Understanding the Effects of High Intensity Treadmill Training on Corticomotor Excitability and Walking in Stroke Survivors

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A stroke survivor is defined as one having survived and living with the conditions of a stroke. There are three main types of stroke: a hemorrhagic stroke, which is a rupture in the blood vessels; an ischemic stroke, which is a blood clot; and a transient ischemic attack (TIA) or a “mini-stroke,” which is a temporary blood clot. A stroke can be cortical or subcortical, which may influence the extent of damage and functionality to the individual. The time period after the onset of the stroke also influences the functionality and recovery of the individual. An acute stroke is categorized as the time period from the onset of having the stroke to one month, a subacute stroke is categorized as the time period from one month to three months after having a stroke, and a chronic stroke is categorized as the time period from six months or more after having a stroke. Stroke affects a person primarily in their walking, but can also cause weakness, spasticity (abnormal muscle tone that causes rigidity in movement), balance problems, cognitive difficulties, and deficits in sensation and perception (Wing, Lyskey, & Bosch, 2012). A stroke survivor’s ambulation speeds decrease greatly (0.4-0.8 m/s) in comparison to a healthy individual (1.2-1.4 m/s), and their walking patterns can become unsymmetrical (Wing et al., 2012). This unsymmetrical gait pattern is related to a stroke survivor relying more on their stronger side (nonparetic) than on their weaker side (paretic). Like their walking, a stroke survivor’s chemical and electrical system becomes imbalanced in their brain, as they rely more on one side of their body than the other (Madhavan & Shah, 2012). It has been suggested that restoring this imbalance of the corticomotor excitability will lead to better functional recovery in stroke survivors (Rogers, Madhavan, Roth, & Stinear, 2011).

Corticomotor Excitability
Cortical excitability is defined as the communication signals of the neurotransmitters between the neurons via their synapses across brain regions (Badawy, Loetscher, Macdonell, & Brodtmann, 2012). Specifically, corticomotor excitability is elicited through the motor cortex, which is responsible for limb movement and control. Excitability can be measured through several brain imaging techniques, such as through an electroencephalogram (EEG), magnetic resonance imaging (MRI), positron emission tomography (PET) scans, computerized axial tomography (CAT) scans, and transcranial magnetic stimulation (TMS). TMS is processed through electromagnetism, which surrounds the head with a magnetic field and stimulates...
the targeted region with an electrical impulse (Bestmann, 2007). This stimulus is used to measure the excitability of that area through motor-evoked potentials (MEPs), which are the muscle responses from the individual (Bestmann, 2007). The larger the MEP is, then the stronger the connection is from the brain to the muscle (Bestmann, 2007).

Thus, it is important to restore this imbalanced brain activity in a stroke survivor in order for them to recover properly. When a stroke occurs, not only do neural tissues deteriorate, but the synapses between the neurons are weakened. The weaker the connection is between the neural synapses, the weaker the responses are in the muscles (Badawy et al., 2012). While recovering initially, a stroke survivor will rapidly recover a substantial amount of their neural and physical functionality; however, a stroke survivor may establish new connections that may be maladaptive (Badawy et al., 2012). This is due to them relying more upon their stronger side, as their non-lesioned region of their brain compensates for their weaker side. This imbalance in corticomotor excitability then leads to gait deficits, such as unsymmetrical patterns, reduced speeds, and poor functionality.

In an effort to restore functionality and corticomotor excitability in stroke survivors, exercises have shown several benefits that are long-lasting. Intensive exercise has been shown to improve the gait performance and cardiovascular health in stroke survivors with hemiparesis (Jorgensen, Bech-Pedersen, Zeeman, Sorensen, Andersen, & Schonberger, 2010). Jorgensen et al. (2010) incorporated a series of different types of intensive exercises as one intervention for stroke survivors over a period of 12 weeks. Intensive exercises included body-weight supported treadmill training (BWSTT), progressive resistance treadmill training (PRST), and aerobic exercise (AE). Results showed that walking speeds and endurance had improved, as well as measurements in cardiovascular health (systolic and diastolic blood pressure, body mass index (BMI), and resting heart rate (HR)) (Jorgensen et al., 2010). Though evident improvements were shown after the training, this study lacked a control group for comparison. In addition, this study had too many variables that were not accounted for, which did not allow it to identify whether each exercise regimen was effective or not. However, this study demonstrates the benefits of exercising in physical functionality, which may also promote brain plasticity and neuromodulation.

Previous Research on Gait Training
There have been many different approaches in therapy that affect the recovery of a stroke survivor (Wing et al., 2012). Traditional approaches to stroke therapy, such as the compensatory approach, have stroke survivors rely on their stronger side to compensate for their weaker side; however, this therapy has been shown to result in gait deficits and poor recovery in the individual (Bogey & Hornby, 2007). Instead of relying on the nonparetic side, other therapy approaches, such as a body-weight supported treadmill training (BWSTT), have been utilizing the strengthening of the paretic side, which has shown to also restore balance in corticomotor excitability on the paretic side (Yen, Wang, Liao, Huang, & Yang, 2008). Particularly, there have been several innovative ways that involve the treadmill to rehabilitate stroke survivors.

Though numerous research studies have examined the improvement of upper limb activity in stroke survivors, there is little research on lower limb activity in stroke survivors. Therefore, we chose to study the lower limbs in stroke survivors to learn more about the nature of their functioning and recovery process. The research that has been done on lower limb rehabilitation has shown that the effects of treadmill training can improve stroke survivors’ life in several ways (Boyne et al., 2013; Globas et al., 2012; Yen et al., 2008).

One type of treadmill training, known as high-intensity treadmill training (HITT), involves vigorous walking in intervals. The goal of HITT is to increase the walking speeds of the individual. To do this, HITT maximizes exercise intensity, while mitigating the effects of fatigue. HITT involves the individual walking in short bursts of their maximum walking speed independently or with little assistance. These high-intensity intervals are alternated with recovery periods that allow the individual to walk at slower speeds (Boyne et al., 2013). It has been observed that HITT has improved functional and aerobic outcomes in the stroke population (Boyne et al., 2013). Globas et al. (2012) found that high-intensity aerobic treadmill exercise (TAEX) increased walking speeds, balance, cardiovascular fitness, self-rated mobility, and quality of life in stroke survivors after three to five months of training. (TAEX and HITT have similar training protocols, as both involve vigorous walking during intervals and slower walking during recovery periods.) For this study, there were two groups, one which received the TAEX treatment while the other group received conventional care physiotherapy. Results revealed that TAEX improved upon the cardiovascular fitness and the gait ability in those with chronic stroke. Additionally, Tyrell, Roos, Rudolph, and Reisman (2011) found that increasing treadmill speeds during training led to increased overground speeds, and improved overall gait ability by increasing the step length, improving step symmetry, increasing single-limb support time, and decreasing double-limb support time in chronic stroke survivors. These findings demonstrate that HITT influences gait performance in a positive way, but have not yet assessed a shorter training period or investigated the relationship that HITT has on corticomotor excitability.

In addition, several studies involving a different method of training called body-weight supported treadmill training (BWSTT) have shown that both gait abilities and corticomotor excitability had increased (Yen et al., 2008; Thomas & Gorassini, 2005).
BWSTT differs from HITT in that there is a harness-counterweight system that supports both the upper and lower portion of the body substantially while walking on the treadmill (Bogey & Hornby, 2007). This system gives support with an overhead suspension that can remove weight from the individual’s extremities, and allow the individual to practice their gait on their weaker side. The goal of BWSTT is for the participant to walk as fast and as far as they can without causing risks to safety or breaking gait pattern (Jorgensen et al., 2010). Yen et al. (2008) showed that BWSTT improved corticomotor excitability, walking speed, step length, and cadence. Their experiment consisted of two groups in which one received BWSTT and general physical therapy, and the other received only general physical therapy. Their results demonstrated that there were significant changes in the measures of gait walking, balance, and cortical excitability. In support of their study, Dobkin, Firestone, and West (2004) also found that BWSTT had induced several changes within the motor cortex of the brain, which was detected by functional magnetic resonance imaging (fMRI). Furthermore, Yen et al. (2008) revealed that there were significant decreases of motor thresholds in the paretic TA muscles. This shows that the connectivity between the TA and primary motor cortex (M1 region) had increased, thereby demonstrating recovery in neuronal synaptic strength. The study also found that there was a positive correlation between corticomotor excitability and improvements in gait and balance functionality. Overall, the study concluded that both gait and balance training may induce changes in corticomotor excitability (Yen et al., 2008).

Even though BWSTT has shown many promising benefits for rehabilitating stroke survivors, its overall costs and attention required are staggering when compared with HITT. While HITT only requires minimal attention of one or two trainers, BWSTT requires several trainers and physical therapists to manually shift the participant’s leg weight while on the treadmill (Bogey & Hornby, 2007). However, HITT cannot be used for all stroke survivors, particularly for those who use a wheelchair, as it requires that the individual be able to stand and walk on their own for at least five minutes. Because of the vigorous and strenuous training of HITT, it excludes many stroke survivors, as they must be functional enough to be able to perform the task without resulting in any major setbacks. While both methods of treadmill trainings have pros and cons, it is essential to understand which is most optimal to apply to an individual based upon their clinical measurements and functionality. Therefore, this study tests the efficacy of HITT on the performance of walking and the corticomotor excitability of stroke survivors.

**Research Study Purpose**

Previous research has shown that intensive interval treadmill training exercise can help stroke survivors to increase their walking speeds and overall quality of life (Boyné et al., 2013; Globas et al., 2012), but how it affects corticomotor excitability is unknown. The purpose of this study is to investigate the effects of four weeks of HITT on the corticomotor excitability and walking in stroke survivors. TMS will be used to measure the neural plastic changes in the motor cortex region of the brain, targeting the paretic and non-paretic tibialis anterior (TA) lower limb muscles. We are focusing on the lower limb muscles because it is an area that is not as extensively researched in individuals who had a stroke. Our hypothesis is that corticomotor excitability and walking velocity will increase after the training. We also predict that the outcomes of corticomotor excitability and walking velocity will be positively related to one another.

**Methods**

**Participants**

Three individuals with chronic stroke, (two males and one female) between 50 and 80 years old, participated in this study. Participants were either paretic on their left or right side of their body (one right paretic and two left paretic). Participants were recruited from previous studies done by the principal investigator, involving post-stroke rehabilitation, and they were also recruited through the University of Illinois at Chicago Medical Center in a post-stroke discharged database. Research fliers were also posted in nearby universities and hospitals where the study was taking place. Participants were primarily from the Chicago area. Participants were initially phone screened about their current general level of comfort in getting around and their history and present status with medications and diseases to determine whether HITT and NIBS were appropriate and safe for them. Participants were further screened in person by a physical therapist, who performed walking, balance, and sensation assessments to determine whether HITT and NIBS were appropriate and safe for the participant. Participants who qualified were given informed consent forms and were also verbally informed about the research purpose, procedures, risks, and benefits. All three participants gave consent and completed the study. Participants were also compensated for their time. In addition, participants were asked to not engage out of their normal habits during the training, so as not to obscure their results in the study.

**Procedure**

Participants had four weeks of training and a baseline assessment and post-assessment in the weeks before and after the training. During the four weeks of training, participants typically came in three times per week, for about two-hour sessions. Weekly training consisted of recording a new gait speed at the beginning of each week and walking on the treadmill.

**Order of the Training:**

1. Before the training session begins

When the participant was ready, they were laid down onto a therapy table and stretched out in their lower limbs by the re-
search assistant for about five minutes. Stretching out the lower limbs is done to help mobility and blood flow during the training, and to also lessen muscle soreness. After the stretching, the participant wore a heart rate (HR) monitor that tightly wrapped around their mid-torso region where the xiphoid process is located. This was done in order to measure the participant’s HR throughout the session.

2. Obtaining a new gait speed
At the beginning of every training week, a new gait speed was recorded, for a total of four gait speeds. These gait speeds were then used as the warm-up and recovery speed for when the participant was on the treadmill. Participants were instructed to walk 10 meters as quickly as possible, but without losing balance or falling over. A gait belt was also wrapped around the participant’s mid region, and the research assistant timed them and walked closely with them for safety. Participants walked the 10-meter path twice in order to have two trials. The research assistant took the average of the two trials in seconds and divided that value by 10 in order to calculate meters per second (m/s).

The speed in m/s was then multiplied by 2.236 in order to be converted into miles per hour (mph) to be applicable to the treadmill machine. The final value was then divided by 2, which determined the participant’s new warm-up and recovery speed for that week on the treadmill.

3. Treadmill training
Before going onto the treadmill, the participant’s blood pressure (BP) and heart rate (HR) were taken. BP and HR must be in a safe zone (around 110/70 mmHg and 60-80 bpm) before doing intensive exercise. If the participant’s BP or HR were not within an adequate range for exercising, the participant sat or lay down to relax. Once ready, participants then proceeded to do the treadmill training for the remainder of the session. The goal of the treadmill training was to have the participant work as hard as they can, but with safety. To do this, the target HR was set at 80% and was not allowed to reach or exceed 100% of the participant’s maximum HR. Treadmill training consisted of 40 minutes. Participants wore a harness tightly fitted around them that physically hooked them up to the treadmill for stabilization and acted as a safety net if the participant were to fall. It also contained a HR monitor that would pick up the signal for the research assistant to constantly monitor. A research assistant stood behind the participant for safety and support. However, the participant was required to independently walk, and support was only given when needed. Another research assistant was nearby to control the participant’s walking speeds, and to record the participant’s walking speeds, time, HR, and the rate of perceived exertion (RPE). The RPE is adapted from Cleveland Clinic with ranges from 0 (no work) to 10 (strenuous work).

The 40 minutes on the treadmill was divided up in several increments. These increments included four categories: the warm-up, the interval speeds, the recovery, and the cool down. The first five minutes on the treadmill was the warm-up and was set at the participant’s gait speed, which was recorded at the beginning of the week. After the warm-up, the participant then entered their first interval. The interval lasted for two minutes, and an additional 10 seconds at the top speed. During the interval, the research assistant gradually increased the speeds in the beginning, and then increased more quickly in the latter two minutes. This was to have the participants not have to work longer at higher speeds than at lower speeds. At the end of the two minutes, the participants then engaged in the top speed of the interval for the next 10 seconds. Since the top speed varied among participants, participants were assessed if speeds could be increased for their workload in order to determine their top speed.

Immediately after the 10 seconds of the top speed, the speed returned to the warm-up speed, which allowed the participant to recover. In this instance, the research assistant asked the participant’s RPE, and their highest HR was recorded from that interval. During the recovery period, participants walked at the lowest speeds in order to recover themselves and their heart rate. The recovery period typically lasted from two to five minutes, but varied among the participants. If their HR was not within the range of their warm-up HR (within 5 bpm), then they could not proceed into the next interval. If participant’s HR and/or RPE were too high for some period of time, then they were allowed to take one-minute pauses that allowed them to stand and drink water to recover. The one-minute pauses counted as a part of the 40 minutes of being on the treadmill, so no additional time was added even when pauses were taken. Once their HR was within the desired range and recorded, the participants were asked for their RPE, and then they proceeded onto the next interval.

The cool down period occurred at the end of the 40 minutes and was required to be at least five minutes. The cool down speed was set as the same as the warm-up speed. Throughout the treadmill training, research assistants took extra care in monitoring the safety of the participants, and they encouraged the participants to do their very best. Once participants completed their 40 minutes on the treadmill, the final BP and HR were taken, and they were asked their final RPE. After the treadmill training, participants were done with the whole session for the day.

Assessments
There were a total of two testing sessions, which were taken before and after the four weeks of training. These assessments lasted for about five hours and were done in two separate sessions. Each of the tests consisted of measuring the participants in two areas: clinically with a physical therapist and neurologically with TMS.
Neurological assessment. The neurological assessment measured participants through the TMS Magstim 200 Stimulator. In this study, TMS was used for measuring the excitability between the lower limbs and the motor cortex of the brain. These measurements of corticomotor excitability were taken in the form of motor-evoked potentials (MEPs), which are electrical signals evoked by a stimulus that is communicated between the nervous system and the body. We looked at the amplitudes of the MEPs, which recorded the highest reactivity from the stimuli. With these measurements, we were able to see the changes over time and find the best hotspot location to apply the TMS.

In order to measure neurological changes, participants’ TA muscles were measured during the pre and post assessments. The participant’s maximum velocity contraction (MVC) is collected on the nonparetic and paretic sides. MVCs were collected by the participants performing dorsiflexion (keeping their heel on the ground while lifting the ball of their foot) against a custom-made strapping machine. Participants were to lift up as hard as they could in three trials of about five seconds each. While the participant was lifting, the research assistant yelled, “pull, pull, pull!” to encourage the participant to pull up as much as they can. The machine placed resistance onto the TA muscles in order to have an accurate reading of muscle contractions. Once the participant’s MVCs were collected, their activity was displayed onscreen. They were required to maintain their muscle force contraction within a certain window displayed onscreen during TMS collection.

Specifically, we looked at the MEPs produced from between the M1 hotspot region and the paretic and non-paretic muscles of the tibialis anterior (TA). Electromyography (EMG) electrodes were placed over the TA muscles to record their activity. A copper, metal ground electrode was placed on the C7 of the cervical vertebrae in order to maintain a balance and complete the circuit between the electrodes. A double cone coil was used to apply the TMS. TMS was applied through a magnetic field, which surrounds the participant’s head, and produces an electrical stimulation via the process of electromagnetic. Larger magnetic waves invoke larger electric stimuli. The TMS coil was strategically placed around the motor cortex region in order to find the best possible hotspot. The participants’ muscle reaction activity was displayed on an oscilloscope monitor, which allows the research assistant to determine whether or not the MEPs produced are high enough.

In order to measure the change in MEPs, TMS is used to find the “hotspot” for invoking the best stimuli in the motor cortex for the lower limbs. To do this, the participant’s cranium vertex was measured first. The anterior to the posterior measurement consists of measuring from the nasal septum to the occipital bun. The lateral measurement consists of measuring from the tragus of the left ear to the tragus of the right ear. These two measurements make up the cranium vertex. Next, the standard hotspot was determined from the cranium vertex. The standard hotspot of the motor cortex’s lower limb is 1 cm contralateral and 1 cm posterior from the cranium vertex. To determine the best hotspot, the TMS coil was moved around systematically in 1-cm steps nearby from where the standard hotspot is, until at least half of the MEPs produced were adequately high. A good MEP reaction spike is characterized of consisting of at least covering three blocks on the oscilloscope monitor. Typically, there must be at least four of eight high enough MEPs (50% threshold) produced from the TMS stimulus. This was done to determine the threshold of the amount of TMS needed to evoke a reaction. After finding the hotspot that produced at least half adequate MEPs, this became the threshold stimulus for the participant. The TMS coil was then placed onto that region and measures its MEPs in seven decreasing and increasing percentages from the threshold. These percentages were set at 80%, 90%, 100%, 110%, 120%, 130% and 140%. One-hundred percent was set as the threshold stimulus. Each percentage intensity was then applied onto the participant in a randomized order. This was done in the pre and post assessments to see whether the participant’s corticomotor excitability had changed after the four weeks of treadmill training.

Gait velocity measurements. Gait velocity measurements of the participants were taken throughout the four weeks of training. One measurement was the 10-meter walk test, which was done once every week in the beginning of the session to get a new gait speed for the treadmill training. This variable was measured through the participant walking as fast, but as safely as they can in a 10-meter walkway. The second measurement was the top speed recorded for each week. During the treadmill training in each session, we strove to reach the highest speed that the participant could go for at least 10 seconds after the two-minute fast walk interval.

Data Analyses

For our analysis, we focused on the trends regarding whether participants’ gait speeds and corticomotor excitability had improved from their baseline. We anticipated that there would be a positive relationship between the participant’s gait speed, top treadmill speed, and corticomotor excitability. Velocity was measured in meters per second, and corticomotor excitability was measured as a slope in the changes in MEP amplitudes from each of the intensities administered. We predicted that an increase in velocity would correspond to an increase in the corticomotor excitability.

To measure the relationship among these variables, we compared their post-assessment values through bivariate correlations. We also looked at the average percent changes from the participants’ baseline in velocity and gait symmetry. Data was entered through IBM SPSS Statistics version 22.0 software for statistical analyses, and graphs were created through Microsoft Excel 2013.
Results
The means and standard deviations were calculated for the predictor and outcome variables. Our sample size had a total of three participants. Because the walking tests were given each week during the four weeks of training, there were a total 12 samples that were collected from the participants. Results are displayed in Table 1. The average amount of velocity walked in the 10 meter test was 1.15 m/s (± .28). The average top pace on the treadmill was 1.39 m/s (± .25). The average percent change in corticomotor excitability in the nonparetic TA was -35%, (± 28%). The average percent change in the corticomotor excitability in the paretic TA was -11%, (± 30%).

The correlation between the 10-meter walk and the top pace on the treadmill was significant, $r(12) = .64, p = .03$, as shown in Table 2. As a participant’s 10-meter pace increased, their top pace on the treadmill increased. The correlation between the percent changes in corticomotor excitability of the paretic TA and the 10-meter walk was not significant, $r(3) = -.96, p = .17$. The correlation between the percent changes in corticomotor excitability of the paretic TA and the top pace on the treadmill was not significant, $r(3) = -.95, p = .20$. The correlation between the percent changes in corticomotor excitability of the nonparetic TA and the 10-meter walk was not significant, $r(3) = -.44, p = .72$. The correlation between the percent changes in corticomotor excitability of the nonparetic TA and the top pace on the treadmill was not significant, $r(3) = -.86, p = .35$. The correlation between the percent changes in corticomotor excitability of the paretic TA and the nonparetic TA was not significant, $r(3) = -.67, p = .54$.

Discussion
Our research question investigated the effects of HITT on stroke survivors’ walking speeds and corticomotor excitability. Previous research has reported that the HITT improves gait velocity and other life factors of a stroke survivor (Boyne et al., 2013). Our hypothesis was that the HITT would positively predict the corticomotor excitability in stroke survivors, and that an increase in walking speeds would therefore be positively related to corticomotor excitability. To test this hypothesis, a bivariate correlation was used to assess the relationships between these variables.

Our results partly supported our hypothesis in that the stroke survivors’ velocity had increased throughout the training, as shown in Figures 1 and 2, but corticomotor excitability did not increase after the four weeks of HITT in stroke survivors, as shown in Figure 3. However, from the data that has been gathered, trends from the graphs have shown that there is a negative relationship between corticomotor excitability and gait velocity. After four weeks of HITT training, it was revealed that there was a decrease in MEP amplitude (shown in Figure 3). HITT did not excite the corticomotor activity, but instead suppressed it. This shows that there may be some negative relationship between corticomotor excitability and gait velocity, in which HITT had increased one outcome, while decreasing the other. However, a small sample size may have skewed results, and there can be many other reasons that explain this phenomenon.

Implications
Our study illustrated that HITT showed a trend towards decreasing corticomotor excitability, while it increased gait velocity in stroke survivors. There may be a number of possible reasons why this paradox exists between corticomotor excitability and gait velocity when influenced by HITT.

Walking may not be activating corticomotor excitability, but may be activating spinal cord excitability. Changes in excitability can occur at the cortical and/or at the spinal level from walking (Hallett, 2007). Martinez et al. (2013) demonstrated that rehabilitative walking in cats increased the neural excitability in the spine more than in the motor cortex region. The cats were inflicted with a partial spinal cord injury, and were placed into two groups that had treadmill walking and no treadmill walking. Results showed that after three weeks of locomotor training, the trained cats’ velocity and overall gait symmetry had improved, and in contrast, the controlled group of cats remained asymmetrical in their gait pattern, but still maintained velocity as high as the trained group of cats. When examining the histology of the spinal cord from T8 to L1, results suggested that neuroplasticity had occurred in not only the supraspinal structures, but also in the spinal cord itself (Martinez et al., 2013).

HITT may be considered as an endurance training. Studies have shown a significant difference between certain types of exercises that influence the corticomotor excitability (Kumpulainen et al., 2014). Kumpulainen et al. (2014) demonstrated that there is a difference in the cortical excitability in skill and endurance trainers when induced by a neuro stimulation while doing a task. They defined a skill trainer as one who continuously and progressively learns new skills, while an endurance trainer is one who does not change their style of training throughout their years of training. Results from their study had showed that skill trainers had a significant change in corticomotor excitability, and that endurance trainers did not (Kumpulainen et al., 2014). From this finding, it may be possible that our study of four weeks of HITT reflects an endurance type of training, which may explain the decreased corticomotor excitability over time.

TMS can only pick up cortical activity. Because TMS can only detect changes within the cortex, it does not readily pick up the changes in the deeper areas of the brain. According to Bestmann (2007), the changes in cortical activity measured by TMS are most effectively seen in the M1 region of the brain, but that other regions do not show clear results. Furthermore, studies
have shown that repetitive training on a task decreases neural activity and shifts the neural activity from the cortical regions unto the subcortical regions of the brain (Floyer-Lea & Matthews, 2004). In this way, the changes detected in our four weeks of HIT may be occurring more in the subcortical regions, rather than the cortical regions of the brain. To detect a wider range of these changes, perhaps an fMRI may be more suitable, although its costs and time requirement are more in comparison to TMS.

Practicing a task may result in lowered corticomotor excitability. It has been reported several times that repetitive training on a task decreases corticomotor excitability (Floyer-Lea & Matthews, 2004). The reason for this phenomenon is that when a task becomes easier, the brain works in an efficient way that does not require as much energy and activity. In this way, the task becomes “automatic” and does not take much conscious attention and thought when doing the task (Floyer-Lea & Matthews, 2004). This is especially prevalent in problem-solving problems, in which practice increases performance, while also decreasing both the time and energy to solve it. This is also similar to how skill trainers and endurance trainers function, in which excitability decreases in endurance trainers because they have practiced their training for years and years (Kumpulainen et al., 2014). Similarly, in our four-week training program, participants may be impacted by these practice effects, with the task becoming a lot easier throughout the training, thereby decreasing their corticomotor excitability.

Individual responses to therapy. Individuals who have had a stroke may respond better or worse to certain types of therapy.

Table 1

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<th>Max</th>
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<td>1.73</td>
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Table 2

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<td>Fastest speed on treadmill</td>
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*p < .05.
Figure 1. The 10-meter walk test. This was given at the beginning of each week during the four-week training period. It consisted of a fast velocity pace.

Figure 2. The top pace recordings. During each week of the training, the participant’s top pace was recorded. The top pace was the highest speed that the participant was able to walk on the treadmill for at least 10 seconds.
It has been reported that lesion size and location, and the interval between the stroke onset to therapy are strong predictors to how one responds to therapy (Lam et al., 2010). Specifically, in two studies that were done using HITT on stroke survivors, Lam et al. (2010) found that stroke survivors, who had subcortical and left-sided lesion, smaller lesions, and a shorter interval period from the time of their stroke to their treadmill training, benefited most from HITT. These characteristics of our stroke survivor participants may have explained much of the variance.

Strengths and Limitations
The sample size of this study was small (n = 3), which in turn, produced a large sampling error. A larger sample size may have given more reliability and increased the validity of the analysis. This ongoing study is collecting more participants, which may strengthen the data and results to show a clearer indication. The times of the day in which the participants were trained were different, which may have affected their performance during the trainings and assessments. Trainers and clinical assessors for participants differed, but stayed consistent within each participant’s individual training sessions and assessments.

In addition, the stroke survivors’ lesion areas differed, the time period from the onset of the stroke differed, and the baseline measurements differed, though it was controlled for each individual. In another study, Lam et al. (2012) found that lesion size and location, and the time period from the onset of the stroke, predicted recovery and gains in functionality and cardiovascular fitness in stroke survivors after three or six months of treadmill exercise. They also found that baseline walking and fitness measurements were not predictive of the health improvements. There was no control group to compare the participants to, and comparisons were made between the participants’ pre and post assessments, like in our study. However, because baseline measurements were independent for each participant, the changes calculated were normalized, which controlled for this factor. Thus, the lesion size and location, and the time onset from after having the stroke, can be confounding factors that are difficult to control. In addition, because our participants qualified and were able to complete this study, they are not representative of all stroke survivors. Stroke survivors can be wheelchair users, home ambulatory, or community ambulatory. Our sample of stroke survivors are representative of chronic stroke patients who have visible hemiparesis and are able to walk independently with or without a walk-aid for at least five minutes. This category would fall under home ambulatory or community ambulatory stroke survivors.

Remaining Questions
It is not completely understood how neuronal activity relates to the functioning of the body. Though this study did not show a clear relationship between corticomotor excitability and gait speeds, several studies have shown that there can be many varying factors that contribute to how the body and the brain system reacts to treadmill training. With this study among others,
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some questions to be asked are: How and why do the treadmill trainings of BWSTT and HITT differ in their effects towards corticomotor excitability in stroke survivors? Is it really necessary to restore corticomotor excitability when the other aspects of a stroke survivor improve? If so, is repetitive practicing of a task a detriment to recovery in stroke survivors? Future studies done should investigate the relationship among these variables.

REFERENCES


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Lenore Tahara-Eckl attended the University of Illinois at Chicago (UIC) from 2012-2015 and received a bachelor’s degree in Applied Psychology. She is currently working in a research laboratory at UIC, which is investigating neurorehabilitation in stroke survivors through brain plasticity changes and exercise. She presented her honors capstone research project at the UIC Student Research Forum, the Chicago Area Undergraduate Research Symposium (CAURS), and at the “Posters Under the Dome” event in Springfield, Illinois. She plans to attend graduate school for a doctoral degree in Cognitive Neuroscience.