treatments, orthotics, and robotic devices. Essential to promoting effective motor learning during these therapies is proper sensory feedback; however, neuromuscular deficits usually limit such feedback. Alternate channels of feedback are thus desirable, so that appropriate muscle actions can be rewarded and inappropriate ones discouraged. The usual mode of muscle registration for biofeedback is the EMG, which has been successful (1). These biofeedback protocols have been enriched using virtual reality environments and computer game playing, in order to encourage users to perform the arduous physical therapies. To extend these promising, but expensive, strategies to the widest target audience new tools are required.

Force myography (FMG), the measure of external muscle pressure, is a simple and reliable method of detecting and providing feedback of muscle activation(2). During concentric and eccentric contractions of muscles close to the surface, changes in muscle diameter are visible by eye and can be detected using force transducers such as, force sensing resistors (FSR). Compared to EMG, FMG is simple to apply and process, and can register activation of large muscle groups adequately for real-time biofeedback. To date FMG has been implemented by only a few groups. Amft et al. created an interface capable of detecting grasp activity by securing the FSRs to the skin with tape, over two large muscle bellies(3) Yungher, et al. used an array of FSRs mounted on a cuff to detect pressures in the leg of a single female subject as she walked on a treadmill(4). Both groups found that the FMG signals corresponded to the EMG signals. Additionally, it was previously established that there is a good correlation to the FMG signal of the calf muscle and ankle rotation ($\rho=.81$)(5).

Insert Figure 1 Here: FMG correlation to ankle flexion.

RESEARCH QUESTION

Our strategy herein is to combine a FMG biofeedback interface with a mouse adapter, enabling patients to play preexisting mouse controlled games using wrist, elbow, or ankle flexion motions. In this project we seek to determine whether our current FMG interface is suitable for mouse cursor control. We hypothesize that the current FMG interface is suitable for mouse cursor control, and together with the mouse emulator will provide an engaging environment for physical rehabilitation.

METHOD

Six non-impaired subjects were recruited to test the device. As a pilot one stroke subject tested the device. Six suitable mouse controlled internet games were downloaded from the internet for testing. A suitable game was said to be any game that involved only two directions of movement. Each subject was asked to complete a questionnaire, designed to collect basic subject demographic data such as activity level and the amount of time spent playing computer games. Written informed consent was obtained from all participants. This study was approved by the Rutgers University IRB.

The FMG cuff hardware is comprised of four force sensitive resistors placed within a standard wrist support band. The FSRs are connected to a silicon laboratories microcontroller board, which is used to power the force sensitive resistors, and to convert the analog voltage signals to a mouse input. A LabVIEW program was created to run games and record the FMG signals.

 Insert Figure 2 Here: FMG cuff

Each subject used two FMG cuffs, one for each calf. The mouse cursor position was proportional to the FMG signals received from each calf muscle. When the ankles were in a neutral position (feet flat on the floor), the mouse cursor remained in the center of the screen. As the left ankle was dorsiflexed the cursor moved to the left of the screen in proportion to the flexion, and as the right ankle was dorsiflexed the cursor moved to the right of the screen in proportion to the dorsiflexion. Before playing the games patients familiarized themselves with the device by controlling a cursor on the computer screen. Subjects then selected a game of their choice and either ran a practice session in which they familiarized themselves with the game, or played the game while ankle flexions were recorded.

RESULTS

All healthy subjects successfully controlled the mouse cursor using ankle flexion. The stroke subject had difficulty controlling the cursor using ankle flexions without a mechanical support. Figure 1 shows the FMG signals of a stroke and healthy subject while playing one round of the *Ponky* car racing game. The ordinate shows the normalized mouse cursor position, with 0 indicating the left most cursor position and 1 indicating the right most cursor position. The stroke subject made fewer flexions and had a shorter round duration (36 seconds) than the healthy subject (100 seconds). Also, the stroke subject made only one flexion with the affected leg and tended to use the un-affected leg for most of the cursor control.

 Insert Figure 3 Here: Sample ankle movement recordings.

The four most popular games, *Trickmaster*, *Ice racer*, *Watch out* and *Ponky*, were studied in more

detail. The relationship between the length of time the games were played and the age of the subject was studied. The games were divided into two categories, sport and juvenile. Sport games were defined to be games that mimicked playing a sport, such as *Trickmaster* (skateboarding), and *Iceracer* (bob sledding). Juvenile games were defined to be games that looked more like cartoons, and did not attempt to mimic a real life situation, such as *Ponky* (a car racing game), and *Watchout* (a game in which the player dodged falling boulders). Although everyone played both types of games, four out of six of the subjects spent more time playing the juvenile games.

 Insert Figure 4 Here: Relationship Between Game Play Time and Age

DISCUSSION

We demonstrated that healthy subjects can control a mouse cursor with ankle motions registered by FMG. Using FMG signals to control a mouse cursor made it easy for us to include games that satisfied people of different ages. Ankle flexions proved to be very difficult for the stroke subject. Flexing the ankle against gravity is a difficult task for many stroke patients, therefore a mechanical assist may be necessary when working with ankle flexions. However, it may be possible to use wrist or elbow flexions without an assist. When given the option to use both legs, it is likely that the patients will rely more on the unaffected leg for cursor control, as seen with our subject. Therefore, we have begun designing a system that can control both directions with one limb. We believe that making a system in which relaxing a muscle, and activating a muscle controls the two directions of the mouse cursor may be more effective.

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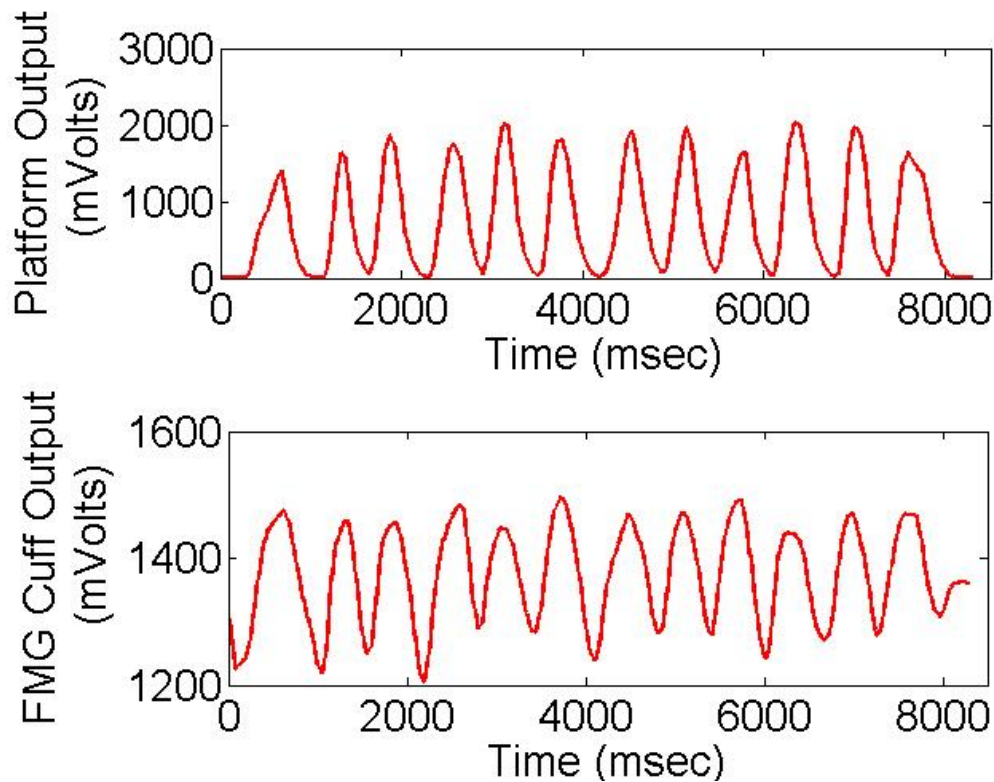
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GRAPHICS PAGE

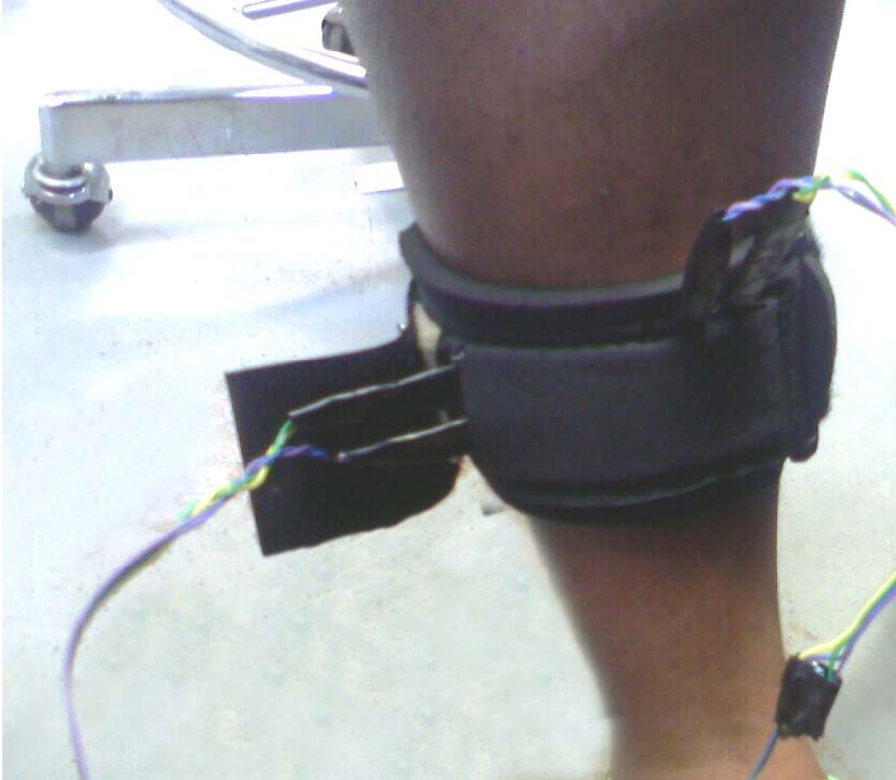
Figure 1: FMG correlation to ankle flexion.



Alternative Text Description for Figure 1: FMG correlation to ankle flexion.

This figure shows the raw signal from an ankle platform designed to measure rotation angle (top), and the FMG signal of the calf muscle (bottom) while a subject flexed the ankle joint 12 times. The signals were highly correlated ($\rho=.81$).

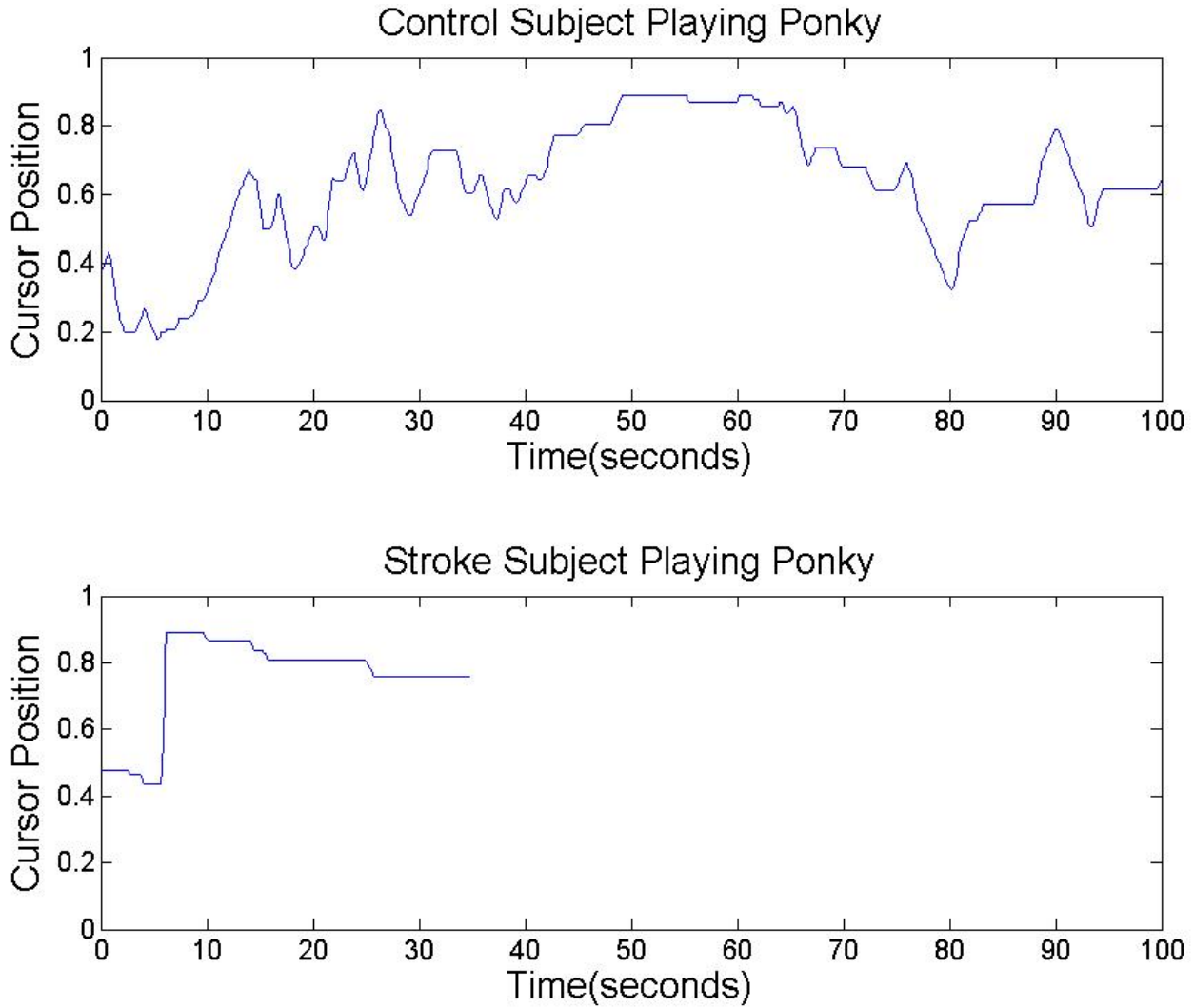
Figure 2: FMG cuff.



Alternative Text Description for Figure 2: FMG Cuff.

This figure shows the FMG cuff placed on the lower portion of the calf muscle. Wires can be seen coming from the four FSRs placed within the cuff.

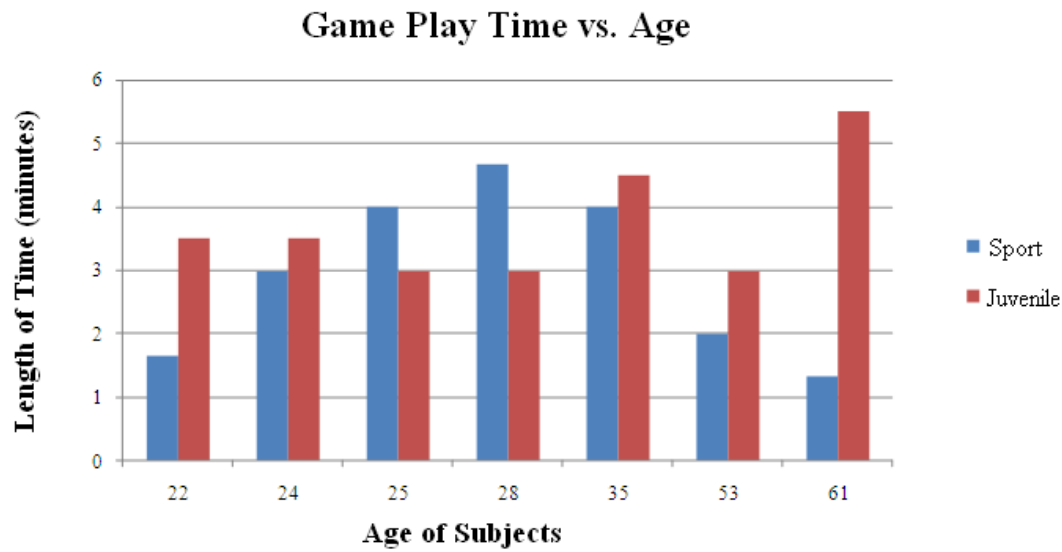
Figure 3: Sample Ankle Movement Recordings.



Alternative Text Description for Figure 2: Sample Ankle Movement Recordings.

This figure shows sample ankle movement recordings of a healthy control (top) and stroke patient (bottom) playing the ponky car racing game. Plots show the normalized mouse cursor position which was proportional to the FMG signal of the calf muscle. The healthy control played this game for 100 seconds, making several flexions with both legs. The stroke patient played this game for only 36 seconds making flexions primarily with the left (unaffected leg).

 Figure 4: Game Play Time vs. Age.



Alternative Text Description for Figure 3: Game Play Time vs. Age.

This figure shows the relationship between the time spent playing the two types of games and the age of the subject. Most subjects played the juvenile games longer than the sport games however both types of games were played by all.