Effectiveness of Low Electrical Sensory Stimulation from Transcutaneous Electrical Nerve Stimulation (TENS) in Promoting Upper Extremity Functionality of Two Individuals Post-stroke

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This research, submitted by Shu-Min Lin, has been approved and accepted in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy from the University of Puget Sound.

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Abstract

The purpose of this study was to examine the effects of low sensory electrical stimulation provided by a TENS unit on improving hand functionality in the treatment of patients post-stroke. An A-B-A single-subject design was used and two subjects participated in this study; one was a 70-year-old female who was 6 years post-stroke and one was a 63-year-old male 2 years post-stroke. For participant 1, there was no significant change in active extension of the first three digits but significant improvement in little finger active extension was shown when the intervention was introduced. The large light object subtest from the Jebsen-Taylor Hand Function Test was modified for participant 1 and the time she required to perform this subtest varied. There was no significant change in the Action Research Arm Test for participant 1. For participant 2, there was a significant improvement in index finger extension in the B phase and no significant change in active extension of other fingers. There was no significant change in finger flexion for all fingers except the little finger. There was no significant change in the large light objects subtest and there was significant change in the A2 phase in the writing subtest from the Jebsen-Taylor Hand Function Test. There was no significant change in the Action Research Arm Test grip subtest. There was significant change in the Action Research Arm Test pinch subtest. However, there were many internal and external factors contributing to the study results. The findings from this study suggest that future study is needed to achieve a better understanding of the low sensory stimulation provided by a TENS unit on promoting upper extremity function in clients post-stroke.

Keywords: low sensory electrical stimulation, TENS, post-stroke, upper extremity function

Effectiveness of Low Electrical Sensory Stimulation from Transcutaneous Electrical Nerve Stimulation (TENS) in Promoting Upper Extremity Functionality of Two Individuals Post-stroke

Advances in medical technology in the United States have promised the population a longer life span than ever before, and they have helped improve the management of many critical medical diagnoses. However, many survivors from serious illness have to confront sequelae that lead to decreased performance of valued activities and a possible decline in the quality of daily life (Wu, Radel, & Hanna-Pladdy, 2011). For years, cardiac disease, cancer, and stroke have been the top three leading causes of death in the United States (Xu, Kochanek, Murphy, & Tejada-Vera, 2010). Among these causes, stroke has the greatest impact on survivors' activities of daily living (ADL) and instrumental activities of daily living (IADL) due to the long-term disabilities it can create.

In addition to being one of the most deadly and debilitating medical conditions, stroke also causes the highest mean per person expenditure and the highest percentage of total expenditures used for home health care (West Virginia Health Statistics Center, 2004). While stroke incidence increases with age (Hollander et al., 2002), Muntner, Garrett, Klag, and Coresh (2002) also reported an increase number of stroke survivors 25 - 74 years of age between1973 and 1991. These studies suggest that stroke affects people from different age groups both medically and financially. It would be beneficial for patients with stroke and for society as a whole to discover the most efficient treatments to improve functional performance.

Occupational therapy plays a crucial role in stroke survivors' rehabilitation through treatment designed to enhance patients' participation in everyday activities (Steultjens et al., 2003). Occupational therapists use many different interventions to address underlying impairments, such as limited active/passive range of motion, decreased dexterity and coordination, muscle weakness, and abnormal tone and movement patterns. Occupational therapists help improve movement aspects of functional tasks in order to prepare survivors with stroke to engage in ADL and IADL more independently.

Studies have shown that electrical sensory stimulation can facilitate performance on functional tests and improve finger movements (Koesler, Dafotakis, Ameli, Fink, & Nowak, 2009; Wu, Seo, & Cohen, 2006). However, electrical stimulation as a physical modality has rarely been employed by occupational therapists in rehabilitation for patients with post-stroke, according to Smallfield and Karges (2009).

Background

Stroke prevalence and cost. According to the American Heart Association (2009), about 795,000 people experience a new or recurrent stroke each year. The number of adults aged 20 and older with a stroke reached over six million in 2005, with the majority of these people over 60 years old. As the 78.2 million baby boomers reach age 65 (U.S. Census Bureau, 2006), it is expected that in the near future more and more people will need medical services, including occupational therapy, to help manage aftereffects of a stroke.

The estimated direct and indirect cost of stroke for 2009 is $68.9 billion. (American Heart Association, 2009), and a substantial part of the cost is rehabilitation services related. Nevertheless, evidence supporting the most effective occupational therapy interventions for stroke rehabilitation is still limited (Smallfield & Karges, 2009).

Although a significant decline from mortality in stroke has been shown over the past several decades (Xu et al., 2010), significant impairments including, spasticity, flaccidity, atrophy, ataxia, apraxia, and aphasia are still often seen (Bartels, Duffy, & Beland, 2011). These conditions often cause a decrease in the quality of everyday life and participation in daily occupations of survivors with stroke. Motor recovery from upper extremity hemiparesis in patients with stroke can be an arduous process. One of the most common disabilities occupational therapists treat for post stroke survivors is upper extremity hemiparesis (Wu et al., 2011). Alon, Levitt, and McCarthy (2007) indicated grasping, holding and manipulating objects are daily functions that remain deficient in 55% to 75% of patients three to six months post-stroke and patients with stroke face daily challenges even months after the acute stage. Due to limitations in functional performance, patients with stroke are expected to benefit from occupational therapy intervention to improve the quality of life months or years after the onset of stroke (Lavelle & Tomlin, 2001).

Intervention approaches. Studies have indicated that patents with stroke can improve functional performance and reduce impairments after occupational therapy intervention (Trombly & Ma 2002; Steultjens et al., 2003). However, these studies did not provide descriptions of the specific intervention methods used in treatment sessions. Since occupational therapists often customize treatment approaches to meet individual goals, it is difficult to characterize a universal approach and determine an optimal strategy (Smallfield & Karges, 2009).

The majority of the research studies have indicated that occupational therapy is effective in post stroke rehabilitation; however, there is limited evidence to shed light on the nature of the interventions that contributes to the effect (Smallfield & Karges, 2009). In recent years, new findings in neuroscience help to provide insights into motor learning, neuroplasticity and functional recovery, and electrical stimulation can be applied to hemiparetic upper extremity following stroke (Hara, 2008). However, the integration of electrical stimulation into a rehabilitation program is not as common as other physical agent modalities (Berner, Kmichi, Spokoiny, & Finkeltov, 2004).

Recently, two studies gathered information on the specific interventions employed by occupational therapists for patients with stroke in seven hospitals with inpatient rehabilitation centers. Smallfield and Karges (2009) found that physical agent modalities, including electrotherapeutic agents were only used in 10 intervention sessions among the total of 1,554 while the survey from Latham et al. (2006) revealed that the most frequently used intervention strategies were musculoskeletal, neuromuscular, and adaptive/compensatory, and no physical agent modalities were utilized. While these two studies only drew samples from seven hospitals, and may not be representative of occupational therapy practitioners in general, they provide an indication that physical agent modalities appear to be underused within occupational therapy intervention.

Physical agent modalities include superficial thermal agents, deep thermal agents, mechanical devices, and electrotherapeutic agents. Among others, the electrotherapeutic agents use electricity and the electromagnetic spectrum to facilitate tissue healing, improve muscle strength and endurance, decrease edema, modulate pain, and decrease the inflammatory process (American Occupational Therapy Association, 2008). Functional electrical stimulation (FES), which elicits muscle contractions using electricity to perform a functional activity, has been found to be effective for hand function and wrist range of motion (Chan, 2008); however, there are limitations to FES, such as muscle adaptation to the stimulation after a period of time, and a stronger stimulation being needed to induce the same level of muscle contraction (Sujith, 2008). Moreover, FES stimulation patterns operate with a regular on/off cycle, and it may not simulate or prepare patients with the complex movement patterns that are required by ADL, and IADL tasks. Therefore, exploring alternative effective treatments to improve upper extremity functions for stroke survivors is suggested.

Studies have reported that changes in the afferent nerve input may alter human motor cortical excitability (Hamdy, Rothwell, Aziz, Singh, & Thompson, 1998; McDonnell & Ridding, 2006; Ridding, Brouwer, Miles, & Thompson, 2000), and that electrical somatosensory stimulation influences motor behavior and possibly functional recovery through motor cortical reorganization (Wu et al., 2006). Hummel et al. (2005) found that patients with chronic stroke obtained improved upper extremity function, measured by the Jebsen-Taylor Hand Function Test, after non-invasive stimulation to the motor cortex. Moreover, according to Nitsche et al. (2003), anodal transcranial direct current stimulation (tDCS) increased the primary motor cortex excitability and reduced reaction time needed for subjects to perform a button push task. A systematic review from Laufer and Elboin-Gabyzon (2011) gave positive results that sensory stimulation from TENS combined with active training may enhance motor recovery following a stroke.

In clinical practice, Transcutaneous Electrical Nerve Stimulation (TENS) is mainly used for relieving pain, but broadly TENS is the electrical stimulation that stimulates nerves underlying the skin through the intact skin surface (Jones & Johnson, 2009). Unlike FES, which creates muscle contractions in on/off cycles that could interfere patient’s functional movement patterns during stimulation, TENS, can be set up to stimulate only the afferent nerve and may offer an alternative to functional electrical stimulation for enhancing motor function after stroke. Therefore, it is reasonable to predict that the low level sensory stimulation provided by a TENS unit may facilitate the recovery of function in upper extremities of patients with stroke through its influence on motor cortex excitability via afferent input and provide an effective treatment approach whereby patients can engage in more complex functional tasks during stimulation.

Occupational therapists contribute their expertise to assess the unique situation of individual clients with stroke and incorporate meaningful functional activities into the interventions to improve underlying motor deficits and promote independence and quality of life. Having additional evidence-based treatment methods to support occupational therapists' work in the rehabilitation of clients post-stoke can increase the effectiveness of therapy. Therefore, the purpose of this study was to investigate whether the low level sensory electrical stimulation provided by a TENS unit would increase the upper extremity motor function of clients who were more than one year post-stroke.

Method

Research Design

In this study, a single-subject research design with A-B-A sequence was employed. There were two participants with each participant acting as his or her own control. Due to the ability to customize the dependent variables in single subject design, a variable important to the participant that was not measured by the above three outcome measures could be identified and measured, allowing the student researcher to customize outcomes that reflect the participants' therapy goals.

The threats to internal validity in such a design can be the participant's life style, medications, or everyday routine, as these factors may contribute to a change in outcome measures. Considering the small number of participants and the customization of a dependent variable in this study, the external validity may be limited. Nonetheless, a single subject design provided for a greater focus on each participant's needs (client-centered treatment), and for the time and budget available, it was an appropriate research design.

Participants

Convenience sampling was used for selecting participants for this study. Potential eligible participants were clients who were enrolled in a student occupational therapy clinic. The recruitment began in early February 2012. To recruit the participants more effectively and ensure their safety, inclusion criteria were that they (a) experienced first stroke at least one year ago, (b) had a single unilateral stroke, (c) were medically stable, (d) were aged over 18, (e) had at least 10° of active wrist extension and 10° of combined active finger extension and flexion, (f) had passive joint range of motion within functional limits in wrist extension and flexion (0–45 degrees), (g) had passive flexion of fingertips to palm, passive extension to 0 degrees, (h) were able to actively place the affected upper extremity on a table to perform outcome measures when seated, (i) had adequate cognition for completing outcome measures, (j) had intact skin in hand and forearm. The exclusion criteria were (a) a comorbid neurological disease, (b) an orthopedic condition that would preclude participation in the outcome measures, (c) an inability to sit in a chair, (d) a pacemaker.

Two participants met the criteria for this study and signed the consent forms approved by the University Institutional Review Board (IRB). Participant 1 was a 70-year-old female, whose onset of stroke was in 2006 and her left upper extremity was affected. Participant 2 was a 63-year-old male, who experienced his stroke in 2010 and his right upper extremity was affected.

Apparatus

In this study, an Empi EPIX-XL™ TENS unit was used to provide low level sensory stimulation. This device includes a stimulator, two lead wires that connect to two electrodes, and has a dual channel with four conventional modes, including continuous, burst, modulated pulse rate, and multi-modulation. The Empi EPIX-XL™ TENS unit produced a balanced asymmetrical rectangular pulse that varied between 0-400μsec pulse duration and its pulse duration adjusted automatically with intensity (Empi, 1997). The intensity used in this study was set to the strongest sensory input that remained below a motor threshold, which was determined by no visible or palpable muscle contraction. The pulse rate was set between 20 to 150 Hz, depending on participant preference since it allowed the participants to choose which rate was most noticeable, suggesting a stronger afferent stimulus. The multi-modulation mode from was used to prevent the accommodation of the sensory nerve system.

Instrumentation

Active range of motion in wrist and fingers, the Action Research Arm Test, and the large light object subtest of the Jebsen-Taylor Hand Function Test were used to measure participants' upper extremity performance. These three outcome measures were used throughout the three phases of the study for both participants. The writing subtest from the Jebsen-Taylor Hand Function Test was also used throughout the three phases for participant 2 who identified writing as a functional goal. Participant 1 did not give a specific goal for this study. The order of the outcome measures was randomized at each session to prevent an order effect.

Wrist and finger active range of motion measurement was measured by goniometer using appropriate protocols for measurements (Flinn, Trombly Lathman, & Podolski, 2008). Total extension and total flexion measures of each finger were calculated by summing measures of each joint, consistent with techniques for measuring total active motion described by Flinn et al. (2008). In this study, zero degrees in finger extension was full extension, meaning better function and 270 degrees in total finger flexion meant the participant could fully flex the finger. Studies have indicated that goniometry has consistent higher intrarater reliability than interrater reliability (Flinn et al., 2008).

Two subtests from the Jebsen-Taylor Hand Function Test were used to evaluate participants' hand function. The large light object subtest (J-T light) is a timed measure of how fast a person can grasp, hold, and move 5 empty cans onto a board in front of them. The second, used only for the participant 2, was the writing subtest (J-T writing), which evaluated the time to complete writing a short sentence. The Jebsen-Taylor Hand Function Test has high inter-tester reliability with ICC ranging from 0.82 to 1.00 (Hackel, Wolfe, Bang, & Canfield, 1992).

The Action Research Arm Test (ARAT) is composed of 19 items, which are divided into four subtests: grasp, grip, pinch, and gross movement. The grasp and pinch subtests required participants to place objects onto a 37-cm shelf. The highest possible score for both grasp and pinch subtests was 18, while it was 12 for the grip subtest. The highest possible score for the gross movement was 9. This test had high interrater reliability, ICC = 0.98, $p = 0.036$ (Hsieh, Hsueh, Chiang, & Ljn, 1998).

Procedures

Prior to conducting this experiment, the approval of the University IRB was obtained. The student researcher was instructed by a licensed physical therapist, on faculty at the University, to use the TENS unit appropriately and safely. Occupational therapy faculties were consulted for developing competence in elected standardized outcome measures.

All occupational therapy clients who attended the on-campus clinic in the spring semester, 2012 were asked for permission to be contacted for participation in research projects. The student researcher informed other second year occupational therapy students about this research project and sent the inclusion and exclusion criteria for this study. Only those clients who had indicated willingness to discuss participation in research were asked by their student occupational therapists. Two clients post-stroke were identified and met the inclusion criteria. They volunteered to participate in this study and the student researcher then scheduled 2 sessions per week to conduct the experiment with each participant.

The length of the experiment was approximately 8 weeks with about 2.5 weeks for each phase. Sessions 1 to 5 constituted the A1 phase (baseline phase) while sessions 6 to 10 made up the B phase (intervention phase) and sessions 11 to 15 were the A2 phase (return to baseline phase). Each session was about 35-40 minutes long. Outcome measure data were collected during each session. In A1 and A2 phases, the participants simply performed the outcome measures of this study without the intervention. In the B phase, the TENS unit was applied to the participants' affected upper extremities to give low electrical sensory stimulation when they performed the outcome measures. For participant 1, electrodes were placed on the forearm over the extensors to facilitate her wrist and finger extension because she presented more limitation in her finger and wrist extension. For participant 2, electrodes were placed on his palm and wrist over the flexors because he had inaccurate control when performing tasks requiring pinch. A brief time, about 1 minute, was utilized for both participants to take a rest between tests.

Data Analysis

Data from each outcome measure were graphed for each participant. The two-standard deviation band method was used to detect if there was a significant change in performance, which was defined as two consecutive points being outside the two-standard deviation band. In each graph, the outcome measure was located on the Y-axis while the session number was on the X-axis. Data from finger extension, finger flexion, wrist extension, ARAT grasp and ARAT grip were graphed for participant 1 while data from finger extension for index and middle finger, finger flexion for each finger, wrist extension, J-T light, J-T write, ARAT pinch, and ARAT grip were graphed for participant 2.

The mean line from the A1 phase was illustrated in each graph while the 2-standard deviation values were displayed next to each graph. The student researcher looked for the data points that were outside the 2-standard deviation band and compared the data from the A1 phase to that in the B phase and compared the data from the A1 phase to that in the A2 phase. For some outcome measure data, the mean line from the B phase and the 2-standard deviation values were also displayed for comparing the data from the B phase to the A2 phase.

Results

The study had a total length of eight weeks. This study was conducted to answer the following research question: Does low sensory stimulation provided by a TENS unit promote hand function measured by AROM in fingers and wrist, the Action Research Arm Test, and the large light object a from Jebsen-Taylor Hand Function Test? For participant 2, an additional hand writing measure was also included.

Since participant 1 required extended time and demonstrated extremely wide variability to complete the J-T light, this subtest was modified to have participant 1 lift only one can and the time was recorded.

Participant 1

This participant fatigued easily and had limited AROM in shoulder flexion. She had visible edema in her affected upper extremity and presented limitation when she was asked to fully extend her digits. The electrodes were placed on her forearm extensor surface to facilitate wrist and finger extension.

AROM in fingers and wrist. In general, there was no significant change in index finger, middle finger, and ring finger active extension (see Figure 1). There was a significant increase in little finger active extension from the A1 phase to the B phase and it continued to improve from the B phase to the A2 phase (see Figure 1). In finger active flexion, there was no significant change in the index finger and there was a significant decrease in the middle, ring and little fingers in the A2 phase (see Figure 2). There was a significant decrease in wrist extension in the B phase but a significant increase in the A2 phase (see Figure 3).

Large light object subtest from the Jebsen-Taylor Hand Function Test. The time that paticipant 1 required to complete the modified the J-T light in the first session was not recorded. The time that this paticipant required to lift one can varied from 2 seconds to 63 seconds in A1 phase, 3 seconds to 121 seconds in B phase, 2 seconds to 15 seconds in the A2 phase. Because of the large variability, these data could not be effectively analyzed.

The Action Research Arm Test. The scores in pinch and gross movement subtests were 0 for every session, meaning that participant 1 was unable to perform the test items in these two subtests throughout the entire experiment. Overall, there was no significant change in the grasp and grip subtests. However, there was a noticeable increase in both grasp and grip subtests in the A1 phase (see Figure 4).

Participant 2

This participant presented with a fairly high level of upper extremity motor function. That is, his AROM in the affected upper extremity was within functional limits. This participant had difficulty feeling the sensory stimulation when the student researcher introduced the electrical sensory stimulation from the TENS unit on his affected hand; therefore, the electrodes were cut into a smaller size to make the sensory stimulation noticeable to him. The electrodes were placed in the palm and wrist, on the flexor surface, to facilitate flexors in his affected hand.

AROM in fingers and wrist. This participant could fully extend his ring finger and little finger at baseline, and no decreased active range of motion in ring finger and little finger was recorded throughout the experiment. There was a significant improvement in index finger extension from the A1 phase to the B phase but a significant decrease from the B phase to the A2 phase (see Figure 5). There was no significant change in middle finger active extension. Visually, there was a trend of better active extension shown in index and middle fingers in the A1 phase (see Figure 5). There was no significant change in finger flexion for the fingers except the little finger, which had significantly decreased flexion in the B phase (see Figure 6). There was no significant change in wrist extension see Figure 7).

Jebsen-Taylor Hand Function Test. There were no significant changes in both large light objects subtest and writing subtest during the B phase. There was a significant improvement in the writing subtest in the A2 phase (see Figure 8).

The Action Research Arm Test. The participant was able to perform the grasp and gross movement subtest effectively to earn the highest possible points and maintained performance throughout the study. There was no significant change in the grip subtest. There was significant improvement in the pinch subtest in the B phase and A2 phase compared to the A1 phase (see Figure 9).

Discussion

The purpose of this study was to investigate the effects of low sensory stimulation from a TENS unit in promoting upper extremity functionality of clients post-stroke. The stimulation targets were different for the two participants. For participant 1, the TENS electrodes were placed on the extensor surface to facilitate her fingers and wrist extension. For participant 2, the TENS electrodes were placed on the palm and wrist over the flexors to facilitate his finger flexion and his intrinsic muscles to help his pinch. Participant 1 did not state an individualized goal while participant 2 identified writing as a goal for this experiment.

This intervention appeared to be effective in promoting little finger active extension in participant 1 because she started to show better performance in little finger flexion when the intervention was introduced. Participant 1's little finger had much less extension compared to her first three fingers; therefore, it left more room for increased active little finger extension. However, participant 1 continued to demonstrate improvement in the A2 phase and the reason was not apparent to the researcher.

Participant 1 demonstrated significantly decreased active flexion in middle, ring, and little fingers in A2 phase. Possible reasons for this finding included her fatigue level, decreased strength, or less motivation during those 2 sessions; however, the real cause of the decreased active finger flexion could not be identified. The declined active wrist extension in the B phase was statistically significant; however, it was only two degrees below the lower standard deviation from the A1 phase and might not be considered clinically significant. There was significant improvement active wrist extension in the A2 phase; however, the reasons were not apparent to the student researcher.

Participant 1 demonstrated improvement in the ARAT grasp and grip subtests in the A1 phase. Improved performance in the A1 phase may have been due to a practice effect in which participant 1 learned to substitute lateral trunk flexion for her limited shoulder flexion to perform these two subtests. For the grasp subtest, the limited active shoulder flexion prevented participant1's ability from placing objects onto a high level shelf.

The low sensory electrical stimulation from the TENS unit did not appear to be effective in promoting participant 2's finger flexion and there was significantly decreased little finger active flexion in the B phase; the reasons for this change were not apparent to the researcher. This intervention also did not show effectiveness in terms of increasing participant 2's scores in the two subtests from the Jebsen-Taylor Hand Function Test, and it might be due to the TENS stimulation not being strong enough to improve this participant's motor movements required for the two subtests. The improvement of participant 2 in the J-T writing in the A2 phase could have been due to the practice effect.

Participant 2 received his student occupational therapy treatment prior to the experimental sessions that focused on improving his hand function and the improved index finger and middle finger extension in the A1 phase in this study could have occurred as a result of his occupational therapy treatment. Participant 2 demonstrated significant change in the ARAT pinch subtest and index finger active extension in the B phase; however, it was uncertain if the significant changes were caused by the implementation of the low sensory electrical stimulation in this study or because he started receiving muscular neuroelectrical stimulation treatment in his occupational therapy session on the sixth session, which coincided with the beginning of Phase B. Overall, it was not clear if the significant changes in index finger active extension, little finger active flexion, and the ARAT pinch subtest was due to the low sensory electrical stimulation from the TENS unit or the treatments that participant 2 received in his occupational therapy clinic immediately prior to data collection for this study.

Implications for Occupational Therapy

This study sought to investigate the effectiveness of the low sensory stimulation from a TENS unit in promoting upper extremity function, which is a vital component of occupation performance. Improving upper extremity function will improve the quality of engagement in everyday life for patients with stroke. Therefore, it is important to seek effective interventions to help clients post-stroke gain better upper extremity function. The low sensory electrical stimulation provided by a TENS unit appeared to be effective in improving finger extension in the two participants, and occupational therapists may wish to consider incorporating this intervention into occupational therapy treatments.

The two participants in this study were at the extremes of the study inclusion criteria and no one whose upper extremity motor performance was between the two participants was included in this study. Participant 1 had limitations in proximal joint control and, while the low electrical sensory stimulation was aimed to improve finger and wrist extension, her limited reach impacted her performance on the functional measures. Participant 2 was able to almost fully extend his digits and the limitations he had were more complex such as coordination as well as timing of muscle contractions. While there is theoretical evidence to suggest that low sensory electrical stimulation facilitates the motor cortex to enhance a muscle contraction, the impact on more complex motor functions is not described in the literature and may be limited.

Occupational therapists who consider employing this treatment approach may want to consider using it with clients whose upper extremity performance is between the two participants in the current study. For example, a client who has adequate proximal control or a client who has the ability to perform gross grasp and release movement but not yet progressed to the point where remaining deficits are primarily in fine motor control and manipulative function. The other important thing for occupational therapists to consider is to select appropriate measures for the goal of the intervention and carefully monitor to ensure effectiveness of the treatment while using this treatment approach.

Limitations

The number of study participants was few, which makes the generalization to a larger population difficult. The short experimental timeframe was also a limitation, as it did not allow the student researcher to obtain a stable baseline of participants' performance prior to initiating the intervention. One of the major confounding intervening external variables was that the participants received student occupational therapy treatments prior to each experimental session which made it difficult to determine the sole effect of the low sensory electrical stimulation from the TENS unit. The inexperience of the student researcher with collecting the outcome measures could also have influenced the results. Other internal factors of the participants, such as CVA severity, time of onset, age, amount of therapy received, prior level of function, and concurrent therapy could also have contributed to the results.

Future Research

Overall, it is important to consider to continue investigating the effectiveness of low electrical sensory stimulation from a TENS unit as it might provide clients post-stroke an alternative method to improve upper extremity function. Although the experimental results from this study did not appear to demonstrate conclusive positive outcomes of this intervention, there were some improvements shown in the intervention phase, which indicated some effectiveness from the low electrical sensory stimulation in terms of promoting upper extremity function.

The participants in this study presented with very different motor deficits in their affected upper extremities. Therefore, for future study, it will be important for the researchers to think more carefully about the inclusion and exclusion criteria to appropriately select the participants. For example, one of the inclusion criteria may be better proximal joint control and one of the exclusion criteria may be less active range of motion in distal joint control. It is also important to design a study with fewer intervening variables. Future researchers could also consider investigating the effectiveness from the low sensory electrical stimulation from a TENS unit in different settings to have the maximum effect.

Conclusion

This study was designed to investigate the effects of the low electrical sensory stimulation on improving upper extremity function in people post-stroke. There were some significant changes seen in both participants in this study, but there was no conclusive evidence to indicate that improvements were the direct results from the low sensory stimulation from the TNES unit. However, there were many internal and external factors that influenced the results of this study and made it hard to identify if the changes were from the intervention. Therefore, more research will be needed to verify the effects of the low sensory stimulation on promoting upper extremity function.

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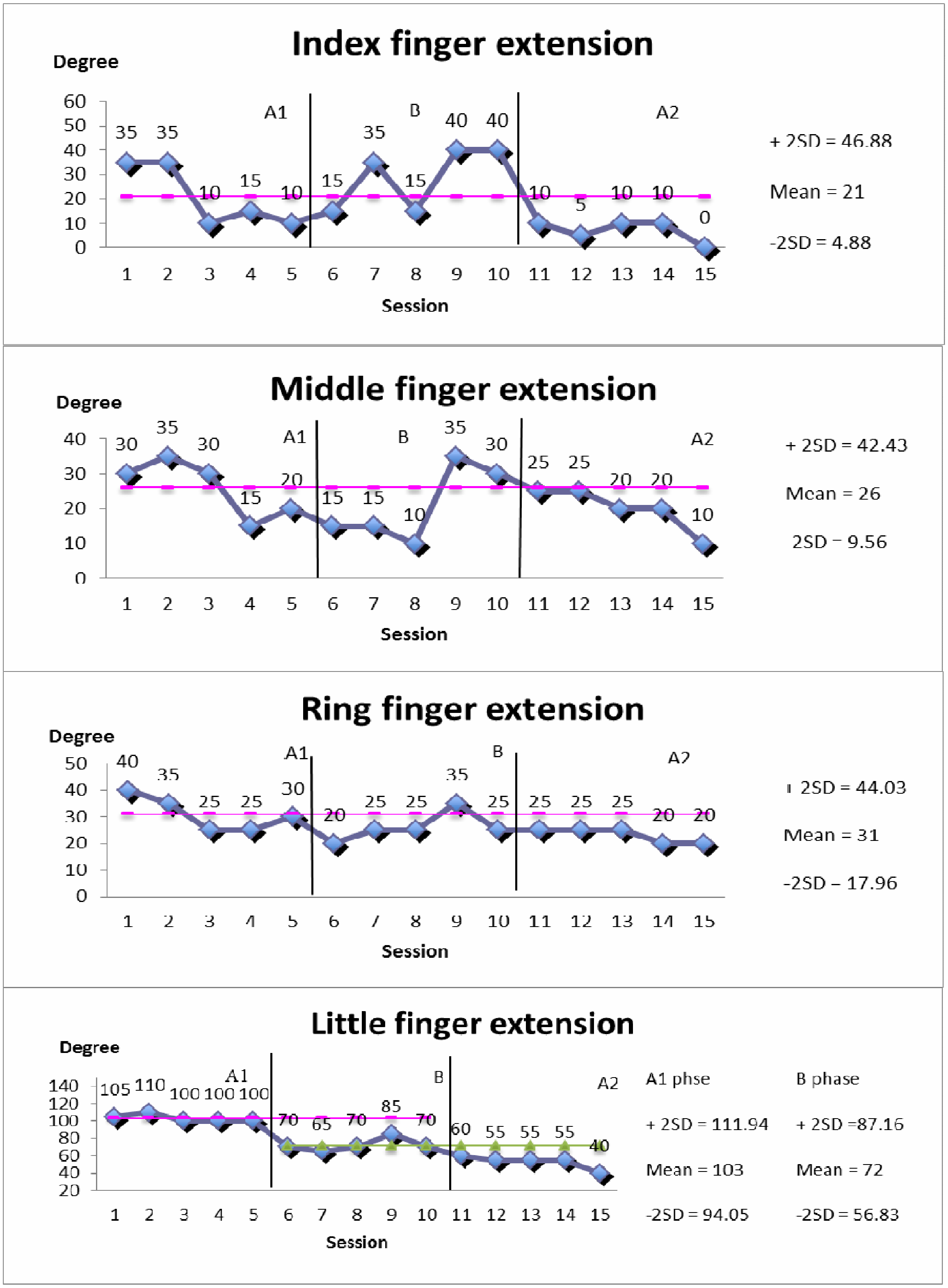

Figure 1. Participant 1 finger extension.

Note: Maximal finger extension is zero degrees; therefore, a decrease indicates better extension.

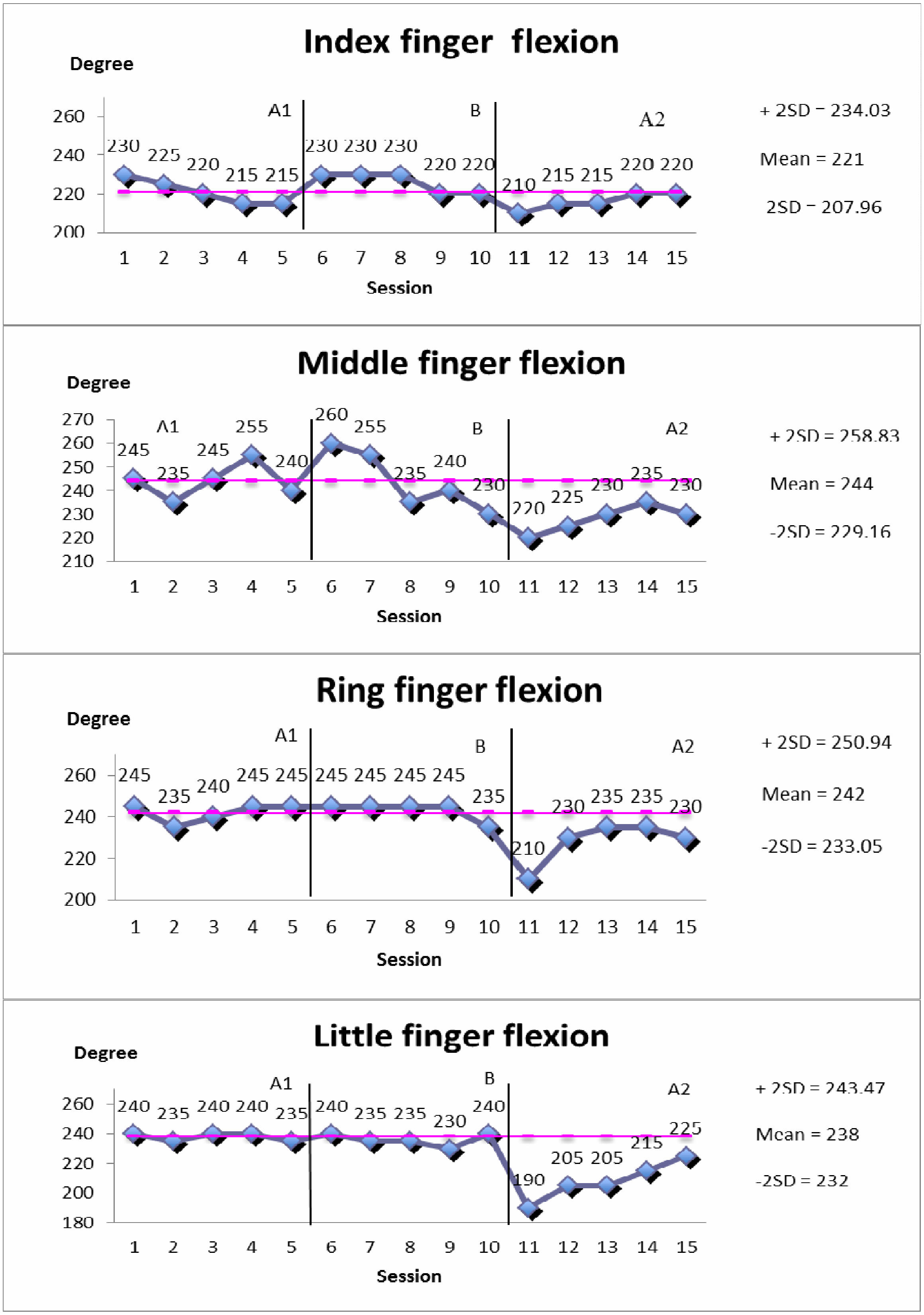

Figure 2. Participant 1 finger flexion.

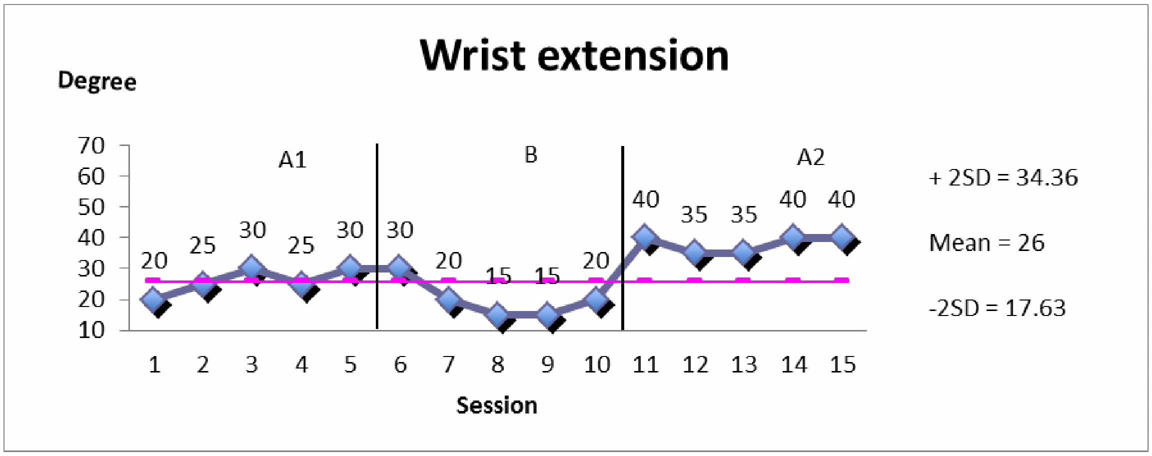

Figure 3. Participant 1wrist extension.

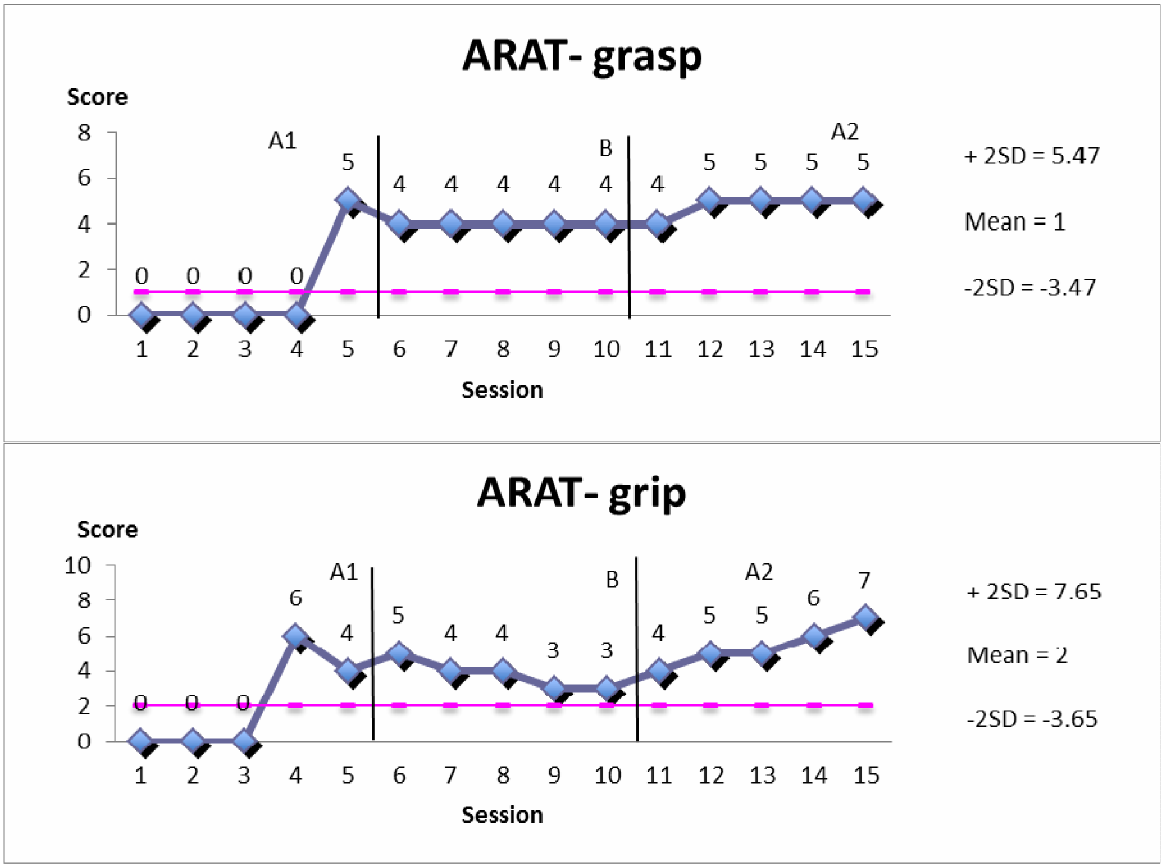

Figure 4. Participant 1 ARAT grasp and grip subtests.

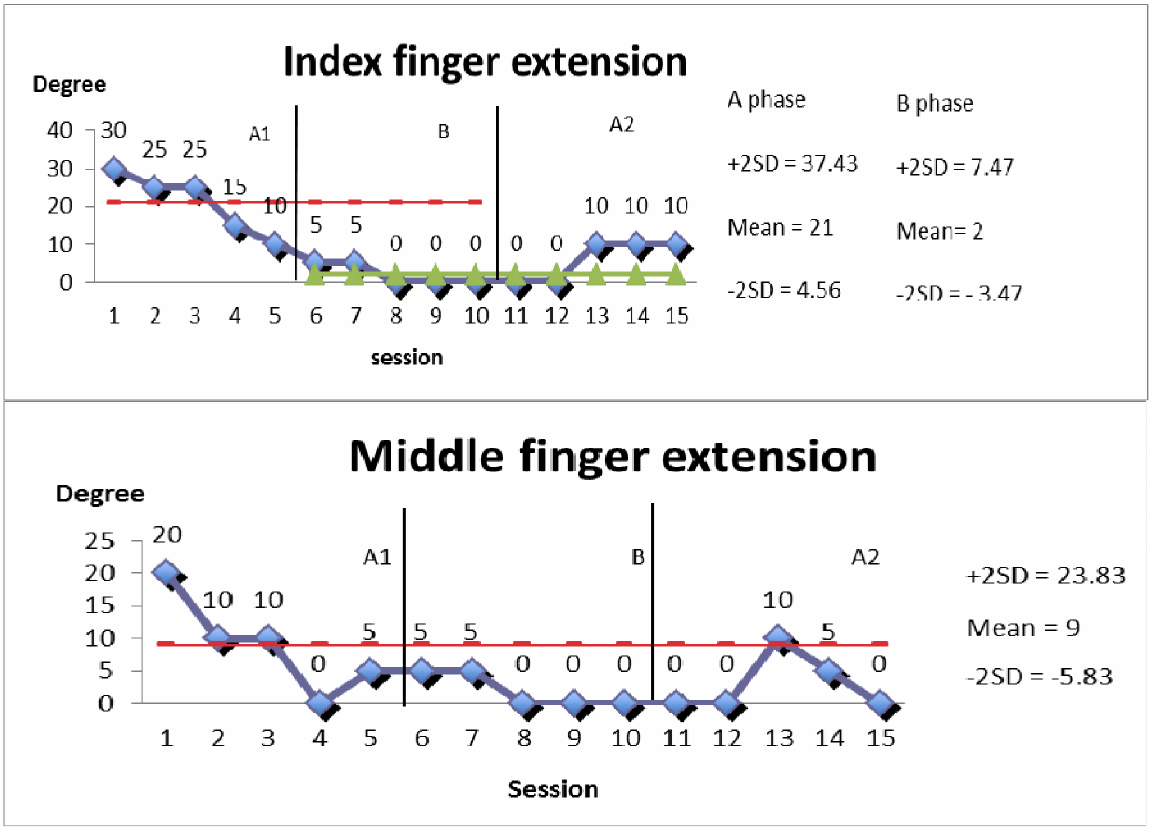

Figure 5. Participant 2 finger extension.

Note: Maximal finger extension is zero degrees; therefore, a decrease indicates better extension.

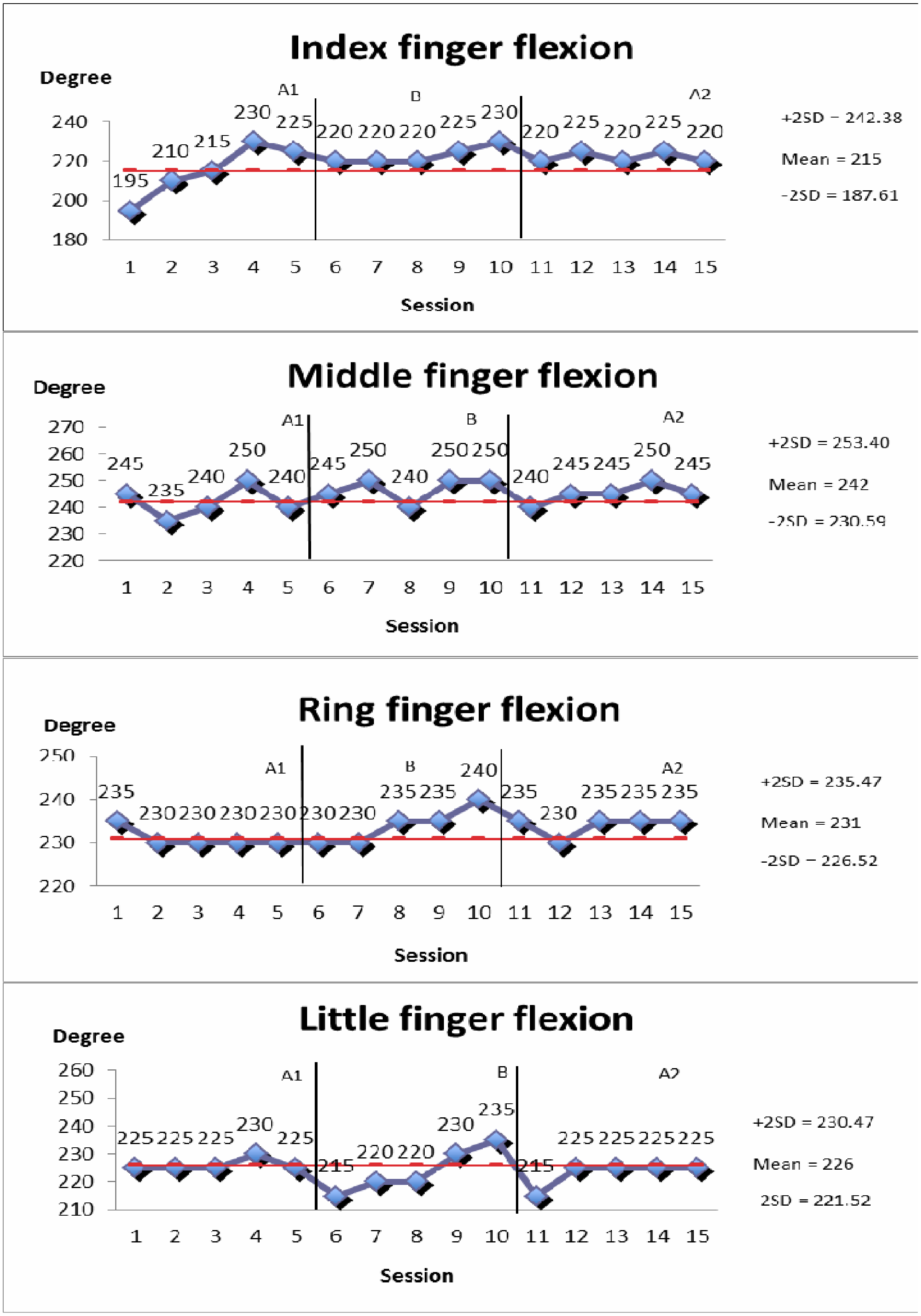

Figure 6. Participant 2 finger flexion.

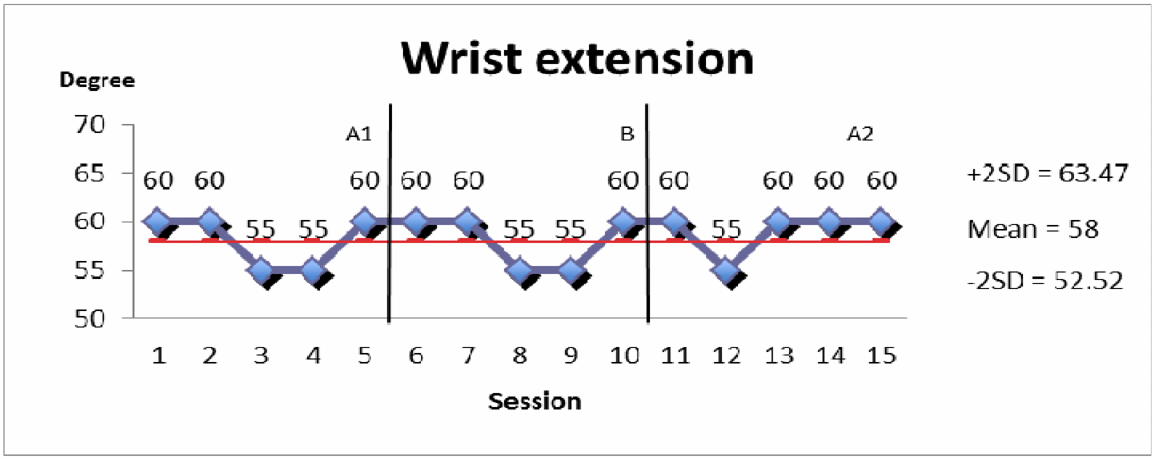

Figure 7. Participant 2 wrist extension.

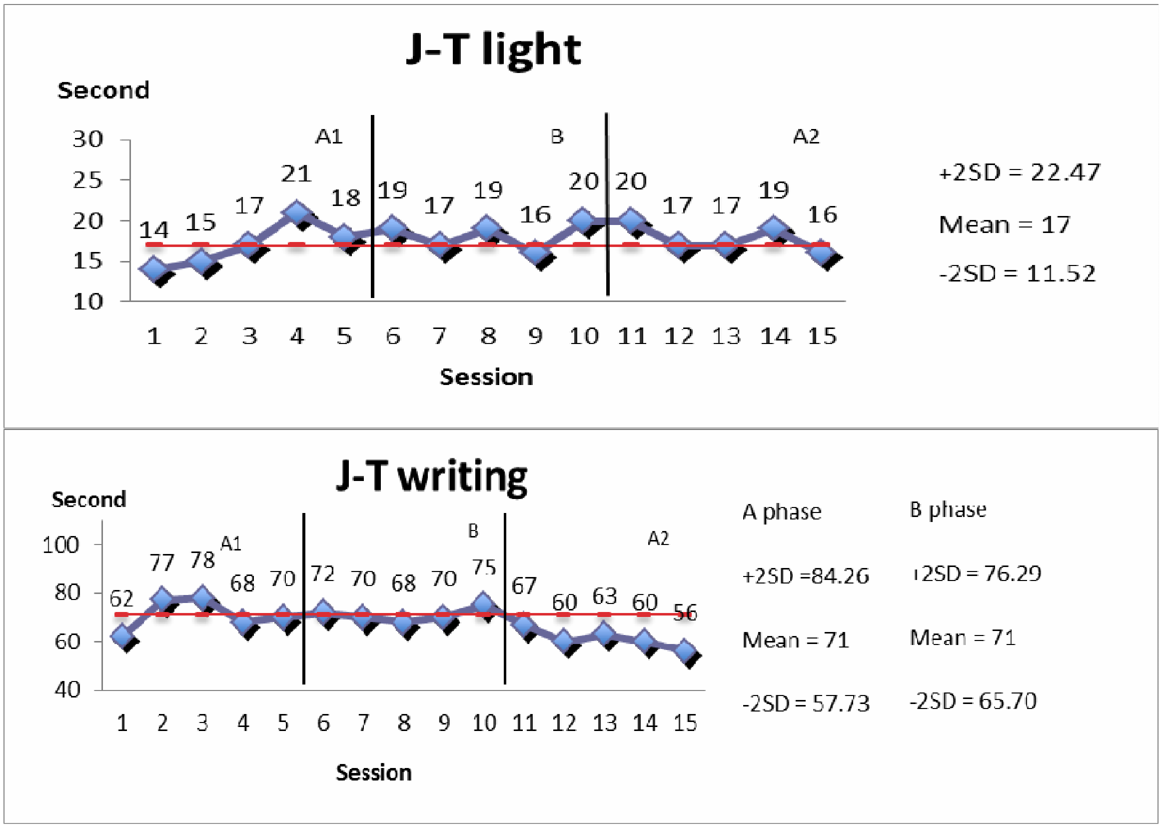

Figure 8. Participant 2 J-T large light object and writing subtests.

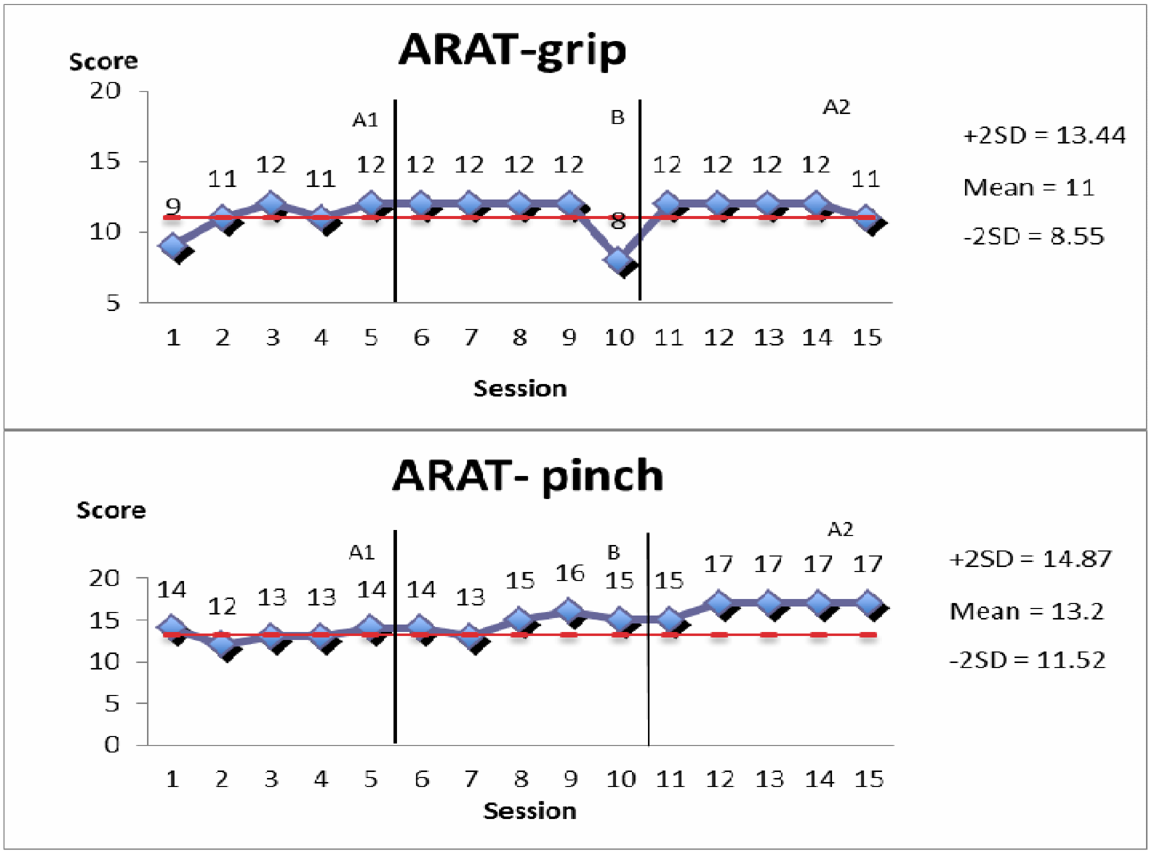

Figure 9. Participant 2 ARAT grip and pinch subtests.